Juta Dekšne

CEĻĀ UZ BEZATKRITUMU PĀRTIKAS PATĒRIŅU: ĒDINĀŠANAS PROCESA ORGANIZĀCIJA LATVIJAS SKOLĀS ILGTSPĒJĪGAS APRITES EKONOMIKAS IETVARĀ

Promocijas darbs

RĪGAS TEHNISKĀS UNIVERSITĀTES
RĒZEKNES AKADĒMIJA
Ekonomikas un pārvaldības centrs

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RTU Rēzeknes akadēmijas, Ventspils Augstskolas un Vidzemes Augstskolas
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CEĻĀ UZ BEZATKRITUMU PĀRTIKAS PATĒRIŅU: ĒDINĀŠANAS PROCESA ORGANIZĀCIJA LATVIJAS SKOLĀS ILGTSPĒJĪGAS APRITES EKONOMIKAS IETVARĀ

Promocijas darbs

Zinātniskās vadītājas
asociētā profesore *Dr. oec.*
LIENĪTE LITAVNIECE
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TATJANA TAMBOVCEVA

Rēzekne 2025

ANOTĀCIJA

Promocijas darbs **"Ceļā uz bezatkritumu pārtikas patēriņu: ēdināšanas procesa organizācija Latvijas skolās ilgtspējīgas aprites ekonomikas ietvarā"** ir sagatavots kā tematiski vienota zinātnisko publikāciju kopa un sastāv no astoņām savstarpēji saistītām zinātniskajām publikācijām. Pētījums ir izstrādāts laika posmā no 2021.gada septembrim līdz 2025.gada augustam ar mērķi izpētīt ēdināšanas procesa organizāciju Rēzeknes pilsētas skolās ilgtspējīgas aprites ekonomikas (AE) ietvarā un, balstoties uz šī gadījuma izpētes rezultātiem, izstrādāt risinājumus bezatkritumu pārtikas patēriņa veicināšanai skolās atbilstoši ilgtspējīgas pārtikas sistēmas principiem.

Pētījuma objekts ir ēdināšanas procesa organizācija skolās ilgtspējīgas AE ietvarā.

Pētījuma priekšmets ir pārtikas patēriņš un pasniegtā ēdiena atkritumi traukos (PĒAT) Rēzeknes pilsētas skolās.

Pētījuma aktualitāti nosaka: 1) pārtikas izšķērdēšanas un atkritumu globālā nozīme; 2) augsts pārtikas atkritumu īpatsvars patēriņa posmā; 3) pārtikas atkritumu samazināšana ir viens no prioritāri risināmiem jautājumiem globālā, ES un nacionālā līmenī; 4) AE loma pārtikas nozarē; un 5) skolu ēdināšanas programmu attīstības potenciāls ilgtspējas kontekstā.

Promocijas darbā izvirzītas hipotēzes:

H1 Latvijas skolās ēdiena pasniegšanas modelis ar iepriekš individuāli servētām pilnībā vai daļēji porcionētām maltītēm, neatbilst ilgtspējīgas AE principiem un neveicina bezatkritumu pārtikas patēriņu.

H2 Atsevišķi īstenotas intervences pārtikas atkritumu mazināšanai nenodrošina ilgtermiņa ietekmi skolu ēdināšanas procesā.

Promocijas darbs sastāv no trīs nodaļām.

Pirmajā nodaļā izstrādāts promocijas darba teorētiskais ietvars, kas ir pamats empīriskajiem pētījumiem. Šajā nodaļā analizēta pārtikas izšķērdēšanas problēma globālā un Eiropas Savienības (ES) līmenī, pārtikas zudumi un atkritumi pārtikas piegādes ķēdē (PPĶ), kā arī atbilstošais politiskais un stratēģiskais ietvars. Izpētīts AE koncepts un loma pārtikas atkritumu samazināšanā. Kā arī analizēta PPĶ patēriņa posma loma plašākas pārtikas sistēmas ilgtspējas kontekstā, iekļaujot skolu ēdināšanas programmu lomu pārtikas sistēmā un pārtikas sistēmas transformāciju ietekmējošos faktorus.

Otrajā nodaļā apkopoti empīrisko pētījumu rezultāti, kuru mērķis bija novērtēt ēdināšanas procesa organizāciju Rēzeknes pilsētas skolās ilgtspējīgas AE ietvarā. Pirmajā pilotpētījumā veikta PĒAT analīze, identificējot pārtikas izšķērdēšanas apjomus un tendences. Otrajā pilotpētījumā praktiski ieviestas un novērtētas mērķtiecīgas intervences pārtikas

atkritumu samazināšanai. Trešajā pētījumā novērtēta skolēnu attieksme un zināšanas par pārtikas atkritumu problēmjautājumiem un viņu skatījums uz pusdienu organizēšanu skolās.

Trešajā nodaļā piedāvāti risinājumi ēdināšanas procesa organizācijas maiņai un pārtikas sistēmas transformācijai ilgtspējīgas AE ietvarā un atbilstoši ilgtspējīgas pārtikas sistēmas principiem. Tika izstrādāts zināšanās balstīts rekomendāciju sistēmas prototips un teorētiski pamatots rīcības plāns bezatkritumu pārtikas patēriņa veicināšanai skolās. Novērtēta PPĶ patēriņa posma nozīme pārtikas sistēmas pārveidē un piedāvāts konceptuāls ietvars pārtikas sistēmas transformācijai caur pārtikas patēriņa posmu, akcentējot patērētāju uzvedību kā katalizatoru plašākām pārmaiņām pārtikas patēriņa posmā.

Promocijas darba noslēgumā izteikti secinājumi, definētas galvenās problēmas un izvirzīti priekšlikumi to risināšanai.

ANNOTATION

The doctoral thesis **"Towards zero-waste food consumption: organisation of the catering process in Latvian schools within the framework of a sustainable circular economy"** has been prepared as a thematically unified set of scientific publications and consists of eight interrelated scientific articles. The research was conducted between 2021 and 2025 with the aim of analysing the organisation of the catering process in Rezekne city schools within the framework of a sustainable circular economy and, based on the results of this case study, developing solutions to promote zero-waste food consumption in schools in accordance with the principles of a sustainable food system.

The object of the study is the organisation of the catering process in schools within the framework of a sustainable circular economy.

The subject of the study is food consumption and plate waste in Rezekne city schools.

The relevance of the study is determined by the following factors: 1) The global significance of food loss and waste; 2) The high share of food waste generated at the consumption stage; 3) The reduction of food waste is a priority issue at the global, EU, and national levels; 4) The role of the circular economy in the food sector; and 5) The development potential of school food programmes in the context of sustainability.

The doctoral thesis puts forward the following hypotheses:

H1 The meal serving model in Latvian schools, based on fully or partially pre-portioned meals individually served in advance, does not align with the principles of a sustainable CE and does not promote zero-waste food consumption.

H2 Single interventions to reduce FW do not ensure a long-term impact in the school catering process.

The doctoral thesis consists of three chapters.

The first chapter develops the theoretical framework of the thesis, which serves as the foundation for the empirical research. This chapter analyses the problem of food waste at the global and EU levels, food losses and waste along the food supply chain, as well as the relevant political and strategic framework. It explores the concept of the circular economy and its role in food waste reduction. In addition, the role of the consumption stage within the food supply chain is examined in the context of the broader sustainability of the food system. This includes the classification of food waste, the role of school food programmes within the food system, and the factors influencing food system transformation, including consumer behaviour change.

The second chapter presents the results of empirical studies aimed at assessing the organisation of the catering process in schools in the city of Rezekne within the framework of

a sustainable circular economy. The first field study involved the analysis of plate waste to identify the volume and patterns of plate waste. The second field study focused on the practical implementation and evaluation of targeted interventions for reducing plate waste. The third study assessed students' attitudes and knowledge regarding food waste issues, as well as their perceptions of school lunch organisation.

The third chapter presents solutions for reorganising the catering process and transforming the food system within the framework of a sustainable circular economy. A knowledge-based prototype of a recommendation system was developed, along with a theoretically grounded action plan to promote zero-waste food consumption in schools. The role of the consumption stage in the transformation of the food system was evaluated, and a conceptual framework for its transformation through the consumption stage was proposed, emphasising consumer behaviour as a catalyst for broader changes in food consumption.

The conclusion of the doctoral thesis presents the main findings, identifies key problems, and proposes recommendations for their resolution.

SATURS

SAĪSINĀJUMU UN APZĪMĒJUMU SARAKSTS

AE – aprites ekonomika

ANO – Apvienoto Nāciju Organizācija

ASV – Amerikas Savienotās Valstis

CDD – spēju virzītas attīstības pieeja (*Capability-Driven Development*)

ES – Eiropas savienība

E-mentors – "E-mentors kā transformācijas rīks bezatlikuma pārtikas patēriņa nodrošināšanai izglītības iestādēs"

FAO - Pārtikas un lauksaimniecības organizācija (*Food and Agriculture Organization*)

FLPP – Fundamentālo un lietišķo pētījumu projekti

HLPE – Augsta līmeņa ekspertu grupa (*High Level Panel of Experts*)

LLM – Lielo valodu modelis (*Large Language Model*)

LR – Latvijas Republika

LZP – Latvijas Zinātnes padome

MOA – Motivācijas–iespēju–spēju (*Motivation–Opportunity–Ability*) ietvars

NAM – Normu aktivācijas modelis (*Norm Activation Model*)

PĒAT – pasniegtā ēdiena atkritumi traukos

PPĶ – pārtikas piegādes ķēde

SDGs – ilgtspējīgas attīstības mērķi (*Sustainable Development Goals*)

SNW – stipro, neitrālo un vājo pušu analīzes metode (*The method for analysis of strengths, neutrals and weaknesses)*

TPB – Plānotās uzvedības teorija (*Theory of Planned Behavior)*

UNEP - Apvienoto Nāciju Organizācijas Vides programma (*United Nations Environment Programme*)

UNGA – Apvienoto Nāciju Organizācijas Ģenerālā asambleja (*United Nations General Assembly)*

VARAM – Viedās administrācijas un reģionālās attīstības ministrija

WRAP - Atkritumu un resursu rīcības programma (*Waste and Resources Action Programme*)

BIEŽĀK LIETOTIE TERMINI

Aprites ekonomika. Ekonomikas modelis, kas, izmantojot "R" stratēģijas, galvenokārt ir vērsts uz resursu izmantošanas palēnināšanu un atkritumu mazināšanu, pagarinot materiālu un produktu dzīves ciklu.

Bezatkritumu pārtikas patēriņš. Ēdināšanas procesa organizācija skolās tādā veidā, lai primāri nodrošinātu PĒAT novēršanu un samazināšanu.

Brīvpusdienas. Valsts un/vai pašvaldības finansētas pusdienu maltītes skolēniem, ko viņi saņem bez maksas.

Ēdiena pasniegšanas modelis. Veids, kā tiek organizēta maltīšu pasniegšana. Piemēram, Rēzeknes pilsētas skolās ēdiena pasniegšanas modelis ir pilnībā vai daļēji porcionētas, iepriekš individuāli servētas maltītes.

Ēdināšanas procesa organizācija skolās. Darbību kopums, kas saistīts ar ēdienkartes plānošanu, maltīšu gatavošanu, pasniegšanu, patēriņu un ēdināšanas procesa uzraudzību skolās.

Ilgtspējīga aprites ekonomika. Holistisks aprites ekonomikas modelis, kas primāri ir vērsts uz atkritumu novēršanu un samazināšanu, vienlaikus mainot patēriņa uzvedību un iekļaujot sociālo dimensiju. Šajā modelī aprites principi tiek īstenoti, nodrošinot līdzsvaru starp ilgtspējīgas attīstības ekonomisko, sociālo un vides dimensijām.

Ilgtspējīgas pārtikas sistēmas principi. Izriet no ilgtspējīgas pārtikas sistēmas definīcijas - pārtikas drošības un uztura nodrošināšana esošajai paaudzei, resursu saglabāšana, atbildīgs patēriņš, uztura paradumu maiņa, pārtikas atkritumu novēršana un sociāli taisnīga pārtikas sistēmas pārvaldība, vienlaikus saglabājot vides, sociālos un ekonomiskos pamatus nākotnes paaudzēm.

Pārtikas sistēma. Sarežģīta un dinamiska sistēma un mijiedarbību tīkls, kas aptver pārtikas piegādes ķēdi, pārtikas vidi (pārtikas pieejamība un informācija par pārtiku) un patērētāju uzvedību un visu ar pārtiku saistīto darbību spektru no ražošanas līdz patēriņam un atkritumu apsaimniekošanai.

Skolu ēdināšanas programmas. Valsts un/vai pašvaldības līmeņa iniciatīvas, kas nodrošina skolēniem regulāras, uzturvielām bagātas maltītes skolās ar mērķi uzlabot bērnu veselību, sociālo vienlīdzību un atbalstīt izglītības pieejamību un kvalitāti.

PROMOCIJAS DARBA VISPĀRĒJS RAKSTUROJUMS

Promocijas darbs ir sagatavots kā tematiski vienota zinātnisko publikāciju kopa par ēdināšanas procesa organizāciju Latvijas skolās ilgtspējīgas AE ietvarā. Promocijas darbā galvenā uzmanība ir vērsta uz mērķtiecīgu rīcību pārtikas atkritumu apjoma samazināšanā un atbildīga patēriņa veicināšanā skolās. Ilgtspējīgas AE koncepts tika izmantots kā stratēģisks ietvars bezatkritumu pārtikas patēriņam, jo tas balstās ne tikai uz atkritumu hierarhiju, kur galvenā prioritāte ir pārtikas atkritumu novēršana un samazināšana, bet ietver arī sociālo dimensiju un patēriņa uzvedības maiņu, nodrošinot līdzsvaru starp ekonomiskajiem, sociālajiem un vides aspektiem. Izmantojot šādu pieeju, tika veikta PĒAT analīze Rēzeknes pilsētas skolās, praktiski ieviestas un novērtētas mērķtiecīgas intervences pārtikas atkritumu samazināšanai, novērtēta skolēnu attieksme un zināšanas par pārtikas atkritumu problēmjautājumiem un viņu skatījums uz pusdienu organizēšanu skolās, izstrādāts zināšanās balstīts rekomendāciju sistēmas prototips, novērtēta ēdināšanas procesa organizācija Rēzeknes pilsētas skolās un analizēta pārtikas patēriņa posma loma plašākas pārtikas sistēmas ilgtspējas kontekstā.

Promocijas darba rezultātā izstrādāts konceptuāls rīcības plāns esošā skolu ēdināšanas modeļa transformācijai, kas balstās uz ilgtspējīgas AE un ilgtspējīgas pārtikas sistēmas principiem un konceptuāls ietvars pārtikas sistēmas pārveidei caur patēriņa prizmu. To pamatā ir motivācijas–iespēju–spēju (*Motivation–Opportunity–Ability* (MOA)) patērētāju uzvedības maiņas teorija, kas nodrošina strukturētu skatījumu uz patērētāju uzvedības maiņas nozīmi pārejā uz ilgtspējīgu pārtikas patēriņu.

Apvienojot ilgtspējīgas AE pieeju ar patērētāju uzvedības teorijām un uzvedības ekonomiku, pētījums ir mērķēts uz resursu efektivitāti, procesu pārvaldību un rīcībpolitikas risinājumiem, kas nodrošina tā atbilstību ekonomikas un uzņēmējdarbības apakšnozarei.

Promocijas darba rezultāti veido zinātniski pamatotu un praktiski pārbaudītu pamatu mērķtiecīgu pārtikas atkritumu samazināšanas stratēģiju izstrādei un īstenošanai Latvijas skolās, kā arī piedāvā konceptuālu risinājumu skolu ēdināšanas modeļa, ar pilnībā vai daļēji porcionētām, iepriekš individuāli servētām maltītēm, un pārtikas sistēmu ilgtspējīgai pārveidei.

Promocijas darbs tika sagatavots divu projektu ietvaros, kuros tas ir noteikts kā projekta sasniedzamais rezultāts:

1) Latvijas Zinātnes padomes (LZP) fundamentālo un lietišķo pētījumu projekts (FLPP) "*Intervenču testēšana un uz zināšanām balstītas rekomendāciju sistēmas izstrāde pasniegtā ēdiena atkritumu traukos samazināšanai skolu ēdināšanā Latvijā*" (Nr. lzp-2022/1-0492);

2) ES Atveseļošanas un noturības mehānisma atbalsta projekts "*Konsolidācijas un pārvaldības izmaiņu ieviešana Rīgas Tehniskajā universitātē, Liepājas Universitātē, Rēzeknes Tehnoloģiju akadēmijā un Latvijas Jūras akadēmijā un Liepājas Jūrniecības koledžā virzībai uz izcilību augstākajā izglītībā, zinātnē un inovācijās*", akadēmiskās karjeras doktorantūras grants (Nr. 5.2.1.1.i.0/2/24/I/CFLA/003).

Papildus šiem diviem projektiem, pētījuma empīriskie dati tika iegūti arī LZP FLPP projekta "*E-mentors kā transformācijas rīks bezatlikuma pārtikas patēriņa nodrošināšanai izglītības iestādēs*" (Nr. lzp-2020/2-0115) (E-mentors) ietvaros.

Šis promocijas darbs kā tematiski vienota publikāciju kopa tika izstrādāts balstoties uz sekojošām publikācijām, kas tekstā tiks apzīmētas ar romiešu cipariem:

I - Lonska, J., Zvaigzne, A., Kotane, I., Silicka, I., Litavniece, L., Kodors, S., **Deksne, J.**, Vonoga, A. (2022). Plate Waste in School Catering in Rezekne, Latvia. *Sustainability, 14(7)*, 4046. https://doi.org/10.3390/su14074046 *(Open Access, ind. Scopus, SCIE (Web of Science), etc., JCR - Q2 (Environmental Studies) / CiteScore - Q1 (Geography, Planning and Development))*

II - **Deksne, J.**, Litavniece, L., Zvaigzne, A., Lonska, J., & Kodors, S. (2022). Analysis of factors affecting zero-waste food consumption in schools. *RESEARCH FOR RURAL DEVELOPMENT, 37,* 150–157. https://doi.org/10.22616/rrd.28.2022.022 *(Open Access, ind. Scopus, Web of Science™, etc.)*

III - **Deksne, J.** (2024). Circular Economy as a Tool for Sustainable Development: A Theoretical Perspective. In *ENVIRONMENT. TECHNOLOGIES. RESOURCES. Proceedings of the International Scientific and Practical Conference* (Vol. 1, pp. 102-110). https://doi.org/10.17770/etr2024vol1.7954 *(Open Access, ind. Scopus)*

IV - **Dekšne, J**., Litavniece, L., Lonska, J., & Zvaigzne, A. (2023). Circular Economy Strategies for Reducing Food Waste in Schools: A Systematic Literature Review. *Journal of Regional Economic and Social Development*, *15*, 29-39. https://doi.org/10.17770/jresd2023vol15.7330 *(Open Access, ind. Copernicus, EBSCOhost Business Source Corporate Plus)*

V - Lonska, J., Kodors, S., **Deksne, J.**, Litavniece, L., Zvaigzne, A., Silicka, I., & Kotane, I. (2025). Reducing Plate Waste in Latvian Schools: Evaluating Interventions to Promote Sustainable Food Consumption Practices. *Foods*, *14*(1), 126. https://doi.org/10.3390/foods14010126 *(Open Access, ind. Scopus, SCIE (Web of Science), etc., JCR - Q1 (Food Science and Technology) / CiteScore - Q1 (Health Professions (miscellaneous)))*

VI - **Deksne, J.**, Lonska, J., Kodors, S., Litavniece, L., Zvaigzne, A., Silicka, I., & Kotane, I. (2025). Insights into Awareness and Perceptions of Food Waste and School Catering Practices: A Student-Centered Study in Rezekne City, Latvia. *Resources*, *14*(4), 59. https://doi.org/10.3390/resources14040059 *(Open access, ind. Scopus, SCIE (Web of Science), etc., JCR - Q2 (Environmental Sciences), Q1 (Nature and Landscape Conservation))*

VII - Kodors, S., Lonska, J., Zarembo, I., Zvaigzne, A., Apeinans, I., & **Deksne, J**. (2024). Knowledge-Based Recommendation System for Plate Waste Reduction in Latvian Schools. *Sustainability*, *16*(19), 8446. https://doi.org/10.3390/su16198446 *(Open Access, ind. Scopus, SCIE (Web of Science), etc., JCR - Q2 (Environmental Studies) / CiteScore - Q1 (Geography, Planning and Development))*

VIII - **Deksne, J.**, Lonska, J., Litavniece, L., Tambovceva T. (2025). Shaping Sustainability Through Food Consumption: A Conceptual Perspective. *Sustainability*, *17*(15), 7138. https://doi.org/10.3390/su1715713 *(Open Access, ind. Scopus, SCIE (Web of Science), etc., JCR - Q2 (Environmental Studies) / CiteScore - Q1 (Geography, Planning and Development))*

Saskaņā ar Ministru kabineta 2005. gada 27. decembra (ar grozījumiem 30.04.2020.) noteikumiem Nr. 1001 "Zinātniskā doktora grāda piešķiršanas (promocijas) kārtība un kritēriji" 9. punktu (Ministru kabinets, 2005), promocijas darbam ir pievienotas promocijas darbā iekļauto publikāciju līdzautoru rakstiskas piekrišanas publikāciju izmantošanai promocijā.

Publikācijas, kas tika sagatavotas, bet nav iekļautas šajā darbā:

- **Deksne, J.**, Lonska, J., Litavniece, L., Kotane I., Zvaigzne, A., & Silicka, I. (2025). Age effect on plate waste in Latvian schools. Iesniegta žurnālā *Discover Sustainability*.

- **Deksne, J.**, & Litavniece, L. (2022). Principles of A Circular Economy in The Food Sector: A Systematic Literature Review. *Journal of Regional Economic and Social Development*, *14*, 20-28. https://doi.org/10.17770/jresd2022vol14.6969

- Kodors, S., Zvaigzne, A., Litavniece, L., Lonska, J., Silicka, I., Kotane, I., & **Deksne, J**. (2022). Plate waste forecasting using the Monte Carlo method for effective decision making in Latvian schools. *Nutrients*, *14*(3), 587. https://doi.org/10.3390/nu14030587

Dalība konferencēs:

- 5. starptautiskā konference "RETASTE: Rethink Food Resources, Losses, and Waste 2025", Harokopio University un Hellenic Mediterranean University, Atēnas, Grieķija

Prezentācija: *Beyond the Bin: Environmental Footprint of Plate Waste in Latvian Schools*.

- 65. starptautiskā zinātniskā konference "Scientific Conference on Economics and Entrepreneurship (SCEE'2024)", Rīgas Tehniskā universitāte, Latvija.

Prezentācija: *Towards sustainable food systems: An analysis of barriers and drivers in the food consumption stage* (uz raksta *Shaping Sustainability Through Food Consumption: A Conceptual Perspective* bāzes).

- 4. starptautiskā konference "RETASTE: Rethink Food Resources, Losses, and Waste 2024", Hellenic Mediterranean University un Harokopio University, Herakliona, Grieķija

Prezentācija: *Assessing Schoolchildren's Awareness and Perceptions of Food Waste and School Catering: a Study of Rezekne City Schools, Latvia* (uz raksta *Insights into Awareness and Perceptions of Food Waste and School Catering Practices: A Student-Centered Study in Rezekne City, Latvia* bāzes).

- 15. starptautiskā zinātniski praktiskā konference "Environment. Technology. Resources.", organizēja Rēzeknes Tehnoloģiju akadēmijas Inženieru fakultāte, rīkoja "Vasil Levski" Nacionālā militārā universitāte, Bulgārijā.

Raksts: *Circular economy as a tool for sustainable development: a theoretical perspective*

- 29. starptautiskā zinātniskā konference "Research for Rural Development 2023", Latvijas Biozinātņu un tehnoloģiju universitātē.

Raksts: *A circular economy approach to reduce food waste in schools*

- 28. starptautiskā zinātniskā konference "Research for Rural Development 2022", Latvijas Lauksaimniecības universitātē.

Raksts: *Analysis of factors affecting zero-wastefood consumption in schools*

IEVADS

Tēmas izvēli un aktualitāti nosaka:

1) Pārtikas izšķērdēšanas un atkritumu globālā nozīme. Tā ir sarežģīta un daudzdimensionāla problēma pārtikas sistēmā, kas būtiski ietekmē visus ilgtspējas aspektus (de los Mozos et al., 2020; Massari et al., 2021) un vispārējo planētas noturību (Caesar et al., 2024). PPĶ ik gadu tiek zaudēta vai izšķērdēta trešā daļa cilvēku patēriņam paredzētās pārtikas (UNEP, 2024; WFP, 2024), saasinot sociālo nevienlīdzību, jo ar izmestās pārtikas daudzumu varētu nodrošināt maltīti aptuveni 2 miljardiem cilvēku, graujot ekonomisko noturību, jo pārtikas atkritumu ekonomiskie zaudējumi sastāda aptuveni 1 triljonu ASV dolāru gadā (WFP, 2024), kā arī vides ilgtspēju, jo rada gandrīz piecas reizes vairāk siltumnīcefekta gāzu emisijas nekā aviācijas nozare - 8-10% gadā (WRAP, 2024)**.**

2) Augsts pārtikas atkritumu īpatsvars patēriņa posmā. Pārtikas atkritumi valstīs ar vidējiem un augstiem ienākumiem ir galvenā problēma PPĶ patēriņa posmā (Derqui et al., 2018; FAO, 2011; García-Herrero et al., 2019; Ishangulyyev et al., 2019; Kasavan et al., 2021; Wunderlich & Martinez, 2018), kur veidojas aptuveni 35% no kopējiem pasaules pārtikas zudumiem un atkritumiem (FAO, 2011; Yahia & Mourad, 2019). ES situācija ir vēl sarežģītāka, jo mājsaimniecības un ēdināšanas pakalpojumu sektors kopā veido 65,4% no kopējā pārtikas atkritumu apjoma. 2022. gadā Latvijā, mājsaimniecības un ēdināšanas pakalpojumu sektors, ģenerēja 68,6% no kopējā pārtikas atkritumu daudzuma valstī, kas pārsniedz vidējo ES līmeni (Eurostat, 2024). Ir izpētīts, ka pārtikas patēriņa posmam, ar patērētāju tā centrā, ir galvenā loma virzībā uz ilgtspējīgu pārtikas sistēmu, jo patērētāju lēmumi un rīcība tieši ietekmē visus pārējos PPĶ posmus un līdz ar to arī visus procesus pārtikas sistēmā kopumā (Deksne et al., 2025b), kas nepārprotami norāda uz nepieciešamību īstenot pārtikas atkritumu samazināšanas pasākumus tieši šajā posmā.

3) Pārtikas atkritumu samazināšana ir viens no prioritāri risināmiem jautājumiem, globālā, ES un nacionālā līmenī. Apvienoto Nāciju Organizācijas (ANO) "Ilgtspējīgas attīstības mērķi 2030. gadam" (angl. – *Sustainable Development Goals, SDGs*) 12. mērķis paredz veicināt atbildīgu ražošanu un patēriņu, un līdz 2030. gadam uz pusi samazināt pārtikas atkritumu apjomu uz vienu iedzīvotāju patērētāju līmenī (UNGA, 2015). ES pamata iniciatīvā un visaptverošajā stratēģijā *Eiropas Zaļais kurss (European Green Deal)* (European Commission, 2019b; European Council, Council of the EU, 2025a)*,* un šīs stratēģijas kontekstā Eiropas Komisijas izstrādātajā "*Jauns aprites ekonomikas rīcības plāns. Par tīrāku un konkurētspējīgāku Eiropu*" (European Commission, 2020b) un stratēģijā "*No lauka līdz galdam*" (European Commission, 2020a; European Council, Council of the EU, 2025b) ir noteiktas skaidras vadlīnijas dalībvalstīm attiecībā uz pārtikas atkritumu mērīšanu un

pārvaldību, akcentēta nepieciešamība mainīt patēriņa paradumus un uzvedību, un integrēt AE principus visos PPĶ posmos ar galveno uzsvaru uz atkritumu novēršanu un optimālu resursu izmantošanu (European Commission, 2020b). Arī Latvijā nacionālā līmenī tiek domāts par pārtikas atkritumu samazināšanu un šis uzdevums ir integrēts vairākos politikas plānošanas dokumentos, kā piemēram, "*Latvijas Ilgtspējīgas attīstības stratēģijā līdz 2030.gadam*" (LR Saeima, 2010b; Pārresoru koordinācijas centrs, 2016), "*Latvijas Nacionālājā attīstības plānā 2021.-2027.gadam*" (Pārresoru koordinācijas centrs, 2020), "*Rīcības plānā pārejai uz aprites ekonomiku 2020.-2027.gadam*" (VARAM, 2020b) u.c.

Jāatzīmē, ka lielākajai daļai politikas plānošanas dokumentu tuvojas īstenošanas beigu termiņš (2027.-2030.gads), kas nozīmē, ka ir būtiska un aktuāla līdz šim veikto pasākumu izvērtēšana un datu apkopošana, lai novērtētu, vai izvirzītie mērķi tiek sasniegti, kā arī, lai nodrošinātu pamatu jaunu stratēģiju plānošanā un politikas dokumentu izstrādē nākošajam periodam.

4) AE loma pārtikas nozarē. Pārtika ir viena no galvenajām AE produktu vērtību ķēdēm un šajā kontekstā tiek pozicionēta kā spēcīgs konceptuāls un politikas instruments ilgtspējīgas pārtikas sistēmas veidošanā (Deksne, 2024; European Commission, 2020b; Skawińska & Zalewski, 2018; The Ellen Macarthur Foundation, 2025). AE stratēģijas balstās uz atkritumu hierarhijas principiem, kur augstākā prioritāte ir pārtikas atkritumu novēršanai un samazināšanai (European Parliament & Council, 2008; Khaw-ngern et al., 2021). Saskaņā ar AE konceptu, tās mērķis ir izveidot bezatkritumu pārtikas sistēmu (The Ellen Macarthur Foundation, 2025).

5) Skolu ēdināšanas programmu attīstības potenciāls ilgtspējas kontekstā. Sabiedriskās ēdināšanas pakalpojumu nozare var būtiski ietekmēt virzību uz ilgtspējīgu pārtikas sistēmu (Kretschmer & Dehm, 2021). Šajā kontekstā skolu ēdināšanas vides transformācija sniedz iespēju piedāvāt bērniem veselīgu un ilgtspējīgu pārtiku, ieviest un īstenot dažādas iniciatīvas pārtikas atkritumu samazināšanai (Lonska et al., 2022, 2025), veicinot nākotnes patērētāju paaudzes atbildīgu pārtikas patēriņu un attieksmi (Newsome et al., 2023), kā arī skolu ēdināšana sniedz kvantitatīvos datus par pārtikas atkritumu apjomiem, kas ļauj apzināt šo problēmu valsts un ES mērogā (Lonska et al., 2022, 2025). Turklāt skolu ēdināšanas transformācijas procesā skolēni darbojas kā pārmaiņu aģenti ne tikai vietējā līmenī, bet arī plašākā pārtikas sistēmas pārvaldības kontekstā (Fudla et al., 2022; World Health Organization, 2017).

Latvijā, salīdzinot ar citām ES valstīm, skolu ēdināšanas programmu potenciāls nav pilnvērtīgi novērtēts. Deksne et al., (2025a) atklāja, ka Latvijā ir īstenotas vairākas iniciatīvas pārtikas atkritumu samazināšanai skolu ēdināšanā, tomēr promocijas darba ietvaros veiktie

empīriskie pētījumi ir vieni no pirmajiem un plašākajiem šajā jomā Latvijā. Šobrīd problēma ir aktualizēta arī valsts mērogā, Zemkopības ministrijai izstrādājot rīcības plānu skolu ēdināšanas programmas pilnveidošanai Latvijā. 2024.gadā Ministru kabinetam ir iesniegts ziņojums "Par skolēnu ēdināšanas sistēmas pilnveidošana Latvijā" ar mērķi palielināt vietējās un bioloģiskās pārtikas īpatsvaru skolēnu ēdināšanā, attīstīt īsās piegādes ķēdes un piesaistīt vietējos ražotājus, kā arī padziļināt izpratni par veselīgu uzturu, ēšanas kultūru un ilgtspējīgu dzīvesveidu visām skolēnu ēdināšanā iesaistītajām pusēm (Zemkopības ministrija, 2024). Pārtikas atkritumu jautājums ziņojumā ir minēts kā viens no aspektiem ilgtspējas veicināšanai, kas jāskata kā daļa no ēdināšanas procesa organizācijas. Tas apliecina, ka nepieciešamība mainīt esošo ēdināšanas procesa organizāciju skolās ir atzīta politikas līmenī un norāda uz mērķtiecīgu skolu ēdināšanas procesa attīstību turpmākajos gados.

Šajā promocijas darbā ēdināšanas procesa organizācija skolās tiek pētīta kā būtiska PPĶ patēriņa posma daļa AE kontekstā, kuras pārveide var veicināt ilgtspējīgu pārtikas patēriņu un kļūt par atspēriena punktu pārmaiņu veicināšanai plašākā pārtikas sistēmā un izvirzīto SDGs sasniegšanā.

Pētījuma objekts: Ēdināšanas procesa organizācija skolās ilgtspējīgas AE ietvarā.

Pētījuma priekšmets: Pārtikas patēriņš un PĒAT Rēzeknes pilsētas skolās.

Pētījuma mērķis: Izpētīt ēdināšanas procesa organizāciju Rēzeknes pilsētas skolās ilgtspējīgas AE ietvarā un, balstoties uz šī gadījuma izpētes rezultātiem, izstrādāt risinājumus bezatkritumu pārtikas patēriņa veicināšanai skolās ar līdzīgu ēdināšanas modeli atbilstoši ilgtspējīgas pārtikas sistēmas principiem.

Uzdevumi:

1. Veikt visaptverošu pārtikas atkritumu problemātikas teorētisko izpēti.

2. Veikt PĒAT analīzi Rēzeknes pilsētas skolās, lai identificētu radīto pārtikas atkritumu apjomus un tos ietekmējošos faktorus.

3. Analizēt AE konceptu un izvērtēt tā lomu bezatkritumu pārtikas patēriņa veicināšanā un pārtikas atkritumu mazināšanā.

4. Izpētīt un apkopot pārtikas atkritumu novēršanas un samazināšanas pasākumus patēriņa posmā, identificējot intervences, kas ir vērstas uz skolēnu uzvedības maiņu un varētu tikt īstenotas skolās, un novērtēt izvēlēto intervenču ietekmi uz PĒAT apjomu trīs skolās, izmantojot ceturto skolu kā kontroles grupu.

5. Izpētīt un novērtēt skolēnu informētību un zināšanas par pārtikas atkritumu jautājumiem, viņu attieksmi pret skolas ēdienu un ēdināšanas organizēšanu, un identificēt subjektīvos PĒAT cēloņus.

6. Izstrādāt uz mākslīgā intelekta bāzes un ekspertu zināšanās balstītu rekomendāciju sistēmas prototipu, kura mērķis ir novērtēt skolas ekosistēmu un sniegt personalizētas rekomendācijas ēdināšanas procesa organizācijas pilnveidošanai skolā, lai samazinātu PĒAT apjomus, un novērtēt tā pielietošanas iespējas skolu ēdināšanas procesa pārvaldībā.

7. Veikt Rēzeknes pilsētas skolu ēdināšanas procesa novērtējumu un izstrādāt teorētiski pamatotu konceptuālu rīcības plānu bezatkritumu pārtikas patēriņa veicināšanai Latvijas skolu ēdināšanā ar līdzīgu ēdināšanas modeli, balstoties uz ilgtspējīgas AE un ilgtspējīgas pārtikas sistēmas principiem.

8. Novērtēt pārtikas patēriņa posma lomu pārtikas sistēmas pārveidē uz ilgtspējīgu modeli, un izstrādāt konceptuālu ietvaru pārtikas sistēmas pārveidei caur atbildīga patēriņa prizmu.

Pētījuma hipotēzes:

H1 Latvijas skolās ēdiena pasniegšanas modelis ar iepriekš individuāli servētām pilnībā vai daļēji porcionētām maltītēm, neatbilst ilgtspējīgas AE principiem un neveicina bezatkritumu pārtikas patēriņu.

H2 Atsevišķi īstenotas intervences pārtikas atkritumu mazināšanai nenodrošina ilgtermiņa ietekmi skolu ēdināšanas procesā.

Pētījuma periods: 2021.gada septembris-2025.gada augusts.

Pētījuma ierobežojumi.

Šajā promocijas darbā ir jānošķir divu veidu rezultāti: empīriskie (gadījuma izpētes dati) un teorētiski-konceptuālie (izstrādātie risinājumi). Šī promocijas darba empīriskie pētījumi tika veikti Latvijā, Rēzeknes pilsētas skolās, kur ēdiena pasniegšanas modelis ir pilnībā vai daļēji porcionētas, iepriekš individuāli servētas maltītes un standartizētas ēdienkartes bez iespējas skolēniem izvēlēties ēdiena daudzumu un veidu, līdz ar to iegūtie rezultāti var ierobežot secinājumu vispārināmību uz citām Latvijas vai ārvalstu skolām ar atšķirīgu ēdināšanas procesa organizāciju. Ierobežojums neattiecas uz izstrādātajiem risinājumiem, jo tie balstās uz pārtikas atkritumu sistēmisko cēloņu identificēšanu patēriņa posmā, MOA uzvedības teoriju, ilgtspējīgas AE un pārtikas sistēmas principiem, līdz ar to ir vispārināmi un izmantojami skolās ar analogu ēdināšanas modeli arī ārpus Rēzeknes.

Empīrisko pētījumu pamats ir PĒAT, t.i., tikai tie pārtikas atkritumi, kas paliek uz skolēnu šķīvjiem pēc ēšanas. Citi pārtikas atkritumu veidi, piemēram, kas rodas gatavošanas laikā, netika analizēti. Turklāt pētījumā iekļautajās 1.-7. klasēs (skolēnu vecums 6/7-13/14 gadi) tika nodrošinātas valsts un pašvaldību finansētas brīvpusdienas, kas varēja ietekmēt skolēnu attieksmi pret skolas ēdienu un pārtikas atkritumiem.

Pētījums ir vērsts uz PĒAT apjoma, cēloņu un ar to saistīto faktoru izpēti, kā arī uz PĒAT samazināšanu un novēršanu. Papildus pētījumā tika identificēti ievērojami finansiālie zaudējumi, kas saistīti ar PĒAT skolās. Šī informācija iekļauta promocijas darbā, lai akcentētu slēptās izmaksas, kas netiek ņemtas vērā valsts un pašvaldības finansējuma uzskaitē un tādējādi norāda uz būtiskiem finanšu resursu zudumiem patēriņa posmā. Padziļināta izmaksu un ieguvumu analīze darbā netika veikta, jo tai nepieciešami plaši finanšu un institucionālie dati un ilgtermiņa darbības rādītāji, kas pārsniedz šī pētījuma empīrisko ietvaru.

Pētījuma ētiskie aspekti. Visi pētījuma ētiskie aspekti tika izskatīti un apstiprināti Rēzeknes Tehnoloģiju akadēmijas Biznesa un sociālo procesu pētniecības institūta Zinātniskajā padomē un atbilst Zinātniskās ētikas pamatprincipiem (izraksts no sēdes protokola Nr. 9, 25.04.2023.).

Par skolēnu iesaisti pilotpētījumā un aptaujā. Skolu administrācijas piekrita iesaistīties projektā un īstenot projekta aktivitātes skolās. Skolēnu vecāki tika informēti par projekta norisi un paredzamajām aktivitātēm, tajā skaitā par viņu bērnu anonīmu un brīvprātīgu dalību aptaujā, izmantojot tiešsaistes skolu vadības sistēmu "E-klase". Vecāku rakstiska piekrišana bērnu dalībai netika prasīta, jo projekta laikā netika vākti skolēnu sensitīvie dati. Tie vecāki, kuri nevēlējās, lai viņu bērni piedalās aptaujā, varēja sniegt rakstisku atbildi uz izsūtīto ziņu "E-klases" e-pastā, bet šajā pilotpētījumā visi vecāki piekrita viņu bērnu anonīmai dalībai aptaujā. Pētījuma gaitā skolēni netika pakļauti fiziskam vai emocionālam riskam.

Pētījuma teorētiskais un metodoloģiskais pamats ir starptautiska un nacionāla līmeņa politikas plānošanas dokumenti, Latvijas un ES normatīvie akti un zinātniskie raksti par bezatkritumu ēdināšanas procesa organizēšanu un AE principu īstenošanu skolās ārvalstīs un Latvijā.

Nozīmīgākie autori, kuri ir veikuši plašus pētījumus par PĒAT, to iemesliem un samazināšanas iespējām skolu ēdināšanā, ir Belena Derki (*Belén Derqui*), Matīass Ēriksons (*Mattias Eriksson*), Luka Falaskoni (*Luca Falasconi*), Laura Garsija-Erero (*Laura García-Herrero*), Kristofers Maleforss (*Christopher Malefors*) un Sarasvati Kasavana (*Saraswathy Kasavan*). Klāra Cikatjelo (*Clara Cicatiello*) ir pētījusi pārtikas atkritumu problēmu plašākā pārtikas sistēmas kontekstā un arī veikusi vairākus nozīmīgus pētījumus par PĒAT skolu ēdināšanā. Klaudija Džordāno (*Claudia Giordano*) ir nozīmīga pārtikas atkritumu mērīšanas metodoloģijas attīstībā, kā arī politikas un pārvaldības izpētē ilgtspējīgu pārtikas sistēmu veidošanā. Aprites ekonomikas koncepta izpētē un attīstībā nozīmīgi ir Valters R. Štahēls (*Walter R. Stahel*), Juliāns Kirhērs (*Julian Kirchherr*), Žozē Pottingsa (*José Potting*) un Daniels Holzers (*Daniel Holzer*). Savukārt, Folke Ēlanders (*Folke Ölander*) un Džons Tēgersens (*John*

Thøgersen) ieviesa MOA ietvaru patērētāju uzvedības skaidrošanai, bet Mateo Vituāris (*Matteo Vittuari*) to ir paplašinājis, analizējot patērētāju uzvedību no daudzlīmeņu perspektīvas.

Pētījuma dizains un izmantotās pētījuma metodes.

Promocijas darba apjoms ir 72 lapas neiekļaujot izmantotās literatūras un avotu sarakstu un pielikumus. Promocijas darbā iekļauti 17 attēli un 2 tabulas. Izmantotās literatūras un avotu sarakstā iekļautas 168 literatūras vienības.

Atbilstoši promocijas darba specifikai un izvērtējot teorētiskās pieejas, par pētījuma struktūras pamatu izvēlēts jaukta tipa pētījuma dizains, kurā kombinētas kvantitatīvās un kvalitatīvās metodes, tajā skaitā eksperimentālie pētījumi. Pētījuma struktūra veidota saskaņā ar definēto mērķi un tā sasniegšanai noteiktajiem uzdevumiem. Pētījums sastāv no vairākiem secīgiem posmiem, kas atspoguļoti zinātniskajās publikācijās. Katrā posmā izmantotas konkrētas metodes, kas nodrošināja mērķa un uzdevumu sasniegšanu (0.1. attēls).
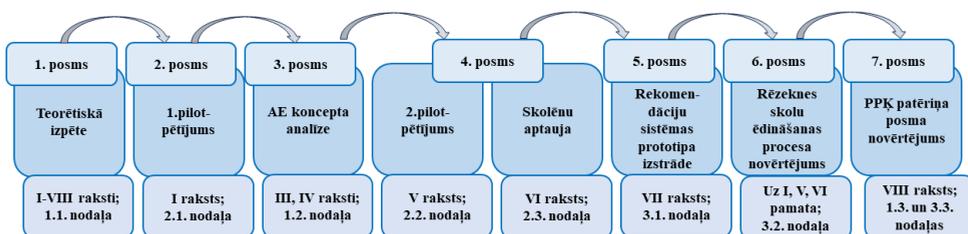
0.1. attēls. Pētījuma struktūras shematisks attēlojums (autores veidots)

1. posmā, izmantojot tādas metodes kā literatūras pārskati (t.sk., sistemātisks, integratīvs, narratīvs), literatūras sintēze un analīze, monogrāfisko jeb aprakstošo un loģiskās konstrukcijas metode, analizēta pārtikas izšķērdēšanas problēma globālā un ES līmenī, pārtikas zudumi un atkritumi PPĶ, kā arī atbilstošais politiskais un stratēģiskais ietvars (I, II raksti, promocijas darbā - 1.1. nodaļa).

2. posmā veikts **pirmais pilotpētījums** – viens 5 dienu lauka pētījums 7 Rēzeknes skolās, lai identificētu radīto pārtikas atkritumu apjomus un tos ietekmējošos faktorus (I raksts, promocijas darbā - 2.1. nodaļa). Pilotpētījumā izmantotas šādas metodes: lauka pētījums, sekundāro datu analīze, PĒAT sveršana, PĒAT izmaksu aprēķins, SNW analīze, novērošana, daļēji strukturētas intervijas, aprakstošā statistika, vienvirziena dispersijas analīze (ANOVA).

3. posmā, izmantojot narratīva un sistemātiska literatūras pārskata, literatūras sintēzes un analīzes, monogrāfiskās jeb aprakstošās un loģiskās konstrukcijas metodes, **tika analizēts AE koncepts** un tā pielietojuma iespējas, lai veicinātu bezatkritumu pārtikas patēriņu skolu ēdināšanas procesā (III, IV raksti, promocijas darbā – 1.2. nodaļa).

4. posmā veikti divi pētījumi, kuru mērķis bija novērtēt ēdināšanas procesa organizāciju Rēzeknes pilsētas skolās ilgtspējīgas AE ietvarā:

- tika veikts **otrais pilotpētījums** (kvazieksperiments) – trīs piecu dienu lauka pētījumi 4 Rēzeknes pilsētas skolās, lai praktiski pārbaudītu un novērtētu izvēlēto intervenču ietekmi uz PĒAT apjomu trīs skolās, izmantojot ceturto skolu kā kontroles grupu (V raksts, promocijas darbā - 2.2. nodaļa). Pilotpētījumā izmantotas šādas metodes: 3 lauka pētījumi, intervenču testēšana (kvazieksperiments), sekundāro datu analīze, PĒAT svēršana, novērošana, aprakstošā statistika, Vilkoksona rangu summas tests.
- veikta **skolēnu aptauja** Rēzeknes pilsētas skolās (VI Raksts, promocijas darbā - 2.3. nodaļa). Pētījumā izmantotas šādas metodes: skolēnu aptauja, pilotintervijas ar skolēniem aptaujas validēšanai, aprakstošā statistika, Kruskala-Valisa H tests, Manna Vitnija U tests (ar Bonferroni korekciju), Spīrmana rangu korelācija.

5. posmā tika izstrādāts uz mākslīgā intelekta bāzes un ekspertu zināšanās balstīts rekomendāciju sistēmas prototips ēdināšanas procesa organizācijas optimizēšanai (VII raksts, promocijas darbā – 3.1. nodaļa). Pētījumā izmantotas šādas metodes: sekundāro datu analīze, audits un ieteikumu izstrāde, ekspertu vērtējums izmantojot pāru salīdzinājuma metodi, spēju virzītas attīstības pieeja (CDD), lielo valodu modeļa (LLM) testēšana klasifikatoru funkcionalitātes pārbaudē.

6. posmā, pamatojoties uz empīrisko pētījumu rezultātiem (I, V, VI raksts), veikts Rēzeknes skolu ēdināšanas procesa novērtējumu un izstrādāts teorētiski pamatots konceptuāls rīcības plāns bezatkritumu pārtikas patēriņa veicināšanai Latvijas skolu ēdināšanas procesa organizācijā, balstoties uz ilgtspējīgas AE un ilgtspējīgas pārtikas sistēmas principiem (promocijas darbā – 3.2. nodaļa).

7. posmā, izmantojot bibliometriskās analīzes un integratīvās literatūras pārskata metodes, analizēts pārtikas patēriņa posms plašākā pārtikas sistēmas transformācijas kontekstā un izstrādāts konceptuāls ietvars pārmaiņu vadīšanai (VIII raksts, promocijas darbā – 1.3. un 3.3. nodaļas).

Promocijas darba noslēgumā izteikti galvenie secinājumi, definētas galvenās problēmas un izvirzīti priekšlikumi to risināšanai.

Šāda struktūra nodrošina visaptverošu skolu ēdināšanas procesa novērtējumu ilgtspējīgas AE ietvarā un ir pielietojama skolās ar līdzīgu ēdināšanas procesa organizāciju. Pielāgojot metodes konkrētajiem skolas ekosistēmas parametriem, pētījuma struktūra var tikt izmantota arī citos ēdināšanas modeļos.

Pētījuma novitāte un zinātniskais nozīmīgums.

Pirmo reizi Latvijā tika veikts visaptverošs jauktu metožu pētījums par pārtikas atkritumu mazināšanu skolu ēdināšanas procesā ilgtspējīgas AE ietvarā, ko var izmantot kā instrumentu skolu ēdināšanas procesa organizācijas novērtēšanai, apvienojot kvalitatīvās, kvantitatīvās un

eksperimentālās metodes. Atšķirībā no līdzšinējiem pētījumiem, kur tiek pētīti atsevišķi aspekti, šajā darbā piedāvāta holistiska pieeja un secīgi pētījuma posmi, kas ļauj ne tikai novērtēt esošo situāciju, bet arī praktiski izmantot izstrādāto rīcības plānu ieviešanai skolu ēdināšanas procesā un konceptuālo ietvaru pārtikas sistēmas transformācijā.

Šī promocijas darba ietvaros:

1. Pirmo reizi Latvijas skolās, nodrošinot vienotu ēdienkarti, veikta PĒAT svēršana pa ēdienu veidiem vienlaicīgi vairākās skolās.

2. Identificēti un apkopoti faktori, kas ietekmē PĒAT veidošanos un kavē bezatkritumu pārtikas patēriņu skolu ēdināšanas procesā.

3. Veikta visaptveroša uz pārtikas atkritumu samazināšanu vērstu intervenču analīze, identificējot un klasificējot intervences, kas vērstas uz skolēnu uzvedības maiņu un varētu tikt ieviestas skolās.

4. Pirmo reizi Latvijā veikts pētījums (kvazieksperiments), kurā pārbaudīta pasaules labās prakses ietvaros izstrādāto pārtikas atkritumu samazināšanas intervenču efektivitāte Latvijas skolu ēdināšanas modeļa apstākļos.

5. Pirmo reizi Latvijā veikta plaša skolēnu aptauja, kurā novērtēta skolēnu izpratne un zināšanas par pārtikas atkritumu problēmu, un attieksme pret skolu ēdnīcās pasniegto ēdienu un ēdināšanas procesa organizāciju.

6. Integrējot ekspertu zināšanas, izstrādāts Latvijā pirmais uz mākslīgā intelekta balstīts rekomendāciju sistēmas prototips personalizētai pārtikas atkritumu samazināšanai skolu ēdināšanas procesā.

7. Padziļināti analizēts un pielāgots AE koncepts pārtikas atkritumu novēršanai un samazināšanai un ilgtspējīga pārtikas patēriņa veicināšanai skolu ēdināšanas procesā, piedāvājot ilgtspējīgas AE konceptu, kas integrē vides, ekonomiskos un sociālos aspektus un risina tradicionālās AE ierobežojumus.

8. Novērtēts Rēzeknes pilsētas skolu ēdināšanas process un izstrādāts zinātniski un praktiski pamatots konceptuāls rīcības plāns ēdināšanas procesa organizācijas transformācijai, balstoties uz ilgtspējīgas AE un pārtikas sistēmas principiem.

9. Veikta padziļināta PPĶ patēriņa posma analīze, atklājot galvenās problēmas un to risinājumus, un izstrādāts konceptuāls ietvars pārtikas sistēmas pārveidei caur patēriņa prizmu. Tas balstās uz MOA ietvaru mikro, mezo un makro līmeņos, un izvirza patērētāju uzvedību ilgtspējīgas pārveides pamatā.

Pētījuma tautsaimnieciskais nozīmīgums

Promocijas darba ietvaros iegūtie rezultāti ir praktiski izmantojami Izglītības un zinātnes ministrijas, Zemkopības ministrijas, Viedās administrācijas un reģionālās attīstības ministrijas

un Veselības ministrijas darbā, gan ēdināšanas procesa organizācijas skolās pilnveidošanā, gan pārtikas atkritumu samazināšanas politikā. Izstrādātos priekšlikumus un rekomendācijas var izmantot pašvaldības, skolu vadība, ēdinātāji un citas ieinteresētās puses ēdināšanas procesa organizēšanas un pārvaldības uzlabošanai, paaugstinot skolu ēdināšanas procesa kvalitāti, samazinot izmaksas valsts budžetā un veicinot skolēnu izpratni par pārtikas atkritumiem un ilgtspējīgu patēriņu.

Izstrādātais konceptuālais rīcības plāns ēdināšanas procesa organizācijas transformācijai nodrošina pamatu skolu ēdināšanas politikas un stratēģiju izstrādē un īstenošanā gan valsts politikas plānošanas līmenī, gan vietējās pašvaldībās un skolās.

Izstrādātais konceptuāls ietvars pārtikas sistēmas pārveidei caur patēriņa prizmu var būt ceļvedis politikas veidotājiem mērķtiecīgu intervenču un stratēģiju izstrādei un ieviešanai, lai risinātu patēriņa posma problēmas un veicinātu pāreju uz ilgtspējīgu pārtikas sistēmu.

Turklāt veicinot ilgtspējīgu un atbildīgu pārtikas patēriņu jau no mazotnes, izglītības posmā, ilgtermiņā tiek veidota sabiedrība, kas apzinās un izprot pārtikas izšķērdēšanas ietekmi uz vidi, kā arī tās ekonomiskās un sociālās sekas. Tas ir nozīmīgs ieguldījums valsts ilgtspējas attīstībā.

Aizstāvēšanai izvirzītās tēzes

1. Pārtikas atkritumi un pārtikas izšķērdēšana ir izaicinoša un daudzdimensionāla problēma pārtikas sistēmā un it sevišķi PPĶ patēriņa posmā.

2. Skolu ēdināšanā tiek radīts ievērojams PĒAT apjoms, kas sastāda aptuveni 20% no kopējā pasniegtā ēdiena apjoma.

3. Ilgtspējīgas AE koncepts nodrošina teorētisko un stratēģisko pamatu bezatkritumu pārtikas patēriņa veicināšanai skolās, primāri akcentējot pārtikas atkritumu novēršanu un strukturētu pieeju to samazināšanai, vienlaicīgi integrējot patēriņa uzvedības maiņu un sociālo dimensiju, tādējādi nodrošinot līdzsvaru starp ekonomiskajiem, sociālajiem un vides aspektiem.

4. Neviena atsevišķi īstenotā intervence nav pietiekama kā ilgtermiņa risinājums pārtikas atkritumu samazināšanai skolās.

5. Rēzeknes pilsētas skolu skolēniem ir ierobežotas zināšanas par pārtikas atkritumu problēmu, zema izpratne par to negatīvo ietekmi, samērā negatīva attieksme pret skolas ēdienu un nepietiekoša personīgās atbildības izjūta un motivācija mazināt pārtikas izšķērdēšanu.

6. Uz mākslīgā intelekta un ekspertu zināšanās balstītas rekomendāciju sistēmas ieviešana var nodrošināt katrai skolai piemērotu personalizētu, praktiski pielietojamu risinājumu piedāvājumu PĒAT samazināšanai skolu ēdināšanā.

7. Ēdiena pasniegšanas modelis ar iepriekš individuāli servētām pilnībā vai daļēji porcionētām maltītēm, Rēzeknes pilsētas skolās nav ilgtspējīgs.

8. PPĶ patēriņa posms ar patērētāju kā centrālo elementu ir stratēģiski svarīgs ilgtspējīgas pārtikas sistēmas transformācijā.

1. TEORĒTISKAIS IETVARS

Šajā nodaļā autore ir analizējusi pārtikas izšķērdēšanas problemātiku ilgtspējīgas attīstības kontekstā, aprites ekonomikas konceptu un tā lomu pārtikas atkritumu samazināšanā, kā arī patēriņa posma nozīmi pārtikas sistēmas pārveidē. Teorētiskā nodaļa nodrošina pētījuma konceptuālo pamatu tālākai empīriskajai izpētei.

1.1. Pārtikas izšķērdēšanas problemātika un tās nozīme ilgtspējīgas attīstības kontekstā

1.1.1. Pārtikas izšķērdēšanas problēma pasaulē un ES

Pārtikas izšķērdēšana ir viena no aktuālākajām globālajām problēmām ar tālejošu ietekmi uz vides ilgtspēju, ekonomisko noturību un sociālo vienlīdzību (de los Mozos et al., 2020; UNEP, 2022). Saskaņā ar 2024. gada UNEP Pārtikas atkritumu indeksa ziņojumu (*Food Waste Index Report 2024*) (UNEP, 2024) PPĶ ik gadu tiek zaudēta vai izmesta viena trešā daļa (1,3 miljardi tonnu) no cilvēku patēriņam saražotās pārtikas, kas ir aptuveni 1 miljards maltīšu dienā un 1 triljons ASV dolāru naudas izteiksmē (UNEP, 2024). ES līmenī katru gadu tiek izšķērdēti aptuveni 59 miljoni tonnu pārtikas (Eurostat, 2024), veidojot 132 miljardu EUR ekonomiskos zaudējumus gadā (European Parliament & Council, 2008). Pārtikas izšķērdēšana rada ievērojamus finansiālos zaudējumus visā PPĶ (Paparella et al., 2023; Phan, 2024), negatīvi ietekmējot valstu ekonomikas, pārtikas sistēmas un iepirkuma procesus. Šādi izmestās pārtikas apjomi arvien vairāk palielina sociālo nevienlīdzību pasaulē, jo aptuveni 43 miljoni ES iedzīvotāju nevar atļauties katru otro dienu ēst kvalitatīvu maltīti, kas satur gaļu, zivis vai līdzvērtīgu veģetāro alternatīvu (Eurostat, 2025). Mūsdienās aptuveni 828 miljoni cilvēku cieš badu, tajā skaitā arī bērni, turpretī vairāk nekā 1 miljards cilvēku visā pasaulē sirgst no aptaukošanās - 650 miljoni pieaugušo, 340 miljoni pusaudžu un 39 miljoni bērnu (World Health Organization, 2022). Ar izmestās pārtikas daudzumu būtu iespējams pabarot 2 miljardus cilvēku, kas ir divas reizes vairāk nekā pašreizējais cilvēku skaits pasaulē, kas cieš no nepietiekama uztura (WFP, 2024). Pārtikas atkritumiem ir arī negatīva ietekme uz vidi, jo tā ir planētas resursu izšķērdēšana (Bishop et al., 2022; Röös et al., 2021; Spiller et al., 2020), kas, savukārt, veicina ekosistēmu degradāciju, bioloģiskās daudzveidības samazināšanos un paātrina klimata pārmaiņas (European Commission: Directorate-General for Research and Innovation and Group of Chief Scientific Advisors, 2023; Lindgren et al., 2018; von Braun et al., 2023; Zeinstra et al., 2020). Ir atklāts, ka pārtikas atkritumi rada 8–10% no globālajām siltumnīcefekta gāzu emisijām, kas ir piecas reizes vairāk nekā aviācijas nozarei, tomēr daudzu valstu stratēģijās un nacionālajās saistībās klimata jomā tas joprojām netiek ņemts vērā (WRAP, 2024).

1.1.2. Pārtikas zudumi un atkritumi pārtikas piegādes ķēdē

Pārtikas zudumi un atkritumi rodas visā PPĶ - no ražošanas līdz patēriņam. Skaidra izpratne par pārtikas zudumu un atkritumu apjomiem un izplatību visā PPĶ ir būtiska mērķtiecīgas politikas izstrādei un ieinteresēto pušu iesaistei. Šajā kontekstā precīzi, pārbaudāmi un salīdzināmi pārtikas atkritumu mērījumi ir pamats, lai būtu iespējams noteikt, uzraudzīt un kontrolēt pārtikas atkritumu samazināšanas pasākumu progresu un rezultātus, sasniegt SDG 12.3. mērķī noteikto pārtikas atkritumu samazinājumu patēriņa līmenī par 50%, kā arī pēc nepieciešamības pielāgot vai mainīt stratēģiju (Kafa & Jaegler, 2021; UNEP, 2021). Savukārt pārtikas zudumu un atkritumu klasifikācija PPĶ ir būtiska, lai izprastu problēmas cēloņus un izstrādātu piemērotākos risinājumus.

Pārtikas zudumu un atkritumu definīciju ietvars atbilstoši PPĶ posmiem ir redzams 1.1. attēlā.

1.1. attēls. Pārtikas zudumu un atkritumu definīciju ietvars pa pārtikas piegādes ķēdes posmiem (Deksne et al., 2025b), autores tulkojums

Zinātniskajā literatūrā jēdzieni "pārtikas zudumi" un "pārtikas atkritumi" tiek nošķirti (Ishangulyyev et al., 2019; Kaur et al., 2021; Lonska et al., 2022; Zvaigzne et al., 2021) un tos klasificē atkarībā no PPĶ posma, kurā tie rodas. Pārtikas zudumi veidojas PPĶ sākuma posmos - ražošanā, pēcražas apstrādē un uzglabāšanā, un pārstrādē. Tos galvenokārt izraisa tādi faktori kā neatbilstoša infrastruktūra, vides apstākļi un neatbilstība drošības vai kvalitātes standartiem, kā rezultātā samazinās cilvēku uzturam piemērotās pārtikas daudzums. Savukārt pārtikas atkritumi rodas PPĶ pēdējos posmos - izplatīšanā un tirgū, kā arī patēriņā, kur pārtika, kas bija paredzēta cilvēku uzturam, tiek izmesta neatkarīgi no tā, vai tā joprojām ir ēdama vai ir sabojāta (Aschemann-Witzel et al., 2017; Ishangulyyev et al., 2019; Kaur et al., 2021; Prescott et al., 2019).

Gan globālā, gan ES līmenī joprojām nepastāv vienotas pārtikas zudumu un atkritumu definīcijas, jo dažādās valstīs un nozarēs pārtika un tās izšķērdēšana tiek uztverta citādi. Tāpat atšķiras datu vākšanas prakse un metodes, kā arī politiskās un stratēģiskās prioritātes. ES kopš 2019. gada ir ieviesta vienota pārtikas atkritumu definīcija un mērījumu metodoloģija

(European Commission, 2019c), kas nenodala pārtikas zudumus no pārtikas atkritumiem, nosakot, ka "pārtikas atkritumi" ir jebkura pārtika, kas kļuvusi par atkritumiem saskaņā ar Direktīvu 2008/98/EK, t.i. gan ēdamās, gan neēdamās pārtikas daļas, kas sākotnēji bija paredzētas cilvēku uzturam (European Parliament & Council, 2008). ANO Pārtikas un lauksaimniecības organizācija diferencē šos jēdzienus, *pārtikas zudumus* attiecinot uz ēdamās pārtikas masas samazināšanos pārtikas ķēdes ražošanas, pēcražas un pārstrādes posmos, galvenokārt jaunattīstības valstīs, bet *pārtikas atkritumus* - uz ēdamās pārtikas izmešanu mazumtirdzniecības un patērētāju līmenī, galvenokārt attīstītajās valstīs (FAO, 2025b). Zinātniskajā literatūrā termini saistīti ar pārtikas atkritumiem, piemēram, "zaudējumi pēc ražas novākšanas" (*Post-Harvest Losses*), "pārtikas zudumi" (*Food Loss*), "pārtikas atkritumi" (*Food Waste*) un "pārtikas zudumi un atkritumi" (*Food Loss and Waste*) bieži tiek lietoti kā sinonīmi, tomēr tie konsekventi neattiecas uz vienas problēmas vieniem un tiem pašiem aspektiem (Delgado et al., 2021; Santeramo, 2021; Schuster & Torero, 2016). Pārtikas zudumi, gan ražošanas laikā, gan pēc ražas novākšanas, visbiežāk saistīti ar nejaušu pārtikas daudzuma vai kvalitātes samazināšanos, piemēram, kaitēkļu, slimību, ierobežotu ražas novākšanas metožu, cenu svārstību vai resursu trūkuma dēļ. Pārtikas atkritumi parasti attiecas uz cilvēku uzturam piemērotas vai sabojājušās pārtikas izmešanu patēriņa posmā (Ishangulyyev et al., 2019; Santeramo, 2021).

Pārtikas atkritumi, kas rodas PPĶ pēdējā - patēriņa posmā, tiek kategorizēti atkarībā no izšķērdēšanas brīža (Lonska et al., 2022) (I raksts) (1.2. attēls).
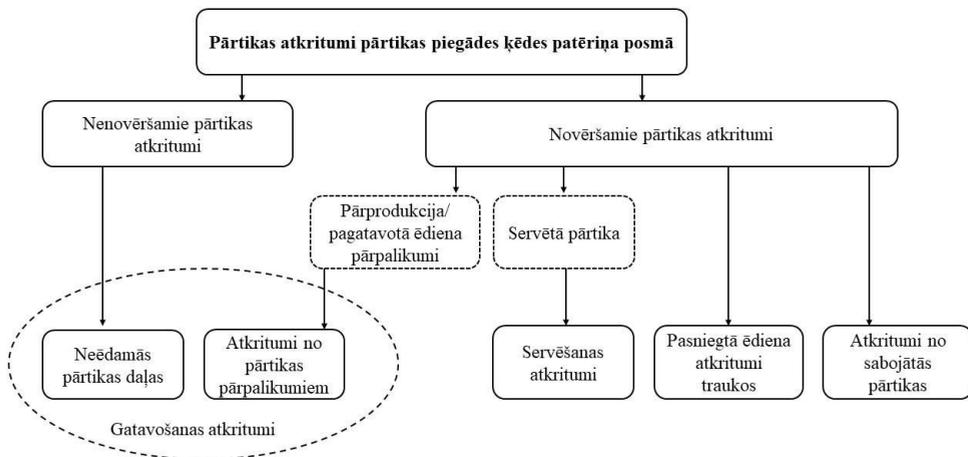
1.2. attēls. Pārtikas atkritumi, kas veidojas pārtikas piegādes ķēdes patēriņa posmā (Lonska et al., 2022), autores tulkojums

Pārtikas atkritumi, kas rodas PPĶ patēriņa posmā, tiek iedalīti divās pamatkategorijās: nenovēršamie un novēršamie pārtikas atkritumi (Lonska et al., 2022; Zvaigzne et al., 2021).

Nenovēršamie pārtikas atkritumi attiecas uz pārtikas daļām, kas parasti netiek lietotas cilvēku uzturā, piemēram, kauli, mizas, čaumalas u.tml. Šāda veida atkritumi parasti rodas ēdiena gatavošanas laikā un ir neizbēgami pat optimāli organizētā un pārvaldītā ēdināšanas procesā. Novēršamie pārtikas atkritumi tiek iedalīti četrās pamatgrupās:

1) pagatavotā ēdiena pārpalikumi (*cooked food leftovers*) - ēdiena gatavošanas laikā radušies atkritumi - mizojot, griežot, vai arī pagatavojot pārāk lielu daudzumu ēdiena (var būt novēršami un nenovēršami) (Dietary Guidelines Advisory Committee, 2015; García-Herrero et al., 2019; Kasavan et al., 2021);

2) servēšanas atkritumi (*serving waste*) - ēdiens, kas tiek pagatavots, bet dažādu iemeslu dēļ netiek pasniegts, piemēram, apmeklētāju skaita prognozēšanas kļūdas (García-Herrero et al., 2019; Kasavan et al., 2021);

3) PĒAT (*plate waste*) - pārtika, kas tika pasniegta patērētājam, taču netika apēsta (Dietary Guidelines Advisory Committee, 2015; García-Herrero et al., 2019; Kasavan et al., 2021);

4) atkritumi no sabojātas pārtikas (*spoilage food waste* vai *storage waste*) - pārtika, kas kļūst nepiemērota lietošanai pirms patēriņa, piemēram, pārtikas iegādes un uzglabāšanas laikā (Kasavan et al., 2021; Persson Osowski et al., 2022).

Promocijas darba ietvaros tiek izmantots jēdziens "pasniegtā ēdiena atkritumi traukos" (PĒAT) (*plate waste*), kas apzīmē patērētājam (skolēnam) pasniegtā ēdiena daudzumu, kas paliek neapēsts uz šķīvja un vēlāk tiek izmests. Šis termins ir ieviests E-mentors projektā, balstoties uz Valsts valodas centra atzinumu, kur *plate waste* nav tulkots burtiski kā "šķīvju atkritumi", bet atbilstiši latviešu valodas terminoloģijas prasībām. Šāda pieeja nodrošina vienotu izpratni un salīdzināmību ar citiem, tajā skaitā starptautiskiem, pētījumiem šajā jomā (Zvaigzne et al., 2021).

Pārtikas atkritumu apjoms PPĶ atšķiras starp valstīm atkarībā no valsts attīstības līmeņa, urbanizācijas pakāpes un ekonomiskā stāvokļa (Chalak et al., 2016; Ishangulyyev et al., 2019). Attīstības valstīs tā ir problēma ražošanas līdz izplatīšanas posmos (FAO, 2025a; Wani et al., 2024), bet attīstītajās valstīs - patēriņa posmā, kas ietver mājsaimniecības un ēdināšanas pakalpojumu sniedzējus (Derqui et al., 2018; FAO, 2025a; García-Herrero et al., 2019; Ishangulyyev et al., 2019; Kasavan et al., 2021).

Lai arī pārtikas izšķērdēšana ir plaši izplatīta problēma visos PPĶ posmos, tomēr vislielākie zaudējumi no izmestās pārtikas rodas tieši PPĶ patēriņa posmā, jo brīdī, kad pārtika sasniedz patērētāju, tā jau ir izgājusi visus PPĶ posmus, patērējot ievērojamu daudzumu dabas resursus, finanšu līdzekļus, elektroenerģiju, darbaspēku u.c., tādējādi radot būtisku slogu videi,

ekonomiskos zaudējumus un arī sociālās sekas (FAO, 2011; Ishangulyyev et al., 2019; UNEP, 2021).

Saskaņā ar (UNEP, 2024) datiem, 2022. gadā pasaulē tika izšķērdēti aptuveni 1,05 miljardi tonnu pārtikas, kas radās mazumtirdzniecības un patēriņa līmenī. Tas atbilst 132 kg pārtikas uz vienu iedzīvotāju gadā, no kuriem 115 kg pārtikas uz vienu iedzīvotāju tika izšķērdēts tieši mājsaimniecībās un ēdināšanas pakalpojumu sektoros kopā (UNEP, 2024). Ir izpētīts, ka PPĶ patēriņa posmā veidojas aptuveni 35% no kopējiem pasaules pārtikas zudumiem un atkritumiem (FAO, 2011; Yahia & Mourad, 2019), bet mājsaimniecībās rodas aptuveni 60% no kopējiem pasaules pārtikas atkritumiem (WFP, 2024). ES pārtikas izšķērdēšana PPĶ saskan ar globālo modeli. Balstoties uz (Eurostat, 2024) datiem, 2022. gadā ES tika radīti aptuveni 59 miljoni tonnu pārtikas atkritumu (132 kg pārtikas atkritumu uz vienu iedzīvotāju), kur mājsaimniecības un ēdināšanas pakalpojumu sektors kopā veidoja 65,4% no kopējā apjoma (Eurostat, 2024). Arī Latvijā lielākais pārtikas atkritumu daudzums tiek radīts patēriņa posmā. Saskaņā ar (Eurostat, 2024) datiem, 2022. gadā Latvijā tas sastādīja 68,6% no kopējā pārtikas atkritumu daudzuma, kas ir vairāk kā vidēji ES, un skaidri norāda uz nepieciešamību vērst atkritumu samazināšanas centienus uz patēriņa posmu.

1.1.3. Politiskais ietvars un stratēģiskie mērķi pārtikas atkritumu problēmas risināšanai

Kopš 2015.gada, kad ANO Ģenerālā asambleja apstiprināja 17 SDGs (UNGA, 2015), pastiprināta uzmanība tiek pievērsta ilgtspējīgai attīstībai, tajā skaitā arī ilgtspējīgu pārtikas sistēmu veidošanai. Ilgtspējīga pārtikas sistēma tiek definēta kā tāda, kas nodrošina pārtikas drošību un uzturu esošajai paaudzei, vienlaikus saglabājot vides, sociālos un ekonomiskos pamatus, kas nepieciešami, lai šos ieguvumus varētu saglabāt arī nākamajām paaudzēm (HLPE, 2014; Nguyen, 2018; United Nations, 2025). Šī definīcija uzsver paaudžu savstarpējās vienlīdzības nozīmi un pārtikas sistēmas spēju saglabāt vai uzlabot savas funkcijas ilgtermiņā sabiedrības labklājības nodrošināšanai (Chandra et al., 2019; Prosperi et al., 2014; UNEP, 2023; Valette et al., 2019). Pētījumi liecina, ka pasaules pārtikas sistēmas darbība ir cieši saistīta ar visiem 17 SDGs, tāpēc pāreja uz ilgtspējīgu pārtikas sistēmu var būtiski sekmēt šo mērķu sasniegšanu (Chaudhary et al., 2018; Kretschmer & Kahl, 2021; Schmitt & Khouri, 2023). Lai nodrošinātu pārtikas sistēmas ilgtspēju, ir nepieciešams uzlabot esošo ekonomisko praksi un novērst nepilnības visā pārtikas sistēmā, galvenokārt, ieviešot ilgtspējīgākus ražošanas un patēriņa modeļus (European Commission, 2019a). Šajā kontekstā ir svarīgi novērst pārtikas izšķērdēšanu, tomēr tas ir sarežģīts uzdevums, jo prasa koordinētus un mērķtiecīgus pasākumus visos pārvaldības līmeņos - mikro, mezo un makro (Kodors et al., 2024). Pārtikas atkritumu

samazināšana var veicināt sasniegt 2. SDG – izskaust badu, nodrošināt pārtikas drošību un ilgtspējīgu lauksaimniecības attīstību, kā arī 12. SDG, kas vērsts uz ilgtspējīgu ražošanas un patēriņa modeļu ieviešanu un īstenošanu, un it īpaši tā 12.3 apakšmērķi, kas paredz līdz 2030. gadam uz pusi samazināt pasaules pārtikas atkritumu daudzumu uz vienu iedzīvotāju mazumtirgotāju un patērētāju līmenī, kā arī samazināt pārtikas zudumus ražošanas un piegādes ķēdēs (UNGA, 2015).

ES līmenī apņemšanās nodrošināt ilgtspējīgu attīstību ir atspoguļota vairākās nozīmīgās politikas iniciatīvās. ES dalībvalstis ir parakstījušas Parīzes nolīgumu, izvirzot mērķi mazināt klimata pārmaiņas, izmantojot visaptverošas stratēģijas (United Nations Climate Change, 2016). Kā viena no pamata iniciatīvām ir visaptverošā stratēģija *Eiropas Zaļais kurss (European Green Deal)*, kas nosaka līdz 2050. gadam sasniegt klimata neitralitāti (European Commission, 2019b; European Council, Council of the EU, 2025a). Savukārt, viens no *Eiropas zaļā kursa* galvenajiem mērķiem ir pāreja uz aprites ekonomiku, kas ir vērsta uz atkritumu samazināšanu un resursu izmantošanas optimizēšanu visās nozarēs (European Council, Council of the EU, 2025a). Šajā kontekstā 2020. gadā tika izstrādāts Eiropas Komisijas "*Jauns aprites ekonomikas rīcības plāns. Par tīrāku un konkurētspējīgāku Eiropu*" (*A new Circular Economy Action Plan. For a cleaner and more competitive Europe*), kura mērķis ir paātrināt pārveides pārmaiņas, kas nepieciešamas *Eiropas zaļajam kursam*, vienlaikus balstoties uz AE darbībām, kas īstenotas kopš 2015. gada. Galvenais uzsvars šajā plānā ir uz atkritumu novēršanu un optimālu resursu izmantošanu (European Commission, 2020b). Papildus ES tiek īstenoti politikas pasākumi, lai uzlabotu un stiprinātu ar atkritumu pārvaldību saistītos tiesību aktus, piemēram, ar Eiropas Komisijas deleģēto lēmumu (European Commission, 2019c) ir papildināta atkritumu pamatdirektīva 2008/98/EK (2008), un ES ir noteikusi līdz 2030. gadam par 30 % samazināt pārtikas atkritumu daudzumu mazumtirdzniecības un patēriņa līmenī, lai būtiski samazinātu ietekmi uz vidi un atbalstītu ilgtspējīgas pārtikas sistēmas. Tāpat ES dalībvalstīm no 2020. gada ir pienākums nodrošināt pārtikas atkritumu mērījumus katrā PPĶ posmā (European Commission, 2019c; European Council, Council of the EU, 2025a). Šī pieeja ir būtisks solis uzraudzības un novērtēšanas sistēmas izveidē, lai iegūtu salīdzināmus un ticamus datus turpmāku politikas lēmumu pieņemšanai.

Paralēli Eiropas Komisija 2020. gadā izstrādāja stratēģiju "No lauka līdz galdam" (European Commission, 2020a; European Council, Council of the EU, 2025b), kur pieņemot AE principus, mērķis ir nodrošināt ilgtspējīgu primāro ražošanu, stimulēt ilgtspējīgu pārtikas pārstrādes, mazumtirdzniecības, viesmīlības un ēdināšanas pakalpojumu praksi, veicināt ilgtspējīgu pārtikas patēriņu, un samazināt pārtikas izšķērdēšanu visā PPĶ, tādējādi virzot

pāreju uz noturīgu, taisnīgu un ilgtspējīgu pārtikas sistēmu (European Commission, 2020a; European Council, Council of the EU, 2025b; Zou et al., 2023).

Arī Latvijā kā ES dalībvalstī ir ieviesti vairāki valsts līmeņa pasākumi, lai atbalstītu globāla un ES mēroga iniciatīvas samazināt pārtikas izšķērdēšanu un veicinātu ilgtspējīgu patēriņu (European Commission, 2024; VARAM, 2021). Ilgtspējas iniciatīvas ir integrētas vairākos ilgtermiņa un vidēja termiņa stratēģijās un politikas plānošanas dokumentos un plānos, kā piemēram, *"Latvijas Ilgtspējīgas attīstības stratēģija līdz 2030.gadam" (Sustainable Development Strategy of Latvia until 2030)* (LR Saeima, 2010b), *"Latvijas Nacionālais attīstības plāns 2021.-2027.gadam" (National Development Plan of Latvia for 2021-2027)* (Pārresoru koordinācijas centrs, 2020) un *"Rīcības plāns pārejai uz aprites ekonomiku 2020.-2027.gadam" (Action Plan for the Transition to a Circular Economy 2020-2027)* (VARAM, 2020b), kur prioritātes ir ilgtspējīgs dzīvesveids, atbildīgs patēriņš, klimata neitralitāte un AE principi (LR Saeima, 2010b; Pārresoru koordinācijas centrs, 2020; VARAM, 2020b). Tādās stratēģijās kā *"Stratēģija klimata neitralitātes sasniegšanai līdz 2050. gadam" (Strategy of Latvia for the Achievement of Climate Neutrality by 2050)* (VARAM, 2020a) un *"Nacionālais enerģētikas un klimata plāns 2021.-2030.gadam" (Latvia's National Energy and Climate Plan 2021-2030)* (Klimata un enerģētikas ministrija, 2024), vēl vairāk norāda uz nepieciešamību samazināt pārtikas zudumus un atkritumus ar mērķtiecīgu rīcību, piemēram, sabiedrības informētību, racionālu resursu izmantošanu un izglītības iniciatīvām (European Commission, 2024; VARAM, 2021). Tāpat ir veikti Atkritumu apsaimniekošanas likuma (LR Saeima, 2010a) grozījumi, nosakot, ka no 2024. gada 1. janvāra ir obligāta bioloģisko atkritumu šķirošana.

1.2. Aprites ekonomikas koncepts un loma pārtikas atkritumu samazināšanā

Balstoties uz politisko ietvaru un stratēģiskajiem mērķiem pārtikas atkritumu problēmas risināšanai, AE ir atzīta par spēcīgu konceptuālu un politikas instrumentu virzībā uz ilgtspēju (Deksne, 2024; European Commission, 2020b; Skawińska & Zalewski, 2018; The Ellen Macarthur Foundation, 2025), jo īpaši pārtikas nozarē, kur pārtikas atkritumi ir pastāvīgs izaicinājums (Ishangulyyev et al., 2019; Khatami et al., 2024; Rabbi & Amin, 2024).

Pārtikas vērtību ķēde tiek uzskatīta par vienu no galvenajām AE vērtību ķēdēm (Diekmann & Germelmann, 2023; European Commission, 2020b; Khatami et al., 2024; Rabbi & Amin, 2024; The Ellen Macarthur Foundation, 2019). Tās transformācija ir būtiska, lai samazinātu resursu patēriņu, pārtikas atkritumu apjomus un negatīvo ietekmi uz vidi (Diekmann & Germelmann, 2023). Veicinot ilgtspējīgu ražošanas un patēriņa praksi, AE mērķis ir izveidot pārtikas sistēmu, kas nodrošina, ka pārtika nav atkritumu avots, bet gan

resurss, kas tiek atkārtoti izmantots un iekļauts slēgtā aprites ciklā (European Commission, 2020b; The Ellen Macarthur Foundation, 2019).

1.2.1. Aprites ekonomikas jēdziens un evolūcija

Deksne, (2024) (III raksts) ir izpētījusi, ka AE jēdziens parādījās 20. gadsimta 70. gados kā ideja par resursu patēriņa samazināšanu rūpnieciskajā ražošanā, īpaši enerģijas aizstāšanai ar cilvēka darbu, uzsverot nepieciešamību aizstāt neatjaunojamo resursu intensīvu izmantošanu ar ilgtspējīgākiem procesiem (Khaw-ngern et al., 2021; Stahel, 2016; Stahel & Reday-Mulvey, 1981). Tambovceva & Titko, (2020) atklāja, ka 1990. gadā tika izstrādāts jauns AE modelis, kas balstījās uz termodinamikas principiem (Pearce & Turner, 1991), ko vēlāk sīkāk izskaidroja (Čiegis & Čiegis, 2008), pētot ekonomiku kā nedalāmu daļu no slēgtas Zemes sistēmas, kurā darbojas termodinamikas likumi, kas nosaka fiziskās robežas resursu izmantošanai, atkritumu pārstrādei un ilgtspējīgas ekonomikas iespējām, tādējādi nostiprinot AE teorētiskos pamatus.

AE koncepts ir radies kā transformējoša alternatīva tradicionālajam lineārajam ražošanas un patēriņa modelim, kas balstās uz pieeju "ražo–lieto–izmet" (Khaw-ngern et al., 2021; Kirchherr et al., 2023). Mūsdienu pasaules apstākļos tas vairs nav piemērots, jo balstās uz neatjaunojamo dabas resursu intensīvu patēriņu un to izsīkšanu, kā arī veicina pārmērīgu ražošanu, tādējādi saīsinot produktu kalpošanas laiku un radot ievērojamu atkritumu daudzumu (Sulich & Rutkovska, 2021). Atšķirībā no lineārā modeļa, AE pēc savas būtības ir atjaunojoša, un tās mērķis ir pakāpeniski atdalīt izaugsmi no neatjaunojamo resursu patēriņa (The Ellen MacArthur Foundation, 2019) (1.3. attēls).
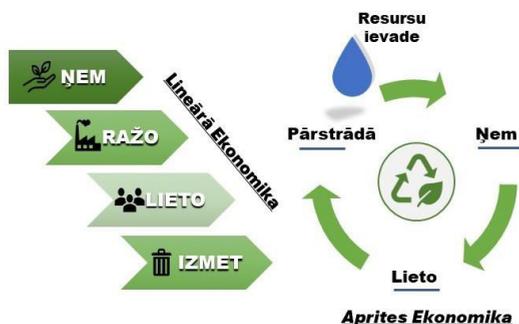
1.3. attēls. Lineārās ekonomikas modelis salīdzinājumā ar aprites ekonomikas modeli (Deksne, 2024), autores tulkojums

Pieaugošie ilgtspējas izaicinājumi lika meklēt jaunu, uz resursu apriti balstītu attīstības modeli, kā rezultātā tika izstrādāts AE koncepts, kas balstās uz slēgtā cikla pieeju "ražo–lieto–pārstrādā", un zinātniskajā literatūrā tiek definēts kā "3R" stratēģiju ietvars (Dekšne et al., 2023; Ghisellini et al., 2016; L. Liu et al., 2017).

ES AE pamatprincipi ir cieši saistīti ar Atkritumu pamatdirektīvā 2008/98/EK (European Parliament & Council, 2008) noteikto atkritumu apsaimniekošanas hierarhiju, kur galvenais mērķis ir novērst atkritumu rašanos, vai izmantot tos atkārtoti kā resursus tādā veidā, lai neradītu apdraudējumu cilvēku veselībai un videi (European Parliament & Council, 2008; Khaw-ngern et al., 2021). Arī ES AE rīcības plānā pārtikas atkritumu novēršana ir atzīmēta kā viena no prioritārajām jomām (European Commission, 2020b). Balstoties uz atkritumu hierarhiju, AE koncepts tika paplašināts uz "4R" stratēģiju ietvaru, ar papildus principu "atgūt" (*Recover*) (European Parliament & Council, 2008), kas dažviet tiek definēts arī kā "atjaunot" (*Regenerate*) (Kirchherr et al., 2017), akcentējot enerģijas un resursu vērtības atgūšanas un dabas sistēmu atjaunošanas nozīmi.

Dekšne et al., (2023) (IV raksts) ir izpētījušas, ka ņemot vērā vispārējo nepieciešamību pieņemt aprites principus un praksi, pieeja AE ieviešanai ar laiku ir kļuvusi niansētāka un strukturētāka, un AE modelis ir attīstījies līdz 10 stratēģiju ietvaram, ko zinātniskajā literatūrā definē kā "9R" vai "10R" (Holzer et al., 2023; Kirchherr et al., 2017; Potting et al., 2017) (1.4. attēls).
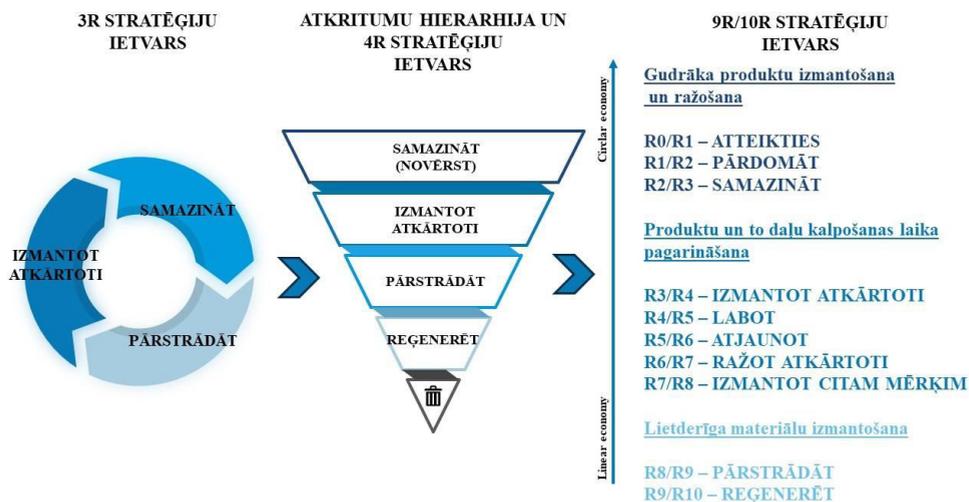
1.4. attēls. AE stratēģiju evolūcija (Deksne, 2024), autores tulkojums

AE stratēģiju evolūcijas mērķis ir sistēmiskas pārmaiņas, lai novērstu atkritumus visā PPĶ, un veicinātu SDGs sasniegšanu, pagarinot produktu dzīves ciklu, nodrošinot resursu maksimālu vērtības saglabāšanu aprītē un mainot patēriņa paradumus (Holzer et al., 2023; Kirchherr et al., 2017; Potting et al., 2017).

Lai arī AE kā ilgtspējas sasniegšanas instruments, ir guvusi plašu uzmanību, tās definīcija joprojām ir nepilnīga, un paredzams, ka AE koncepts un definīcija nepārtraukti attīstīsies (Deksne, 2024). Esošās AE definīcijas pilnībā neaptver visus ilgtspējīgas attīstības aspektus un

pārsvarā ilustrē pētnieku un politikas veidotāju pašreizējo izpratni par to (Deksne, 2024; Kirchherr et al., 2017, 2023). Turklāt, to mērķis galvenokārt ir palēnināt resursu izmantošanu un atkritumu veidošanos, nevis pilnībā pārveidot ekonomikas sistēmu (Suárez-Eiroa et al., 2019). Tādējādi līdzšinējais AE koncepts neaptver būtiskus sociālos un ekoloģiskos aspektus, kas ir neatņemama daļa no ilgtspējīgas attīstības paradigmas. Lai pilnībā realizētu tās pārveidojošo potenciālu, AE koncepts būtu holistiski jāintegrē visos ilgtspējīgas attīstības aspektos un jāaplūko plašākā ilgtspējīgas attīstības sistēmā. Šajā kontekstā visaptverošais jēdziens "Ilgtspējīga AE" ir parādījies kā vienojošs jumta jēdziens, kas apvieno resursu racionālu izmantošanu un slēgta cikla sistēmas ar svarīgiem sociālās atbildības un vides aizsardzības elementiem. Tas atspoguļo paradigmas maiņu uz holistisku un nepārtrauktu pieeju ilgtspējai, kur ekonomiskā darbība ir cieši saistīta ar sociālās labklājības saglabāšanu un vides aizsardzību (Deksne, 2024).

1.2.2. Aprites ekonomikas loma pārtikas sistēmu transformācijā

AE principu integrēšana pārtikas sistēmā, aptverot visus PPĶ posmus no ražošanas līdz patēriņam, īpaši koncentrējoties uz pārtikas zudumu un atkritumu novēršanu, ir būtisks priekšnosacījums arī ES un globālo SDGs sasniegšanai. Kā tika minēts iepriekš, ES stratēģija "No lauka līdz galdam" (*A Farm to Fork Strategy*) (European Commission, 2020a), uzsver nepieciešamību veidot ilgtspējīgu pārtikas sistēmu, vispusīgi un holistiski risinot ilgtspējas problēmas un uzsverot savstarpējo saistību starp indivīdiem, sabiedrību un planētu (European Commission, 2020a; European Council, Council of the EU, 2025b; Zou et al., 2023). Tāpēc arvien vairāk aktualizējas vajadzība pēc ilgtspējīgas pārtikas sistēmas, kas spēj ne tikai nodrošināt cilvēku un planētas vajadzības, bet arī atjaunot un saglabāt dabas resursus nākamajām paaudzēm.

Šajā kontekstā integrējot AE principus pārtikas sistēmā, veidojas jauns modelis – aprites pārtikas sistēma, kas balstās uz optimālu dabas resursu izmantošanu un pārvaldību, atbildīgu un ilgtspējīgu pārtikas patēriņu, kas ietver pārtikas atkritumu samazināšanu un uztura paradumu maiņu (piemēram, samazinot augsti pārstrādātu un dzīvnieku izcelsmes olbaltumvielu produktu patēriņu), un atbildīgu pārtikas atkritumu pārvaldīšanu (Rood et al., 2017). Aprites pieeja ir īpaši svarīga pārtikas patēriņa posmā, kur patērētāju izvēles un paradumi tieši ietekmē visu PPĶ – pārtikas pieprasījumu, ražošanas praksi, resursu izmantošanu, pārtikas atkritumu daudzumu un kopējo ietekmi uz vidi (Biresselioglu et al., 2023; Pais et al., 2023; Spiller et al., 2020; Wintschnig, 2021). Līdz ar to patērētāju uzvedības maiņa ir būtisks priekšnoteikums pārejai uz ilgtspējīgu pārtikas sistēmu (Deksne et al., 2025a, 2025b; HLPE, 2017; Lonska et al., 2025),

kur pārtikas izšķērdēšana tiek risināta kā dziļi iesakņojusies sistēmiska problēma pašreizējos patēriņa modeļos (Diekmann & Germelmann, 2023; García-Herrero et al., 2019).

Ilgtspējīgas pārtikas sistēmas izveidei ir nepieciešama strukturēta, daudzlīmeņu holistiska pieeja, integrējot mikro, mezo un makro līmeņa ieinteresētās puses visā pārtikas vērtību ķēdē (Diekmann & Germelmann, 2023; Kodors et al., 2024), lai vienlaikus risinātu vides, ekonomiskās un sociālās problēmas un stiprinātu iedzīvotāju veselību, sabiedrības labklājību un planētas ilgtspēju.

1.2.3. Aprites ekonomikas koncepts kā pamats bezatkritumu pārtikas patēriņam skolās

Skolu ēdināšanas programmu kontekstā AE var būt stratēģiski piemērots instruments iepriekš minēto sistēmisko problēmu risināšanai, īpaši to, kas saistītas ar PĒAT, kas ēdināšanā ārpus mājas kļuvuši par nozīmīgu ilgtspējas izaicinājumu (Dhir et al., 2020). Kā minēts iepriekš, AE stratēģiju pamatā ir atkritumu hierarhija, kas integrēta no ES Atkritumu pamatdirektīvas. Hierarhijas augšgalā ir atkritumu novēršana un samazināšana (European Parliament & Council, 2008; Khaw-ngern et al., 2021), kas veido teorētisko un praktisko pamatu bezatkritumu ēdināšanas organizācijai skolās.

Pārtikas atkritumu novēršana tiek uzskatīta par prioritāru rīcības virzienu ilgtspējīgas pārtikas sistēmas ietvaros, kas ir īpaši svarīga skolās, kur iespējams ieviest un īstenot vairākas atbildīgas prakses, kas ietver ilgtspējīgu pārtikas patēriņu un patēriņa uzvedības maiņu skolēnu vidū, tādējādi uzlabojot nodrošinātību ar pārtiku, samazinot ietekmi uz vidi un sniedzot ekonomisku labumu dažādiem PPĶ dalībniekiem (Camilleri, 2021; Lopez et al., 2019). Turklāt ilgtspējīgas AE koncepts paredz plašāku ilgtspējas principu integrāciju, iezīmējot paradigmas maiņu uz visaptverošu un ilgtermiņā noturīgu pieeju, kas tiek skatīta kā plaša sociālā transformācija ar mērķi veidot tādu sabiedrību, kas ražošanā, patēriņā un pārvaldībā ievēro AE principus (Deksne, 2024). Skolu kontekstā tas nozīmē, ka sekmīga pāreja uz bezatkritumu pārtikas patēriņu iespējama vien tad, ja tiek ņemta vērā pārtikas sistēmas daudzlīmeņu struktūra un tiek veicināta aktīva iesaiste visos mikro, mezo un makro līmeņos (Diekmann & Germelmann, 2023; Vittuari et al., 2023). Visām iesaistītajām pusēm ir jādarbojas kopā, lai veidotu atbildīgu un ilgtspējīgu pārtikas patēriņa kultūru, kas pārsniedz tehniskus risinājumus un balstās uz līdzdalību, sadarbību un kopīgu atbildību par nākotni.

Tādējādi ilgtspējīgas AE koncepts šajā darbā tiek izmantots kā teorētiskais pamats praktiskajiem risinājumiem, kas vērsti uz pārtikas atkritumu novēršanu un mazināšanu skolās.

1.3. Patēriņa posma nozīme pārtikas sistēmas pārveidē

1.3.1. Skolu ēdināšanas programmu loma pārtikas sistēmā

Skolu ēdnīcas ir daļa no PPĶ pēdējā - patēriņa posma (Amicarelli & Bux, 2020; Derqui et al., 2018; FAO, 2011; García-Herrero et al., 2019; Ishangulyyev et al., 2019; Kasavan et al., 2021; Wunderlich & Martinez, 2018). Atskaitot mājsaimniecības, skolas ir atzītas par būtisku pārtikas atkritumu avotu (Derqui et al., 2018; Qian & Xiong, 2022; Zhang et al., 2024).

Lai gan skolu ēdināšana sniedz būtisku atbalstu vairāku SDGs sasniegšanā, pārtikas izšķērdēšana mazina tās ietekmi un potenciālu šajā jomā. Daudzviet pasaulē skolās tiek nodrošinātas bezmaksas un uzturvērtīgas maltītes, tomēr ne visi bērni tās atbildīgi patērē (Deksne et al., 2025a; Mauer et al., 2022). Vairāki pētījumi apstiprina, ka skolās tiek radīts liels pārtikas atkritumu daudzums, kur lielākā daļa ir PĒAT (Derqui et al., 2018; Eriksson et al., 2017; Lonska et al., 2022, 2025; Malefors, 2022; Vizzoto et al., 2021). Piemēram, Zviedrijas skolās, kur dominē pašapkalpošanās (*self-service*) tipa ēdiena pasniegšanas modelis, 20-23% pasniegtā ēdiena nonāk atkritumos (Eriksson et al., 2017; Malefors, 2022), Itālijas skolās 20–29% jeb 1/3 no pasniegtā ēdiena tiek izmesta (García-Herrero et al., 2019). Pētījumos Latvijas skolās, kur dominē iepriekš servēta, pilnībā vai daļēji porcionēta ēdiena pasniegšana, ir līdzīgas tendences. Lauka pētījumos, kas veikti Rēzeknes skolās, tika atklāts, ka aptuveni 20% no pasniegtā ēdiena nonāk atkritumos (Lonska et al., 2022, 2025). Abos pētījumos tika atklāts, ka uz galdiem bieži paliek neskartas servētās maltītes. Tas ir saistīts gan ar neprecīzu skolēnu skaita prognozēšanu, gan skolēnu personīgo attieksmi, piemēram, neierodas uz pusdienām, vai neēd pasniegto ēdienu (Lonska et al., 2022, 2025). Šie atklājumi parāda, ka pārtikas atkritumi ir plaši izplatīta un pastāvīga problēma skolu ēdināšanas procesā, un norāda uz ievērojamu resursu izšķērdēšanu un nepilnībām ēdināšanas procesa organizēšanā.

Pārtikas izšķērdēšanu un atkritumu rašanos skolās ietekmē dažādi faktori. Balstoties uz plašu literatūras pārskatu, tika identificēti PĒAT izraisošie faktori (I raksts - 1.tabula), ko pētnieki iedalīja ārējos jeb objektīvajos, kas ietekmē skolēna ēšanas uzvedību no ārpuses, un iekšējos jeb subjektīvajos, kas izriet no paša skolēna psiholoģiskā vai fizioloģiskā stāvokļa (Lonska et al., 2022; Zvaigzne et al., 2021). Papildus balstoties uz sistemātisku literatūras analīzi, tika identificētas astoņas faktoru grupas, kas ietekmē bezatkritumu pārtikas patēriņu skolās: demogrāfiskie, politiskie, skolu pārtikas politika, vides, sociāli ekonomiskie, personīgie, fiziskie un ģeogrāfiskie faktori (Deksne et al., 2022) (II raksts). Kopumā var secināt, ka PĒAT rašanos skolās ietekmē ļoti plašs un daudzveidīgs faktoru klāsts, tāpēc nepieciešama pārdomāta un kompleksa pieeja šīs problēmas risināšanai.

Skolu ēdināšanas programmas ir viens no plašākajiem risinājumiem pasaules līmenī cīņā ar nevienlīdzību, nabadzību, pārtikas trūkumu un nepietiekamu uzturu (Howard, 2018; WFP, 2022, 2023). Saskaņā ar Pasaules pārtikas programmas (WFP, 2022) ziņojumu 2022. gadā aptuveni 418 miljoni bērnu 176 valstīs saņēma ēdināšanu skolā, kas ir par 30 miljoniem vairāk kā 2020.gadā, un liecina par skolu ēdināšanas programmu atjaunošanos un paplašināšanos pēc Covid-19 pandēmijas. Diemžēl 153 miljoni bērnu 79 valstīs joprojām saskaras ar akūtu pārtikas trūkumu un badu. Šajā kontekstā skolu ēdināšanas programmām ir izšķiroša nozīme, lai nodrošinātu vismaz vienu ēdienreizi dienā, tādējādi ne tikai mazinot badu un nevienlīdzību, bet arī uzlabojot bērnu veselību, uzturu un izglītības rezultātus (WFP, 2022).

Pasaulē skolu ēdināšanas procesa organizācijas prakse ievērojami atšķiras atkarībā no katras valsts politikas, ekonomiskās situācijas un kultūras tradīcijām (Global Child Nutrition Foundation, 2022; Storcksdieck et al., 2014). Daudzās valstīs skolas pusdienas pilnībā vai daļēji finansē valsts (Guio, 2023). Līdzīgi kā Latvijā, arī Zviedrijā un Somijā ir ieviestas valsts mēroga bezmaksas pusdienu programmas, tādējādi nodrošinot bērniem vienu uzturvielām bagātu maltīti dienā (Mauer et al., 2022). Savukārt Vācijā tiek īstenoti uz ienākumiem balstīti finansējuma atbalsta modeļi, kur valsts subsidētas maltītes saņem tikai bērni no maznodrošinātām ģimenēm (Nationale Qualitätszentrum für Ernährung in Kita und Schule (NQZ), 2023; WBAE – Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim BMEL, 2020). Norvēģijā nav valsts līmenī regulētas skolu ēdināšanas programmas, un skolēni ņem līdzi ēdienu no mājām. Tomēr, līdzīgi kā Latvijā, Norvēģijā ir ieviesta valsts atbalsta programma, kas pamatskolu un vidusskolu skolēniem nodrošina bezmaksas augļus, dārzeņus un pienu (Mauer et al., 2022; Waling et al., 2016). Nīderlandes skolās tradicionāli nav pieņemts nodrošināt ēdināšanu skolā, bet tiek veiktas ievērojamas pārmaiņas politikas līmenī, lai ieviestu ēdināšanu skolās, primāri to piedāvājot bērniem no maznodrošinātām ģimenēm (NL Times, 2023; Rongen et al., 2019; van Kleef et al., 2020).

Arī ēdināšanas modeļi skolās ievērojami atšķiras. Pētījumos atklāts, ka dominē divas pieejas - pašapkalpošanās jeb bufetes tipa ēdināšana un pilnībā vai daļēji iepriekš porcionētas un pasniegtas maltītes (Lonska et al., 2022, 2025; Zvaigzne et al., 2021). Bufetes tipa ēdināšana ir plaši izplatīta ASV, kā arī vairākās Eiropas valstīs, piemēram, Zviedrijā un Somijā. Šī pieeja ļauj bērniem patstāvīgi izvēlēties gan ēdiena veidu, gan porcijas lielumu, pielāgojot to individuālajām vēlmēm un apetītei (Bucher et al., 2016; Malefors et al., 2022; Waling et al., 2016). Tomēr šī pieeja prasa papildus uzraudzību, lai nodrošinātu sabalansētu uzturu (Deksne et al., 2025a). Savukārt, līdzīgi kā Latvijā, iepriekš porcionētu un servētu maltīšu pieeju izmanto arī tādās valstīs kā Francija, Itālija un Brazīlija (Boschini et al., 2020; Favuzzi et al., 2020;

Sehnem et al., 2023; Vieux et al., 2013). Šī pieeja ierobežo skolēnu iespējas izvēlēties ēdiena veidu un daudzumu, taču nodrošina pusdienu maltītes atbilstību uztura standartiem (Deksne et al., 2025a; Lonska et al., 2022, 2025; Zvaigzne et al., 2021). Lai arī bufetes tipa ēdināšanas modelim ir trūkumi, šobrīd tas ir atzīts par piemērotāko risinājumu, kas paaugstina skolēnu apmierinātību ar skolas pusdienām, veicina atbildīgu pārtikas patēriņu un mazina pārtikas izšķērdēšanu (Y. Liu et al., 2016; Lonska et al., 2022, 2025; Zvaigzne et al., 2021).

ES izglītības iniciatīvām ir prioritārā loma pārtikas atkritumu samazināšanā (Giordano et al., 2020; Piras et al., 2023), un atbildīga patēriņa prakse ir pamats ilgtspējīgas attīstības veicināšanai (United Nations Department of Economic and Social Affairs, 2023). Šajā ziņā skolu vide ir pamata platforma, kur jau no mazotnes iemācīt un ieaudzināt bērniem veselīgus ēšanas paradumus un atbildīgu pārtikas patēriņu, veidojot izglītotus un atbildīgus nākotnes patērētājus, kuri spēj pieņemt apzinātas un videi draudzīgas izvēles (Newsome et al., 2023). Turklāt skolēni darbojas kā pārmaiņu aģenti gan savās ģimenēs, gan plašākā sabiedrībā, veicinot ilgtspējīgāku pārtikas patēriņu (Fudla et al., 2022; World Health Organization, 2017), kas vēl vairāk izceļ skolu vidi kā nozīmīgu pagrieziena punktu pārtikas sistēmas pārveidē un ilgtspējas veicināšanā.

Ēdināšana skolās ir būtiska skolēnu ēšanas paradumu un attieksmes pret pārtiku veidošanā (García-Herrero et al., 2019, 2021), līdz ar to skolām ir centrālā loma sociāli atbildīgas prakses veicināšanā. Atbildīgs pārtikas patēriņš un pārtikas atkritumu samazināšana skolās var radīt vides, ekonomiskos un sociālos ieguvumus (Hamid et al., 2020; Leal Filho et al., 2024). Kā piemēram, samazināt resursu patēriņu un pārtikas sistēmas radīto ekoloģiskās pēdas nospiedumu, tādējādi samazinot vides slogu, veicinot 12. un 13. SDGs sasniegšanu, kā arī bioloģiskās daudzveidības un dabas resursu saglabāšanu (Aldaco et al., 2020; Antón-Peset et al., 2021; Batlle-Bayer et al., 2020; UNEP, 2021; UNGA, 2015). No ekonomiskā viedokļa pārtikas atkritumu samazināšana var optimizēt izmaksas un resursu izmantošanu visā PPĶ, kā arī sniegt iespēju ietaupītos līdzekļus reinvestēt ēdināšanas kvalitātes uzlabošanā vai citu atbalsta iniciatīvu īstenošanā (Deksne et al., 2025a; Lonska et al., 2022). Atbildīga pārtikas patēriņa prakse var uzlabot arī nodrošinātību ar pārtiku, uztura drošību, veicināt sociālo vienlīdzību un attīstīt pāreju uz ilgtspējīgu pārtikas patēriņu (Canali et al., 2017; Lindgren et al., 2018; Manzoor et al., 2024).

Kā tika minēts iepriekš, ES ir ieviestas vairākas iniciatīvas, kas vērstas uz pārtikas atkritumu samazināšanu patēriņa līmenī, piedāvājot praktiskus rīkus un stratēģijas pārtikas atkritumu mazināšanai (European Commission, 2025). Ir atklāts, ka jebkuras sekmīgas pārtikas atkritumu mazināšanas programmas pamatā ir spēja precīzi izmērīt un uzraudzīt radīto pārtikas atkritumu apjomu (Kodors et al., 2024; Swannell et al., 2023; UNEP, 2021), tomēr tieši

patērētāju līmenī šādu datu trūkums ir aktuāla problēma, ko nosaka gan metodoloģiskās nepilnības, gan ar mērījumiem saistītās augstās izmaksas (FAO, 2019; UNEP, 2024).

Šajā kontekstā skolu ēdnīcas ir unikāla vieta, kur ar izglītību un praktisku rīcību ir iespēja tieši ietekmēt patērētāju attieksmi un uzvedību jau no bērnības, kontrolētā vidē mērīt pārtikas atkritumu apjomus, kā arī testēt uz pārtikas atkritumu samazināšanu vērstas intervences, padarot to par ideālu platformu pārtikas sistēmas pārveides iniciatīvu īstenošanai un uzraudzībai, kā arī uz pierādījumiem balstītas politikas izstrādei.

1.3.2. Pārtikas sistēmas transformāciju ietekmējošie faktori patēriņa posmā

Pārtikas patēriņa posmā tiek pieņemti ikdienas lēmumi, sākot no pārtikas izvēles, porciju lieluma un ēšanas paradumiem, līdz attieksmei pret pārtikas atkritumiem, kas savukārt tieši ietekmē visus pārējos procesus PPĶ, sākot no ražošanas līdz pat atkritumu apsaimniekošanai. Šajā kontekstā patēriņa posms kļūst par būtisku saskares punktu, kurā patērētājs ieņem centrālo lomu. Tieši viņa lēmumi un rīcība ietekmē pārtikas sistēmas virzību uz ilgtspēju (Deksne et al., 2025b).

PPĶ posmi ir savstarpēji saistīti un atkarīgi no dažādiem strukturāliem faktoriem, kā piemēram, infrastruktūra, institucionālais regulējums, pieejamie resursi, pārtikas kvalitāte un patēriņš (Abideen et al., 2021; Aday & Aday, 2020; Govindan, 2018), kur patērētāju uzvedība ir viens no dinamiski mainīgākajiem aspektiem šajā sistēmā. 1.5. attēlā redzama pārtikas sistēmas struktūra, kas uzskatāmi ilustrē, kā patērētāju uzvedība veidojas mijiedarbībā ar pārtikas vidi un personīgajām izvēlēm. Tādejādi patēriņa posms kalpo kā galvenais ietekmes punkts pārtikas sistēmas pārveidē, kur saskaņota rīcība visos līmeņos, no individuāliem lēmumiem līdz sistēmiskām pārmaiņām, var veicināt pāreju uz ilgtspējīgu bezatkritumu pārtikas sistēmu.
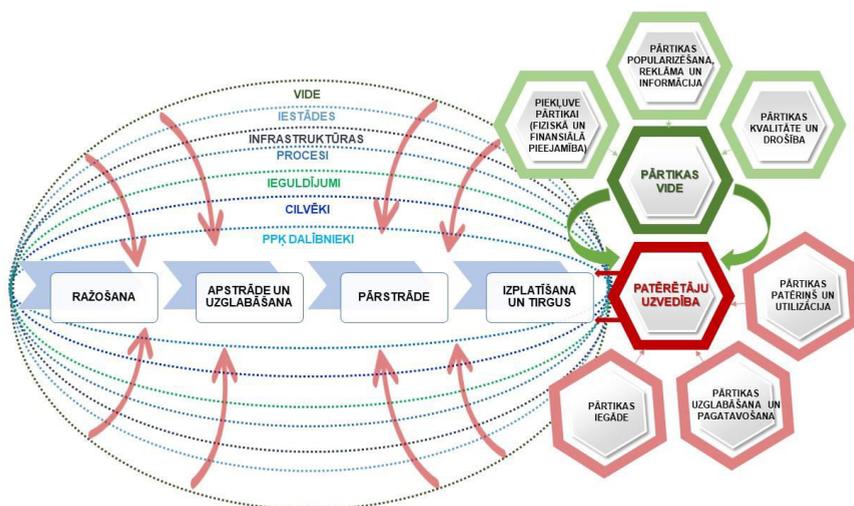
1.5. attēls. Pārtikas patēriņa posms pārtikas sistēmas ietvaros (Deksne et al., 2025b), autores tulkojums

Balstoties uz integratīvu literatūras pārskatu, kā arī izmantojot bibliometriskās analīzes pieeju (VIII raksts), tika identificēti galvenie aspekti patēriņa posmā, kas ietekmē pārtikas sistēmas pārveidi uz ilgtspējīgu modeli (Deksne et al., 2025b):

●**Pārtikas atkritumi un to samazināšana**. Pārtikas atkritumi ir centrālā problēma patēriņa posmā, jo tie tieši ietekmē visus ilgtspējas aspektus. To novēršana ir viens no galvenajiem nosacījumiem pārejā uz ilgtspējīgu pārtikas sistēmu.

●**Nepieciešamība mainīt uztura modeļus**. Pārmērīgs gaļas un citu dzīvnieku izcelsmes produktu patēriņš būtiski ietekmē pārtikas sistēmas ilgtspēju, līdz ar to pāreja uz vairāk augu izcelsmes uzturu ir svarīga gan vides ilgtspējai, gan sabiedrības veselībai, tomēr pāreju kavē sociāle, ekonomiskie un kultūras šķēršļi, kā arī šādu pārtikas produktu pieejamība un cenas.

●**Sarežģītā patērētāju uzvedība**. Patērētāju lēmumus, izvēles un rīcību nosaka daudz un dažādi iekšējie un ārējie faktori, kas ietekmē patērētāju spējas, motivāciju un iespējas veidot ilgtspējīgu pārtikas patēriņu. Uzvedības maiņu apgrūtina nepietiekamas zināšanas, paradumi, kultūra un sistēmiskie trūkumi, tāpēc nepieciešama holistiska pieeja, kas apvieno izglītojošus pasākumus, skolēnu praktisku iesaisti un organizatoriskas izmaiņas ēdināšanas sistēmā.

●**Politiskais un normatīvais ietvars**. Pārejai uz ilgtspējīgu pārtikas patēriņu ir nepieciešams stiprināt tiesisko regulējumu, pieņemt starpnozaru, daudzlīmeņu pārvaldības pieeju, integrējot AE principus, izglītības iniciatīvas un ekonomiskos stimulus.

Vienlaikus tika secināts, ka galvenais pārmaiņu virzītājs ir patērētāju uzvedības maiņa, kas ietver dziļāku uztveres un attieksmes maiņu ilgtspējīga patēriņa apzinātai pieņemšanai. Tādēļ nepieciešama mērķtiecīga un kompleksa pieeja, kas ietver uzvedības maiņas mehānismus

un atbalstošu politiku, lai veidotu tādu vidi, kur ilgtspējīgs patēriņš kļūst par ikdienas dzīvesveida daļu (Deksne et al., 2025b).

Lai izprastu, kā sekmēt pārmaiņas patērētāju uzvedībā, ir būtiski zināt faktorus un iemeslus, kas ietekmē viņu lēmumus, izvēles un rīcību (Pais et al., 2023). Zinātniskajā literatūrā patērētāju uzvedība tiek analizēta, izmantojot dažādas uzvedības teorijas un modeļus, kas skaidro lēmumu pieņemšanas procesus un uzvedības motivāciju. Analizējot skolēnu pārtikas patēriņa uzvedībai skolu ēdināšanas procesā, tika aplūkotas uzvedības teorijas, kas tiek izmantotas pārtikas patēriņa un atkritumu mazināšanas kontekstā.

Plānotās uzvedības teorijā (*Theory of Planned Behavior* (TPB)) (Ajzen, 1985, 1991) tiek pieņemts, ka uzvedību nosaka attieksme pret konkrēto rīcību, subjektīvās sociālās normas un uztvertā kontrole. Tomēr TPB koncentrējas galvenokārt uz kognitīviem aspektiem un paredz, ka, piemēram, pārtikas izšķērdēšana ir apzināta izvēle, tādējādi ierobežo tās piemērotību netīšiem uzvedības modeļiem.

Normu aktivācijas modelis (*Norm Activation Model* (NAM)) (Schwartz, 1977), izskaidro, kā morāles normas, seku apzināšanās un personīgā atbildība ietekmē rīcību. Tas parāda, ka uzvedību iespējams mainīt, stiprinot cilvēka izpratni par problēmu un viņa personīgo lomu tās risināšanā.

MOA ietvars (Ölander & Thøgersen, 1995) uzsver, ka uzvedību ietekmē ne tikai iekšējā motivācija (attieksme, normas, nolūki), bet arī ārējie apstākļi (piemēram, resursu pieejamība, fiziskā vide) un individuālās spējas (zināšanas, prasmes). MOA ietvara priekšrocība ir tā spēja vienlaikus ņemt vērā gan kognitīvos, gan praktiskos un sociālos faktorus, kas nosaka rīcību. Vittuari et al., (2023) ir papildinājuši šo ietvaru, analizējot patērētāju uzvedību no daudzlīmeņu perspektīvas — mikro (indivīds), mezo (mājsaimniecība, skola) un makro (politikas un tirgus konteksts) (Vittuari et al., 2023).

Pamudinājuma jeb pavirzīšanas teorija (*Nudge theory*) (Thaler & Sunstein, 2008) parāda, kā nelielas vides vai kontekstuālas izmaiņas (pamudinājumi/pavirzīšanas) var netieši, bet paredzami ietekmēt lēmumu pieņemšanu, neierobežojot indivīda izvēles brīvību.

Turklāt, papildus psiholoģijā balstītām uzvedības teorijām, arī uzvedības ekonomika ir vērtīgs instruments pārtikas patēriņa uzvedības izpratnei. Atšķirībā no tradicionālajām ekonomikas pieejām, kas pieņem cilvēka rīcību kā racionālu un loģisku, uzvedības ekonomika uzsver psiholoģisko, sociālo un emocionālo faktoru nozīmi lēmumu pieņemšanā (Cartwright, 2011, 2014; Ogaki & Tanaka, 2017). Šī pieeja ļauj padziļināti analizēt, kā vide, kultūra, identitāte un pat indivīda labsajūta ietekmē viņa izvēles, tajā skaitā arī pārtikas izvēli un izšķērdēšanas uzvedību (Ogaki & Tanaka, 2017). Uzvedības ekonomika ir īpaši noderīga

praktisku risinājumu izstrādē, piemēram, izmantojot pamudinājuma jeb pavirzīšanas tehnikas (*nudging techniques*), lai neuzbāzīgā veidā virzītu cilvēku uz ilgtspējīgāku rīcību.

Promocijas darba ietvaros skolēnu skolas ēdiena patēriņa uzvedība tika analizēta, izmantojot MOA ietvara pieeju (1.6. attēls), izvērtējot viņu motivāciju, iespējas un spējas samazināt pārtikas izšķērdēšanu ēdināšanā ārpus mājas, konkrēti Rēzeknes skolu vidē (V un VI raksts). Šāda pieeja ļāva izprast uzvedību daudzdimensionāli un sasaistīt ar strukturāliem un vides faktoriem.
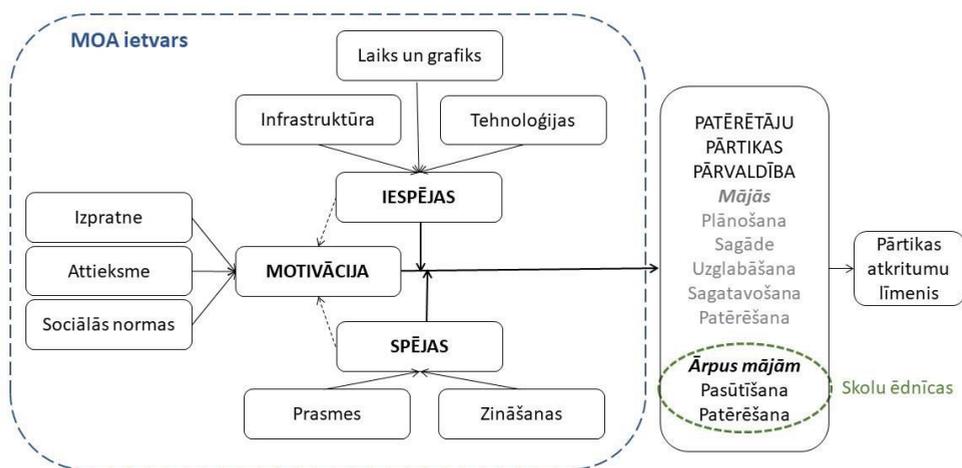
1.6. attēls. MOA ietvara un patērētāju pārtikas pārvaldības modelis patēriņam mājās un ārpus mājām (Lonska et al., 2025), autores tulkojums

Pārtikas atkritumu samazināšana patēriņa posmā prasa kompleksu, konkrētai darbības videi pielāgotu pieeju, jo to ietekmē savstarpēji saistīti uzvedības, sociālie un strukturālie faktori. Šo faktoru daudzveidība liecina, ka nav viena universāla risinājuma, kā panākt uzvedības maiņu un samazināt pārtikas izšķērdēšanu. Tāpēc pēdējos gados gan ES, gan citur pasaulē ir izstrādātas un analizētas dažādas aktivitātes jeb intervences pārtikas atkritumu novēršanai un samazināšanai patērētāju līmenī, tajā skaitā arī skolās (Lonska et al., 2025). Balstoties uz plašu literatūras pārskatu (V raksts, 2.-5.tabulas) tika identificēti, apkopoti un analizēti praktiski risinājumi, kas vērsti uz patērētāju uzvedības maiņu ar mērķi samazināt pārtikas izšķērdēšanu. Šīs pieejas ietver informatīvas kampaņas, izglītojošas aktivitātes, uzvedības ietekmēšanas mehānismus, tehnoloģiskos risinājumus, politikas instrumentus, kā arī strukturālas izmaiņas ēdināšanas organizatoriskajos aspektos. Īpaša uzmanība tika pievērsta skolēnu patēriņa uzvedības maiņai un pārtikas atkritumu novēršanai skolu ēdināšanā. Pamatojoties uz ārvalstu pieredzi, eksperimenta organizēšanai tika izvēlēti trīs intervenču veidi, kas bija optimālākie no organizatoriskā viedokļa, lai tos varētu īstenot Rēzeknes pilsētas skolās

un notestēt to efektivitāti esošā skolu ēdināšanas modeļa (daļēji porcionēts iepriekš servēts ēdiens) apstākļos (Lonska et al., 2025).

Tika atklāts, ka vislabākie rezultāti pārtikas atkritumu samazināšanā var tikt sasniegti ar koordinētu un stratēģiski plānotu rīcību dažādos līmeņos, īstenojot kompleksas un konkrētajam kontekstam (skolas ekosistēmai) pielāgotas pieejas, kas vienlaikus ietver informētības veicināšanu, uzvedības maiņu un sistēmiskas izmaiņas. Šādas mērķtiecīgas iniciatīvas var nodrošināt būtisku ietekmi, tomēr to rezultāti lielā mērā ir atkarīgi no ieviešanas apstākļiem, ilguma un izvēlēto intervenču veida (Lonska et al., 2025).

Balstoties uz teorētisko analīzi (VIII raksts) tika atklāts, ka PPĶ patēriņa posmam ir stratēģiski svarīga loma pārtikas sistēmas pārveidē, jo tajā iespējams tieši ietekmēt patērētāju uzvedību un veicināt ilgtspējīgu, bezatkritumu pārtikas patēriņu (Deksne et al., 2025b). Skolu ēdināšanas process tiek pozicionēts kā unikāla vieta šo pārmaiņu īstenošanai, kur kontrolētā vidē, apvienojot izglītības procesu ar praktisku rīcību, ir iespējams īstenot pārtikas sistēmas pārveides veicinošas iniciatīvas un uzraudzīt to progresu. AE koncepts šajā promocijas darbā ir izmantots kā teorētiskais pamats praktiskiem risinājumiem, kas vērsti uz bezatkritumu pārtikas patēriņu skolu ēdināšanas procesā. Teorētiskais ietvars veido pamatu turpmākajai empīriskajai izpētei, kurā tiek veikts Rēzeknes skolu ēdināšanas procesa novērtējums AE ietvarā.

2. ĒDINĀŠANAS PROCESA ORGANIZĀCIJAS NOVĒRTĒJUMS RĒZEKNES SKOLĀS ILGTSPĒJĪGAS APRITES EKONOMIKAS IETVARĀ

2.1. Pārtikas izšķērdēšana skolu ēdināšanas procesā: pirmais pilotpētījums Rēzeknes skolās

Šis pētījums bija pirmais posms kopējā izpētes procesā, kas tika uzsākts ar mērķi identificēt PĒAT tendences septiņās Rēzeknes pilsētas skolās un izstrādāt ieteikumus iesaistītajām pusēm par to, kā samazināt PĒAT apjomu, apvienojot novērošanu (tika novērots ēdamzāles izkārtojums, ēdiena izvietojums uz šķīvja, pasniegšanas veids, kā arī maltītes baudīšanas process un ilgums), fizisko PĒAT svēršanu, daļēji strukturētas intervijas, kā arī statistisko dispersijas analīzi (Lonska et al., 2022) (I raksts). Ņemot vērā, ka Latvijā iepriekš nebija veikti plaša mēroga zinātniski pētījumi par pārtikas atkritumiem skolu ēdināšanas organizēšanā, šī pētījuma rezultāti palīdzēja konstatēt, ka PĒAT ir pastāvīga un nozīmīga problēma Latvijas skolās un kalpoja kā pamats turpmākajiem pētījumiem.

Lauka pētījums tika veikts 2021. gada rudenī septiņās Rēzeknes pilsētas skolās, aptverot 1. līdz 7. klases, kurās tika nodrošinātas valsts un pašvaldības finansētas brīvpusdienas. Pētījums tika veikts vienu mācību nedēļu jeb piecas darba dienas, nodrošinot vienlaicīgu datu vākšanu visās iesaistītajās skolās.

Pētījuma metodoloģiskā priekšrocība bija vienota ēdienkarte visās septiņās iesaistītajās skolās. Tā tika izstrādāta, balstoties uz daļēji strukturētu interviju ar skolu pārstāvjiem rezultātiem un viņu ēdienu novērtējumu, izmantojot SNW analīzes metodi (*The method for analysis of strengths, neutrals and weaknesses*). Intervijās piedalījās 11 personas – 7 skolu ēdnīcu vadītāji, 3 ēdnīcu darbinieki un viena medmāsa, kas bija iesaistīta ēdienkartes izstrādē. Visi respondenti sniedza pieredzē balstītu, daļēji subjektīvu informāciju par skolēnu pārtikas izvēlēm – par ēdieniem, kas bērniem garšo, negaršo un pret kādiem ir neitrāla attieksme. Rezultātā tika identificēti pieci ēdieni, ko parasti apēda vairāk nekā 90% skolēnu, pieci ēdieni, ko skolēni ēda negribīgi (mazāk nekā 20%), un pieci ēdieni, pret kuriem skolēniem bija neitrāla attieksme (apmēram 65%). Šāda pieeja nodrošināja datu salīdzināmību starp skolām, klašu grupām un pārtikas kategorijām.

Datu vākšanu skolās veica projekta pētnieki, kas darbojās pēc vienota protokola un ciešā sadarbībā ar ēdināšanas personālu. Pētījumā tika apvienotas kvantitatīvās un kvalitatīvās metodes. Tika veikta PĒAT tieša svēršana pa pārtikas produktu kategorijām, kopā iegūstot datus no 7064 pusdienu šķīvjiem. Kā arī pētījuma laikā pētnieki dokumentēja ēdināšanas organizācijas procesu, tostarp veica fotofiksācijas (bez personu identifikācijas). Tika novērots ēdamzāles dizains, ēdienu izvietojums uz šķīvja, pasniegšanas veids, skolēnu uzvedība ēšanas

procesā un fiksēts ēšanas laiks. Veikti arī nepieciešamie sagatavošanas darbi PĒAT kvantitatīvai mērīšanai (trauku marķēšana, porciju uzskaite utt.).

Kvantitatīvie PĒAT dati tika analizēti, izmantojot aprakstošo statistiku, un ANOVA vienvirziena dispersijas analīzi.

Rezultāti atklāja, ka skolās rodas ievērojams PĒAT apjoms. PĒAT veidoja 28,75% no kopējā pasniegtā ēdiena svara, ieskaitot dzērienus, t.i. - gandrīz viena trešdaļa no pasniegtā ēdiena tika izmesta (2.1. tabula).

2.1. tabula

PĒAT īpatsvars (%) no kopējā pasniegtā ēdiena svara Rēzeknes pilsētas skolu ēdnīcās (pa skolām) (Lonska et al., 2022), autores tulkojums

Skola	Kopējais PĒAT svars, g/nedēļā	Kopējais pasniegtā ēdiena svars, g/nedēļā*	PĒAT īpatsvars, %
S1	52 578	145 970	36,02
S2	163 750	696 962	23,49
S3	197 674	629 858	31,38
S4	297 603	684 707	43,46
S5	71 131	305 503	23,28
S6	256 933	1 122 945	22,88
S7	216 630	783 191	27,66
Kopā:	1 256 299	4 369 136	28,75

*Piezīme: kopējais pasniegtā ēdiena svars (g/nedēļā) tika aprēķināts, pamatojoties uz ēdienkartē norādīto ēdienu svaru (skatīt I Rakstu - 3. tabulu), reizinot katru dienu pasniegto ēdienu svaru ar tajā dienā pārbaudīto paraugu skaitu un saskaitot rezultātus pa visām dienām un visām skolām.
Avots: Lonska et al., 2022 aprēķini, kas balstīti uz lauka pētījuma rezultātiem.

Lielākais reģistrētais PĒAT apjoms bija 44,08% (1.–4.kl. grupā) un 42,55% (5.–7.kl. grupā). Vidējais PĒAT svars uz vienu skolēnu bija 178 grami, ieskaitot dzērienus. Jaunāko klašu skolēniem (1.–4. klasē) atkritumu bija nedaudz vairāk (182g) nekā vecāko klašu (5.–7. klasē) skolēniem (172g) (2.2. tabula). Tomēr vienvirziena ANOVA tests neuzrādīja statistiski nozīmīgas atšķirības PĒAT apjomos starp vecuma grupām (p = 0,678644).

2.2. tabula

Rēzeknes pilsētas skolu ēdnīcās lauka pētījumā konstatētais PĒAT svars (pa skolām un klašu grupām) (Lonska et al., 2022), autores tulkojums

Skola	Klašu grupa	PĒAT kopējais svars (g/nedēļā)	Faktiskais pusdienu dalībnieku skaits (paraugu skaits)	Vidējais PĒAT apjoms uz vienu skolēnu (g)
S1	7.klase	52 578	234	225

Skola	Klašu grupa	PĒAT kopējais svars (g/nedēļā)	Faktiskais pusdienu dalībnieku skaits (paraugu skaits)	Vidējais PĒAT apjoms uz vienu skolēnu (g)
S2	1.-4. klases	99 397	677	147
	5.-7. klases	64 353	450	143
S3	1.-4. klases	109 544	603	182
	5.-7. klases	88 130	421	209
S4	1.-4. klases	180 518	663	272
	5.-7. klases	117 085	447	262
S5	1.-4. klases	15 416	94	164
	5.-7. klases	55 715	399	140
S6	1.-4. klases	190 644	1 239	154
	5.-7. klases	66 289	574	115
S7	1.-4. klases	152 566	829	184
	5.-7. klases	64 064	434	148
Kopā 1.-4. klasēs		748 085	4 105	182
Kopā 5.-7. klasēs		508 214	2 959	172

Analizējot PĒAT pa pārtikas produktu kategorijām, visvairāk izšķērdētā pārtikas kategorija bija dzērieni, kas veidoja 42,24% no kopējiem PĒAT, kam sekoja pamatēdiens (kartupeļi, makaroni, rīsi) (28,38%) un gaļa (11,77%). Viszemākais PĒAT īpatsvars bija dārzeņiem, augļiem, maizei un biezpiena produktiem, piemēram, biezpiena sieriņam. Atšķirībā no citiem starptautiskiem pētījumiem, kur dominē dārzeņu atkritumi, šajā pētījumā tie bija salīdzinoši zemi, ko varētu skaidrot ar nelielu svaigu dārzeņu apjoma iekļaušanu skolu ēdienkartē, kas izriet no nepietiekamā valsts un pašvaldību finansējuma skolēnu pusdienām, kas ierobežo skolu iespējas dažādot ēdienkartes ar plašāku svaigo produktu klāstu.

Papildus tika veikta PĒAT monetārās vērtības analīze, kas atklāja, ka vidējās izmaksas par PĒAT (izņemot dzērienus) vienam skolēnam bija 0,236 EUR, kas uz to brīdi veidoja 16,6% no valsts un pašvaldības finansējuma 1,42 EUR par ēdiena porciju. Sarēķinot izmaksas 5 dienu periodā, zaudējumi bija 1666,88 EUR jeb aptuveni 333 EUR dienā, kas mācību mēnesī (21 darba diena) būtu aptuveni 7000 EUR. Ņemot vērā cenu līmeņa atšķirības dažādās valstīs, nebija iespējams viennozīmīgi noteikt šīs summas vērtību, tomēr vietējā kontekstā zaudējumi bija ievērojami. Tika aprēķināts, ka par brīvpusdienu izmaksām 1,42 EUR apmērā par porciju, ar šiem zaudējumiem varētu apmaksāt ēdināšanu gandrīz 5000 skolēniem mēnesī.

Šajā pētījumā būtiska problēma bija arī servētās maltītes, kas palika neskartas. Tā kā PĒAT svēršana notika COVID 19 pandēmijas laikā, bija sarežģīti prognozēt skolēnu skaitu, kas apmeklēs pusdienas, jo bērni varēja pēkšņi saslimt. Virtuves darbiniekiem bieži trūka precīzas

informācijas, lai pielāgotu maltīšu daudzumu, tādējādi palielinot risku pasūtīt un sagatavot pārtiku, kas palika pilnībā neskarta.

Balstoties uz iegūtajiem lauka pētījuma rezultātiem tika izstrādātas rekomendācijas ēdināšanas procesa organizācijas uzlabošanai Rēzeknes skolās, kas var būt pamats arī citu Latvijas skolu ēdināšanas procesa organizācijas uzlabošanai (Lonska et al., 2022):

1) Izstrādāt un ieviest skolās izglītības un komunikācijas stratēģijas, kas vērstas uz ilgtspējīgu un veselīgu pārtikas patēriņu.

2) Aktīvi iesaistīt skolas vadību un pedagogus ilgtspējīga pārtikas patēriņa veicināšanā.

3) Plānot ēdienkarti, lai tā balstītos ne tikai uztura vadlīnijās, bet ņemtu vērā arī skolēnu pieprasījumu un vēlmes.

4) Optimizēt ēdināšanas plānošanu, precīzi prognozējot ēdiena daudzumu.

5) Pārdomāti plānot pusdienu pārtraukumus un pielāgot ēdamzāles vidi.

6) Uzlabot ēdiena pasniegšanas veidu.

7) Nodrošināt modernas virtuves iekārtas un profesionālu virtuves personālu.

Kopumā pētījums atklāja, ka esošā ēdināšanas procesa organizācija Rēzeknes skolās nav ilgtspējīga, jo gandrīz trešdaļa no pasniegtās maltītes netiek apēsta, radot būtiskus resursu un finansiālus zaudējumus, tajā skaitā neefektīvu valsts budžeta līdzekļu izlietojumu. Tika identificēti galvenie PĒAT cēloņi Rēzeknes pilsētas skolu ēdināšanas procesā - ēdienkartes neatbilstība skolēnu gaumei, ierobežotas izvēles iespējas, nepietiekama skolēnu iesaiste un nepilnības ēdināšanas procesa organizēšanā. Pamatojoties uz iegūtajiem rezultātiem, tika izstrādātas rekomendācijas, kas vērstas uz ēdināšanas procesa organizācijas uzlabošanu, skolēnu informētības paaugstināšanu un optimālāku resursu izmantošanu. Tika secināts, ka turpmākajos pētījumos būtu nepieciešams izstrādāt individuālus ieteikumus skolu vadībai, kā arī pārbaudīt to praktisko pielietojumu skolu ēdnīcās.

2.2. PĒAT samazināšanas intervenču efektivitātes novērtējums: otrais pilotpētījums Rēzeknes skolās

Balstoties uz AE konceptuālo ietvaru, nākošajā pētniecības posmā tika plānoti praktiski pasākumi, ar mērķi uzlabot ēdināšanas procesa ilgtspēju un samazināt pārtikas atkritumu apjomu skolu ēdināšanā, jo neskatoties uz AE un ilgtspējas principu un stratēģiju integrēšanu politikas plānošanas dokumentos un vispārējās rekomendācijās, joprojām trūkst praksē pārbaudītu risinājumu, kas būtu pielāgoti šai videi un kontekstam. Arī Latvijā līdz šim nebija veikti pētījumi, kuros praktiski izmēģināti pasākumi PĒAT samazināšanai skolu ēdināšanā, tādēļ kārtējā pētījuma ietvaros tika izstrādāts un testēts pasākumu kopums, kas balstīts gan uz

pasaules labās prakses piemēriem, gan uz vietējā konteksta situācijas analīzi (Lonska et al., 2025) (V raksts).

Eksperiments un lauka pētījumi tika veikti 2023./2024. mācību gadā četrās Rēzeknes pilsētas skolās (S1, S2, S3, S4), aptverot 1.-7. klases, kurās tiek nodrošinātas valsts un pašvaldības finansētas brīvpusdienas. Lai novērtētu uz PĒAT samazināšanu vērstu intervenču ietekmi, trīs Rēzeknes skolās tika ieviesti un eksperimentāli pārbaudīti dažādi risinājumi, savukārt ceturtā S4 bija kontroles jeb testa skola, kurā intervences netika īstenotas, taču tika veikti PĒAT mērījumi.

S1 skolā tika uzstādīts PĒAT izsekotājs (*plate waste tracker*) (Matomatic AB, Uppsala, Sweden) (LOWINFOOD, 2022). Tas bija digitāls rīks - virtuves svari, kas savienoti ar planšetdatoru, kurā darbojās īpaša programmatūra. Skolēni tajā atzīmēja PĒAT iemeslus (piemēram, pārāk liela porcija, negaršoja u.tml.), un vienlaikus saņēma vizuālu atgriezenisko saiti par izmestās pārtikas daudzumu un kāda ir šīs izšķērdēšanas ietekme.

S2 skolā tika īstenota izpratnes veicināšanas un izglītošanas kampaņa, kuras laikā skolas ēdnīcā tika izvietoti informatīvi plakāti ar saukļiem, kas mudina neizšķērdēt pārtiku, galda kartes ar interesantiem faktiem par dažādiem pārtikas produktiem, lai izraisītu skolēniem interesi tos apēst, kā arī tika novadītas mācību stundas par pārtikas atkritumu problēmjautājumiem. Papildus tika organizēts radošo plakātu konkurss, kurā iesaistījās skolēni no 1. līdz 9. klasei, tādējādi veicinot viņu līdzdalību un uzvedības maiņu caur vienaudžu piemēru.

Savukārt S3 skolā tika ieviestas organizatoriskās izmaiņas - lielāka diametra pusdienu šķīvji, pagarināts pusdienu pārtraukums līdz 30 minūtēm un katrai klasei nodrošināta uzraugošā pedagoga klātbūtne pusdienu pārtraukuma laikā.

Lai novērtētu intervenču ietekmi, PĒAT mērījumi tika veikti trīs periodos: septembrī pirms intervenču uzsākšanas, lai noteiktu PĒAT apjomu sākumpunktā; tad decembrī, lai novērtētu intervenču īstermiņa ietekmi, un aprīlī, lai novērtētu intervenču ilgtermiņa ietekmi. Katrā pētījuma posmā PĒAT tika mērīti vienu mācību nedēļu jeb piecas darba dienas, nodrošinot vienlaicīgu datu vākšanu visās iesaistītajās skolās. Arī šajā pētījumā PĒAT mērījumu nedēļās tika nodrošināta vienota ēdienkarte visās četrās iesaistītajās skolās, lai mazinātu ārējo faktoru ietekmi uz eksperimentu un nodrošinātu PĒAT datu salīdzināmību starp skolām. Kopā trīs mērījumu kārtās tika iegūti PĒAT dati no 17144 šķīvjiem (paraugu skaits): 5772 - 2023. gada septembrī, 5751 - 2023. gada decembrī un 5621 - 2024. gada aprīlī.

Sākumā tika aprēķināts kopējais PĒAT apjoms, iekļaujot visu pasniegto ēdienu – gan atsevišķi servēto pamatēdienu, gan koplietošanas traukos pasniegtos ēdienus, tajā skaitā zupu, salātus un maizi. Šoreiz dzērieni netika iekļauti PĒAT analīzē (2.1. attēls).
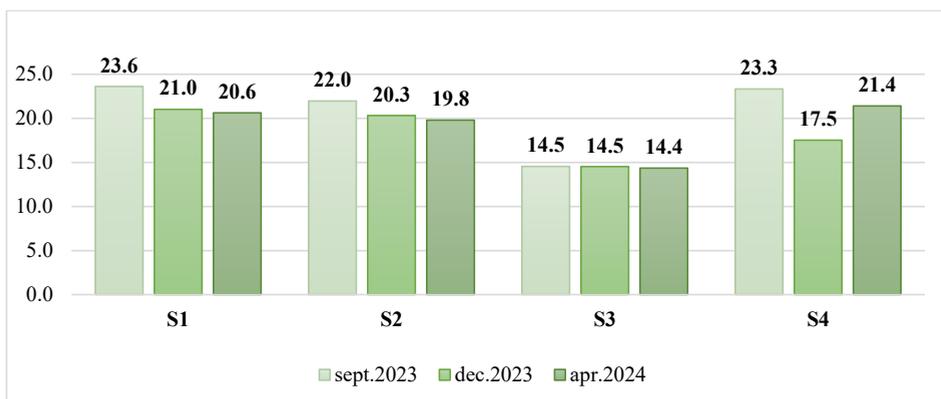
2.1. attēls. Kopējais PĒAT apjoms no pasniegtā ēdiena, % (Lonska et al., 2025), autores tulkojums

2.1. attēlā ir redzams, ka PĒAT apjoms sastādīja no 14,4% līdz 23,6% no kopējā pasniegtā ēdiena.

Tā kā dažu ēdienu, piemēram, zupas, salātu un maizes, pasniegšanas veids S4 skolā atšķīrās no pārējām skolām, dati tika filtrēti, lai nodrošinātu to salīdzināmību. S4 skolā zupa, salāti un maize, kas tika pasniegti koplietošanas traukos, netika papildināti pēc katra pusdienu pārtraukuma kā pārējās skolas, bet tika izmesti pēc katra pusdienu pārtraukuma. Statistiskajā analīzē tika iekļauti tikai atsevišķi pasniegto pamatēdienu, augļu, konditorejas izstrādājumu un biezpiena sieriņu atkritumi. PĒAT dati tika analizēti, izmantojot divus modeļus – pa klasēm (1. modelis) un pa dienām (2.modelis), īstermiņā un ilgtermiņā, kā arī pielietojot Vilkoksona rangu testu, lai statistiski izvērtētu izmaiņu nozīmīgumu.

Pētījuma rezultāti atklāja, ka neviena no īstenotajām intervencēm nenodrošināja būtisku un noturīgu PĒAT samazinājumu. Lai arī īstermiņā tika novērotas dažas pozitīvas tendences, ilgtermiņā PĒAT apjoms atkal pieauga.

Īstermiņā (2023.gada septembris–decembris), balstoties uz 1. modeļa (klašu griezumā) datiem (2.2. attēls), tika konstatēts, ka PĒAT būtiski samazinājās tikai S1 skolā, kur tika uzstādīts digitālais PĒAT izsekotājs. Šajā gadījumā novērotais PĒAT samazinājums ar Vilkoksona rangu testa p vērtību=0,000<0,001 bija statistiski nozīmīgs, kas norādīja uz pozitīvu skolēnu uzvedības maiņu, iespējams, ieinteresētības dēļ. Savukārt S3 skolā, kur tika veiktas organizatoriskas izmaiņas ēdināšanas procesā, PĒAT īstermiņā statistiski nozīmīgi palielinājās (p=0,011<0,05). Kā iespējamais iemesls tika noteikts ilgākas pusdienu pauzes, kuru laikā skolēniem bija pietiekoši daudz laika iegādāties konkurējošo pārtiku skolas ēdnīcā par maksu. S2 skolā, kur tika īstenota izpratnes veicināšanas un izglītojoša kampaņa, kā arī kontroles skolā (S4), īstermiņa izmaiņas PĒAT apjomā nebija statistiski nozīmīgas (S2: p=0,159; S4: p=0,095).
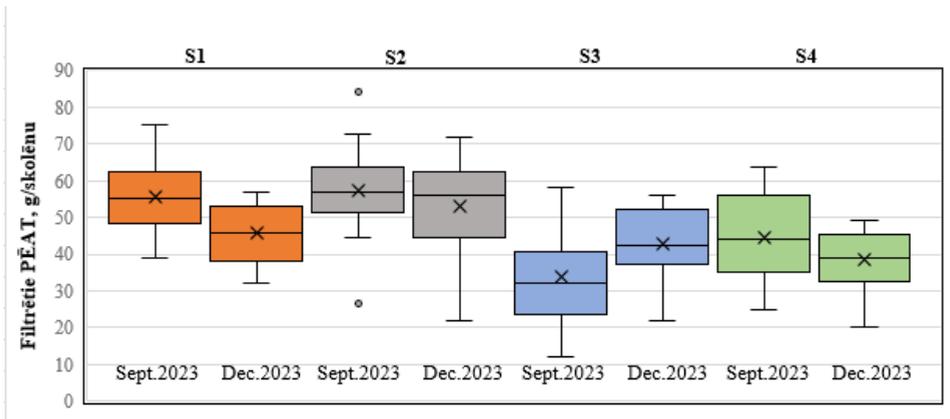
2.2. attēls. Filtrēto PĒAT datu analīze īstermiņā, g/skolēnu, 2023. gada septembris–2023. gada decembris (pa klasēm) (Lonska et al., 2025), autores tulkojums

Ilgtermiņā (2023.gada septembris–2024.gada aprīlis) 1. modeļa dati (2.3. attēls) balstoties uz Vilkoksona rangu testa rezultātiem uzrādīja, ka nevienā no skolām, izņemot S3, statistiski nozīmīgas izmaiņas PĒAT apjomos netika konstatētas: S1 (*p*-vērtība=0,107>0,05), S2 (*p*-vērtība=0,890>0,05), un S4 (*p*-vērtība=0,639>0,05). Savukārt S3 skolā PĒAT apjoms ilgtermiņā turpināja palielināties, un atšķirība bija statistiski nozīmīga (p=0,004<0,01), apstiprinot negatīvu tendenci jau novēroto īstermiņa rezultātu kontekstā.
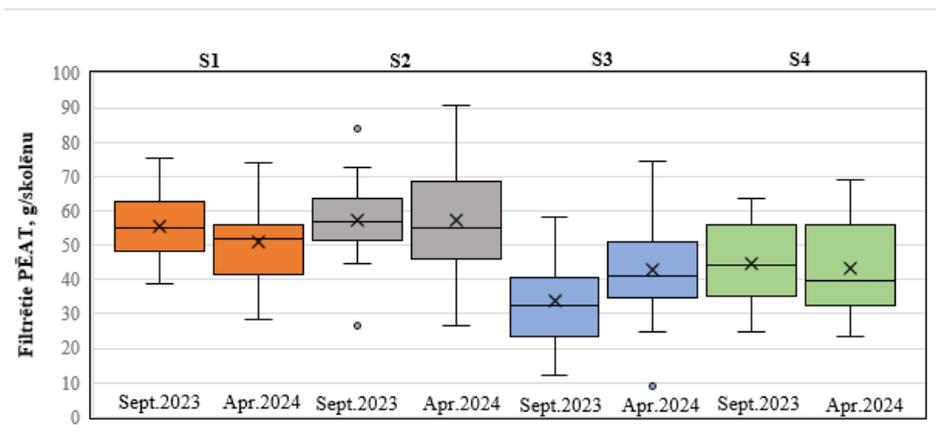
2.3. attēls. Filtrēto PĒAT datu analīze ilgtermiņā, g/skolēnu, 2023. gada septembris–2024.gada aprīlis (pa klasēm) (Lonska et al., 2025), autores tulkojums

Balstoties uz 2. modeļa (dienu griezumā) datiem (2.4. un 2.5. attēli), ne īstermiņā, ne ilgtermiņā netika konstatētas statistiski nozīmīgas atšķirības PĒAT apjomā nevienā no skolām. Vilkoksona rangu testa rezultāti visos gadījumos apstiprināja, ka novērotās izmaiņas nav statistiski nozīmīgas. Tas norāda, ka neviena no īstenotajām intervencēm dienu griezumā nav radījusi būtiskas izmaiņas skolēnu pārtikas patēriņa uzvedībā vai PĒAT apjomos. Tomēr

jāatzīmē, ka S3 skolas gadījumā ilgtermiņā p-vērtība=0,063 bija tuvu statistiskās nozīmes robežvērtībai 0,05, norādot uz iespējamo PĒAT pieauguma tendenci ilgtermiņā, taču apstiprinājumam nepieciešama padziļināta analīze.
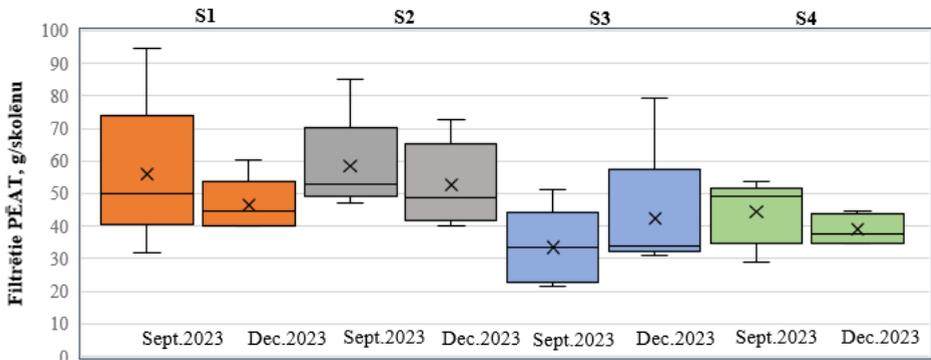
2.4. attēls. Filtrēto PĒAT datu analīze īstermiņā, g/skolēnu, 2023. gada septembris–2023. gada decembris (pa dienām) (Lonska et al., 2025), autores tulkojums
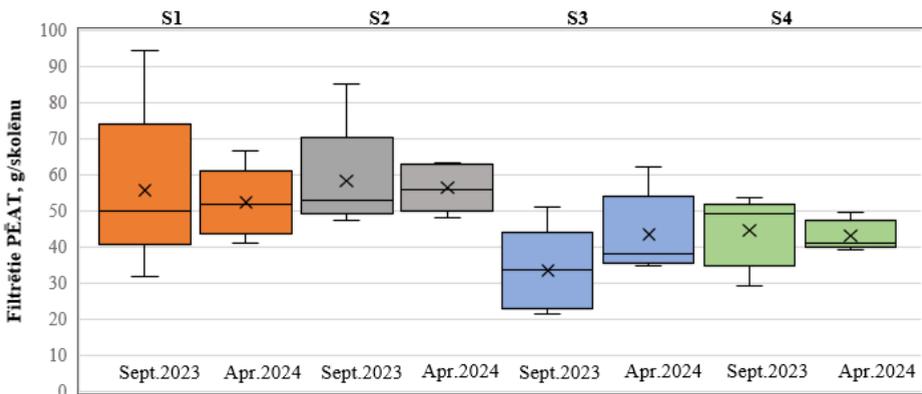
2.5. attēls. Filtrēto PĒAT datu analīze ilgtermiņā, g/skolēnu, 2023. gada septembris– 2024.gada aprīlis (pa dienām) (Lonska et al., 2025), autores tulkojums

Arī šajā lauka pētījumā tika atklāts, ka skolās servētās maltītes bieži palika neskartas. Šī situācija galvenokārt saistīta ar neprecīzu skolēnu skaita plānošanu, jo informācija par bērnu prombūtni ne vienmēr laicīgi nonāca pie virtuves darbiniekiem. Īpaši S2 un S4 skolās servēto maltīšu skaits bija lielāks nekā faktiskais skolēnu skaits, kas piedalījās pusdienās. Lielāko daļu no tām daļēji apēda klases biedri (parasti apēda gaļas ēdienu, bet piedevas tika atstātas uz šķīvja) vai pārdeva vecāko klašu skolēniem, tomēr liela daļa no tām tika izmestas atkritumos. Šādas maltītes veicināja kopējo PĒAT pieaugumu un ietekmēja rezultātu svārstības starp skolām.

Šī pētījuma ietvaros skolēnu pārtikas patēriņa uzvedība tika analizēta, balstoties uz MOA uzvedības modeli, kas ļauj daudzdimensionāli izvērtēt uzvedības priekšnoteikumus un šķēršļus ilgtspējīga pārtikas patēriņa veidošanai skolu vidē. Pētījuma rezultāti atklāja, ka neviena no īstenotajām intervencēm viena pati nav pietiekama kā vienots risinājums PĒAT samazināšanai ilgtermiņā. Lai veicinātu skolēnu uzvedības maiņu un efektīvi samazinātu pārtikas izšķērdēšanu, nepieciešamas kompleksas, kontekstam un videi pielāgotas stratēģijas, kas apvieno izglītošanu, praktisku iesaisti un sistēmiskas pārmaiņas skolu ēdināšanas programmās. Īpaši jāatzīmē strukturālie šķēršļi Latvijas skolu ēdināšanas modelī, kur dominē iepriekš pilnībā vai daļēji porcionēts un individuāli servēts ēdiens bez iespējas skolēniem izvēlēties ēdiena veidu vai porcijas lielumu. Saskaņā ar MOA uzvedības modeli, šādos apstākļos tiek ierobežotas skolēnu iespējas (*Opportunities*) rīkoties atbildīgi un samazināt pārtikas atkritumus, jo ilgtspējīga patēriņa prakse iespējama tikai tad, ja tiek nodrošinātas visas trīs komponentes – motivācija, iespējas un spējas.

Intervenču ietekmes rezultāti pa skolām apstiprina, ka PĒAT samazināšana skolu ēdināšanā ir daudzdimensionāls izaicinājums un nav vienas universālas pieejas tā risināšanai. Ilgtspējīgu rezultātu sasniegšanai nepieciešama kompleksa un kombinēta pieeja, kas apvieno pārmaiņas ēdināšanas modelī ar porciju un ēdiena izvēli, PĒAT monitoringu un ēdienreižu plānošanu, izglītojošām aktivitātēm un skolotāju iesaisti. Turklāt īstenotajiem risinājumiem jābūt pielāgotiem konkrētai darbības videi un regulāri jāpilnveido, balstoties uz novērtējumu un atgriezenisko saiti.

2.3. Ilgtspējīgs pārtikas patēriņš skolu ēdināšanas procesā: skolēnu izpratne un vērtējums

Tā kā skolēni ir galvenie pārtikas patērētāji skolu ēdināšanā, viņu personīgais redzējums ir īpaši nozīmīgs, izvērtējot ilgtspējīga pārtikas patēriņa iespējas skolās. Situācijas izvērtējums no pašu skolēnu skatu punkta var būt pamats mērķtiecīgu iniciatīvu un stratēģiju izstrādei pārtikas atkritumu samazināšanai. Tāpēc, lai novērtētu skolēnu izpratni un zināšanas par pārtikas atkritumu problēmām, viņu attieksmi pret skolas ēdienu un pusdienu organizāciju, kā arī identificētu subjektīvos PĒAT cēloņus, tika veikta skolēnu aptauja četrās Rēzeknes pilsētas skolās (Deksne et al., 2025a) (VI raksts).

Aptauja tika organizētā divās kārtās: pirms intervenču periodā 2023. gada septembrī un pēc intervenču laikā 2024. gada aprīlī vienlaicīgi četrās Rēzeknes pilsētas skolās, aptverot skolēnus no 1.-7. klasei, kam tiek nodrošinātas valsts un pašvaldības apmaksātas brīvpusdienas. Pirms aptaujas veikšanas, aptaujas anketa tika validēta 2023. gada maijā, veicot klātienes intervijas ar 28 skolēniem (pa vienam skolēnam no katras klases katrā no četrām skolām). Šī

procedūra ļāva novērtēt jautājumu skaidrību un atbilstību skolēnu vecumam un izpratnes līmenim. Taču pirms intervenču aptaujas laikā tika konstatēts, ka 1. klašu skolēnu lasīšanas un rakstīšanas prasmes tomēr nav pietiekami labas, lai varētu pilnvērtīgi piedalīties aptaujā, jo viņiem bija nepieciešams ilgs laiks, lai izprastu katru jautājumu, līdz ar to tika pieņemts lēmums izslēgt 1. klašu skolēnus no aptaujas procesa. Ir jāatzīmē, ka vairāku iemeslu dēļ pētījuma rezultātu analīzei tika izmantoti pēc intervenču, t.i. 2024. gada aprīlī organizētās aptaujas rezultāti, savukārt pirms intervenču aptaujas dati tika iekļauti Spīrmena korelācijas analīzē, lai izpildītu izlases lieluma prasību.

Aptaujas anketā iekļautie jautājumi aptvēra četras dimensijas:

I Respondentu demogrāfiskais profils;

II Vides dimensija - pamatzināšanas par skolas ēdienu, pārtikas produktiem un to negatīvo ietekmi;

III Personīgā dimensija - skolēnu individuālā attieksme pret pārtikas produktiem, un viņu personīgie pārtikas patēriņa paradumi;

IV Organizatoriskā dimensija - skolēnu viedokļi par ēdiena sensoro kvalitāti (garša, smarža, izskats, temperatūra) un viņu vērtējums par skolas ēdnīcas organizāciju un vadību.

Anketā bija iekļauti gan atvērta tipa jautājumi, gan strukturēti slēgta tipa jautājumi ar atbilžu variantiem. Aptaujas anketas aizpildīšanai bija pieejamas papīra un digitālā formā: 2.–4. klašu skolēni pārsvarā pildīja papīra anketas, savukārt 5.–7. klašu skolēni - digitālās anketas. Piekļuve e-anketai tika nodrošināta, izmantojot projekta tīmekļa vietni, ievadot paroli. Šī pieeja tika izvēlēta, ņemot vērā jaunāko skolēnu digitālās prasmes, kā arī datorklašu pieejamību skolās.

Visi skolēni aptaujas anketas pildīja sava skolotāja un projekta pārstāvja klātbūtnē, lai nepieciešamības gadījumā būtu iespēja izskaidrot jautājumu būtību, it īpaši sākumskolas skolēniem.

Kopumā pēc intervenču aptaujā piedalījās 944 skolēni, kas veidoja 82% no ģenerālkopas. Respondentu sadalījums visās kategorijās un grupās bija līdzsvarots (VI raksts - 1.tabula), tādējādi nodrošinot, ka izlase ir reprezentatīva un aptaujas rezultātus nesamērīgi neietekmē vienas grupas pārsvars.

Aptaujas rezultātu analīzei tika izmantotas statistiskās analīzes metodes - aprakstošā statistika, Kruskala-Valisa H-tests (*Kruskal–Wallis H test*), Manna Vitnija U tests (*Mann–Whitney U post hoc test*), Spīrmena korelācijas analīze (*Spearman's correlation analysis*).

Aptaujas II dimensijas rezultāti atklāja, ka skolēnu izpratne un zināšanas par pārtikas atkritumiem ir nepilnīgas. Lielākā daļa skolēnu saistīja pārtikas atkritumus ar sabojātu ēdienu (66,4%) un mizām vai kauliem (59,3%), tikai 45,4% atzina, ka arī neapēsts ēdiens uz šķīvja ir

uzskatāms par pārtikas atkritumiem, turklāt ⅓ skolēnu tos asociēja ar pārtikas iepakojumu. Neliela daļa (14,6 %) skolēnu uzskatīja, ka skolas ēdiens nav veselīgs, un 24,1% nezināja atbildi uz šo jautājumu. Attiecībā uz vides aspektiem - 21,7 % respondentu nepiekrita viedoklim, ka pārtikas atkritumiem ir negatīva ietekme uz vidi, bet ⅓ nevarēja atbildēt uz šo jautājumu. Arī ekonomiskie aspekti nebija pilnībā skaidri, 18,7% (atbildes "Nē" un "Drīzāk nē") skolēnu nepiekrita, ka pārtikas izšķērdēšana nozīmē arī naudas izšķērdēšanu, savukārt 17,4% nevarēja atbildēt uz šo jautājumu. Atklājās ierobežota izpratne un zināšanas par pārtikas atkritumu apsaimniekošanu. Lielākā daļa respondentu (43,9%) uzskatīja, ka PĒAT nonāk atkritumos, gandrīz tikpat daudz skolēnu uzskatīja, ka PĒAT tiek izbarots mājdzīvniekiem, 1/3 atzīmēja, ka nezina, kas notiek ar PĒAT.

Kopumā rezultāti atklāja, ka <u>Rēzeknes pilsētas skolu skolēniem ir nepilnīga izpratne un ierobežotas zināšanas par pārtikas atkritumu problemātiku</u>. Tika secināts, ka skolēniem trūkst skaidras izpratnes par pārtikas atkritumu jēdzienu, to ietekmi uz vidi un ekonomiku, kā arī par atkritumu apsaimniekošanas iespējām. Līdz ar to būtisks priekšnoteikums efektīvai pārtikas atkritumu samazināšanai skolās ir skolēnu izpratnes veidošana un zināšanu par ilgtspējīgu pārtikas patēriņu stiprināšana.

Analizējot aptaujas III dimensijas rezultātus attiecībā uz skolēnu attieksmi pret pārtikas atkritumiem un skolā pasniegto ēdienu, tika atklāts, ka lielāko daļu skolēnu (65,4%) Rēzeknes pilsētas skolās neuztrauc pārtikas izšķērdēšana, tomēr ⅓ atzina, ka šī problēma viņus uztrauc. Analizējot skolēnu atbildes uz jautājumiem par to, cik daudz no pusdienās pasniegtā ēdiena parasti tiek apēsts, atklājās būtiskas atšķirības dažādu ēdienu patēriņā (2.6. attēls).
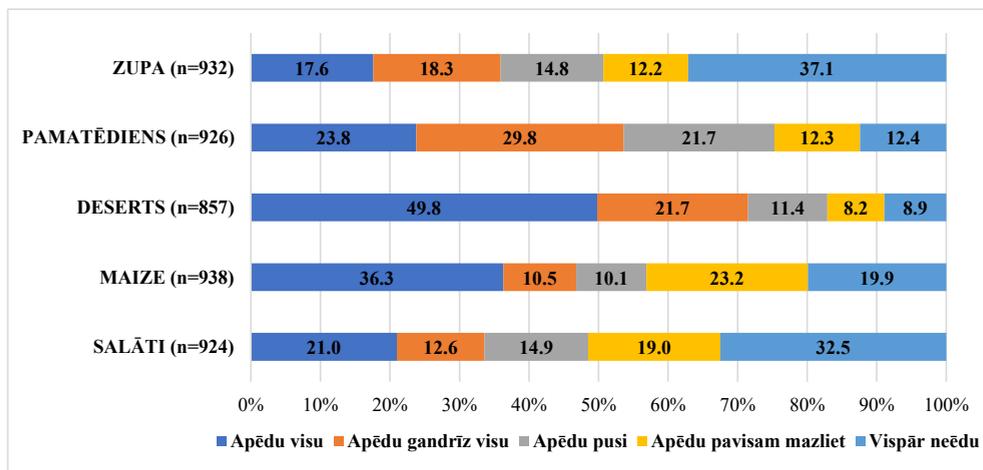
2.6. attēls. Respondentu atbilžu sadalījums uz jautājumiem par to, cik daudz no pusdienās pasniegtā ēdiena parasti tika apēsts, % (Deksne et al., 2025a), autores tulkojums

Datu analīzes rezultāti atklāja, ka deserts (saskaņā ar skolas ēdienkarti tas parasti ir smalkmaizīte, kekss, biezpiena sieriņš vai fasēts jogurts) ir vislabāk patērētais ēdiens - 71,5% respondentu norādīja, ka to apēd visu vai gandrīz visu, tam sekoja pamatēdiens - 53,6% atzīmēja, ka to apēd visu vai gandrīz visu, un maize, ko apēd visu vai gandrīz visu aptuveni puse respondentu (46,8%). Savukārt visssliktāk patērētie ēdieni bija dārzeņu salāti - 32,5% respondentu atzīmēja, ka tos vispār neēd. Kā arī zupa, ko vispār neēd 37,1% skolēnu.

Tika secināts, ka šāda ēdienu izvēles disproporcija nenodrošina pietiekamu uzturvielu uzņemšanu un var negatīvi ietekmēt skolēnu ikdienas uztura kvalitāti. Līdz ar to nepieciešamas visaptverošas izmaiņas ēdienkartes plānošanā, kas vienlaikus veicinātu dārzeņu un citu pārtikas produktu patēriņu, un arī ņemtu vērā ne tikai uztura prasības, bet arī skolēnu vēlmes un ēšanas paradumus. Šāds līdzsvars ļautu uzlabot gan ēšanas pieredzi skolā, gan samazināt PĒAT apjomu.

Attiecībā uz iemesliem, kāpēc netiek apēsts pusdienās pasniegtais ēdiens, aptaujas rezultāti atklāja galvenos PĒAT cēloņus no skolēnu skatu punkta (2.7. attēls).

	Porcija ir pārāk liela	Man negaršo pasniegtais ēdiens	Man nepietiek laika, lai apēstu pasniegto ēdienu	Pusdienas tiek pasniegtas pārāk agri, man vēl negribas ēst	Tāpēc, ka citi tā dara
ZUPA (n=943)	20.0%	46.7%	24.8%	9.4%	4.3%
PAMATĒDIENS (n=942)	17.7%	41.7%	20.4%	10.2%	3.9%
DESERTS (n=942)	8.3%	31.4%	16.0%	6.4%	3.6%
MAIZE (n=940)	5.4%	22.7%	11.4%	7.3%	4.1%
SALĀTI (n=943)	10.9%	46.2%	12.8%	5.2%	3.3%
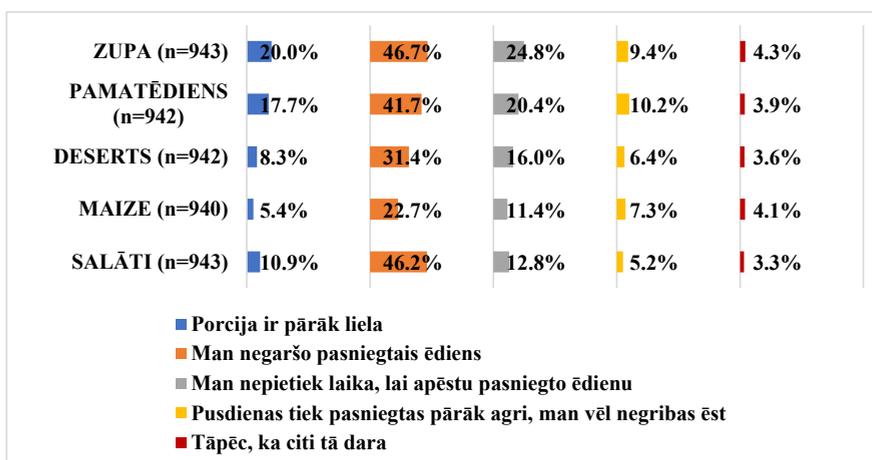
2.7. attēls. Respondentu atbilžu sadalījums uz jautājumiem par galvenajiem iemesliem, kāpēc viņi neapēd vai neēd pasniegto ēdienu, % (Deksne et al., 2025a), autores tulkojums

Viens no galvenajiem iemesliem, ko atzīmēja gandrīz puse respondentu attiecībā uz zupu (46,7%), salātiem (46,2%) un pamatēdienu (41,7%), bija tas, ka skolēniem negaršo pasniegtais ēdiens. Otrs visvairāk atzīmētais iemesls bija nepietiekams laiks ēšanai – 24,8% respondentu šo iemeslu atzīmēja attiecībā uz zupu un 20,4% - attiecībā uz pamatēdienu. Tāpat 20% respondentu atzīmēja pārāk lielas porcijas kā iemeslu PĒAT attiecībā uz zupu un 17,7% - attiecībā uz pamatēdienu.

Interpretējot rezultātus, tika secināts, ka katram iemeslam var būt dažādi kontekstuāli un individuāli faktori – ierobežota pieredze ar konkrētiem ēdieniem mājas vidē, personīgā garšas

uztvere, ēšanas paradumi, fizioloģiskās vajadzības u.d.c. Līdz ar to, lai veicinātu atbildīgu pārtikas patēriņu un efektīvi samazinātu PĒAT, ir būtiski ņemt vērā šo faktoru savstarpējo mijiedarbību un skolēnu individuālās īpatnības, piedāvājot elastīgāku, skolēnu vēlmēm un vajadzībām pielāgotu ēdienkarti.

Uz to norāda arī aptaujas rezultāti par to, ko skolēni dara ar ēdinu, kas paliek neapēsts. Gandrīz trešdaļa skolēnu atzīmēja, ka to atdod klasesbiedram, neliela daļa (14,2%), to ko var (auglis, maize, deserts) paņem līdzi un apēd vēlāk, bet lielākā daļa respondentu (58,7 %) atzīmēja, ka ēdiens tiek atstāts uz šķīvja. Šāda izvēle lielā mērā ir saistīta ar ierobežotajām iespējām Rēzeknes skolās, kur skolēniem faktiski netiek piedāvātas alternatīvas, ko darīt ar neapēsto ēdienu. Tāpēc, lai veicinātu uzvedības izmaiņas, nepietiek tikai ar informēšanu, izglītošanu vai ēdienkartes maiņu. Nepieciešamas arī organizatoriskas izmaiņas, kas dotu skolēniem izvēles iespējas attiecībā uz ēdiena veidu un daudzumu. Šāda pieeja varētu uzlabot skolēnu ēšanas paradumus un samazināt PĒAT apjomu skolu vidē.

Analizējot aptaujas IV dimensijas rezultātus par skolēnu apmierinātību ar skolā pasniegtā ēdiena sensorajām īpašībām – garšu, smaržu, izskatu un temperatūru – tika atklāts, ka skolēnu vērtējumi šajās kategorijās ievērojami atšķiras starp skolām, klasēm un dzimumiem. Tomēr kopumā iegūtie dati norādīja, ka skolēnu apmierinātība ar ēdiena sensorajām īpašībām Rēzeknes pilsētas skolās ir relatīvi zema, un īpaši zems novērtējums tika sniegts attiecībā uz ēdiena temperatūru un smaržu (2.8. attēls).
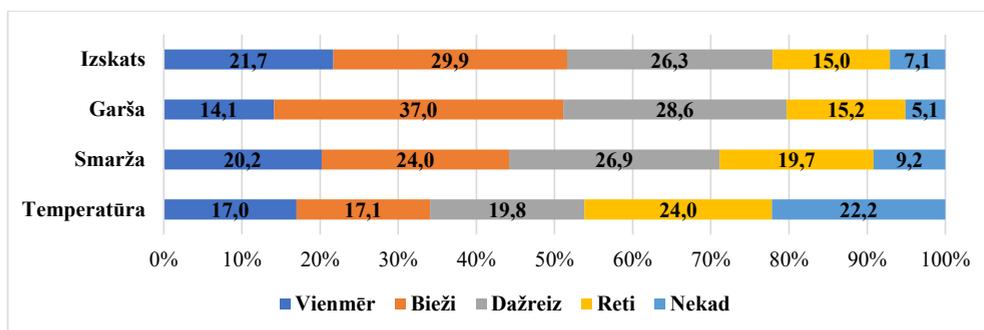
2.8. attēls. Respondentu atbilžu sadalījums uz jautājumiem par apmierinātību ar skolā pasniegtā ēdiena sensorajām īpašībām, % (n = 944) (Deksne et al., 2025a), autores tulkojums

Tikai neliela daļa skolēnu norādīja, ka vienmēr ir apmierināti ar ēdiena sensorajām īpašībām. Apvienojot atbildes "vienmēr" un "bieži", vislabāk tika novērtēts ēdiena izskats (51,6%) un garša (51,1%). Savukārt vissliktāk – ēdiena temperatūra (46,2%) un smarža (28,9%).

Kopumā tika secināts, ka skolā pasniegtais ēdiens lielākoties neatbilst skolēnu uztverei par kvalitatīvu maltīti. Tika novērotas arī vecuma un dzimuma atšķirības – jaunāko klašu

skolēni kopumā sniedza pozitīvākus vērtējumus, kamēr vecāko klašu skolēni vairāk pauda neapmierinātību. Tāpat zēni vērtēja ēdienu pozitīvāk, savukārt meitenes bija kritiskākas. Arī šie rezultāti atspoguļo Rēzeknes skolu ēdināšanas modeļa trūkumus, jo ēdiens, kas tiek iepriekš porcionēts un servēts, līdz ēšanas brīdim bieži vien jau ir atdzisis, kas negatīvi ietekmē arī tā garšu.

Lai noskaidrotu, vai pastāv saistība starp skolēnu ēdiena sensoro īpašību novērtējumu un PĒAT apjomu, tika veikts Spīrmena korelācijas tests, iekļaujot pirms un pēc intervenču perioda datus (VI raksts – A1 tabula). Rezultāti atklāja, ka nepastāv statistiski nozīmīga saistība starp skolēnu apmierinātību ar skolas ēdiena sensorajām īpašībām un PĒAT (p>0,05), norādot uz citiem ietekmes faktoriem, tajā skaitā ēdiena veida un porciju lieluma izvēles iespējām.

Aptaujas rezultāti atklāja, ka vairāk kā puse skolēnu ir apmierināti ar būtiskākajiem ēdināšanas organizācijas aspektiem. 55,2% skolēnu pauda apmierinātību ar pusdienu pasniegšanas laiku, 56,8% – ar pusdienu pārtraukuma ilgumu un 60% respondentu atzina, ka viņiem patīk, ka ēdiens jau ir servēts uz galdiem. Tomēr aptuveni 1/3 skolēnu vēlētos, lai pusdienas tiktu pasniegtas agrāk, būtu garāks pusdienu pārtraukums un iespēju pašiem izvēlēties ēdiena veidu un porcijas lielumu. Šie rādītāji norāda uz būtiskām nepilnībām pašreizējā ēdināšanas modelī. Tika secināts, ka nepieciešami uzlabojumi ēdināšanas organizācijā, kas ietvertu ne tikai pusdienu laika un ilguma pielāgošanu, bet arī elastīgāku pieeju porciju un ēdiena izvēlē, kas varētu veicināt lielāku skolēnu apmierinātību un vienlaikus mazināt PĒAT.

Lielākā daļa skolēnu pozitīvi vērtē gan ēdnīcas personāla, gan skolotāju attieksmi un iesaisti pusdienu laikā. 74,7% respondentu norādīja, ka ēdnīcas darbinieki vienmēr vai bieži ir laipni un izpalīdzīgi, 77,6% – ka skolotāji vienmēr vai bieži palīdz pusdienu laikā, savukārt 58,4% atzīmēja, ka skolotāji bieži vai vienmēr ēd kopā ar viņiem pie viena galda. Tomēr, lai arī kopējais skolēnu novērtējums par ēdnīcas personāla un pedagogu iesaisti pusdienu laikā ir pozitīvs, jāatzīmē, ka Rēzeknes pilsētas skolās skolotāju iesaiste ēdināšanas procesā būtiski atšķiras starp skolām un klašu grupām. Tika novērots, ka skolotāji visbiežāk asistē tikai jaunāko klašu (1.–4. klase) skolēniem. Latvijā skolotāju iesaiste pusdienu laikā ir brīvprātīga un netiek iekļauta oficiālajā darba slodzē, līdz ar to pedagogu motivācija piedalīties šajā procesā ir atkarīga no viņu personīgās iniciatīvas un attieksmes. Ārvalstu prakses, piemēram, Zviedrijas pieeja, kur skolas pusdienas ir integrētas izglītības programmā kā "pedagoģiskās maltītes" un šis darbs tiek apmaksāts, ieviešana Latvijas skolu ēdināšanas procesā varētu būtiski uzlabot pusdienu laika izglītojošo vērtību, veicinot pozitīvu un atbildīgu pārtikas patēriņa uzvedību skolēnu vidū, kā arī potenciāli samazinātu PĒAT apjomu skolās. Skolotāju klātbūtne ne tikai

nodrošina praktisku palīdzību, bet arī rada cieņpilnu, drošu un koordinētu ēšanas vidi, kas ilgtermiņā var veicināt ilgtspējīgākus ēšanas paradumus.

Aptaujas rezultātu analīze MOA ietvarā skaidri atklāja, ka pašreizējais skolu ēdiena pasniegšanas modelis Rēzeknes pilsētā nav orientēts uz ilgtspēju un PĒAT mazināšanu. Esošā ierobežojošā sistēma, kurā ēdiens tiek iepriekš individuāli porcionēts un servēts, liedz skolēniem vienu no būtiskākajiem uzvedības maiņas elementiem – iespējas rīkoties, tādējādi patstāvīgi pieņemt atbildīgus lēmumus par ēdiena izvēli un daudzumu. Šis aspekts kavē uzvedības maiņu ilgtspējīga pārtikas patēriņa virzienā. Rezultāti norāda uz nepieciešamību pārskatīt skolu ēdināšanas organizācijas principus, nodrošinot lielāku elastību, izvēles iespējas un skolēnu līdzdalību. Tikai tad būs iespējams izveidot ilgtspējīgu, uz skolēnu vajadzībām orientētu ēdināšanas modeli, kas sekmē atbildīgu pārtikas patēriņu un palīdz samazināt pārtikas atkritumu apjomu ilgtermiņā.

3. RISINĀJUMI SKOLU ĒDINĀŠANAS PROCESA ORGANIZĀCIJAS UN PĀRTIKAS SISTĒMU TRANSFORMĀCIJAI

3.1. Tehnoloģiskie risinājumi pārtikas atkritumu novēršanai

Balstoties uz iepriekšējos pētījumu posmos iegūtajiem rezultātiem par PĒAT apjomiem un to cēloņiem skolu ēdināšanā, kā arī identificētajām ar ēdināšanas organizāciju saistītajām nepilnībām, tika secināts, ka nepieciešama ēdināšanas pārvaldības procesa optimizācija Latvijas skolās ar mērķi samazināt PĒAT daudzumu. Tika atklāts, ka šajā kontekstā būtiska loma ir tehnoloģiskajām inovācijām, kas visā pasaulē tiek plaši izmantotas pārtikas atkritumu samazināšanā dažādās nozarēs (Kodors et al., 2024) (VII raksts). Teorētiskā analīze atklāja, ka arī AE ietvarā digitālie un tehnoloģiskie risinājumi ir būtiski atkritumu novēršanā un ilgtspējīgā resursu pārvaldībā.

Lai risinātu identificētās problēmas un veicinātu ilgtspējīgu skolu ēdināšanas procesa pārvaldību, tika izstrādāts uz zināšanām balstītas rekomendāciju sistēmas (*knowledge-based recommendation system*) prototips, kas darbojas uz mākslīga intelekta bāzes un ir paredzēts kā praktisks lēmumu pieņemšanas atbalsta rīks skolu vadībai un personālam. Tā mērķis ir sekmēt lēmumu pieņemšanu par skolas ekosistēmas sakārtošanu tā, lai samazinātu PĒAT apjomu un vienlaikus sekmētu atbildīgu pārtikas patēriņu, uzlabojot ēdināšanas procesa organizāciju skolās.

Rekomendāciju sistēmas prototips tika izstrādāts balstoties uz CDD pieeju, kas ļauj sasaistīt rekomendācijas ar skolas ekosistēmas izmērāmiem parametriem, lai apmierinātu uz datiem balstītas pieejas prasības. Tās pamatā bija ekspertu zināšanas, kas iegūtas E-mentors projektā. Eksperti identificēja 26 galvenās rekomendācijas pārtikas atkritumu samazināšanai, kuras tika saistītas ar konkrētiem izvērtēšanas kritērijiem, un kopumā tika izstrādāti 53 pašnovērtējuma jautājumi, kas aptver būtiskākos skolu ēdināšanas organizācijas aspektus un līdz ar to ļauj noteikt katras skolas aktuālās problēmas un sniegt visatbilstošākos ieteikumus.

Prototips tika veidots, iekļaujot trīs funkcionālos komponentus:

- Audita moduli, kas nodrošina strukturētu pašnovērtējuma ceļvedi skolu ēdināšanas procesa izvērtēšanai. Šis modulis ļauj lietotājiem atbildēt uz jautājumiem, kas aptver būtiskākās ar ēdināšanas organizāciju saistītās jomas, un rezultāti tiek attēloti vizuāli, veidojot pamatu ieteikumu sniegšanai.

- Zināšanu bāzi, kurā iekļauti 53 pašnovērtējuma jautājumi un 26 digitāli strukturētas rekomendācijas, kas izstrādātas, balstoties uz ekspertu diskusijām, literatūras analīzi un Rēzeknes skolu ēdināšanas īpatnībām. Katra rekomendācija ir sasaistīta ar vienu vai

vairākiem izvērtēšanas kritērijiem, kas ļauj sistēmai sniegt pielāgotus ieteikumus atbilstoši konkrētās skolas situācijai.

- PĒAT prognozēšanas rīku, kas integrēts no E-mentors projektā izstrādāta simulatora. Tas balstās uz skolu administratīvajiem parametriem un skolēnu aptauju datiem, ļaujot modelēt PĒAT potenciālos apjomus un sniegt datos balstītu pamatojumu rekomendāciju piemērošanai.

Papildus šo komponentu ietvaros eksperimentāli tika pārbaudīta LLM klasifikatora funkcionalitāte, kura mērķis ir nodrošināt lietotājiem iespēju filtrēt jautājumus un ieteikumus, izmantojot brīvā teksta pieprasījumus. LLM tika apmācīts ar pielāgotiem datiem un testēts dažādos scenārijos, tomēr šobrīd šī funkcionalitāte vēl nav pilnībā integrēta lietotājiem pieejamā prototipā. Lai nodrošinātu rekomendāciju digitalizāciju atbilstoši CDD pieejai, bija nepieciešama ekspertu iesaiste. Eksperti piedalījās ieteikumu pārstrukturēšanā, sasaistot tos ar izmērāmiem rādītājiem un konkrētām audita pazīmēm, kas raksturo ēdināšanas procesa organizāciju skolās. Turklāt, lai novērtētu rekomendāciju nozīmīgumu, tika izmantota strukturēta pāru salīdzināšanas metode. Četras ekspertes ar pieredzi pārtikas atkritumu mazināšanas jomā individuāli izvērtēja katras rekomendācijas potenciālo ietekmi uz PĒAT samazināšanu. Apkopotie rezultāti ļāva noteikt to relatīvo svaru un klasificēt tās trīs prioritātes līmeņos – no visbūtiskākajām līdz mazāk nozīmīgajām. Ekspertu balsojuma rezultātā visaugstāk tika novērtētas šādas rekomendācijas: iespēja skolēniem izvēlēties starp diviem ēdieniem, bufetes tipa ēdināšanas modeļa ieviešana, kā arī koordinēta un savlaicīga informācijas apmaiņa starp skolas un ēdināšanas personālu, kas ļauj precīzi plānot skolēnu skaitu un attiecīgi – nepieciešamo pagatavojamā ēdiena daudzumu.

Ar izstrādāto rekomendāciju sistēmas prototipu ir iespējams:

- veikt strukturētu skolu ēdināšanas procesa pašnovērtējumu, aptverot 10 būtiskās kontekstuālās jomas (piemēram, ēdamzāles vides organizācija, pusdienu laika grafiks, ēdiena pasniegšanas veids u.c.);
- balstoties uz konstatētajiem audita rezultātiem un identificētajiem riska faktoriem, sniegt katrai skolai pielāgotus ieteikumus pārtikas atkritumu samazināšanai;
- izmantojot prognozēšanas rīku, kas, balstoties uz skolas parametriem un skolēnu aptaujas datiem, ļauj novērtēt paredzamo PĒAT apjomu;
- eksperimentāli izmantot LLM klasifikatoru, kas ļauj ar brīvā teksta pieprasījumiem filtrēt atbilstošas rekomendācijas un audita jautājumus.

Zināšanās balstītas rekomendāciju sistēmas izstrāde ir būtisks solis ceļā uz datos un pierādījumos balstītu pārtikas atkritumu samazināšanu skolu ēdināšanas procesā. Šāds rīks var būt praktisks atbalsts skolu ēdināšanas procesa pašnovērtējumam, ar kura palīdzību identificēt

būtiskākās problēmas un saņemt individuāli pielāgotus risinājumus, lai mērķtiecīgi virzītos uz optimālāku resursu pārvaldību, atbildīgāku pārtikas patēriņu un uzlabotu ēdināšanas procesa kvalitāti Latvijas skolās.

3.2. Konceptuāls rīcības plāns bezatkritumu pārtikas patēriņa veicināšanai skolu ēdināšanas procesā

Promocijas darba ietvaros veikto empīrisko pētījumu rezultāti atklāja vairākus būtiskus aspektus, kas kavē pāreju uz bezatkritumu pārtikas patēriņu Rēzeknes skolu ēdināšanas procesā.

Pamatā tie ir saistīti ar esošo ēdiena pasniegšanas modelis, kur skolu ēdināšanas procesu organizē un pārrauga pašvaldība. Pakalpojums tiek nodrošināts slēgta tipa skolu ēdnīcās, centralizēti pārvaldot pārtikas iepirkumus, ēdienkaršu plānošanu un personāla darbu. Ēdināšanas organizācija balstās uz stingru normatīvo regulējumu, kas nosaka obligātās uztura normas, izcenojuma ierobežojumus, kā arī higiēnas un pārtikas drošības prasības. Lai arī šie nosacījumi ir būtiski skolēnu veselības aizsardzībai un nodrošina pusdienu maltītes atbilstību uztura standartiem, tie nav pielāgoti viņu individuālajām īpatnībām, vēlmēm un apetītei, līdz ar to veicina pārtikas atkritumu veidošanos (Deksne et al., 2025a; Lonska et al., 2022, 2025).

Ēdiens skolās tiek iepriekš servēts un ir pilnībā vai daļēji porcionēts, bez iespējas skolēniem izvēlēties porcijas lielumu vai ēdiena veidu. Nav vienotas sistēmas, kas ļautu operatīvi pielāgot porciju daudzumu faktiskajam skolēnu skaitam, kas apgrūtina precīzu plānošanu. Pusdienu pārtraukumi tiek organizēti pārāk agri un ir īsi, kas ietekmē gan ēšanas tempu, gan vēlmi ēst. Ēdienkartes tiek sagatavotas bez skolēnu vai vecāku iesaistes, kā rezultātā tiek gatavoti un pasniegti skolēnu gaumei un vēlmēm neatbilstoši ēdieni. Tāpat trūkst vienotas pārtikas atkritumu audita sistēmas, līdz ar to nav precīza priekšstata par PĒAT apjomiem, kas ierobežo datos balstītu lēmumu pieņemšanu un efektīvu stratēģiju izstrādi. Šie faktori samazina ēdināšanas procesa kvalitāti, ierobežo skolēnu patstāvību un neveicina atbildīgu pārtikas patēriņu (Deksne et al., 2025a; Lonska et al., 2022, 2025).

Rezultāti atklāj, ka pie šāda ēdināšanas organizācijas modeļa nav iespējama skolēnu uzvedības maiņa. Balstoties uz iepriekš minēto MOA modeli - Rēzeknes skolu skolēniem ir ierobežotas spējas (*Ability*), trūkst motivācijas (*Motivation*) un ir liegtas iespējas (*Opportunities*) atbildīgi patērēt pārtiku un novērst vai mazināt PĒAT apjomu. Lielai daļai skolēnu ir ierobežota izpratne un zināšanas par pārtikas atkritumiem, to negatīvo ietekmi un apsaimniekošanu. Skolās trūkst sistemātisku un kompleksu izglītojošo aktivitāšu, kas aktualizētu šos jautājumus un palīdzētu veidot atbildīgus pārtikas patēriņa paradumus. Tāpat tika novērota zema personīgās atbildības izjūta un motivācija rīkoties ilgtspējīgi, jo pārtikas atkritumu problēma skolās netiek akcentēta. Trūkst arī pozitīvu uzvedības stimulu un nav

līdzdalības vai iesaistes iespēju, kas palīdzētu veidot atbildīgus patēriņa paradumus. Līdz ar to skolēni neapzinās savu lomu pārtikas atkritumu samazināšanā, un viņu uzvedību lielā mērā nosaka ārējie apstākļi, nevis iekšējā motivācija. Ir liegtas iespējas izvēlēties ēdiena daudzumu un veidu. Porcijas netiek diferencētas atbilstoši vecumam vai apetītei, kā arī netiek nodrošināta iespēja paņemt līdzi neapēsto ēdienu. Šie strukturālie un organizatoriskie ierobežojumi liedz pat informētam un motivētam skolēnam atbildīgi rīkoties un kavē uzvedības maiņu.

Tā kā šāds ēdiena pasniegšanas modelis ir izplatīts arī citās Latvijas skolās, šī gadījuma izpētes rezultāti var tikt izmantoti kā pamats secinājumu un priekšlikumu attiecināšanai plašākā mērogā.

Kopumā rezultāti apstiprina H1 hipotēzi par to, ka Latvijas skolās ēdiena pasniegšanas modelis ar iepriekš individuāli servētām pilnībā vai daļēji porcionētām maltītēm, neatbilst ilgtspējīgas AE principiem un neveicina bezatkritumu pārtikas patēriņu.

Rezultāti apstiprina arī H2 hipotēzi par to, ka atsevišķi īstenotas intervences pārtikas atkritumu mazināšanai nenodrošina ilgtermiņa ietekmi skolu ēdināšanas procesā.

Lai sekmētu pārmaiņas ēdināšanas procesa organizācijā skolās, nepieciešams veidot tādu sistēmu, kas vienlaikus stiprina skolēnu zināšanas un prasmes, attīsta motivāciju un nodrošina reālas iespējas atbildīgi rīkoties.

Lai risinātu esošā ēdiena pasniegšanas modeļa ierobežojumus un nodrošinātu pāreju uz ilgtspējīgu, bezatkritumu pārtikas patēriņu skolās, tika izstrādāts konceptuāls rīcības plāns, kas balstās uz ilgtspējīgas AE un ilgtspējīgas pārtikas sistēmas principiem (3.1. attēls).
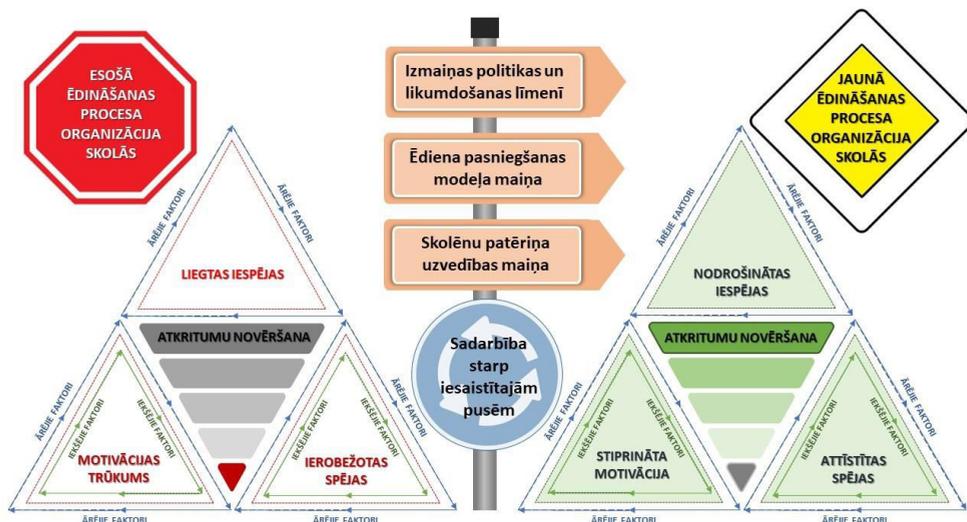
3.1. attēls. Konceptuāls rīcības plāns bezatkritumu pārtikas patēriņa veicināšanai skolu ēdināšanas procesa organizācijā, balstoties uz ilgtspējīgas aprites ekonomikas un ilgtspējīgas pārtikas sistēmas principiem (autores veidots)

3.1. attēlā redzamais konceptuālais rīcības plāns ilustrē pārejas procesu no esošās, ierobežojošās ēdināšanas procesa organizācijas skolās uz ilgtspējīgu, bezatkritumu pārtikas patēriņa modeli. Tas veidots, balstoties uz MOA uzvedības teoriju un atspoguļo, kā konkrēti rīcības virzieni var nodrošināt ēdināšanas procesa organizācijas transformāciju.

Rīcības plānā iezīmēti trīs galvenie pārmaiņu virzieni:

Izmaiņas politikas un likumdošanas līmenī. Balstoties uz esošo stingro regulatīvo ietvaru, skolas bieži vien ir spiestas mehāniski izpildīt normatīvos aktus, neņemot vērā reālo situāciju, kā arī skolēnu vēlmes un vajadzības. Tādēļ ir nepieciešamas izmaiņas spēkā esošajā normatīvajā regulējumā, lai nodrošinātu skolām lielāku rīcības brīvību un iespēju ieviest konkrētajam kontekstam un darbības videi piemērotus risinājumus. Šādi risinājumi varētu ietvert, piemēram, porciju diferencēšanu atbilstoši skolēnu vecumam un apetītei, ēdienkartes pielāgošanu atbilstoši skolēnu pieprasījumam vai neapēstā ēdiena lietderīgu izmantošanu. Tāpat būtu jāparedz iespēja izmēģināt alternatīvus uz ēdināšanas procesa organizācijas uzlabošanu vērstus risinājumus, nebaidoties no normatīvā pārkāpuma riska.

Ēdiena pasniegšanas modeļa maiņa. Ir nepieciešamas būtiskas izmaiņas ikdienas skolu ēdināšanas procesā, nodrošinot iespēju skolēniem izvēlēties ēdiena daudzumu un veidu atbilstoši savām vēlmēm un vajadzībām. Tāpat jāparedz iespēja paņemt līdzi neapēsto ēdienu, kā arī jāattīsta pasniegto porciju plānošana, samazinot pārprodukciju. Šīs izmaiņas palīdzētu samazināt PĒAT apjomus un uzlabotu ēdināšanas procesa kvalitāti un skolēnu apmierinātību.

Skolēnu patēriņa uzvedības maiņa, stiprinot skolēnu izpratni un zināšanas par pārtikas atkritumu problēmām un skolas ēdienu, attīstot personīgo atbildības izjūtu, radot motivējošu vidi un nodrošinot iespējas atbildīgai un ilgtspējīgai rīcībai, ko var panākt ar kompleksām, konkrētam kontekstam un darbības videi pielāgotām stratēģijām, kas apvieno izglītojošus pasākumus, skolēnu praktisku iesaisti un organizatoriskas izmaiņas ēdiena pasniegšanas modelī.

Rīcības plāna centrā ir uz sadarbību balstīta pieeja, kuras īstenošana iespējama tikai tad, ja visas ieinteresētās puses, t.i., politikas veidotāji, skolu administrācija, ēdinātāji, pedagogi, vecāki un skolēni, darbojas saskaņoti, apzinoties savu lomu un atbildību pārmaiņu procesā. Tikai šāda pieeja var nodrošināt sekmīgu pāreju uz ilgtspējīgu, bezatkritumu pārtikas patēriņa ēdināšanas procesa organizāciju skolās.

3.3. Konceptuālais ietvars uz patēriņu balstītai pārtikas sistēmas transformācijai

Promocijas darba noslēdzošajā posmā tika analizēts PPĶ patēriņa posms kā stratēģiski nozīmīgs pagrieziena punkts pārtikas sistēmas transformācijā uz ilgtspējīgu modeli. Šajā pētījumā skatījums ir paplašināts no institucionālā uz sistēmisko līmeni, iekļaujot plašākus

pārtikas patēriņa aspektus. Iegūtie rezultāti papildina promocijas darba teorētisko un empīrisko ietvaru, iezīmējot plašākas iespējas veidot patērētājam pielāgotas stratēģijas ilgtspējīga pārtikas patēriņa veicināšanai un būt par pamatu mērķtiecīgām pārmaiņām (Deksne et al., 2025b) (VIII raksts).

Balstoties uz bibliometrisko analīzi un integratīvās literatūras pārskatu, tika identificētas četras galvenās tematiskās jomas, kas ietekmē pāreju uz ilgtspējīgu pārtikas patēriņu: pārtikas atkritumu daudzums un to mazināšana, nepieciešamība mainīt uztura modeļus, sarežģītā patērētāju uzvedība un politiskais un normatīvais ietvars (Deksne et al., 2025b). Šie aspekti bija pamats konceptuālā ietvara izstrādei.

3.2. attēlā ir redzams konceptuālais ietvars, kurā pārtikas patēriņa posma galvenās problēmas ir sasaistītas ar iespējamiem risinājumiem un atbalsta rīkiem, kas veicina ilgtspējīgu pārtikas patēriņu, tādējādi pārveidojot pārtikas sistēmu.
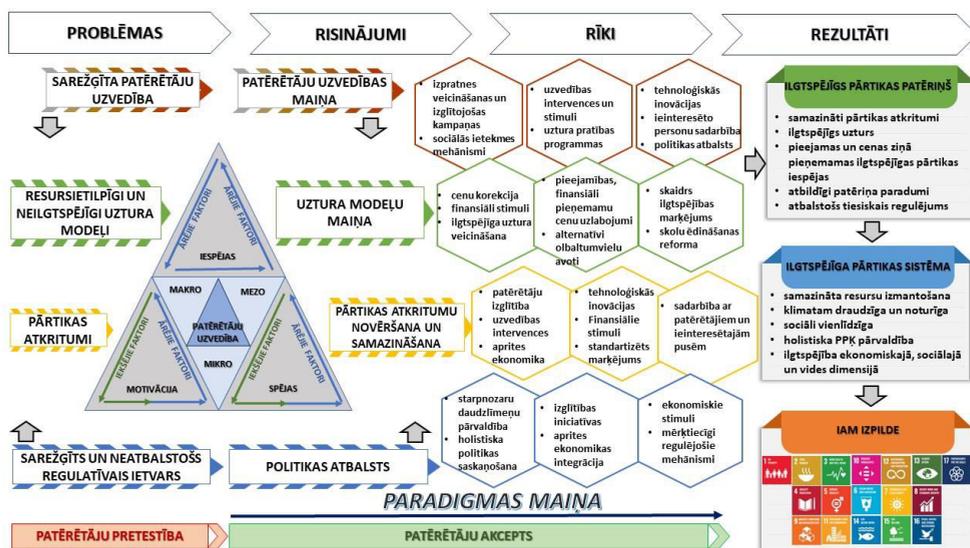
3.2. attēls. Konceptuāls ietvars pārtikas sistēmas transformācijai caur pārtikas patēriņa posmu (Deksne et al., 2025b), autores tulkojums

Pamatojoties uz teorētiskās analīzes rezultātiem, konceptuālā ietvara centrā ir patērētājs, kura lēmumi un uzvedība būtiski ietekmē visus procesus PPĶ. Patērētāja rīcību nosaka mikro, mezo un makro līmeņu faktori, kā arī motivācija, spējas un iespējas, kas balstās uz MOA patērētāju uzvedības teoriju (Deksne et al., 2025b).

Ietvarā tiek akcentēts, ka patērētāju uzvedības maiņu var panākt ar politikas atbalstu, piemēram, izglītojošām aktivitātēm, uzvedības intervencēm, tehnoloģiskām inovācijām, finansiāliem stimuliem u.c. rīkiem. Patērētāju uzvedības maiņa var būt katalizators plašākām pārmaiņām pārtikas patēriņa posmā. Tomēr, lai notiktu paradigmas maiņa, ir nepieciešama

pāreja no patērētāju pretestības uz ilgtspējīga patēriņa pieņemšanu. Tikai tad, kad ilgtspējīgs pārtikas patēriņš tiks pieņemts kā ikdienas izvēle un dzīvesveids, būs iespējama noturīga pārtikas sistēmas transformācija. Lai panāktu šādas pārmaiņas nepieciešama kompleksa, konkrētai darbības videi pielāgota un uz patērētāju vērsta pieeja, kas apvieno mērķtiecīgas aktivitātes jeb rīkus un politikas atbalstu, lai nodrošinātu pāreju uz ilgtspējīgu pārtikas patēriņu, kas tālāk veido ilgtspējīgu pārtikas sistēmu, un sekmē ANO SDGs izpildi (Deksne et al., 2025b).

Lai gan ietvars tika izstrādāts uz literatūras analīzes pamata, arī promocijas darbā veiktie empīriskie pētījumi atklāja līdzīgas problēmas, kas norāda uz ietvara aktualitāti un praktisku pielietojumu pārmaiņu plānošanā un īstenošanā. Tas var tikt izmantots kā praktisks rīks pārtikas politikas plānošanā un īstenošanā, izglītības jomā un ēdināšanas organizēšanā, īpaši skolās, kur pastāv unikāla iespēja veidot patēriņa kultūru, kas balstīta uz izpratni, atbildību un ilgtspēju. Šajā kontekstā izstrādātais ietvars ir ne tikai teorētiska sistēma, bet ceļvedis pārmaiņu virzīšanai praksē, it īpaši skolās, kur jau no mazotnes ir iespējams veidot nākotnes patērētāju paradumus un uzvedību un ir vislielākais potenciāls paradigmas maiņai.

SECINĀJUMI

1. Promocijas darbā iegūtie rezultāti apstiprina, ka pārtikas atkritumi ir globāla, daudzdimensionāla un pastāvīga problēma ar tālejošām sekām, jo īpaši PPĶ patēriņa posmā.

2. Izpētot AE konceptu, tika atklāts, ka plašāks "ilgtspējīgas AE" ietvars ir teorētiski un praktiski piemērots pamats bezatkritumu pārtikas patēriņa īstenošanai, jo primāri ir vērsts uz atkritumu novēršanu, kā arī resursu apriti un patērētāju patēriņa paradumu maiņu. Tas atspoguļo paradigmas maiņu uz holistisku un nepārtrauktu pieeju ilgtspējai, kur ekonomiskā darbība ir cieši saistīta ar sociālās labklājības saglabāšanu un vides aizsardzību.

3. Balstoties uz teorētisko analīzi, tika identificēts plašs un daudzveidīgs faktoru klāsts, kas ietekmē PĒAT veidošanos un kavē bezatkritumu pārtikas patēriņu skolu ēdināšanas procesā. Tos var iedalīt ārējos jeb objektīvajos un iekšējos jeb subjektīvajos, kā arī plašākās faktoru grupās, kā piemēram, demogrāfiskie, politiskie, skolu pārtikas politikas, vides, sociālekonomiskie, personiskie, fiziskie un ģeogrāfiskie. Līdz ar to nepieciešami stratēģiski mērķēti, koordinēti un sistemātiski risinājumi šīs problēmas risināšanai.

4. Empīrisko pētījumu rezultāti atklāja, ka ēdināšanas process ar iepriekš individuāli servētām pilnībā vai daļēji porcionētām maltītēm Rēzeknes pilsētas skolās nav ilgtspējīgs, jo aptuveni 20% no pagatavotā ēdiena netiek apēsti, radot būtiskus resursu zaudējumus, tajā skaitā neefektīvu valsts budžeta līdzekļu izlietojumu.

5. Empīrisko pētījumu rezultātā tika identificēti galvenie PĒAT cēloņi Rēzeknes pilsētas skolu ēdināšanas procesā - ēdienkartes piedāvājuma neatbilstība skolēnu vēlmēm, ierobežotas ēdienu veidu un porciju lieluma izvēles iespējas, nepietiekama skolēnu iesaiste un nepilnības ēdināšanas procesa organizēšanā.

6. Skolu ēdnīcas ir unikāla vieta, kur ar izglītību un praktisku rīcību ir iespējams tieši ietekmēt patērētāju attieksmi un formēt viņu uzvedību jau no bērnības, kontrolētā vidē mērīt pārtikas atkritumu apjomus, kā arī testēt uz pārtikas atkritumu novēršanu un samazināšanu vērstas intervences, padarot to par ideālu platformu pārtikas sistēmas pārveides iniciatīvu īstenošanai un uzraudzībai, kā arī uz pierādījumiem balstītas politikas izstrādei.

7. Otrā pilotpētījuma rezultāti apstiprināja, ka neviena no atsevišķi īstenotajām intervencēm nav pietiekama kā vienīgais risinājums PĒAT samazināšanai ilgtermiņā. Digitālais PĒAT izsekotājs S1 skolā (pa klasēm) uzrādīja īstermiņa statistiski nozīmīgu PĒAT samazinājumu, tomēr efekts nebija noturīgs. Savukārt organizatoriskās izmaiņas S3 skolā veicināja PĒAT pieaugumu gan īstermiņā, gan ilgtermiņā. Tas norāda, ka izmaiņas, kas nav balstītas konkrētā konteksta un darbības vides analīzē, var radīt pretēju efektu. Intervenču ietekmes rezultāti pa skolām apstiprina, ka PĒAT samazināšana skolu ēdināšanā ir daudzdimensionāls izaicinājums un nav vienas universālas pieejas tā risināšanai. Ilgtspējīgu rezultātu sasniegšanai nepieciešama

kompleksa un kombinēta pieeja, kas apvieno pārmaiņas ēdiena pasniegšanas modelī ar porciju un ēdiena izvēles pielāgošanu skolēnu pieprasījumam, PĒAT monitoringu un ēdienreižu plānošanu, izglītojošām aktivitātēm un skolotāju iesaisti. Turklāt īstenotajiem risinājumiem jābūt pielāgotiem konkrētai darbības videi un regulāri jāpilnveido, balstoties uz skolēnu novērtējumu un atgriezenisko saiti.

8. Saskaņā ar MOA uzvedības teoriju skolu ēdiena pasniegšanas modelis, kur dominē iepriekš pilnībā vai daļēji porcionēts un servēts ēdiens katram skolēnam individuāli bez iespējas izvēlēties ēdiena veidu vai porcijas lielumu, būtiski ierobežo skolēnu "iespējas" (*opportunities*), kas savukārt apgrūtina uzvedības maiņu pat tad, ja skolēniem ir spējas (zināšanas, prasmes) un motivācija (izpratne, attieksme) atbildīgi un ilgtspējīgi patērēt pārtiku.

9. Lai veicinātu uzvedības formēšanu, nepietiek tikai ar informēšanu, izglītošanu vai ēdienkartes maiņu. Nepieciešamas arī organizatoriskas izmaiņas, kas dotu skolēniem iespēju pielāgot pārtikas patēriņa uzvedību atbilstoši savām vajadzībām, nodrošinot elastīgu ēdiena veidu un daudzuma izvēli. Šāda pieeja varētu uzlabot skolēnu ēšanas paradumus un samazināt PĒAT apjomu skolu vidē.

10. Aptaujas rezultāti apstiprināja, ka Rēzeknes pilsētas skolu skolēniem ir nepilnīga izpratne un ierobežotas zināšanas par pārtikas atkritumu problemātiku. Skolēniem trūkst izpratnes par pārtikas atkritumu jēdzienu, to ietekmi uz vidi un ekonomiku, kā arī par atkritumu apsaimniekošanas iespējām. Līdz ar to būtisks priekšnoteikums efektīvai pārtikas atkritumu samazināšanai skolās ir skolēnu izpratnes veidošana un zināšanu stiprināšana par ilgtspējīgu pārtikas patēriņu.

11. Skolēnu ēšanas paradumu novērtējums atklāja izteiktu ēdienu veidu izvēles disproporciju - salīdzinoši lielu desertu (50% - apēd visu) un zemu salātu un zupu (30-40% - neēd vispār) patēriņu, kas nenodrošina pietiekamu uzturvielu uzņemšanu un var negatīvi ietekmēt skolēnu ikdienas uztura kvalitāti.

12. Skolēnu ēdienu izvēli nosaka dažādi kontekstuāli un individuāli faktori, piemēram, ierobežota pieredze ar konkrētiem ēdieniem ģimenēs, subjektīvā garšas uztvere, ikdienas ēšanas paradumi, fizioloģiskās vajadzības un daudzi citi. Līdz ar to, lai veicinātu atbildīgu pārtikas patēriņu un efektīvi samazinātu PĒAT, ir būtiski ņemt vērā visu šo faktoru savstarpējo mijiedarbību un skolēnu individuālās īpatnības, piedāvājot elastīgāku, skolēnu vēlmēm un vajadzībām pielāgotu ēdienkarti, bet nodrošinot atbilstību bērnu uztura vadlīnijām, saglabājot veselīga uztura kvalitāti.

13. Rēzeknes skolās pasniegtais ēdiens lielākoties neatbilst skolēnu uztverei par kvalitatīvu maltīti, jo skolēnu apmierinātība ar ēdiena sensorajām īpašībām Rēzeknes pilsētas skolās ir relatīvi zema, un īpaši zems novērtējums tika sniegts attiecībā uz ēdiena temperatūru, ar ko reti vai

nekad nav apmierināti 46,2% skolēnu, un smaržu, ar ko nav apmierināta gandrīz trešā daļa skolēnu. Tika novērotas arī vecuma un dzimuma atšķirības - jaunāko klašu skolēni kopumā sniedza pozitīvākus vērtējumus, kamēr vecāko klašu skolēni vairāk pauda neapmierinātību. Tāpat zēni vērtēja ēdienu pozitīvāk, savukārt meitenes bija kritiskākas. Arī šie rezultāti atspoguļo Rēzeknes skolu ēdiena pasniegšanas modeļa trūkumus, jo ēdiens, kas tiek iepriekš porcionēts un servēts, līdz ēšanas brīdim bieži vien jau ir atdzisis, kas negatīvi ietekmē arī tā garšu un citas sensorās īpašības.

14. Spīrmena korelācijas rezultāti atklāja, ka nepastāv statistiski nozīmīga saistība starp skolēnu apmierinātību ar skolas ēdiena sensorajām īpašībām un PĒAT (p>0,05), norādot uz citiem ietekmes faktoriem, tajā skaitā porcijas lieluma un ēdiena veida izvēles iespējām.

15. Skolotāju klātbūtne pie pusdienu galda ne tikai nodrošina praktisku palīdzību, bet arī rada cieņpilnu, drošu un koordinētu ēšanas vidi, kas ilgtermiņā var veicināt ilgtspējīgākus ēšanas paradumus, tomēr Latvijā skolotāju iesaiste ēdināšanas procesā ir brīvprātīga un dažkārt pasīva, jo ir atkarīga no viņu personīgās iniciatīvas un attieksmes.

16. Zināšanās balstītas rekomendāciju sistēmas izstrāde ir būtisks solis ceļā uz datos un pierādījumos balstītu pārtikas atkritumu samazināšanu skolu ēdināšanas procesa organizācijā. Šāds rīks var būt praktisks atbalsts skolām ēdināšanas ekosistēmas auditam, ar kura palīdzību identificēt būtiskākās problēmas un saņemt individuāli pielāgotus risinājumus, lai mērķtiecīgi virzītos uz optimālāku resursu pārvaldību, atbildīgāku pārtikas patēriņu un uzlabotu ēdināšanas procesa kvalitāti skolās.

17. Skolu ēdināšanai kā daļai no pārtikas patēriņa posma ir stratēģiski nozīmīga loma pārtikas sistēmas transformācijā, jo tā sniedz unikālu iespēju jau no mazotnes veidot skolēnu izpratni, attieksmi un uzvedību atbildīga un ilgtspējīga pārtikas patēriņa virzienā. Veidojot tādu skolu ēdināšanas vidi, kas vienlaikus attīsta zināšanas, motivāciju un nodrošina reālas iespējas ilgtspējīgai rīcībai, ir iespējams veicināt atbildīgu un ilgtspējīgu pārtikas patēriņu un mazināt PĒAT apjomu.

18. Promocijas darba rezultāti apstiprina, ka ilgtspējīgas pārtikas sistēmas izveide nav iespējama bez strukturētas, daudzlīmeņu un holistiskas pieejas, kas ietver mikro, mezo un makro līmeņa ieinteresēto pušu iesaisti visā pārtikas vērtību ķēdē. Šāda integrēta pieeja ir būtiska, lai vienlaikus risinātu vides, ekonomiskos un sociālos izaicinājumus un stiprinātu gan sabiedrības veselību un labklājību, gan planētas ilgtspēju.

19. Promocijas darba rezultāti apstiprina, ka patērētāju uzvedības maiņa var būt katalizators plašākām pārmaiņām pārtikas patēriņa posmā. Tomēr, lai notiktu paradigmas maiņa, ir nepieciešama pāreja no patērētāju pretestības uz ilgtspējīga patēriņa pieņemšanu. Šajā kontekstā ir būtiski, lai ilgtspējīgs pārtikas patēriņš būtu nevis kā pienākums, bet ikdienas

prakse un pašsaprotama izvēle. Tikai tad, ja šāda attieksme nostiprināsies jau no bērnības, būs iespējama noturīga pārtikas sistēmas transformācija. Lai panāktu šādas pārmaiņas ir nepieciešama kompleksa, konkrētai darbības videi pielāgota un uz patērētāju vērsta pieeja, kas apvieno mērķtiecīgas aktivitātes jeb rīkus un politikas atbalstu, lai nodrošinātu pāreju uz ilgtspējīgu pārtikas patēriņu, kas tālāk veido ilgtspējīgu pārtikas sistēmu, un sekmē ANO SDGs izpildi.

20. Empīrisko pētījumu rezultāti apstiprināja H1 hipotēzi par to, ka Latvijas skolās ēdiena pasniegšanas modelis ar iepriekš individuāli servētām pilnībā vai daļēji porcionētām maltītēm, neatbilst ilgtspējīgas AE principiem un neveicina bezatkritumu pārtikas patēriņu.

21. Empīrisko pētījumu rezultāti apstiprināja H2 hipotēzi - atsevišķi īstenotas intervences pārtikas atkritumu mazināšanai nenodrošina ilgtermiņa ietekmi skolu ēdināšanas procesā.

22. Promocijas darbā veikti vairāki pilotpētījumi, kas ir pirmie šāda veida pētījumi Latvijā, tāpēc turpmākie pētījumi būtu jāveic plašākā mērogā - citos reģionos un valsts līmenī. Nākotnē nepieciešams novērtēt kompleksu intervenču ietekmi ilgtermiņā, un testēt digitālos risinājumus praksē, lai novērtētu to noturību un efektivitāti dažādos kontekstos. Lietderīgi būtu salīdzināt dažādus ēdināšanas modeļus skolās.

PROBLĒMAS UN TO RISINĀJUMI

Pirmā problēma:

Skolu ēdināšanas procesā rodas ievērojams PĒAT daudzums. Veiktie pētījumi Rēzeknes skolās apstiprina, ka aptuveni 20% jeb viena piektā daļa no pasniegtā ēdiena tiek izmesti.

Priekšlikumi problēmas risināšanai:

1. Priekšlikumi balstoties uz E-mentors projekta ietvaros izstrādātajiem ieteikumiem (Lonska et al., 2022):

1) Izglītības un zinātnes ministrijai un pašvaldībām izstrādāt un ieviest skolās izglītības un komunikācijas stratēģijas, kas vērstas uz ilgtspējīgu un atbildīgu pārtikas patēriņu, integrējot pārtikas atkritumu problemātikas un veselīga uztura tēmas mācību saturā un skolu ikdienā.

2) Pašvaldību izglītības pārvalžu vadībai panākt aktīvāku skolu vadību un pedagogu iesaisti ilgtspējīga pārtikas patēriņa veicināšanā, kas var būt par piemēru skolēniem un viņu vecākiem.

3) Skolu vadībai un ēdinātājiem plānot ēdienkarti, lai tā balstītos ne tikai uztura vadlīnijās, bet atbilstu arī skolēnu pieprasījumam un vēlmēm, regulāri pārskatot un dažādojot ēdienkarti saskaņā ar skolēnu vēlmēm.

4) Skolu un ēdināšanas procesa vadībai optimizēt ēdināšanas organizāciju, ieviešot digitālus risinājumus skolēnu apmeklējuma uzskaitei un plānošanai un savlaicīgai informācijas apmaiņai ar ēdinātājiem, lai precīzāk prognozētu nepieciešamo pārtikas daudzumu.

5) Skolu un ēdināšanas procesa vadībai pārdomāti plānot pusdienu pārtraukumus un pielāgot ēdamzāles vidi, izmantojot dažādas pieejas, piemēram, nodrošinot iespēju pagaršot ēdienu pirms likt to uz šķīvja (*tasting spoons*), *Smarter Lunchrooms Movement* stratēģijas elementu ieviešana - vienkārši un izmaksu ziņā lēti risinājumi (plakāti, uzmanību piesaistošie ēdienu nosaukumi u.c.), kas rosina skolēnu interesi par pārtiku, veicina atbildīgu pārtikas patēriņu un noved pie pārtikas atkritumu samazināšanas.

6) Skolu vadībai un ēdinātājiem uzlabot ēdiena pasniegšanas veidu, nodrošinot skolēniem iespēju izvēlēties porcijas lielumu un ēdiena veidu, kā arī uzlabot ēdiena sensorās īpašības un panākt tā ērtāku patēriņu, piemēram, sākumskolas skolēniem pasniegt augļus un dārzeņus nomizotus un sagrieztus nelielos, viegli apēdamos gabaliņos.

7) Izglītības un zinātnes ministrijai, Zemkopības ministrijai un pašvaldībām rast iespēju nodrošināt finansiālu atbalstu modernizēt skolu ēdnīcu virtuves, iegādājoties mūsdienīgas virtuves iekārtas un tehniku, kā arī profesionāla virtuves personāla piesaistei.

2. Latvijas valsts valdībai integrēt digitālo pārvaldību ēdināšanas procesa organizācijā skolās valsts mēroga ilgtspējas stratēģijās nākošajos periodos (pēc 2027.gada), un Zemkopības

ministrijai nodrošināt vadlīniju izstrādi un sadarbību ar pašvaldībām, lai veicinātu inovatīvu tehnoloģisko risinājumu ieviešanu skolu ēdināšanas procesa pārvaldībā, piemēram, uz zināšanām balstītu rekomendāciju sistēmu, kas ļauj veikt skolas ekosistēmas auditu un pašnovērtējumu, identificēt problēmas un saņemt personalizētas rekomendācijas PĒAT samazināšanai. Būtu ieteicams skolām kā obligātu prasību noteikt vismaz vienu reizi gadā veikt pašnovērtējumu ar sistēmas palīdzību, kā arī pārtikas atkritumu auditu. Balstoties uz rezultātiem un piedāvātajām personalizētajām rekomendācijām, izstrādāt rīcības plānu nākamajam mācību gadam PĒAT apjoma samazināšanai un ēdināšanas procesa kvalitātes uzlabošanai.

Otrā problēma:

Ēdiena pasniegšanas modelis skolās ar pilnībā vai daļēji porcionētām, iepriekš individuāli servētām maltītēm neveicina bezatkritumu pārtikas patēriņu, jo balstās uz stingru normatīvo regulējumu un būtiskām nepilnībām ēdināšanas procesa organizācijā, kas liedz skolēnu patēriņa uzvedības maiņu.

Priekšlikumi problēmas risināšanai:

1. Atbildīgajām ministrijām izvērtēt un mainīt esošo skolu ēdināšanas normatīvo ietvaru, nodrošinot skolu ēdināšanas procesa vadībai lielāku rīcības brīvību, kas būtu noteikta ēdināšanas procesa organizācijas vadlīnijās:

- ēdienkartes plānošanu balstīt uz skolēnu vēlmēm un pieprasījumu;
- iespēju drošā veidā izmantot nepasniegto ēdienu nākamajā dienā citu ēdienu pagatavošanā;
- ēdiena pasniegšanas modelis, kas sniedz iespēju skolēniem pašiem izvēlēties ēdiena daudzumu un veidu;
- uz skolu ēdināšanas procesa uzlabošanu vērstu risinājumu īstenošanā, piemēram, izmēģinot jaunas receptes, ieviešot bufetes tipa ēdināšanas organizēšanu u.c.

2. Pašvaldībām un ēdinātājiem sadarbībā ar skolu vadību katrā skolā izveidot Skolas pārtikas padomi (*Food Council* - Zviedrijā, Somijā u.c.) vecāku, pedagogu un virtuves personāla sadarbībai ilgtspējīgas ēdināšanas jautājumos ar mērķi veicināt dialogu starp iesaistītajām pusēm par ēdināšanas jautājumiem, veikt kvantitatīvu un kvalitatīvu pārtikas atkritumu auditu un izvērtēt to cēloņus, veicināt praktisku risinājumu ieviešanu, piemēram, tematiskās ēdienu dienas, skolēnu iesaiste ēdienkartes plānošanā u.c., kā arī sekot līdzi ēdināšanas procesa uzlabojumiem, ņemot vērā skolēnu vajadzības, pieprasījumu un atgriezenisko saiti.

3. Izglītības un zinātnes ministrijai izstrādāt vienotu mācību saturu un metodiskos materiālus, kas iekļauj izglītojošas aktivitātes, informatīvas kampaņas, skolēnu līdzdalību, uzvedības ietekmēšanas mehānismus un digitālos risinājumus PĒAT samazināšanai skolu ēdināšanas procesā, lai attīstītu un stiprinātu skolēnu spējas (zināšanas un prasmes), personīgās atbildības

izjūtu un motivāciju ilgtspējīgam pārtikas patēriņam. Īstenotie pasākumi regulāri jāpilnveido, balstoties uz skolēnu novērtējumu un atgriezenisko saiti.

Trešā problēma:

Skolu ēdināšanas programmas ir stratēģiski būtiska PPĶ patēriņa posma daļa, tomēr to potenciāls mērķtiecīgu pārmaiņu plānošanā un īstenošanā plašākā kontekstā nav pilnvērtīgi novērtēts un atzīts.

Priekšlikums problēmas risināšanai:

Atbildīgajām ministrijām un pašvaldībām politikas plānošanā un stratēģiju izstrādē, kas vērstas uz tādu problēmu kā pārtikas atkritumi, neilgtspējīgi uztura paradumi un patēriņa uzvedība, risināšanu, kā pamata pārmaiņu platformu izmantot skolu ēdināšanas procesu. Tā ir unikāla vide, kur apvienojot izglītību ar praktisku rīcību, ir iespējams ne tikai īstenot pārtikas sistēmas pārveides iniciatīvas, bet arī panākt, novērtēt un uzraudzīt to progresu. Ilgtspējīgas pārtikas patēriņa uzvedības formēšana jau no mazotnes var būt pamats plašākai paradigmas maiņai sabiedrībā, veicinot pāreju uz ilgtspējīgu pārtikas sistēmu ilgtermiņā.

Ceturtā problēma:

Pārtikas atkritumu samazināšanu un pāreju uz ilgtspējīgu pārtikas sistēmu kavē nepietiekama ieinteresēto pušu sadarbība un iesaiste problēmu risināšanā makro, mezo un mikro līmeņos.

Priekšlikums problēmas risināšanai:

Nepieciešams īstenot koordinētus un mērķtiecīgus pasākumus visos pārvaldības līmeņos:

●Atbildīgajām ministrijām un pašvaldībām nepieciešams nodrošināt skolu un sabiedrības līdzdalību ilgtspējīgas ēdināšanas procesa organizācijas ieviešanā skolās un finansiālu atbalstu ilgtspējas iniciatīvu īstenošanai, kā arī veidot starpnozaru sadarbību ar mērķi samazināt pārtikas atkritumus, uzlabot uztura kvalitāti un stiprināt sabiedrības veselību.

●Ēdinātājiem, skolu un virtuves vadībai jāveicina abpusēja sadarbība divos virzienos, gan ar skolēniem, vecākiem un pedagogiem, nodrošinot viņu aktīvu iesaisti lēmumu pieņemšanā, ēdienkartes izstrādē, pārtikas atkritumu mazināšanā un izglītojošās aktivitātēs, gan ar izglītības pārvaldi un pārtikas piegādātājiem, nodrošinot ēdināšanas procesa kvalitāti.

●Skolēniem un viņu ģimenēm jābūt aktīviem un atbildīgiem dalībniekiem ilgtspējīga patēriņa veicināšanā. Ir jāiesaistās skolu ēdināšanas procesa uzlabošanā, izsakot savu viedokli un ieteikumus un sadarbībā ar skolu vadību un ēdinātājiem, jāattīsta personīgā atbildības sajūta un patēriņa paradumi ne tikai skolās, bet arī savā mājsaimniecībā. Tāpat ir būtiski paust savu nostāju, aktīvi iesaistoties sabiedriskās apspriedēs vai piedaloties sabiedriskās iniciatīvās, tādā veidā ietekmējot arī plašākus politiskos lēmumus valsts līmenī un veicinot pārmaiņas pārtikas sistēmā.

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Plate Waste in School Catering in Rezekne, Latvia

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Abstract: This research was conducted within the framework of a research project aimed at detecting patterns of plate waste and developing recommendations for improving catering in seven schools in Rezekne city (Latvia) by a combination of observation, physical weighing, semi-structured interview approaches and statistical analysis of variance (ANOVA). We identified plate waste (including wasted beverages), which remains after the lunch of schoolchildren in grades 1–7, examining a total of 7064 lunch samples. The originality of the research is due to the fact that a unified menu was designed for the field study, which ensured the same field study conditions in all the schools. The results of the research revealed that the average weight of plate waste per schoolchild reached 178 g, and the total weight of plate waste accounted for 28.75% of the total weight of food served. No significant differences in plate waste weight between various age groups and grades of schoolchildren were found, which was also confirmed by a one-way ANOVA test. An analysis of plate waste by food category showed that beverages accounted for the largest share of total plate waste (42.24%), followed by staple food (28.38%) and meat (11.77%). An analysis of plate waste shares of food served (%) by food category revealed a similar situation: the largest share of food served was made up of beverages (37.56%), followed by staple food (36.48%) and meat (28.77%). An analysis of the monetary value of food waste showed that the average cost of plate waste (excluding beverage) per schoolchild was EUR 0.236, which represented 16.6% of the national and municipal funding of EUR 1.42 per portion. Given the research results, the authors have concluded that in order to reduce the amount of plate waste generated by Rezekne city schools, school menus should be based not only on the requirements prescribed by relevant legal acts but also on cooking processes that meet the requirements of modern consumers (learners), e.g., by following trends in cooking practices in society to make the learners interested in consuming school food.

Keywords: food waste; plate waste; school menu; eating habits; eating behavior; school catering

1. Introduction

1.1. Food Waste and Sustainability

Every year, significant amounts of food are lost or discarded throughout the food supply chain, from primary production to final consumption. Over the last 10 years, food loss (FL) and food waste (FW) have become a global problem with a negative impact on sustainable resource consumption, nature and the environment as well as on the development of society [1–4].

Reducing FW is an important prerequisite for achieving the Sustainable Development Goals set in 2015, namely SDG 2 (ending hunger) and SDG 12 (ensuring responsible consumption and production patterns) by 2030 [5]. In 2019, according to the Food and Agriculture Organization of the United Nations (FAO), 690 million people or 8.9% of the

world's population suffered from malnutrition, and this figure is projected to increase significantly due to the negative impacts of the COVID-19 pandemic [6].

1.2. Theoretical Framework

Although there is no general definition of food loss and waste, the FAO [7] states that food loss and waste are "the masses of food lost or wasted in the part of food chains leading to edible products going to human consumption". Therefore, food originally intended for human consumption but later addressed to other non-food uses (e.g., animal feed, energy recovery) must be considered as lost or wasted [8].

Kaur et al. (2021) distinguish FL from FW and refer to "food loss" as the food that leaves the food supply chain at its initial stages, while "food waste" refers to the food that is not consumed at the places of consumption [9].

Ishangulyyev et al. (2019) conclude that FL represents a decrease in the weight of edible food at the first three stages of the food supply chain due to infrastructure constraints, environmental factors and quality or safety standards. In contrast, FW is food that was originally produced or processed for human consumption but was not consumed. FW also includes food that is edible or spoiled at the time of disposal. FW occurs at the distribution and marketing and consumption stages of the food supply chain (see Figure 1) [10].
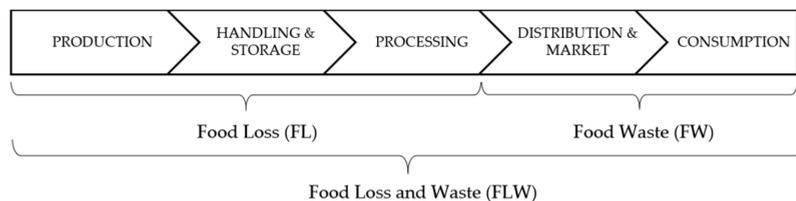
Figure 1. Framework of Food Loss and Food Waste definitions [10].

Falasconi et al. (2015) define FW as all foods that are removed from the food supply chain but still retain their nutritional value and meet safety standards [11].

Papargyropoulou et al., (2014), developing a food waste prevention strategy, recommend distinguishing avoidable food waste (foods or components of food that are generally considered edible) from unavoidable food waste (includes foods that are not normally edible, e.g., bones, fruit peel, etc.) [12].

FW at the consumption stage of the food supply chain could also be categorized according to when the waste occurs. For example, FW produced during the purchase and storage of food is considered to be "spoilage food waste" (or "storage waste" [13]); "preparation food waste" occurs during cooking, i.e., due to peeling, cutting, as well as overproduction or food surplus; "leftover waste" occurs when the prepared food is not served to the consumer (unserved food); "plate waste" pertains to the food served to the consumer but not eaten [14].

García-Herrero et al., (2019), conducting a study on FW in Italian schools, divided FW into the following categories: (1) preparation waste: the FW that occurs during cooking (might be both avoidable and unavoidable); (2) serving waste: the food left on the serving dishes and not served to the students in the canteen (avoidable FW); (3) plate waste: the food left by students on their plates in the canteen (avoidable FW) [15].

Clarke et al. (2015) distinguish the following kinds of FW: (1) waste generated during preparation and cooking, (2) discards due to preparation of too much food, (3) discards due to expired use-by or open dates, (4) spoilage food waste and (5) plate waste [16].

A summary of the opinions available in the scientific literature on the kinds of FW at the consumption stage of the food supply chain is presented in Figure 2.
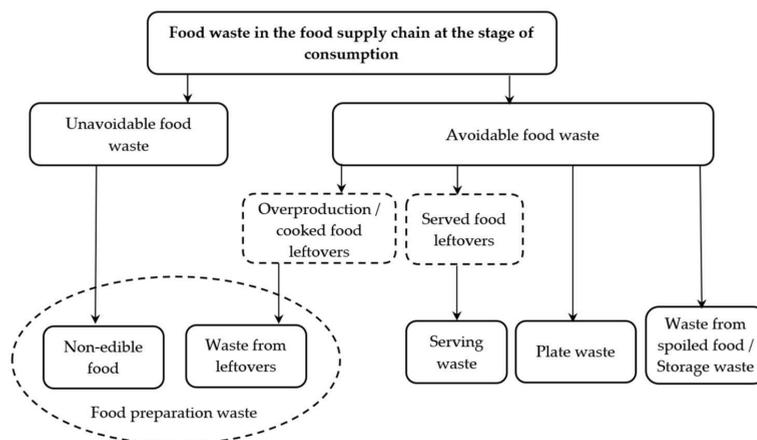
Figure 2. Kinds of FW at the consumption stage of the food supply chain. Source: authors' construction based on [11–16].

As shown in Figure 2, FW generated at the final stage of the food supply chain, i.e., the consumption stage, can be both avoidable and unavoidable. Most of the FW generated at the food consumption stage is avoidable food waste, which in turn consists of waste from spoiled food (it is discarded due to changes in quality that make it undesirable and unfit for human or animal consumption, as evidenced by signs of deterioration such as unpleasant odor, changes in texture and appearance), plate waste (food served to consumers that remains uneaten on the plate and is discarded), served food leftovers (food served but not eaten (intact) and discarded) and waste from leftovers (food prepared in excess of what was needed (overproduction) and not served go to waste). It should be noted that waste from leftovers comprises food preparation waste together with non-edible food (unavoidable food waste), which usually are not edible, e.g., peel of fruit or vegetables, bones, seeds, etc.

It should be mentioned that in 2019, at the distribution and marketing as well as consumption stages of the food supply chain, approximately 931 million tons of FW were generated, of which 61% were by the household sector, 26% by the catering sector and 13% by the retail sector. This means that around the world, 17% of the total food production was wasted (11% by the household sector, 5% by the catering sector and 2% by the retail sector), thereby increasing environmental pollution and unnecessary pressure on nature [17].

In this research field, researchers have a common understanding of the term plate waste, which refers to the amount of food served to consumers that remains uneaten on their plates and is subsequently discarded.

Plate waste is the largest source of food waste in schools [18], followed by food waste from serving lines [19]. It should be noted that most of the researchers working on food waste analysis focus specifically on plate waste analysis [11,12,15,16,18,20–25]. Derqui and Fernandez (2017) have found that approximately 80% of research in this field directly relates to plate waste analysis, without auditing FW at the entire stage of food consumption, i.e., not considering the FW generated during cooking in the kitchen or the FW from serving lines [19].

1.3. Literature Review

The plate waste generated in schools is influenced by multiple factors. The authors of the present paper have analyzed a number of research papers focusing on this field with the aim of summarizing the factors contributing to plate waste in schools (see Table 1).

Table 1. Factors contributing to plate waste in schools referred to in the scientific literature.

Factor	Explanation	Source
Exogenous (objective) factors		
School administration position	The restrained position of the school administration and a lack of interest in the implementation of a sustainable management policy, a lack of responsible personnel, a lack of attention to the amount of food waste in the school canteen, etc., increase the irrational consumption of food, which also indirectly affects schoolchildren's eating behavior	[26,27]
Class schedule at school	A poorly planned schedule of classes leads to a lack of time for lunch; due to the short lunch break, schoolchildren do not have enough time to eat a full meal	[13,20,28–32]
Atmosphere and environment in the dining hall	A lot of noise in the canteen, a large number of schoolchildren and crowding put psychological pressure on the schoolchildren to finish their meals faster	[18,26,33–39]
Cooking techniques	The incompatibility of the cooking technique with the kind of food can adversely affect the appearance and sensory properties of the food	[23,30,34,40]
Way of serving food	The way food is served (e.g., peeled and sliced fruit, etc.) is an essential prerequisite for reducing plate waste: "The easier the food is to eat, the less plate waste is generated"	[27]
Cooking skills of kitchen personnel and kitchen equipment	Poor cooking skills of kitchen personnel and insufficient kitchen equipment can adversely affect the appearance and sensory properties of food	[27,41]
Competitive foods	Availability of competitive food from other sources (i.e., sweet/savory snacks and beverages), including food brought from home, can also reduce schoolchildren's appetite	[20,25,34,42,43]
Catering service management and coordination policy	The way catering is managed (e.g., portioned or buffet-style catering, on-site cooking in the school kitchen or an outsourced service), a lack of flexibility to adapt the centrally planned menu to schoolchildren's needs, a lack of timely information on changes in the number of schoolchildren and other organizational aspects can lead to an inadequate amount of food prepared, thereby creating leftovers	[11,23,26,27,30,44]
Non-involvement of supervisory or support personnel in the catering process	The non-involvement of supervisory or support personnel (e.g., a teacher or kitchen worker) in the catering process, which could otherwise promote the schoolchildren's healthy attitudes towards food and new tastes and help to reduce food waste	[13,34,39]
Inadequacy of food portions to schoolchildren's age, appetite and nutritional needs	The portion size of food served is not differentiated according to the age of schoolchildren (including their nutritional needs); consequently, the schoolchildren are simply unable to eat the whole portion	[20,26,41,45–49]
Endogenous (subjective) factors		
Schoolchildren preferences	Schoolchildren may refuse to eat or not eat all the food served to them because they might not like the particular food or kind of food	[20,24,26,30,39,50–54]
Schoolchildren's appetite level, total daily nutritional energy requirements and body mass index	Schoolchildren might or might not eat the food served to them due to a reduced appetite and/or need for nutritional energy	[20]
Appearance and sensory properties of food	Schoolchildren might refuse to eat or not eat all the food served to them if they are not satisfied with the appearance, taste, texture, color and temperature of the food. This factor is partly subjective, as the appearance and sensory properties of food also depend on the cooking skills of kitchen personnel and kitchen equipment	[26,30,33,39,41,43,46,49,50,55–57]
Schoolchildren's desire to socialize during free time	Schoolchildren might refuse to eat or not eat all the food served to them because they communicate with others at the table, or they might leave the dining hall to meet their fellow students during the lunch break	[28,38]
Schoolchildren's unhealthy eating habits	Schoolchildren might refuse to eat or not eat all the food served to them due to their unhealthy eating habits, which often come from their families	[11,58]
Schoolchildren's knowledge and understanding of and attitude towards food	Schoolchildren might refuse to eat or not eat all the food served to them due to a lack of understanding of the negative effects of food waste on the environment and the associated ethical and socio-economic consequences, as well as of the sources and production of food	[27,37,58–60]

The summary of factors influencing plate waste shown in Table 1 reveals that the authors have divided the factors into exogenous or objective ones that do not depend on schoolchildren's (consumers') subjective preferences and physiological condition, but tend to influence their eating behavior externally, and endogenous or subjective factors arising from the schoolchildren's (consumers') psychological and/or physiological condition.

Derqui et al. [27] point out that the catering sector is one of the largest sources of FW generated by schools, which also provides an opportunity to improve the dietary habits of the population and educate the public about sustainable resource consumption and development, thereby affecting the food system in the future. According to a delegated decision of the European Commission [61], from 2020 onwards, the measurement of FW and leftovers needs to be carried out at each stage of the food supply chain. This also applies to the FW generated by educational institutions, which has been little researched in Latvia to date. Research on waste generated by an educational institution have been conducted by some enthusiasts, whereas larger-scale research that would allow for drawing overall conclusions and continuous science-based, qualitative research, has not been carried out in Latvia yet.

1.4. Scope of Research

The purpose of this pilot study was to identify the patterns of plate waste in seven schools of Rezekne city (Latvia) and to develop recommendations for stakeholders on how to reduce the amount of plate waste by a combination of observation (the design of the dining hall, the placement of food on a plate, the way food was served and the process and time of enjoying the meal were observed), physical weighing and semi-structured interview approaches, as well as statistical analysis of variance.

The novelty of the research stems from the fact that no research studies have been conducted in Latvia that placed a focus on zero-waste food consumption, including plate waste in schools, and although there are publicly available reports on this problem by individual researchers, the reports are not considered scientifically relevant for further research. The present pilot study provides a first sign of examining the normally ignored amount of plate waste in Latvian schools. The authors believe that the results of this study are a good basis for further analysis in this field, and can help to inform stakeholders and policy makers in the field of education about the current situation in catering in Latvian educational institutions. This study also aims to promote the implementation of the recommendations developed (supported by the fact that the preliminary survey results were discussed with the head of the Education Department of the Rezekne State City and the observed schools' representatives, as well as the fact that the research report was submitted to the Ministry of Education and Science of Latvia).

The fact that we performed an analysis of plate waste instead of an analysis of all food waste generated by school canteens could be considered to be a research limitation. This was due to the insufficient capacity of human resources involved in the present research. Otherwise, a comprehensive analysis of food waste would provide comprehensive information on the amount of food wasted.

2. Materials and Methods

2.1. Sample Selection

A field study was conducted in schools of Rezekne city in the Latgale region of the Republic of Latvia. Rezekne is the seventh largest city in the Republic of Latvia and the largest eastern border city of the European Union, with a total population not exceeding 30 thousand (Figure 3). The field study was performed in 7 publicly funded schools (one primary school, one gymnasium and 5 secondary schools). In all the schools, catering was provided on-site and funded from the Rezekne city municipality budget and the state budget. The selection of the surveyed schools was based on the fact that there were only 8 schools in the city, one school that was not surveyed was a school for children with special

needs, and catering was managed differently in this school, therefore, it was excluded from the analysis.

During the observations, emphasis was put on quantitative measurements of plate waste by examining 7064 school lunch plates.
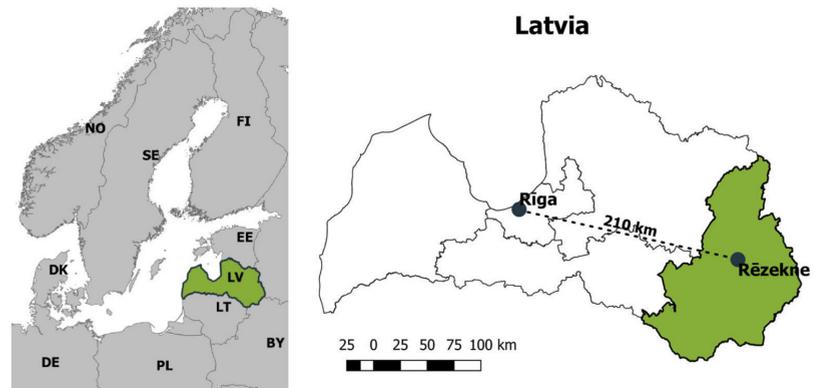
Figure 3. Map with the observation location; authors' construction.

Regarding the research methodology, the following plate-waste parameters were identified by the field study:

- number and grades of schoolchildren;
- work organization in school canteens or opportunities for a caterer to prepare food, the way of serving food, the capacity of the dining hall and other factors;
- free lunches for schoolchildren (grades entitled to free lunches funded jointly by the national and local governments were selected for the field study in Rezekne city schools: grades 1–7).

During the research, the authors, based on a number of legal acts [62–64], as well as after getting acquainted with the public food procurement situation in Latvia [65] and requests for tenders to procure food and catering services placed on the website of the Procurement Monitoring Bureau [66] and the Electronic Procurement System [67], concluded that in Latvia, catering in educational institutions was organized in the following ways:

- Type 1. The municipality in whose territory the schools are located organizes catering for schoolchildren on its own, equipping canteens in the schools in accordance with the requirements of safe food handling and creating special workplaces for canteen personnel;
- Type 2. Catering for schoolchildren is provided on an outsourced basis, i.e., the entire service is purchased from catering companies, delivering the food to the schools and serving it in accordance with the requirements stipulated in the procurement contract;
- Type 3. Catering for schoolchildren is provided as an outsourced service, provided that the catering provider prepares the food on-site in the schools.

In all the schools covered by the field study, the catering process was organized in closed-type canteens (hereinafter referred to as school canteens), which were provided by the local government of Rezekne city (Type 1). This means that catering services are supplied only to certain social groups—only to those who study, work or stay in the institutions that have an operating catering facility. The local government of Rezekne city covers the maintenance costs of school canteens, salaries of school canteen personnel, purchases of food and other functions related to catering services (control of compliance with hygiene requirements, monitoring of compliance with healthy nutrition requirements, etc.).

In accordance with the provisions of legal acts, including Cabinet Regulation No. 614 "Procedures for Calculating, Allocating and Using Funding Provided from the

State Budget for Catering to Learners" [68] and the Rezekne City Council's Education Board's Order No. 197 of 3 September 2020 "On Catering for Learners" [69], in the schools of Rezekne city, catering is provided free of charge for the following schoolchildren:

- grades 1–4, free lunches are funded by the national government;
- grades 5–7, free lunches are funded by the local government of Rezekne city.

Only schoolchildren in grades 1–7 were included in the field study sample, i.e., those who were entitled to free lunch, and in this case, the schoolchildren had a specific lunch menu (Table 2). It should be noted that school S1 was a state gymnasium that starts from grade 7; therefore, only the schoolchildren in grade 7 were included in the sample of the field study.

Table 2. Unified menu designed for the field study.

	Placed/Portion/ Planned Weight in Grams	Weight of Food Served on a Plate in Grams		Placed/Portion/ Planned Weight in Grams	Weight of Food Served on a Plate in Grams
Monday			**Thursday**		
Pasta	150	150	Stewed rice with carrots and corn	150	150
Pork goulash	50/50	100	Chicken cutlet	80	80
Fresh cabbage salad	50	50	Fresh tomato	30	30
Glazed curd cheese	1 piece	46	Lemon drink	200	200
Bread	25	25	Bread	25	25
Tea with sugar	200/10 *	200	Apple	1 piece	95
Tuesday			**Friday**		
Pickled cucumber	25	25	Milk soup with pasta	125	125
Pork cutlet	75	75	Mashed potatoes	130	130
Mashed potatoes	130	130	Fish in breadcrumbs	60–65	63
Juice drink	200	200	Carrot salad with sunflower seeds	50	50
Bread (optional)	25	25	Juice drink	200	200
Banana	1 piece	160	Bread	25	25
Wednesday					
Borscht (beet soup) with fresh cabbage, sour cream	250/5 **	250			
Mashed potatoes	130	130			
Stewed liver in cream sauce	50/45	95			
Fresh cucumber	30	30			
Juice drink	200	200			
Bread	25	25			

* Note: 10 g of sugar per 200 g of tea. ** Note: 5 g of sour cream is put in a common pot of soup, providing 5 g per 1 child. The weight of soup in each plate is 250 g. Source: menu calculations performed by the Rezekne City Council's Education Board based on the research conducted by the authors.

2.2. Description of the Unified Menu and Catering Processes

Before performing plate-waste quantification, it was necessary to design a unified menu for the field study week that would eliminate differences in food availability and ensure laboratory conditions, thereby minimizing the impact of gastronomic distraction on the study. In Rezekne city schools, menus are designed by the canteen employees of each school together with the school nurse in accordance with Cabinet Regulation No. 610 "Hygiene Requirements for Educational Institutions Implementing General Primary Education, General Secondary Education, Professional Basic Education, Vocational Education or Professional Secondary Education Programmes" [70] and Cabinet Regulation No. 172 "Regulations regarding Nutritional Requirements for Learners of Educational Institutions, Clients of Social Care and Social Rehabilitation Institutions and Patients of Medical Institutions" [62], which set dietary requirements and require that the lunch menu include a second course and a soup or dessert. Cabinet Regulation No. 172 restricts the use of salt, sugar and other flavor enhancers in school meals, bans unhealthy foods (e.g., French fries and other foods cooked in oil, mayonnaise, ketchup, tomato sauce, sausages with a meat content of less than 90%, dried, smoked and salted meat and fish). Processed foods such as dumplings and fish fingers may be included in the diet of schoolchildren no more than once a week and only if meeting certain requirements (i.e., contain at least 70% meat or 60% fish; do not contain flavorings (E620–E650) and dyes, do not contain mechanically

separated meat, do not contain raw foods produced from genetically modified organisms, contain less than 1.25 g of salt per 100 g of meat and 1.5 g per 100 g of fish) [62]. The menu is agreed and approved by the head of the educational institution or an authorized person.

It should be noted that in the autumn of 2021, in order to reduce the spread of COVID-19 in schools, legislative amendments were made to reduce the number of learners staying in the dining hall for a long time (i.e., food delivery and consumption time was reduced), allowing for one main course instead of two dishes, while at the same time ensuring that it complied with the nutritional requirements stipulated by Cabinet Regulation No. 172.

To design a unified menu, individual structured interviews were conducted with the canteen managers and specialists of the Rezekne city schools with the aim of obtaining information about school menus, schoolchildren's preferences regarding the food served in each school, the frequency of serving particular foods, the factors influencing whether schoolchildren eat or do not eat the free lunch provided by school canteens, as well as food-waste management. A total of 11 individuals took part in the interviews: 7 canteen managers, 3 canteen specialists and a nurse who was also responsible for designing the school menu. All the interviewed canteen managers and canteen specialists had the professional qualification of a cook, they had at least 5–10 years working experience in school canteen service and had a good understanding of children's food preferences.

The Interview provided experiential, semi-subjective opinions of the personnel of educational institutions and school canteens about the categories of food that children liked, did not like or were indifferent to. During the interviews, the researchers identified five foods that children preferred (i.e., more than 90% children ate them), five that they ate reluctantly (i.e., only up to 20% preferred them) and five foods that children were indifferent to (i.e., at least 65% preferred them). Based on the information obtained, the responsible employee of the Rezekne City Education Board (a chief specialist in nutrition who knew all the requirements for designing menus) prepared a unified menu for the field study for all the schools, considering the nutrition requirements stipulated by Cabinet Regulation No. 172 (Table 2).

The method for analysis of strengths, neutrals and weaknesses (SNW) was employed to evaluate the dishes prepared at the Rezekne city schools and a typological group index was calculated for the menu according to the equation [71]:

$$I = \frac{1*S + 0,5*N - 1*W}{n} \qquad (1)$$

where

I—typological group index (ranging from 1 to −1);
S, N, W—number of respective indicators;
N—number of respondent replies.

The typological group index calculated for the dishes prepared at the Rezekne city schools, which showed the rating of 7 dishes prepared at the schools, was 0.47, i.e., moderately high and positive. An analysis of the Rezekne city school menus showed that schoolchildren were indifferent to a total of 351 dishes prepared at the schools, 82 dishes they ate reluctantly, and 209 dishes they enjoyed (Table 3).

In all the Rezekne city school canteens, serving of the food partly takes the form of self-service, and the food is partly served, i.e., shortly before the lunch break, the school canteen personnel set a table reserved for each class. Only at school S1 is the food served at the canteen distribution point (at the distribution counter) where the schoolchild is given a tray with portioned food plates (except for fruit and glazed curd cheese), which are available in shared dishes on the tables). At the other schools, canteen personnel serve portions of a set meal on the tables (staple food and meats on a single plate), at some schools, vegetables with a set meal could be served on a single plate (e.g., schools S1, S4, S5 and S6), while at schools S2, S3 and S7 vegetables are served in shared dishes on the tables for each class separately. Except for school S1, where soup is served on separate plates for each schoolchild, at schools S2–S7 the soup is served in shared soup pans on

the tables for each class (the amount of soup to be served is calculated according to the number of schoolchildren in each class by applying standardized measures and serving cups). A beverage is served in separate glasses for each schoolchild. Except for school S1, where a piece of bread is given to each schoolchild individually on the tray, in schools S2–S7 the slices of bread are placed on tables in shared containers according to the number of schoolchildren in each class. At all the schools, fruits (whole unpeeled apples or bananas) are placed on tables in shared containers according to the number of schoolchildren in each class; the way of serving glazed curd cheese, which is served in packaging in shared containers according to the number of schoolchildren in each class, is similar.

Table 3. Schoolchildren's attitudes to the dishes prepared at the Rezekne city schools analyzed by the SNW method.

School	Number of Dishes Enjoyed by More Than 90% Children, or the Strength (S)	Number of Dishes Eaten by at Least 65% Children, or the Neutral (N)	Number of Dishes Eaten by Less Than 20% Children, or the Weakness (W)	Typological Group Index
S1	46	36	13	0.54
S2	21	70	5	0.53
S3	21	75	10	0.46
S4	12	62	5	0.48
S5	27	54	12	0.45
S6	53	30	22	0.44
S7	29	24	15	0.38
Total	209	351	82	0.47

Source: authors' calculations based on the results of an interview with canteen personnel.

2.3. Data Collection

In the present research, the authors have considered plate waste as the amount of food served to schoolchildren that remains uneaten on their plates and is subsequently discarded. The total measured weight of plate waste includes uneaten food and beverages that remain on plates and in glasses, bowls, etc., after free lunches for schoolchildren in grades 1–7 in Rezekne city schools.

The field study was conducted in late September 2021. The field study was first tested at school S1 from 13 to 17 September 2021, evaluating the process of catering management in accordance with the unified menu, which was designed for the needs of the project, including plate-waste weighing. In the period from 20 to 24 September 2021, the field study was conducted simultaneously at schools S2, S3, S4, S5, S6 and S7. At each school, the field study lasted for 5 working days, from Monday to Friday, except for school S1 (grade 7) and school S7 (grades 5–7), where the field study lasted only for 4 days (from Monday to Thursday) because on Friday all the schoolchildren went on study tours and did not have lunch at school.

Each school had a different lunch break schedule. The average lunch time for schoolchildren in grades 1–4 was from 9:30 to 11:30, and for schoolchildren in grades 5–7 it was from 11:30 to 13:00. The researchers arrived at the schools at about 9:00 in the morning and finished their work at about 14:00 (depending on the school) for 5 consecutive days of the field study. Before the meal, the researchers identified the expected number of schoolchildren, considering the number of schoolchildren in the classes examined, and during the lunch they noted the number of schoolchildren who actually participated in the meal.

The research employed the following methods: observation, photography and direct manual weighing of plate waste by food category and by grade of schoolchildren [15,38,41,72,73]. The authors of the paper observed the design of the dining hall, the interior, the ergonomics, the table setting, the placement of food on a plate, the way food was served and the process and time of enjoying the meal. During the field study, the schoolchildren were asked to leave their dirty dishes on the tables (usually the schoolchildren had to bring their own dirty dishes to a special place). When the schoolchildren had finished their lunch, the researchers measured the plate waste by dividing the plate waste into the following food

categories: soup, staple food, meat/fish, salad/vegetables, beverage, bread, fruit, curd products (glazed curd cheese). Later, each bucket was weighed, and the data on the weight of the waste were entered into a waste registration protocol. The following measurement tools were used to quantify the plate waste: two kinds of high-density polymer buckets (a large bucket with a capacity of 2 L, weight 61 g, and a small bucket with a capacity of 1 L, weight 35 g; each bucket was marked with the food category and the number of the class for which it was intended) and electronic kitchen scales (model—Clatronic KW3412, art. No. 271680, measuring range—up to 5 kg, units of measurement—grams).

2.4. Data Analysis

All the survey data were analyzed using the data-processing program IBM SPSS (version 26) and MS Excel.

The research employed a statistical analysis method—one-way ANOVA—to identify the effect of an independent variable on the dependent variable, i.e., whether the average plate waste, measured in grams per schoolchild, differed significantly across grades. The independent variable was a qualitative variable representing several, at least three, categories; therefore, for the analysis of variance, the grades were divided into three groups: grades 1–2, grades 3–4 and grades 5–7. An appropriate sample was selected for each of the grade groups, and the metric values of dependent variables were recorded for the sample.

To determine the cost of plate waste, the research also calculated the monetary value of waste (see equation No. 3) [19]. However, given that most of the waste consisted of liquid waste (beverages), as well as the fact that the most important component of this food category was water, the weight of plate waste excluding beverage waste per schoolchild and the cost of plate waste excluding beverages were also calculated (see equations No. 4 and No. 5).

3. Results

In total, 7064 schoolchildren were involved in the field study; of the total, 4105 or 58.11% were in grades 1–4, and 2959 or 41.89% were in grades 5–7. The total number of schoolchildren who actually ate lunch was equivalent to the number of portions of food served (Table 4).

Table 4. Basic information on the 7 sample schools.

School	Grade Group	Age Range	Number of Children in Grades	Number of Field Study Days (per Week)	Actual Number of Lunch Participants (Number of Samples) *	
S1	Grade 7	13 (14)	76	4	234	234
S2	Grades 1–4	(6) 7–10	176	5	677	1127
	Grades 5–7	11–13 (14)	126	5	450	
S3	Grades 1–4	(6) 7–10	150	5	603	1024
	Grades 5–7	11–13 (14)	126	5	421	
S4	Grades 1–4	(6) 7–10	184	5	663	1110
	Grades 5–7	11–13 (14)	130	5	447	
S5	Grades 1–4	(6) 7–10	206	5	94	493
	Grades 5–7	11–13 (14)	147	5	399	
S6	Grades 1–4	(6) 7–10	314	5	1239	1813
	Grades 5–7	11–13 (14)	165	5	574	
S7	Grades 1–4	(6) 7–10	202	5	829	1263
	Grades 5–7	11–13 (14)	174	4	434	
Total:		-	2176	-	7064	

* Note: the sample of the field study included only the number of schoolchildren who actually ate lunch, which might not correspond to the actual number of schoolchildren at school, as some schoolchildren did not eat lunch during the field study due to illness or self-isolation because of COVID-19.

It should be noted that the number of participants in the field study was significantly affected by COVID-19. For example, in school S4, grade 3 (24 schoolchildren) was in self-isolation throughout the week, and grade 7 (28) was in self-isolation from Tuesday. In school S7, grade 6 (25) was in self-isolation throughout the week. The number of participants in the field study was most significantly affected by COVID-19 in school S5: from Monday to Wednesday, 9 classes with a total of 212 schoolchildren, on Thursday 8 classes with a total of 201 schoolchildren and on Friday 7 classes with a total of 177 schoolchildren were in self-isolation.

The results of the interview with the personnel of the schools and their canteens showed that no food waste sorting nor food waste inventory were performed in any of the schools included in the field study. However, school S6 sorted food waste into fractions, i.e., solid and liquid food waste. At school S5, however, waste from vegetable preprocessing was partially sorted.

This is because the local government of Rezekne city has not entered into contracts with any waste-management company to dispose of FW generated by schools and preschool educational institutions, as Rezekne waste management companies do not provide biodegradable waste-disposal services. Currently, such services are available only in the regions of Riga and Pieriga. Sorting biodegradable waste needs to be introduced throughout Latvia by the end of 2023. According to the principles of a circular economy, disposing of food waste is the least desirable option. However, if this cannot be avoided, food waste needs to be collected separately from other municipal waste. It should be noted that the management of biodegradable waste, including the management and control of food waste, is very poorly implemented in Latvia, which still makes the population overpay for the service received and hinders the fulfillment of national commitments to achieve the goals of the EU economy [74].

In the schools examined, some of the solid FW, e.g., cereals, potato, meat, etc., were often used informally for pet food. If there was no one to give such FW to, it was disposed of into general waste containers. However, beverage and soup waste were discharged into sewerage.

The field study revealed that the average weight of plate waste per schoolchild per day ranged from 142 g (school S6) to 268 g (school S4) (Table 5).

Table 5. Weights of plate waste identified by the field study at the Rezekne city school canteens (by school and by grade group).

School	Total Weight of Plate Waste (g/Week)	Average Plate Waste per Schoolchild (g) *	Grade Group	Total Weight of Plate Waste (g/Week)	Actual Number of Lunch Participants (Number of Samples)	Average Plate Waste per Schoolchild (g)
S1	52,578	225	Grade 7	52,578	234	225
S2	163,750	145	Grades 1–4	99,397	677	147
			Grades 5–7	64,353	450	143
S3	197,674	193	Grades 1–4	109,544	603	182
			Grades 5–7	88,130	421	209
S4	297,603	268	Grades 1–4	180,518	663	272
			Grades 5–7	117,085	447	262
S5	71,131	144	Grades 1–4	15,416	94	164
			Grades 5–7	55,715	399	140
S6	256,933	142	Grades 1–4	190,644	1239	154
			Grades 5–7	66,289	574	115
S7	216,630	172	Grades 1–4	152,566	829	184
			Grades 5–7	64,064	434	148
Total:	1,256,299	178	Total for grades 1–4	748,085	4105	182
			Total for grades 5–7	508,214	2959	172

* Note: the average weight of plate weight per schoolchild (g) was calculated as the total weight of plate waste divided by the actual number of schoolchildren [19]. Source: authors' calculations based on the results of the field study.

As shown in Table 5, the field study identified differences in the average weight of plate waste per schoolchild between the youngest schoolchildren (i.e., grades 1–4) and older ones (i.e., grades 5–7) (except for school S1 that starts from grade 7). Higher weights of plate waste were found for grades 1–4 in 5 out of the 6 schools (S2, S4, S5, S5 and S7). The average weight of plate waste per schoolchild registered in grades 1–4 exceeded that registered in grades 5–7 by 10 g, or 5.81%.

To perform a one-way ANOVA test, the schoolchildren of the seven Rezekne city schools were divided into three grade groups: grades 1–2, grades 3–4 and grades 5–7. The analysis of variance showed that the average weight of plate waste per schoolchild, in grams, was not affected by the grade which the schoolchildren were in (Table 6).

Table 6. Results of the ANOVA test for the average weights of plate waste per schoolchild, in grams, identified at the Rezekne city school canteens.

Grade Group	Count	Sum	Average	Variance
Grades 1–2	22	4147.681	188.531	3670.868
Grades 3–4	27	4754.659	176.0985	2988.212
Grades 5–7	39	6830.969	175.1531	3965.215
One-way ANOVA				
Source of variation	SS	df	MS	F	*p*-value	F crit
Between groups	2798.964	2	1399.482	0.389432	0.678644	3.103838661
Within groups	305,459.9	85	3593.646			
Total	308,258.9	87				

F < Fcrit, = grades do not statistically significantly affect the amount of plate waste. Source: authors' calculations based on the results of the field study.

The share of plate waste (%) in the total weight of food served was calculated to identify the share of the food served that went to waste.

The share of plate waste at the schools examined was on average 28.75% of the total weight of food served, which means that on average almost one-third of the served food went to waste (Table 7).

Table 7. Shares of plate waste (%) in the total weight of food served at the Rezekne city school canteens (by school).

School	Total Weight of Plate Waste (g/Week)	Total Weight of Food Served, g/Week *	Share of Plate Waste, % **
S1	52,578	145,970	36.02
S2	163,750	696,962	23.49
S3	197,674	629,858	31.38
S4	297,603	684,707	43.46
S5	71,131	305,503	23.28
S6	256,933	1,122,945	22.88
S7	216,630	783,191	27.66
Total:	1,256,299	4,369,136	28.75

* Note: the total weight of food served (g/week) was calculated based on the weight of food indicated by the menu (see Table 3), multiplying the weight of food served each day by the number of samples examined that day and adding up the results for all the days and all the schools. ** Note: the share of plate waste (%) in the total weight of food served was calculated as the ratio of the total weight of plate waste (g) to the total weight of food served (g) × 100% [19]. Source: authors' calculations based on the results of the field study.

As shown in Table 7, a lower share of plate waste than the average was identified in schools S2, S5, S6 and S7, while a higher share than the average was found in schools S1, S3 and S4.

The shares of plate waste in the total weight of food served were analyzed also by grade group, revealing a 1.68%-point difference between grades 1–4 and 5–7: the average for grades 1–4 was 29.46%, while the average for grades 5–7 was 27.78% (Figure 4).

Figure 4 shows that a higher share of plate waste in the total weight of food served than the average for grades 1–4 (i.e., 29.46%) was found in two out of the six schools, i.e., school S4—44.08% and school S7—29.72%; in school S3 this coincided with the average of

29.46%; however, in three schools the figure was below the average, i.e., school S2—23.73%, school S5—26.97%, school S6—24.79%. In the group of grades 5–7, a higher figure than the average (i.e., 27.78%) was found in three out of the seven schools, i.e., school S1—34.89%, school S3—34.16% and school S4—42.55%, whereas in four schools it was below the average: school S2—23.14%, school S5—22.43%, school S6—18.72% and school S7—23.73%. It should be noted that the largest share of plate waste in the total weight of food served among grades 1–4 (44.08%) and grades 5–7 (42.55%) was found in school S4.
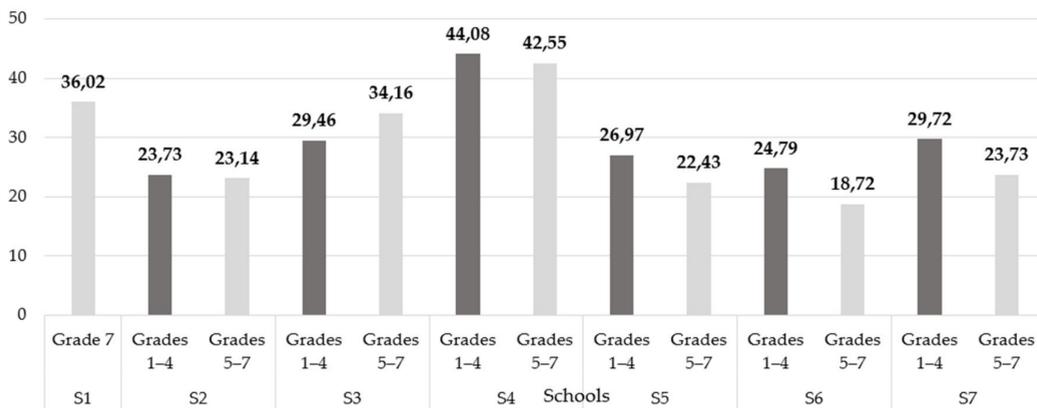

Figure 4. Share of plate waste (%) in the total weight of food served at the Rezekne city school canteens (by school and by grade group). Source: authors' construction based on the results of the field study.

The food served during the field study at the Rezekne city school canteens consisted of the following food categories: soup, staple food, fish or meat, beverages, fruit, vegetables, bread and curd products (glazed curd cheese). An analysis of the data obtained during the field study on the weight of plate waste by food waste category revealed that in all the schools, the largest share of plate waste in the total weight of plate waste was made up of beverages at 42.24%, followed by staple food (potato, pasta)—28.38% and meats—11.77% (Table 8). The authors of the paper note that in the present research, the plate waste analysis involved beverages (because all of them contain calories), as this method was suggested as the most comprehensive accounting of plate waste [75]. In some research studies, this method is called tray waste measurement, as all foods and beverages on schoolchildren trays are included in the total amount of food wasted [76].

Table 8. Breakdown of plate waste by food waste category at the Rezekne city school canteens, as a % of the total weight of plate waste (by school).

Plate Waste by Food Category, Share of Total Plate Waste	School							Total
	S1	S2	S3	S4	S5	S6	S7	
Soup	2.66	4.45	5.48	12.09	6.17	12.94	5.56	8.37
Staple food	19.21	29.90	22.25	29.72	40.77	34.19	22.24	28.38
Fish	0.00	1.71	0.75	1.33	0.96	1.97	1.00	1.28
Meat	12.55	13.25	12.97	10.03	16.22	14.53	7.00	11.77
Beverage	45.89	43.18	53.31	37.92	22.33	31.49	55.76	42.24
Fruit *	14.24	1.66	2.30	1.63	0.00	3.15	0.57	2.30
Vegetables	5.14	5.03	1.41	6.98	13.33	1.07	6.82	4.89
Bread	0.32	0.75	1.53	0.26	0.22	0.65	1.05	0.74
Glazed curd cheese	0.00	0.07	0.00	0.05	0.00	0.01	0.01	0.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Note: regarding fruit waste, it is difficult to draw any conclusion because the schoolchildren were given whole bananas and whole apples during the field study, which they often took with them. For example, in school S5, fruits were served in a box, which was usually taken to the classroom where the fruits were later consumed. Source: authors' calculations based on the results of the field study.

As shown in Table 8, an analysis of plate waste shares by food waste category revealed a similar situation, as the largest share of plate waste was represented by beverages, followed by staple food and meat, which was found in three out of the seven schools: S2 (43.18%, 29.90% and 13.25%, respectively), S3 (53.31%, 22.25% and 12.97%) and S7 (55.76%, 22.24% and 7.00%). In two out of the seven schools, i.e., S5 and S6, the largest share of plate waste was found for staple food (S5—40.77% and S6—34.19%), followed by beverages (S5—22.33% and S6—31.49%) and meat (S5—16.22% and S6—14.53%). In school S4, however, the largest share of plate waste was found for beverages (37.92%), followed by staple food (29.72%) and soup (12.09%). In school S1, the largest share of plate waste was found for beverages (45.89%), followed by staple food (19.21%) and fruit (14.24%). Such shares of plate waste by food category were directly related to the weight of food served by food category, as beverages, staple food and meat had the largest share in the total weight of food served. Therefore, it would be more correct to analyze the shares of plate waste by food category by considering the weight of each food category served, using Equation (2):

$$\text{Share of Plate Waste by Food Category, \% } = \frac{\text{Weight of Plate Waste by Food Category, g}}{\text{Weight of Served Meal by Food Category, g}} \times 100 \tag{2}$$

At the same time, the calculations also showed which categories of food served the schoolchildren consumed the most and the least (Table 9).

Table 9. Plate waste shares of food served (%) at the Rezekne city school canteens by food category (by school).

School	Soup	Staple Food	Fish	Meat	Beverage	Fruit	Vegetables	Bread	Glazed Curd Cheese
S1	7.99	30.84	0.00	32.52	51.56	50.18	34.32	2.85	0.00
S2	8.63	31.47	20.81	27.10	31.37	4.74	19.79	4.34	1.00
S3	14.76	31.07	10.93	36.32	51.46	8.59	7.30	11.83	0.00
S4	44.56	57.62	29.64	37.87	50.83	8.62	50.38	2.75	1.33
S5	12.40	42.44	15.29	31.32	16.11	0.00	53.62	1.25	0.00
S6	24.65	35.05	25.77	28.44	22.31	8.43	4.15	3.70	0.20
S7	13.67	27.53	21.29	15.80	47.82	1.68	32.94	7.23	0.25
Total	20.45	36.48	21.64	28.77	37.56	7.65	23.90	5.26	0.49

Source: authors' calculations based on the results of the field study.

As shown in Table 9, the largest share of plate waste in the total weight of food served was represented by beverages at 37.56%, followed by staple food—36.48% and meat—28.77% (see Figure 5). An analysis of the data by school revealed that there were categories of food that the schoolchildren consumed less than 50% of, i.e., the share of plate waste exceeded half of the total weight of food served, for example, in school S4, the share of plate waste for the category of staple food reached 57.62%, in schools S4 and S5, the shares of plate waste for the category of vegetables were 50.38% and 53.62%, respectively, and for the category of beverages, the figures were the highest in schools S1 (51.56%) and S3 (51.46%), followed by school S4—50.83%.

The authors of the paper point out that in Latvia, the planning and management of menus in educational institutions is conducted strictly in accordance with the dietary guidelines stipulated by various legal acts. After analyzing the menus used in the Rezekne city schools, the authors concluded that the menus were based on the government's recommendations on nutrition for children; however, given the large share of meat and staple food in the total weight of food served during the field study, in this case compliance with the dietary guidelines did not guarantee a balanced diet for children. The large number of wasted beverages also indicated that the beverages given to the schoolchildren did not taste good. In the Rezekne city schools, beverages were poured into glasses and served on tables for each schoolchild individually. The observations during the field study showed that the schoolchildren often did not even taste their beverages. Due to COVID-19

restrictions, the intact beverages could not be given to other schoolchildren; therefore, they went to waste.

The monetary value of plate waste [19] was calculated using Equation (3); the weight of plate waste excluding beverage waste per schoolchild (see Equation (4)) and the cost of plate waste excluding beverages (see Equation (5)) were also calculated:

$$\text{Cost of Plate Waste, EUR} = \frac{\text{Average Weight of Plate Waste per Schoolchild, g}}{\text{Average Weight of Served Meal , g}} \times 1.42 \tag{3}$$

$$\text{Average Weight of Plate Waste excluding Beverage Waste per Schoolchild, g} = \text{Average Weight of Plate Waste per Schoolchild, g} - \text{Average Weight of Beverage Waste per Schoolchild, g} \tag{4}$$

$$\begin{aligned}\text{Cost of Plate Waste excl. Beverage Waste, EUR} \\ = \frac{\text{Average Weight of Plate Waste excl. Beverage Waste per Schoolchild,g}}{\text{Average Weight of Served Meal , g}} \times 1.42\end{aligned} \tag{5}$$

where EUR 1.42 is the cost of free lunch per schoolchild that is provided for learners in grades 1–7 in Rezekne city schools and funded from the state and local government budgets in accordance with the requirements of legal acts [68].

The calculation results by school and by grade group, as well as for the entire period of the field study, are presented in Table 10.
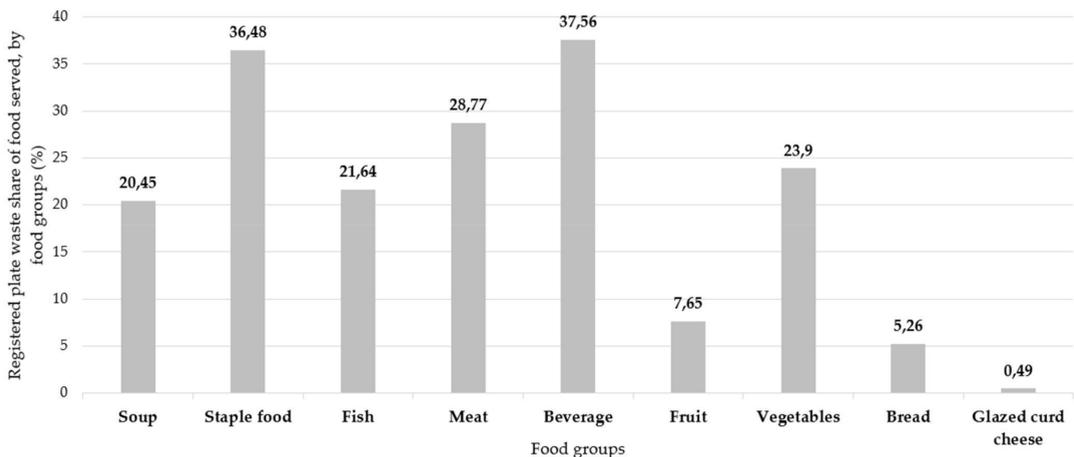

Figure 5. Shares of plate waste in the total weight of food served at the Rezekne city school canteens (%). Source: authors' construction based on the results of the field study.

After analyzing the costs of plate waste (excluding beverage waste) per schoolchild, shown in Table 10, it could be concluded that the average cost of plate waste (excluding beverage waste) per schoolchild was EUR 0.236 (EUR 1666.88/7064 samples). An analysis by grade revealed that except for schools S3 and S4, the figure was higher in all the other schools in the group of grades 1–4; in school S4, this figure was the same for both groups of grades, while in school S3, the cost of plate waste (excluding beverage waste) per schoolchild was lower in grades 1–4 than in grades 5–7. It should be noted that the highest cost of plate waste (excluding beverage waste) per schoolchild was found in school S4 at EUR 0.38. The average cost of plate waste (excluding beverage waste) per schoolchild found in the group of grades 1–4 was EUR 0.243 (EUR 997.06/4105 samples), and in the group of grades 5–7 it was EUR 0.226 (EUR 669.82/2959 samples), which made up a difference of EUR 0.017, or 7.5%. Given that the cost of plate waste for the period of the field study, i.e.,

for 5 working days (in some schools for 4 working days), totaled EUR 1666.88, per day it was about EUR 333.38, per month or on average 21 working days it was about EUR 7000.00.

Table 10. Weights (g) and costs (EUR) of plate waste at the Rezekne city school canteens (by school and by grade group).

Schools	Groups of Grades	Average Weight of Served Meal, g	Average Weight of Plate Waste Per Schoolchild, g	Cost of Plate Waste per Served Meal, EUR	Average Weight of Beverage Waste Per Schoolchild, g	Average Weight of Plate Waste Excluding Weight of Beverage Waste Per Schoolchild, g	Cost of Plate Waste Excluding Beverage Waste Per Schoolchild, EUR	Actual Number of Lunch Participants (Number of Samples)	Total Cost of Plate Waste Excluding Beverage Waste, EUR
S1	Grade 7	613	225	0.52	103	122	0.28	234	66.13
S2	Grades 1–4	618	147	0.34	58	89	0.20	677	138.45
	Grades 5–7	618	143	0.33	69	74	0.17	450	76.51
S3	Grades 1–4	618	182	0.42	94	88	0.20	603	121.93
	Grades 5–7	618	209	0.48	116	93	0.21	421	89.96
S4	Grades 1–4	618	272	0.62	105	167	0.38	663	254.41
	Grades 5–7	618	262	0.60	97	165	0.38	447	169.47
S5	Grades 1–4	618	164	0.38	34	130	0.30	94	28.08
	Grades 5–7	618	140	0.32	32	108	0.25	399	99.01
S6	Grades 1–4	618	154	0.35	52	102	0.23	1239	290.38
	Grades 5–7	618	115	0.26	29	86	0.20	574	113.43
S7	Grades 1–4	618	184	0.42	98	86	0.20	829	163.81
	Grades 5–7	624	148	0.34	92	56	0.13	434	55.31
	Total for grades 1–4							4105	997.06
	Total for grades 5–7							2959	669.82
	Total								1666.88

Source: authors' calculations based on the results of the field study.

4. Discussion

4.1. Comparison with Other Studies

The management of catering in the schools of Rezekne city differs significantly from the approach applied in several European countries and the USA, where it mostly takes the form of buffet-type catering. In Rezekne city schools, before each lunch break, tables reserved for individual classes are set by placing portions of a set meal (staple food and meats on a single plate) according to the expected number of lunch participants, while vegetables can be served together with a set meal on a single plate or served in shared dishes on tables for each class individually, while soup is usually served in shared dishes on each table. The menus are designed based on government recommendations on child nutrition and are agreed and approved by the head of each educational institution.

The results of the quantification of plate waste that was performed at the canteens of the Rezekne city schools, examining the plate waste of 7064 school lunches for schoolchildren in grades 1–7, showed that the average weight of plate waste per schoolchild reached 178 g: in the group of grades 1–4 it was 182 g, in the group of grades 5–7 it was 172 g. The

share of the total weight of plate waste in the total weight of food served was 28.75%: in the group of grades 1–4 the figure was 29.46%, while in the group of grades 5–7 it was 27.78%.

It could be concluded that the share of plate waste calculated by the field study exceeded that identified by previous research studies conducted in other European countries and the USA. This could be due to the fact that in the present field study, the beverages that were not consumed were also included in the weight of plate waste. Many plate waste measurement studies considered only solid plate waste (excluding beverage waste), and often the components of plate waste were not discussed in detail at all. Eriksson et al. identified that 23% of food served in Swedish school canteens went to waste. Waste from beverages was not recorded or quantified in this study [35]. A research study on Italian schools by Garcia-Herrero et al. found that the average weight of food waste (excluding beverage waste) per primary school pupil was 136 g, of which about 95% was plate waste and about 5% was served food waste [15]. In an audit of food waste (excluding beverage waste) in Spanish schools, Derqui and Fernandez (2017) found that the largest amount of food waste came from plate waste, i.e., ranging from 21 g to 47 g per pupil per day in primary schools and from 23.7 g to 88.0 g per student per day in secondary schools, concluding that the plate waste tended to increase with the age of students [19]. This observation showed the importance of taking measurements for the quantification of food waste by age group. Conducting food waste research at three U.S. schools in Florida, Wilkie et al. found that school A had the highest average food waste per pupil among all the three schools, even though the kitchen did not generate a measurable amount of food waste. This was due to the higher number of school-provided meals in school A and the number of primary schoolchildren who were more selective, or the fact that they were served larger portions than they could eat. In this research, the amount of wasted milk was measured separately [37]. Buzby and Guthrie, and Niaki et al. also concluded that food waste tended to decrease with the age of schoolchildren [20,48]. Steen et al., in contrast, found that the amount of plate waste tended to increase with the age of schoolchildren [38]. The results of our field study showed that no significant differences in the share of plate waste in the total weight of food served were observed between the groups of grades; it was found that there was a difference of 1.68 percentage points between the groups of grades 1–4 and 5–7: the average for grades 1–4 was 29.46%, while for grades 5–7 it was 27.78%.

An analysis of plate waste by food category showed that beverages accounted for the largest share of total plate waste (42.24%), followed by staple food (28.38%) and meat (11.77%). An analysis of plate waste shares of food served (%) by food category revealed a similar situation: the largest share of food served was made up of beverages (37.56%), followed by staple food (36.48%) and meat (28.77%). The results of the present field study, broken down by plate-waste food category, differed from the results of other research studies conducted worldwide, which were as follows: in Italian schools, analyzing plate waste by food category, it was found that about 22.4% pasta or rice, 31% livestock food products and 43.6% vegetables were wasted [73]; in a research study conducted in Boston schools, Cohen et al. (2013) found that students discarded about 19% of their food, including 47% fruit, 25% milk and 73% vegetables [24]; a research study of students in grades 3 to 8 in four U.S. schools found that the share of vegetable waste reached 58.9% [77]; research studies conducted in China found that vegetables accounted for the largest share of plate waste, i.e., 42% [78] and 31% to 53% [41]. It could be concluded that vegetables were wasted the most, and this was a very common situation all over the world [20,23].

The results of the present field study on vegetable plate waste were as follows: the share of vegetables in the total amount of plate waste was only 4.89%, while the share of discarded vegetables in the total amount of vegetables served was 23.90%, which was the fourth largest plate waste food category. The authors of the paper attribute this to the relatively small share of vegetables in the school menu (only fresh vegetables such as fresh cucumbers, tomatoes, carrots and cabbage), which accounted for only 4–8% of the total weight of food included in the school menu. This mostly depended on the insufficient funding for free lunches (i.e., only EUR 1.42), which limited the possibility to introduce

different kinds of vegetables to the menu. It is also necessary to consider the fact that Latvia is located in Northern Europe, where fresh vegetables such as cucumbers, tomatoes, peppers, etc. are mostly available at the end of summer when their prices are the lowest, yet during the school year their prices increase significantly, which does not encourage the diversification of the menu.

4.2. Monetary Value of Plate Waste

Regarding the monetary value of food waste, as noted by Derqui and Fernandez, such a measurement was very seldom taken by researchers due to the fact that the research objectives rarely related to costs [19].

The aim of the present research was not to perform a detailed analysis of the monetary value of food waste. However, given the fact that in Rezekne city, lunches for schoolchildren in grades 1–7 are funded by the national or local governments whose main source of revenue is personal taxes, in this case it was worth calculating the monetary value of food waste. To make the calculation of plate-waste costs as correct as possible, the weight of beverages was deducted from the total weight of plate waste, as the authors of the paper believed that the most significant component of any beverage was water, which was cheaper than, for example, meat or vegetables. The calculations showed that the average cost of plate waste (excluding beverage waste) per schoolchild was estimated at EUR 0.236 (or 16.6% of the cost of a portion of free lunch at EUR 1.42).

Given that the cost of plate waste for the period of the field study, i.e., for 5 working days (in some schools for 4 working days) totaled EUR 1666.88, per day it was about EUR 333.38, and per month or on average 21 working days it was about EUR 7000.00. Due to the different price levels across various countries, it is difficult to compare our figures in terms of whether they are high or low. However, given that the cost of one free lunch portion is EUR 1.42, almost 5000 schoolchildren a month could be provided with free lunch for this funding. Additionally, this is a significant figure, considering that the number of schoolchildren in grades 1–7 in Rezekne city schools was 2176: the monetary value of plate waste would be enough to provide free lunch for schoolchildren in the grades for about 2 days a month.

4.3. Policy Recommendations

One of the research methods was observation. The researchers observed the atmosphere in the dining halls of the school canteens, the interior, the table setting, the way the food was placed on the plate, the way the food was served for lunch and the process and time for enjoying the food. The plate-waste analysis was only one of the activities of the research project that developed recommendations for several areas of school catering management: designing of school menus, organization of the catering process, assessment of catering infrastructure and equipment, school canteen personnel, food waste management, etc.; for example, one of the recommendations developed was as follows *(1) designing and implementing an education and communication strategy in schools, which is focused on sustainable and healthy food consumption.* This recommendation is based on the idea of education and communication as the most effective approach to changing learners' food-consumption behavior [79]. Food waste in school canteens could be reduced by educating learners and school personnel, thereby changing their behaviors [37,80,81], especially given that childhood food consumption behaviors and habits tend to continue into adulthood [20]. An awareness of food waste, healthy eating and waste needs to be raised among both learners and school personnel (teachers, administrators, kitchen personnel) [27,82–84]. Often it is one-way communication, through posters or table talkers, which conveys messages such as "Eat as much as you can—but throw away as little as you can" [85]. In addition, schools were recommended to integrate nutrition education and healthy food awareness into the school canteen environment, using a competency approach to the curriculum.

The use of various digital tools to track plate waste also allows the responsible personnel to gain an understanding of why the meal is wasted, as well as providing food planning,

which could have a positive effect on the amount of waste in the long term [85]. One of the results of our research project was the development of a prototype of an e-mentor tool that is able to predict the quantity of food required for educational institutions with the aim of reducing food waste. The mathematical calculations for the prototype of the e-mentor tool showed that if the lunch break was less than 20 min (considering also the time it takes for schoolchildren to get to the canteen and go back to the classroom after the lunch), the weight of plate waste increased exponentially. By means of the prototype of the e-mentor tool, it is possible to predict not only the effect of the lunch break duration on the amount of plate waste but also to identify the effects of other parameters such as schoolchildren's attitudes to certain categories of food and competitive food consumption (e.g., food brought from home) [86]. The authors of the paper plan to develop the e-mentor tool within future research projects so that it would be practically applicable in Rezekne city schools.

The other recommendations developed pertain to:

(2) the focus of school administration on the sustainability of food resources, which means that the more school administrators and teachers focus on sustainability, the larger the potential for waste-reduction initiatives [27,87];

(3) diversification of school menus, including identifying learners' wishes for designing a menu [11,27], as well as the revision of and improvement in nutritional guidelines considering the changing demand for food by learners in today's conditions, but based on the consumption of healthy food. It is highly recommended to review the menu periodically and to not include dishes that are not preferred by the learners [88];

(4) careful planning of the quantity of food to be prepared. Forecasting canteen attendance can help canteens to identify the number of learners they need to provide catering for, i.e., plan the demand [89]. Derqui et al. (2018) point out that timely and fast communication between the school administration and the kitchen about the actual number of learners is needed in order to be able to adjust the quantity of food prepared [27]. Previous research studies have shown that canteen attendance forecasting can reduce food waste and save financial resources [82,89–91]. The authors of the paper concluded that in the Rezekne city schools, due to external circumstances (mainly because of sick schoolchildren or the COVID-19 pandemic), the number of schoolchildren participating in lunch on a given day was variable. This is one of the risk factors in food waste, as from the organizational perspective, the educational institution does not always have a system in place that allows the catering provider to receive timely information on the actual number of schoolchildren on a given day to avoid unnecessary food production;

(5) prudent planning of lunch breaks and dining hall environment adaptation. Several research studies have examined the impacts of changes in the dining hall on food waste, e.g., the implementation of the Smarter Lunchrooms Movement (SLM) strategy [92] and its impact on the consumption of fruit, vegetables and dairy products by learners [31,93,94]. Research studies show that the implementation of fruit and vegetable-oriented marketing activities in schools significantly increase the consumption of the foods [95–97]. However, an extensive research study by Cohen et al. on school food promotion strategies conducted in 2021 showed that in the long term, the interventions yielded conflicting results, meaning that not all school food promotion methods included in the SLM strategy actually worked. The best results could be achieved by applying the holistic approach, e.g., giving students an opportunity to choose meal components (especially fruit and vegetables), improving the taste of food, offering cut fruit, allowing more time for lunch breaks (~30 min), limiting access to competitive foods, etc. [98].

(6) the way the food is served. Liu et al. (2016) have concluded that it is buffet-type catering that is effective in serving food in schools, as it makes students more flexible in relation to the food choice, taste and weight (compared with a way of serving food that is of an oppressive nature) [78]. However, Simanovska points out that in some schools in Latvia, the Food and Veterinary Service inspectors objected to the possibility for schoolchildren to choose the components and size of the portion themselves, stating that this could

be contrary to strict legal requirements concerning a certain amount of nutrients to be provided to every schoolchild. Nevertheless, the official opinion of the National Food and Veterinary Service states that it is acceptable for schoolchildren to choose their own food and portion size if the average nutritional requirements for every child are met [99]. Methods of serving foods that make it practically difficult for schoolchildren to consume them should be avoided [26]. The supply of unpeeled and uncut fruit to schoolchildren significantly increases the amount of plate waste [100]. The size of plates also plays an important role in placing the food in an attractive way for schoolchildren. The field study found that in most of the schools examined, the plate size was too small, often the food on the plate was placed in such a way that the components of each food were not visible, which made a negative impact on the schoolchildren's attitudes to the food;

(7) modern kitchen equipment and professional kitchen personnel. The amount of food waste generated by schools is influenced by the diverse resources of their canteens, both physical (facilities and infrastructure) and human (school and canteen personnel). Some of the resources are structural, e.g., the size and equipment of the kitchen or canteen, while human resources are more closely linked to the school administration's focus on sustainability [19,27]. The appearance and taste of food are influenced by factors such as the cooking skills of kitchen personnel, the quality of the food, cooking equipment and the storage of foods [27,41]. Despite the fact that 70.91% of school canteen personnel involved in the field study had the required qualifications to perform the responsibilities of a cook, it was recommended to develop a training plan for the school canteen personnel to acquire or improve the skills and knowledge required for the job. Regarding improvements in school canteen infrastructure, the schools were recommended to purchase modern technological equipment to prepare food by applying newer, more food-friendly methods, e.g., convection ovens or combination ovens. It is also necessary to consider the fact that the Rezekne school canteens mainly used manual work; therefore, equipment was needed that could automate many processes, e.g., a machine for portioning semi-finished foods, etc.

The authors of the paper believe that within the research project, significant work was conducted and basic information about the management of catering in Rezekne schools was obtained on which to build on future research. This future research would relate to the implementation of individual recommendations for the management of catering, as well as the improvement of the e-mentor tool with the aim of applying it in practice at school canteens.

5. Conclusions

Within the research project "E-mentor as a Transformation tool for Ensuring Zero-Waste Food Consumption in Educational Institutions" No. lzp-2020/2-0115, funded by the Latvian Council of Science, an analysis of plate waste was performed in seven schools of Rezekne city, and recommendations for stakeholders on how to reduce the amount of plate waste were developed. It should be noted that, to date, no research studies have been conducted in Latvia placing a focus on zero-waste food consumption, including plate waste generated by educational institutions.

The distinguishing feature of the present research was that during the week of the field study, a unified menu was introduced into all the schools examined, which eliminated differences in food availability and ensured the same research conditions, thereby reducing the impact of factors influencing gastronomic choices on the study.

The research results showed that in Rezekne city schools, the average weight of plate waste per schoolchild reached 178 g. The weight of plate waste accounted for 28.75% of the total weight of food served. The figures were higher than those obtained by earlier research studies conducted worldwide, and the authors of the paper explain this by a different methodology for measuring plate waste—the present field study also took into account beverages because all of them contain calories, and this method is considered to be the most comprehensive accounting of plate waste. The field study did not find significant differences in the average weight of plate waste between different age groups of

schoolchildren: in the group of grades 1–4 it was 182 g, in the group of grades 5–7 it was 172 g. Regarding the share of plate waste in the total weight of food served, in the group of grades 1–4 the figure was 29.46%, while in the group of grades 5–7 it was 27.78%. A one-way analysis of variance showed that the average weight of plate waste per schoolchild, in grams, was not affected by the grade which the schoolchildren were in.

After analyzing the amounts of plate waste by food category, the authors of the paper found that the results obtained differed from those of previous research studies conducted worldwide, which found that vegetables were wasted the most. In the schools of Rezekne city, the largest share of plate waste in the total weight of plate waste was made up of beverages (42.24%), followed by staple food (28.38%) and meat (11.77%). An analysis of plate waste shares of food served (%) by food category revealed a similar situation: the largest share of food served was made up of beverages (37.56%), followed by staple food (36.48%) and meat (28.77%). The authors of the paper explain this via the relatively small share of fresh vegetables in the school menu, which, in the opinion of the authors, depends on insufficient national and municipal funding for school lunches, which does not allow the schools to diversify their menus with a variety of fresh vegetables.

The aim of the present research was not to perform a detailed analysis of the monetary value of food waste. However, given the fact that in Rezekne city, lunches for schoolchildren in grades 1–7 are funded by the national or local governments whose main source of revenue is personal taxes, in this case it was worth calculating the monetary value of food waste. To make the calculation of plate waste costs as correct as possible, the weight of beverages was deducted from the total weight of plate waste. The calculations showed that the average cost of plate waste (excluding beverage waste) per schoolchild was estimated at EUR 0.236, or 16.6% of the cost of a portion of free lunch at EUR 1.42.

Given the research results, the authors conclude that in order to reduce the amount of plate waste generated by Rezekne city schools, school menus should be based not only on the requirements prescribed by relevant legal acts but also on modern learners' understanding of nutrition, their perception of food consumption and whether it is in line with their understanding of a "modern" and self-evident process. It is necessary to ensure that the schools' cooking processes meet the requirements of modern consumers (learners) by introducing cooking techniques that are understandable and familiar to them (e.g., offering smoothies). By following the trends in cooking practices in society, it is possible not only to increase the consumption of school food but also to make the learners interested in consuming school food.

Nowadays, children's eating habits have changed significantly. Many dishes that are preferred by school menu makers and children's parents are not aligned with children's understanding of a delicious and healthy diet. The observations made by the authors of the paper revealed that in relation to competitive foods, children often chose a food that they consider healthy, and its physical volume was smaller than the volume of free lunch food. Most often, a competitive food chosen by learners did not meet the requirements of a healthy diet. The authors of the paper believe that serving school food in a modern way could change learners' attitude to the food offered. For example, packed small carrots, chopped peppers or cucumbers placed in disposable snack dishes allows schoolchildren to take the vegetables with them and eat them later. Expanding schoolchildren's choices of the kinds of free lunch dishes could reduce the amount of plate waste. The authors recommend that schoolchildren be provided with food choices (e.g., pre-ordering or organizing buffet meals). The authors further recommend reviewing and improving the dietary guidelines by considering changes in the demand for food by learners in today's world, while also ensuring the guidelines remain based on healthy food consumption.

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II Raksts

ANALYSIS OF FACTORS AFFECTING ZERO-WASTE FOOD CONSUMPTION IN SCHOOLS

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Abstract

The research aims to identify the factors affecting food waste and waste generation in schools and, consequently, barriers to zero-waste food consumption based on a systematic review of literature for the period 2015-2022. The research employed qualitative methods: systematic literature review, analysis and synthesis, as well as the monographic method. The literature review examined 1702 research papers and the abstracts. Using a PRISMA 2020 flow diagram, 54 papers were selected from the ScienceDirect, Scopus and Google Scholar databases for an in-depth analysis. Based on the literature review, 8 groups of factors that affected the generation of food waste in schools in the consumption process were identified: demographical, political, school food policy, environmental, socio-economic, personal/human, physical/human and geographical. The factors identified and aggregated might provide a basis for further discussions on zero-waste food consumption and food waste reduction in schools, as well as specific actions to optimize school food consumption and promote effective food and food waste management.

Key words: zero-waste, food consumption, factors, food waste.

Introduction

Every year, one third of the food produced for human consumption worldwide is lost or wasted at some stage in the food supply chain, totalling approximately 1.3 billion tonnes of food, which causes significant economic, social and environmental damage (Massari *et al*., 2021). To protect the planet and contribute to prosperity, in 2015 the UN developed the Sustainable Development Goals for 2030. Goal 12 involves ensuring responsible consumption and production patterns – it is necessary to halve global food waste per capita at the level of retailers and consumers, as well as reduce food losses in production and supply chains, which could help to ensure food security and shift to a more resource-efficient economy (UNDP, 2022).

In developed countries, raising awareness of food waste and loss is particularly important at the stage of consumption, which is the main source of food waste. In this respect, public school canteens create a unique environment that shows eating habits and the way the available resources are managed (García-Herrero *et al*., 2019). School canteens, where sustainable food consumption habits need to be passed on to future generations, produce a lot of food waste. There is a need to find a solution to the conflict between education on best practices and schoolchildren behaviour through incorporating school catering into a sustainability strategy (García-Herrero *et al*., 2021).

To date, the factors affecting food waste in schools in the consumption process have not been extensively researched in Latvia; therefore, the research aims to identify the factors affecting food waste and waste generation in schools and, consequently, barriers to zero-waste food consumption based on a systematic review of literature for the period 2015-2022. To achieve the aim, the following specific research tasks were set: to make a systematic literature review to identify the factors that hinder zero-waste food consumption in schools; to summarize the results and draw conclusions.

The zero-waste approach has been introduced not only in several industries of the economy but also in educational institutions (Munguía *et al*., 2018). Food consumption and food waste reduction is a social responsibility of every educational institution; therefore, food waste management requires a holistic approach to sustainable resource use and waste management (Hamid *et al*., 2020). Food waste relates to the final consumption stage and is a consequence of consumer behaviour (Principato *et al*., 2018); therefore, it is important to identify the factors that affect food waste and food waste generation in schools in order to optimize food consumption and promote effective food and food waste management.

Materials and Methods

The research employed qualitative methods: systematic literature review, analysis and synthesis, as well as the monographic method. The literature review examined 1702 research papers and the abstracts. Using a PRISMA 2020 flow diagram, 54 papers were selected from the ScienceDirect, Scopus and Google Scholar databases for an in-depth analysis.

Results and Discussion

Systematic literature reviews could be defined as a kind of research synthesis that is conducted to identify and obtain international evidence or practices and answer a specific question (Munn *et al*., 2018).

The research question is as follows: what factors affect food waste and food waste generation in schools and are therefore a barrier to zero-waste food consumption?

The process of selecting and synthesising the relevant literature is shown in Figure 1, i.e. a PRISMA
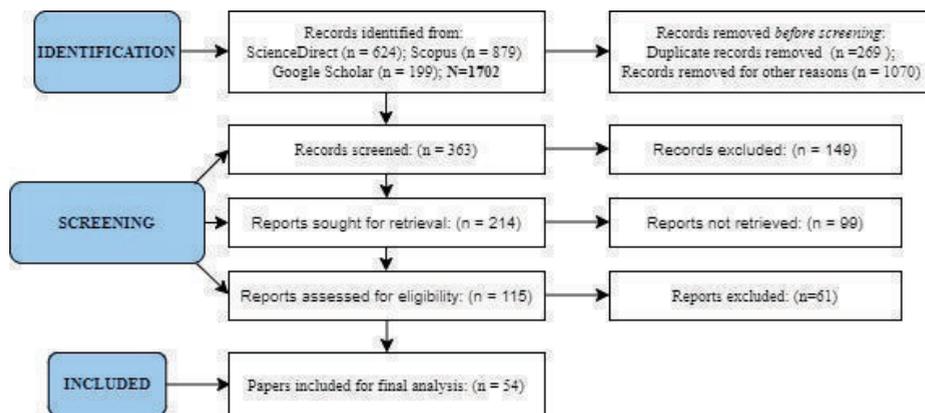
Figure 1. PRISMA 2020 flow diagram for new systematic literature reviews.

Source: authors' construction based on (Page *et al*., 2021).

2020 flow diagram, which was developed to help the researchers to clearly represent the process of literature selection (Page *et al*., 2021).

To select the most relevant literature, it is important to choose the right keywords (Linnenluecke, Marrone, & Singh, 2020; Tseng *et al*., 2019). Since food consumption closely relates to food waste, the authors chose the keywords 'food consumption in schools', 'food waste in schools', 'plate waste in schools' for the selection of research papers. Using the keywords and selecting the period of 2015 to 2022, several thousand papers were initially found, of which 1702 were selected using the advanced search technique (ScienceDirect – 624, Scopus – 879, Google Scholar – 199). Of the total, 269 overlapped and 1070 were excluded because of their titles. At the next step, 363 papers were left for screening, which were evaluated by the abstract, and 214 were left for reading. After analysing the papers, another 99 papers were excluded because they did not answer the research question. Finally, 54 out of the 115 most relevant papers were selected for further analysis.

Based on the literature review, 8 groups of factors that affected food waste in schools in the consumption process were identified.

Demographical factors. The amount of food waste in schools is significantly affected by the age of schoolchildren (Derqui & Fernandez, 2017; Park, Choi, & Kim, 2015). However, no unambiguous conclusions could be drawn based on the available research studies due to conflicting research findings that younger schoolchildren waste more than older ones (Niaki *et al*., 2017) and that the amount of food waste in educational institutions increases with age (Steen *et al*., 2018), and adolescents have a negative attitude towards school food (Tuorila *et al*.,

2015). Based on the findings, children at the age of 6-7 years begin to form their food waste behaviour; therefore, environmentally friendly interventions aimed at reducing food waste should begin at this age (Sorokowska *et al*., 2020). Food consumption is also affected by gender (Park, Choi, & Kim, 2015; Qian *et al*., 2022a). It has been observed that boys tend to eat more food and are even willing to eat someone else's uneaten portion, thus producing less food waste than girls do (Moreno-Black & Stockard, 2018; Painter, Thondhlana, & Kua, 2016), whereas girls prefer fruits and vegetables, thus wasting less food of this category (Cerrah & Yigitoglu, 2022; Moreno-Black & Stockard, 2018). It is emphasized that the level of education also shapes food consumption behaviour (Chen & Chen, 2018; Qian *et al*., 2021; Qian *et al*., 2022a), i.e. the lower the level of education, the more food is wasted (Wu *et al*., 2019).

Political factors. School catering is governed by laws, regulations and policies at several levels, which must comply with a number of standards: hygiene, health, etc., as well as international standards and various regulations regarding procurement, waste management, etc. (Derqui, Fernandez, & Fayos, 2018; Priefer, Jörissen, & Bräutigam, 2016), not focusing on nutrition or taste issues (Göbel *et al*., 2015). In addition, the rigidity and inflexibility of procurement specifications in adjusting various foods (Falasconi *et al*., 2015) and issues related to catering policies and school catering management plays some role (Boschini *et al*., 2020). It has been found that changing school dietary guidelines reduced the amount of food waste of plant origin by up to 28%, and it is suggested that a healthy diet could be part of strategies to reduce food waste (Reynolds *et al*., 2019). Schoolchildren comments and feedback from

the school kitchen are equally important, which helps to develop appropriate food waste reduction measures (Malefors, Eriksson, & Osowski, 2017). Often the main barrier to reducing food waste is inappropriate and unsupportive school policies, e.g. food is not allowed to be shared or taken away (Panizza *et al*., 2017; Zhao *et al*., 2019), which could relate to the old and common but ineffective habits (Persson Osowski *et al*., 2022). Schoolchildren's eating habits vary from school to school, yet the habits are strongly linked to school management priorities and positions regarding waste management and nutrition education for schoolchildren (Derqui & Fernandez, 2017; Torres-Pereda *et al*., 2020). Education, training, additional activities and awareness about nutrition, as well as the negative impacts of wasteful behaviour and food waste have been identified as key success factors in reducing food waste in schools (Chen & Chen, 2018; Schanes, Dobernig, & Gözet, 2018).

School food policy. Catering providers could have different strategies for planning and managing the catering process (Boschini *et al*., 2020; Pirani & Arafat, 2016). A lot of food waste is generated after cooking or serving the food, as well as because the food is not consumed before the expiry date (Ishangulyyev, Kim, & Lee, 2019). Canteen employee professional skills (Heikkilä *et al*., 2016) to cook well or reuse leftovers are also important (Pires *et al*., 2022). The menu and designing it are also considered to be important factors, as the reduction of food waste requires a change in practices, in particular improved planning and management based on past experience (Silvennoinen, Nisonen, & Pietiläinen, 2019), as the cause of additional food waste from school meals is associated with the composition of the menu, e.g. non-standard food (Prescott *et al*., 2019), the presence of alternative foods (Falasconi *et al*., 2015) or special diets in schools (Eriksson *et al*., 2017). Food leftovers could be reduced by providing enough time to eat (Kodors *et al*., 2022; Painter, Thondhlana, & Kua, 2016), as the amount of food waste is affected by the duration of lunch, a sense of urgency and a lack of time to eat (Burton *et al*., 2022; Painter, Thondhlana, & Kua, 2016; Qian *et al*., 2021; Silvennoinen, Nisonen, & Pietiläinen, 2019). Several research studies emphasized the role of a lunch supervisor as crucial, as a lack of control over food leftovers made by schoolchildren is a major source of food waste (Derqui & Fernandez, 2017; Martins *et al*., 2020). Teachers should be encouraged to have lunch with their schoolchildren, as they play an important role in shaping long-term eating habits (Martins *et al*., 2016). The different and unequal availability of resources in schools, e.g. kitchen facilities and human resources, can affect the amount of food waste generated (Derqui & Fernandez, 2017; Derqui, Fernandez, & Fayos, 2018). Too large portions are also

one of the most important factors in food waste (Betz *et al*., 2015; Boschini *et al*., 2020; Pires *et al*., 2022; Shanks, Banna, & Serrano, 2017; Steen *et al*., 2018; Talwar *et al*., 2021), and reducing food waste could be achieved by simply reducing portions (Visschers, Gundlach, & Beretta, 2020) or by offering portions of different sizes (Vizzoto, Testa, & Iraldo, 2021). The size and shape of the plate also significantly affects the food waste generated (Betz *et al*., 2015; Priefer, Jörissen, & Bräutigam, 2016; Richardson, Prescott, & Ellison, 2021), with larger plate sizes generating more food waste per schoolchildren per meal (Qian *et al*., 2022a), which could be prevented by introducing smaller oval plates in catering establishments (Gwozdz *et al*., 2020), or by changing the size of the plates from large to small (Ravandi & Jovanovic, 2019). The design of food (Falasconi *et al*., 2015; Gwozdz *et al*., 2020) and the serving dishes are not less important (Talwar *et al*., 2021).

Environmental factors. There are many reasons for consuming and wasting food, including the environment in which schoolchildren eat (Shanks, Banna, & Serrano, 2017). The amount of food waste increases with the capacity of the dining hall, which is associated with increased levels of stress and noise (Steen *et al*., 2018). The availability of food at the school snack bar also increases food waste, which encourages schoolchildren to eat more than they can (Priefer, Jörissen, & Bräutigam, 2016). Schoolchildren waste less food if there is a positive atmosphere in the dining hall (Elnakib *et al*., 2021).

Socio-economic factors. Several researchers have pointed out that food waste is affected by the family's socio-economic status and income level (Park, Choi, & Kim, 2015; Qian *et al*., 2021; Qian *et al*., 2022a; Wu *et al*., 2019). The family's socio-economic status also affects schoolchildren's attitude to food, as it has been found that primary school children from families with lower socio-economic status associate healthy food with something tasty rather than tasteless, thus wasting less healthy food (van der Heijden *et al*., 2020).

Personal/human factors. The amount of food waste generated by school canteens is also affected by schoolchildren's eating habits (Shanks, Banna, & Serrano, 2017) and dietary choices (Moreno-Black & Stockard, 2018; Wu *et al*., 2019). It has been observed that food brought from home and breakfasts in the classroom generate less food waste in the school canteen (Farris *et al*., 2019); however, the schoolchildren who ate snacks high in saturated fat or calories in the morning, which cause loss of appetite at noon, were more likely to waste lunch food (Falasconi *et al*., 2015; Martins *et al*., 2020). School lunch food is adequate for schoolchildren's daily diet and is generally more nutritious than other foods, including those taken from home (Pagliarino, Santanera, &

Falavigna, 2021). Schoolchildren eating habits are extremely different, as it could be associated with the regularity of meals, the kind of breakfast, even the age at which schoolchildren start smoking (Park, Choi, & Kim, 2015), as well as their appetite (Martins *et al*., 2016; Wu *et al*., 2019), as food is wasted more when the schoolchildren are not hungry (Betz *et al*., 2015) or are not satisfied with the taste of the food served (Qian *et al*., 2021; Talwar *et al*., 2021) or other sensory properties of the food (Tuorila *et al*., 2015; Martins *et al*., 2020). It has been found that most of the schoolchildren discarded uneaten food from school lunch (60%), and much fewer did that at a restaurant (8%) (Mitchell & Prescott, 2020), which indicates that it is acceptable to discard unwanted food, but it is not acceptable to discard wanted food (Zhao *et al*., 2019). In addition, stress (Philippe *et al*., 2021), peers, pressure from others and the presence of other people during lunch (Qian *et al*., 2021; Qian *et al*., 2022a) can increase food waste. The behaviours of teachers and schoolchildren also affect food consumption (Blondin *et al*., 2018). In China, it is believed that the only child in the family is more likely to waste food than someone who has siblings (Qian *et al*., 2022a). People often blame other individuals for food waste and waste generation or mention other conditions that they cannot influence or control; therefore, knowledge and an in-depth understanding of food waste and personal attitudes could reduce the effects but not completely eliminate them (Malefors *et al*., 2022; Qian *et al*., 2021; Visschers, Gundlach, & Beretta, 2020).

Physical human factors. Food consumption is affected by body weight (Park, Choi, & Kim, 2015), metabolism (Shanks, Banna, & Serrano, 2017), as well as the body mass index (BMI); it was found that the lower the BMI, the higher the probability of food waste, and various tests showed that the slimmest participants tended to waste more food (Qian *et al*., 2022b).

Geographical factors. Attitudes to food waste vary from culture to culture (Qian *et al*., 2022a). The development of a menu and the wishes of schoolchildren are also associated with the region where the school is located; therefore, food waste differs for each kind of menu (Bustamente, Afonso, & De los Ríos, 2018).

The results show that a very wide range of factors affect food waste in schools in the consumption process, what should be taken into account developing effective strategies to reduce food waste in schools.

Conclusions

Comprehensive research studies on the problem of food consumption and waste in schools is available in the scientific literature. Using a PRISMA 2020 flow diagram and applying the systematic literature review method, 54 most relevant research papers were selected to answer the research question. Based on the literature review, 8 groups of factors were identified: demographic, political, school food policy, environmental, socio-economic, personal/human, physical/human and geographical, which affected food waste and food waste generation in schools and were therefore a barrier to zero-waste food consumption. The factors identified and aggregated might provide a basis for further discussions on zero-waste food consumption and food waste reduction in schools, as well as specific actions to optimize school food consumption and promote effective food and food waste management.

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III Raksts

Circular Economy as a Tool for Sustainable Development: A Theoretical Perspective

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Abstract. Climate change, depletion of natural resources, social inequality and poverty, a lack of food resources, etc. issues related to world sustainable development has become increasingly relevant in the last 50 years, negatively affecting people's opportunities, and living standards in various countries. Despite these problems, the average level of wealth of the population in the world is gradually increasing over time. Considering forecasts on population growth by the end of the 21st century, it must be admitted that the current world-dominant linear economic model is fully unsustainable in resource consumption, as there is a natural barrier to economic growth. The aim of the present research study is to explore the potential of the circular economy as a tool for achieving sustainable development, based on a theoretical framework. This paper was built based on a broad literature review to examine the limitations and conceptual gaps of the circular economy concept as a tool for achieving sustainable development. It has been concluded that the circular economy concept undeniably has huge potential to promote sustainability within planetary boundaries as well as it can be implemented to decouple economic growth from the utilization of finite resources. However, a broader analysis of the circular economy concept allows us to assert that to date, a clear and effective approach for the transition to this economic model, affecting all areas of sustainable development (i.e. environmental, economic, social) has not been developed. In addition, the circular economy concept is still evolving, there is a tendency to view the circular economy concept holistically, covering various sub-concepts of the circular economy under the common Sustainable Circular Economy concept's umbrella.
Keywords: circular economy, planetary boundaries, resource consumption, sustainable development.

I. INTRODUCTION

The sustainable development (SD) framework encompasses strategies and practices aimed at reducing our ecological footprint while fostering development rooted in principles of social justice and equality. The three core dimensions of sustainability are economic, environmental, and social. True sustainability is attained only when there is an equilibrium or a careful trade-off among these three aspects [1], [2], [3].

Since the creation of a definition of SD in the 1980s, many stakeholders still seek workable solutions to achieving SD at the macro (local and national government) and micro (entrepreneur and consumer) level. However, it is a complex process affected by various external factors. The United Nations (UN) Department of Economic and Social Affairs forecasts that the world population will increase by at least 2 billion people by 2100 [4], while World Bank data indicate an increase in the wealth of nations and the proportion of the middle class since 1995 [5], [6]. Although overall the changes can be viewed positively, it simultaneously raises concerns about the risks of resource overconsumption and social inequality: the populations of Global South countries lack equal access to education, health care and balanced diets, on the other hand the overconsumption of resources by the people of Global North countries causes the depletion of world resources, increases the greenhouse effect and environmental pollution, thereby contributing to an increase in social inequality in the world [7], [8], [9], [10]. Teixidó-Figueras et al. [11] argue that the top 10% of global income earners contribute to 25-43% of the environmental impact. At the same time, the bottom 10% of income earners worldwide are responsible for only approximately 3-5% of the environmental impact. Obviously, the current levels of consumption by most people in the Global North, in most cases overconsumption, is unsustainable, unethical or unjust on a global scale.

UN Environment Programme data show that resource extraction has more than tripled since 1970, including a fivefold increase in the use of non-metallic minerals and a 45 percent increase in fossil fuel use; by 2060, global material use could double to 190 billion tonnes (from 92 billion), while greenhouse gas emissions

could increase by 43 percent; the extraction and processing of materials, fuels and food contribute to half of total global greenhouse gas emissions and over 90 percent of biodiversity loss and water stress [12]. Given that the current world-dominant linear economic model is inherently unsustainable, it is obvious that it is necessary to change the paradigm of existence and development of society through eco-economic decoupling.

It should be noted that there is a lack of specific management models or tools for putting the SD framework into practice. Among different management models used in the 21st century, the model (concept) of the circular economy (CE) is the one meeting the prerequisites for SD in the most accurate way [13].

In contrast to the 'take-make-use-waste' linear model, a CE is regenerative by design and aims to gradually decouple growth from the consumption of finite resources [14] (see Fig. 1).
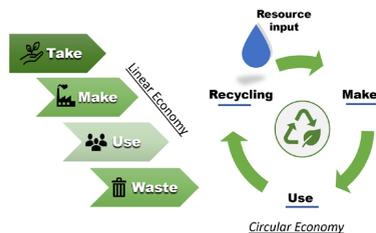

Fig. 1. Linear Economy model vs Circular Economy model (compiled by the author based on [2], [14], [15], [16], [17])

However, some authors criticize the CE for a lack of real definition, arguing that the goals and ways of implementation thereof are still unclear and inconsistent, and the limited conceptual basis thereof does not provide an idea of how the CE can contribute to SD [2], [15], [16], [17].

The research problem: despite the fact that the CE has emerged as a potential solution to achieving SD, there are still concerns and uncertainties about the implementation of the CE model, ignoring one or the other dimension of SD. Therefore, the main question of the research study is: could the CE be a tool for SD?

The research hypothesis: the dominant CE concept, which is primarily focused on resource efficiency, does not apply a holistic approach to linking economic growth, social justice and responsible environmental resource consumption. A theoretical analysis reveals the need for a more detailed CE concept to effectively integrate the above-mentioned dimensions, thus fostering SD.

II. MATERIALS AND METHODS

The research methods applied: scientific literature review, reports and research papers by various organizations in the research field for comprehensive coverage of relevant research studies pertaining to the research question, logical construction for making judgments and analysis of results, the synthesis method for combining elements into a unified system for researching the concepts of SD and CE, the monographic method for an in-depth examination of specific scholarly works and comprehensive studies related to the research question.

III. THE EVOLUTION OF THE SD CONCEPT

Historically, the concept of sustainability referred to the constraints of natural resources and economical use thereof, considering the need therefor in the long term and the future.

TABLE 1 TIME PERIODS AND TURNING POINTS IN THE FORMATION OF THE SD CONCEPT (COMPILES BY THE AUTHOR BASED ON [1], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31])

Time periods and turning points in the formation of the SD concept
First period: before 1972
1798: predictions by Thomas Robert Malthus about a lack of food resources due to the constant growth of the population;
1864: George Perkins Marsh's articles on the risk of human extinction due to interference with the natural environment;
Turn of the 18th and 19th centuries: the idea of sustainability appeared during the industrial revolution;
19th century: there were two factions within the environmental movement: conservationists who advocated the responsible use of natural resources and preservationists who advocated the protection of nature from use;
1950-1970: negative environment impacts of rapid economic growth, leading to concerns about sustainability;
1972: the Club of Rome report The Limits to Growth - a warning that the growth of population, industrialization, resource depletion and pollution in the next century could exceed the capacity of the Earth.
Second period: 1972–1987
1972: *The UN Conference on the Human Environment* in Stockholm was the beginning of a global change agenda introducing the concept of SD, which emphasizes the alignment of human development with environmental constraints; under the slogan '*Only One Earth*', a declaration and action plan for environmental conservation was published; the United Nations Environment Programme (UNEP) was launched;
1983: the Brundtland Commission report *"Our Common Future"* defined SD as development that *"meets the needs of the present without compromising the ability of future generations to meet their own needs"*; the basic principles of SD include satisfying human needs while considering certain environmental constraints; a transition to a global socio-economic policy, with SD becoming a key aspect in environmental management and other areas of human activity.
Third period: 1987 – present
1992: the Earth Summit in Rio de Janeiro developed Agenda 21 - an action plan for creating a global partnership to solve environmental problems; the social dimension was integrated into the SD concept: the three dimensions of SD were considered to be the economy, society, and the environment; a holistic approach to solving SD problems;
2000: the UN Millennium Summit defined a set of *the Millennium Development Goals* (MDGs) as a globally accepted framework to shape development and cooperation in countries over the next 15 years;
2012: the Earth Summit *"Rio +20"* in Rio de Janeiro adopted *"The Future We Want"* declaration on SD and the green economy, recognizing poverty as the main challenge to humanity and defined a set of *Sustainable Development Goals* (SDGs) beyond 2015;
2015: the UN Sustainable Development Summit assessed the implementation of MDGs and adopted *"Transforming our World — the 2030 Agenda for Sustainable Development"* (includes a set of 17 SDGs to be met by 2030, which are accompanied by specific targets – 169 in total), thus emphasizing coordinated economic, social and environmental development towards sustainability.

Shi et al. [18] and Klarin [19] have distinguished three historical periods in the evolution of the SD concept: (1) The Embryonic Period (Before 1972, or the

first period); (2) the Molding Period (1972–1987, or the second period), and (3) the Developing Period (1987–Present, or the third period) (see Table 1).

As shown in Table 1, initially, the concept of sustainability was mainly viewed in terms of lack of natural resources (environmental dimension of sustainability), yet over the course of two centuries, there has been a paradigm shift in the evolution of the SD concept, applying a holistic approach and integrating the social dimension into the SD framework.

IV. THE MAIN DIMENSIONS OF SD

SD involves approaches and methods that reduce human environmental impacts and foster development based on social justice and equity. To achieve sustainability, it is necessary to harmonize the three dimensions of sustainability: economic, environmental and social, or at least reach a trade-off between them. There are several models that seek to conceptualize SD, and each of them provide a different interpretation of the three dimensions. The models could be represented in different ways, e.g. as "pillars", as concentric circles, or as interlocking circles (Fig. 2). As a result, the ambiguities have complicated the perception and understanding of the SD concept, which vary across literature sources [32].
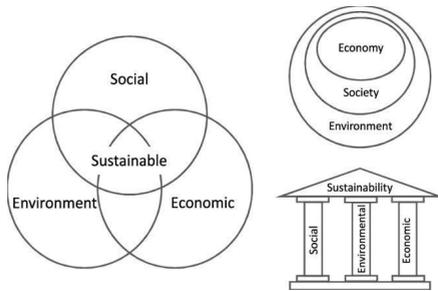

Fig. 2. Three dimensions of SD [3]

The recent reviews suggest replacing the environmental, economic and social dimensions with satisfying human needs, ensuring social equity and respecting environmental limits [33]. Despite this suggestion, it is widely recognized that in the context of SD, progress in one dimension should not come at the expense of the other two dimensions, and it is important to maintain a balance and take equal account of economic, environmental and social aspects in order not to harm overall sustainability [2], [34].

However, the widely used Brundtland definition [27] focuses on meeting global needs and ensuring intergenerational equity. According to research studies on SD, for an approach to be considered compatible with the principles of SD, it should not limit opportunities for future generations to live in conditions that are available to the current generation [35]. Accordingly, it could be concluded that the developments that disrupt or impede the ability of future generations to meet their own needs will not allow SD to be achieved if the three dimensions are not in harmony [2].

V. THE ESSENCE AND DEFINITION OF CE

Tambovceva & Titko [36] have found that the CE concept was introduced by Pierce and Turner in 1990, developing a new economic model based on the principles of thermodynamics. Later this idea was explained by Ciegis and Ciegis [37].

The modern understanding of the CE is based on the principles of industrial ecology, the environmental economy and the green economy with the aim of reducing environmental pressure in industrialized nations [38], [39].

The basic principles of CE strategies are "reduce", "reuse" and "recycle", which are defined in the scientific literature as "3R" [38], [40], [41]; however, the European Union (EU) Waste Framework Directive refers to "4R", with "recover" being the fourth R [42], as several definitions were found to refer to "regeneration" [43]. This framework has evolved into a framework of 10 strategies, with some authors referring to it as the "9R" [43], [44], or the "10R" (see Fig. 3).
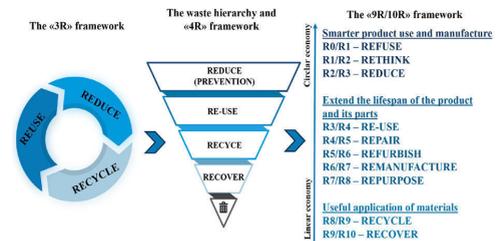
Fig. 3. Evolution of CE strategies (compiled by the author based on [38], [41], [42], [43], [44])

As regards the definition of CE, Millar et al. [2] have pointed out that no universal and generally accepted definition of CE has been proposed to date. The CE has gained momentum in the past decade, primarily through the approach of practitioners such as the Ellen MacArthur Foundation and often the CE is generally understood by the business world as *"a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature"* [14]. The CE concept as an alternative model that can promote production and consumption with lower environmental impact while promoting economic growth has been accepted in academic, policy-making and business circles [46], [47], [48]. The author points out that this widely accepted definition of CE does not include the social equity dimension, which is important if accepting the CE as a tool for achieving SD.

It should be noted that different definitions of CE have increasingly appeared in the scientific literature in recent years. In 2017, after analysing 114 definitions of CE available in the last decade, Kirchherr et al. [43] proposed defining the CE as *"an economic system that replaces the 'end-of-life' concept with reducing,*

alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish SD, thus simultaneously creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. It is enabled by novel business models and responsible consumers". It could be concluded that this definition covers all the three dimensions of SD (environmental quality, economic development, social equity). According to Kirchherr et al. [43], of the total CE definitions analysed, only 11 percent referred to SD as a principal aim.

In 2023, after re-analysing the recent CE definitions, Kirchherr et al. [49] concluded that all the three dimensions of SD were mentioned more frequently in the new set of definitions – a threefold increase compared with the 2017 study –, pointing out that fewer authors agreed that economic prosperity should be an aim of the CE. Kirchherr et al. [49] also pointed out that the largest shift since 2017 has been within CE enablers who are not only consumers and producers but also policymakers and scholars.

However, the most important conclusion made by Kirchherr et al. [49] is that considering the continually changing landscape of technology, environmental factors, and economic and socio-political contexts, the definitions of CE are expected to undergo a continuous evolution and **"the development of a 'final' and consensus definition of CE is elusive"**, and all current attempts to define the CE simply *"illustrate where the academic field currently sits in its own understandings of CE"* [49].

VI. THE CE AS A TOOL FOR SD

Millar et al. [2] argue that numerous contradictions and knowledge gaps exist regarding how the CE can improve social equity, promote economic growth and permanently reduce the rate of extraction of raw materials by closing material loops. And there have been no reviews that explicitly (i.e. by covering all the three dimensions of SD) analyse how the CE can serve as a tool for achieving SD.

To be able to answer the main question of the present research study, the limitations of the CE should be analysed, as pointed out by sceptical scholars who do not have a consensus about the contribution of the CE to sustainability [15], [50], [51]; therefore, the CE is viewed as simply a more environmentally sustainable model than the "linear" economy.

Despite the growing interest, the progress of the CE concept towards SD has not yet been formally identified. There are CE concepts that focus only on the reduction of raw materials and waste, the preservation of resource value and the reintegration of products [52], thereby indicating that the social dimension of SD is missing and creating potential limitations to achieving sustainability.

Limitations of the CE concept.

To be able to examine the limitations of the CE in more detail, the author of the study divided them into SD dimensions: economic, social and environmental, and also analysed the limitations of CE implementation (see Table 2).

TABLE 2 LIMITATIONS OF THE CE CONCEPT IN SD CONTEXT (COMPILED BY THE AUTHOR BASED ON [2], [16], [39], [43], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68])

SD dimensions	Limitations
Environmental dimension	- The CE as a closed-loop system is not practically or theoretically possible due to the second law of thermodynamics, which states that the continuous need for energy in recycling processes inevitably creates waste and by-products, ultimately leading to resource depletion, pollution and waste generation; - The CE is seen as a potentially more environmentally sustainable tool than the linear economy. However, it could still lead to similar consequences of environmental degradation, albeit at a slower pace; - The "rebound effects" challenge arises in the CE model, where improved secondary production efficiency reduces costs, potentially leading to increased consumption; this could offset the initial environmental benefits gained from enhanced efficiency; - There is no evidence that secondary production in the CE model could fully replace primary production, as technological limitations prevent the breakdown of certain wastes and the treatment of certain liquids; - Extending product lifetimes proposed by the CE to reduce dependence on continuous extraction of finite virgin materials, poses uncertainties about its impact on material flows, threatening long-term sustainability and challenging the assumption that it is a better alternative to the current linear model.
Economic dimension	- Due to increasing consumption, achieving a closed loop in CE is not possible: *"if demand is growing, the circle cannot remain closed"*. The CE could be feasible only if global demand for products in terms of both volume and composition stabilizes; - Information resources on the CE do not emphasize the importance of changing consumption patterns: if the current unsustainable economic paradigm is not changed and consumption patterns are not revised, the CE may remain only a technical tool without enabling sustainability; - There is no certainty that the CE can stimulate economic growth without endangering the environment.
Social dimension	- Whilst the CE has the potential to benefit society, there is a lack of the social aspect being integrated into the current framework, especially with regards to issues of governance, justice, and cultural change; - The lack of social indicators, which prevents the evaluation of the impact of the CE on social aspects, which raises doubts about the ability of the CE to promote social equality; - The CE concept does not illustrate the ways in which the social equity on the intra-generational (between the Global North and South) and the inter-generational (between the current and next generations) levels could be promoted; - Limited extraction of natural resources proposed by the CE could be considered antisocial for developing economies that are still growing resource stocks to build infrastructure that are essential for well-being.

SD dimen- sions	Limitations
Implementation aspect	- There are still challenges in the implementation of SD strategies and tools, which suggests that the implementation of the CE could face similar problems: both "top down" (commonly characterized as implementation enforced by government institutions or their equivalents) and "bottom up" (generally identified as initiatives advanced from the individual level) approaches face conflicts with other stakeholders;
	- SD is a society objective concept defined at the macro-level ("top down" approach) while the CE approach is mainly defined at the micro-level ("bottom up") through a model of consumption and production; it is not clear if they meet mid-way;
	- There is a lack of comprehensive global overviews of CE implementation and its alignment with SD goals;
	- There are conflicting motivations among CE stakeholders that need to be aligned and combined for successful implementation;
	- There is a deficiency in collaboration among policymakers, governmental bodies, manufacturing industries, and consumers, along with an overall lack of vision on how they implement the CE; without the sharing of knowledge and responsibilities among stakeholders, there are no guarantees of enhancing the success of implementing the CE as a tool for SD;
	- The CE introduces a range of tools that can be utilized for sustainable purposes, yet the ultimate objective appears unclear and decidedly more limited than that of SD;
	- Implementation of the CE is always associated with extra cost as long as the benefit is greater than or equal to the cost.

After analysing Table 2, it can be concluded that the CE implementation within the environmental dimension faces significant challenges to achieving a fully closed-loop system. While the CE is seen as a potentially more environmentally sustainable economic model, concerns about rebound effects, technological limitations, and uncertainties regarding the extension of product lifetimes underscore the complexity of implementing it as a superior alternative to the current linear model.

Regarding the economic dimension, the feasibility of a closed loop in the CE is hindered by constantly increasing consumption, necessitating the stabilization of global demand for products in terms of both volume and composition. The lack of emphasis on changing consumption patterns and without addressing the unsustainable economic paradigm, the CE may merely function as a technical tool without achieving sustainability. Additionally, uncertainties persist regarding the potential of the CE to stimulate economic growth without posing risks to the environment.

The social dimension of the CE is also debatable. Obviously, the CE holds societal potential, but its current framework lacks integration of different social aspects as well as the absence of social indicators raises doubts about the CE's ability to promote equality and address global and intergenerational disparities. Additionally, the CE's proposed limited resource extraction may be considered antisocial for developing economies reliant on resource growth for vital infrastructure.

To effectively implement the CE as a tool for SD, addressing challenges is crucial. This involves reconciling conflicts between "top-down" and "bottom-up" approaches,

clarifying the alignment between micro-level CE and macro-level SD, and resolving conflicting motivations among stakeholders. Enhancing collaboration, providing comprehensive global overviews, and establishing a clear vision for CE implementation are vital steps toward ensuring success. Despite the introduction of tools for sustainable purposes, the overarching objective of the CE remains uncertain, and the potential extra costs associated with implementation need careful consideration in the pursuit of SD.

VII. RESULTS AND DISCUSSION

The potential of the CE to foster economic growth while concurrently safeguarding the natural environment and enhancing social equity for current and future generations remains uncertain, challenging the validity of this assertion.

Undeniably both SD and the CE rely on the decoupling of resource exploitation from economic growth. Although the SD concept prioritizes people, emphasizing economic prosperity as a path to fulfilling lives in harmony with nature, the CE remains focused on technological solutions, the implementation of which is driven by a promise of traditional economic growth [17].

To view the CE as a tool to accomplish sustainability, the full integration of the CE with SD is crucial. This requires a comprehensive reassessment of the CE, expanding its focus beyond closed-loop recycling and immediate economic benefits. Instead, the shift should be towards a transformed economy that strategically manages resource access to uphold or enhance social well-being and environmental quality.

The concept of the CE should address inquiries such as whether it is possible for individuals to genuinely replenish natural capital, especially critical natural capital, while promoting high quality of life and well-being. Determining the size of our resource economy without depleting natural capital and the planet's absorptive capacity, as well as evaluating the resource intensity of a service-based economy, are also essential questions to be considered.

The CE concept should be transformed towards regenerative socio-economic structures that align with the Earth's system boundaries. This transformation can address the CE's current shortcomings, particularly its insufficient consideration of the social dimension and the need for system-wide thinking regarding entropy and biophysical limits [38], [69], [70], [71].

The CE should focus on a set of environmental, social and economic values, in which the economy becomes a means to reorganize society and the environment and not an end in itself [17].

The model of the Doughnut Economics (DE) developed by Kate Raworth [72] was proposed as a framework for the enhancement of the CE concept, providing a comprehensive and integrated approach that incorporates not only the efficient use of resources but also a strong emphasis on social equity, justice, and environmental sustainability. The model of the DE shows the minimum and maximum limits that humanity must respect in order to develop [72] (see Fig. 4).
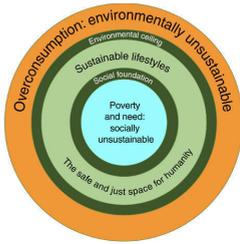
Fig. 4. Simplified version of the doughnut: a safe space within social and environmental limits [72]

Fig. 5. Conceptual differentiation between the Circular Economy and a Circular Society [15]

The inner ring of the doughnut represents the social foundation (basic needs that everyone should have access to), the outer ring of the doughnut represents the ecological ceiling (planetary boundaries), between social and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive [72].

By aligning the principles of the DE with CE practices, it is possible to create an economic system that operates within a safe and just space for humanity, simultaneously meeting the essential needs of all individuals while respecting the ecological boundaries of the planet. This collaborative integration seeks to foster a regenerative and equitable economic paradigm, reinforcing the broader vision of SD and responsible resource management. DE mainly focuses on rethinking the purpose and goals of economic activity by applying holistic and systemic thinking to various domains and scales. It is a conceptual and normative model that offers a vision and a direction for achieving social justice and an ecological balance.

Friant et al. [15] classify the DE as one of a set of new holistic circularity views. In recent decades, the original concept of the CE has constantly developed and transformed, absorbing new holistic and transformational views on circularity such as the Blue Economy [73], the DE [72], the Spiral Economy [74], Transition Degrowth [75], Post-growth [76], the Permacircular Economy [77], etc. Limited attention has been given to transformational views of circularity and alternative concepts from the Global South, such as "ubuntu" [78], "ecological swaraj" [79], and the "Buddhist middle path" [80], which emphasize values and principles that promote a sustainable and harmonious relationship between humanity and the environment [15].

Friant et al. [15] identify two overarching trends within the CE concept: the first involves reformist discourses operating within the boundaries of the capitalist system, while the second encompasses transformational discourses aiming for a comprehensive overhaul of the socio-economic structure. Both types of discourse address concerns related to planetary boundaries, the rebound effect, social justice, and good governance. However, they differ in their perspectives on the ability of capitalism to surpass resource constraints and separate ecological degradation from economic growth. The term **circular society** is proposed to distinguish discourses that go beyond market-based solutions and economic considerations and **view circularity as a holistic social transformation** (see Fig. 5).
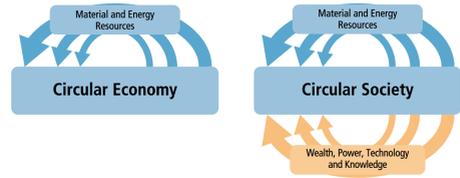
According to Fig. 5, a circular society encompasses discourses with a vision of circularity where not only resources circulate in sustainable loops but also wealth, knowledge, technology, and power are circulated and redistributed throughout the society. These discourses, therefore, inclusively **embrace the three pillars of sustainability and perceive circularity as an all-encompassing transition, addressing issues of political empowerment and social justice**. In contrast, the CE concept primarily focuses on the circulation of resources, predominantly dealing with circularity through a technical lens of ecological and material efficiency alone [15].

VIII. CONCLUSIONS

The current concept and application of the CE does not fully cover all aspects of sustainability, as it may focus mainly on resource efficiency or waste reduction but may not sufficiently consider social issues. The SD framework establishes goals to be achieved to solve the problems and their consequences, whereas the CE is a tool to address some of the causes of these problems.

It can be concluded that the concept and definition of the CE are anticipated to undergo continuous transformation. It is acknowledged that all current attempts to define the CE merely serve to illustrate the present state of the academic field's understanding of this concept.

The concept of the CE should be viewed through the framework of SD, recognizing the synergy between economic practices, social well-being, and environmental conservation. This synergy would further enhance the holistic approach to achieving lasting global sustainability goals by addressing resource efficiency, social equity, and environmental stewardship within a unified framework.

Within the broad views of CE conceptualizations and adaptations, the overarching concept of **the Sustainable Circular Economy** emerges as a unifying umbrella concept. It synthesizes the multifaceted dimensions of circularity, encapsulating not only resource efficiency and closed-loop systems but also incorporating the crucial elements of social responsibility and environmental stewardship. The Sustainable Circular Economy concept signifies a paradigm shift towards a holistic and enduring approach to sustainability, where economic activities are intricately interconnected with the preservation of social well-being and the conservation of the environment.

The Sustainable Circular Economy thus represents a comprehensive evolution that acknowledges the interconnectedness of economic, social, and

environmental factors in the pursuit of a resilient and regenerative global system.

IX. ACKNOWLEDGEMENTS

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IV Raksts

CIRCULAR ECONOMY STRATEGIES FOR REDUCING FOOD WASTE IN SCHOOLS: A SYSTEMATIC LITERATURE REVIEW

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Abstract.

Purpose and aim of the study: As the transition to a circular economy (CE) and the reduction of food waste is a priority strategic goal for policy planning at global and European Union (EU) level, but food waste in catering has become a major sustainability issue, the aim of the paper is to identify CE strategies to reducing food waste in schools based on a systematic literature review.

Design / Methodology / Approach: The research employed qualitative methods: five-step systematic literature review methodology by Denyer & Tranfield, (2009), analysis and synthesis, as well as the monographic method. The literature was selected using the databases Google Scholar, MDPI, ScienceDirect and Scopus.

Main Findings: Based on the systematic literature review, approaches for implementing CE strategies to reduce food waste in school canteens were discovered.

Originality: This study provides a new perspective on the implementation of CE "R strategies" to reduce food waste in schools.

Implications: The results of the study can be a basis for school and canteen administration to implement CE policies and waste management practices that will promote responsible food consumption and support sustainable food consumption and waste reduction strategies, and create added value for school canteens, the environment and society in general.

Keywords: circular economy, R strategies, food waste, sustainability.

Introduction

Since 2011, questions about zero-waste food policy in the EU Member States were increasingly considered on the EU agenda at all political levels. In 2015, the group of Ministers of Finance and Governors of Central Banks of G20 Countries (hereinafter G20) announced that "the reduction of food

losses and wastes is a good goal for G20 collective actions" (European Court of Auditors, 2016), and the UN General Assemblies adopted the Sustainable Development Programme for 2030 (or Agenda 2030), which includes 17 sustainable development goals (hereinafter SDGs) and 169 related goals that should be achieved by 2030. In relation to the author's theme, Goal 12 envisages responsible consumption and production - halving the amount of global food wastes per capita at the retailer and consumer level, as well as reducing food losses in production and supply chains, which can help to ensure food security and move towards a resource-efficient economy (UNGA, 2015).

Food waste from out-of-home dining has become a major sustainability issue (Dhir et al., 2020), therefore, hospitality businesses, including school canteens, must follow responsible practices and consider sustainable production and consumption behaviours to reduce food wastes (Camilleri, 2021). It has been found that food service businesses can pursue a number of responsible practices by implementing preventative measures and recycling practices to limit food losses and waste, as well as reduce environmental impacts (Camilleri, 2021; Lopez et al., 2019). That is why the food industry can become one of the main areas to apply the CE model, yet the current level of CE implementation in the food system makes it difficult to combine theory and practice (Fassio & Tecco, 2019).

CE is currently being popularized all over the world. Issues such as food security and environmental impacts such as resource depletion and greenhouse gas emissions associated with food wastes are the focus of local, national, and European policy makers, as well as international organizations and researchers from various sectors (Schanes et al., 2018).

The transition to a CE requires innovative solutions in all value chains (Holzer et al., 2022), and food is one of the main CE product value chains. The CE concept aims to create a food system that ensures that food does not create waste. (Ellen MacArthur Foundation, 2022).

Catering in schools is essential in shaping students' eating habits and attitudes toward food (García-Herrero et al., 2019; 2021), so it is important for school management to plan and organize the catering process in such a way that it promotes responsible food consumption and supports sustainable food consumption and waste reduction strategies.

Therefore, the aim of the research is to identify the CE strategies to reducing food waste at schools based on a systematic literature review.

The tasks of the research are to perform a literature analysis on CE strategies in reducing food waste and to identify how they could be used in the catering process in schools.

This research used the five-step systematic literature review method by Denyer & Tranfield (2009), analysis, and synthesis, as well as the monographic method.

Research results and discussion

To achieve the goal, the present research was carried out using a five-step systematic literature review methodology (Denyer & Tranfield, 2009): 1) question formulation; 2) locating studies; 3) study selection and evaluation; 4) analysis and synthesis; 5) reporting and using the results.

The research question is as follows: how can a CE approach be used to reduce food waste in schools?

Using the keywords "circular economy" and the name of the relevant R strategy, "in school catering", the literature was selected using the databases Google Scholar, MDPI, ScienceDirect and Scopus.

Based on the titles of the papers, abstracts, keywords in the text, the most relevant papers were selected, from which those that answered the research question were chosen and analysed. The results are reported below.

The CE is a new concept that emphasizes various strategies (e.g., reduce, reuse and recycle) to decouple resource use from economic growth, reduce wastes and emissions, and keep the highest utility throughout the product life cycle (Holzer et al., 2022). Various CE strategies can be used to prevent excessive and rapid environmental degradation and social inequality, both locally and globally. The main purpose of the CE is to eliminate waste. If waste is unavoidable, it should be adequately controlled to be safe for human health and the environment (Khaw-ngern et al., 2021).

In the scientific literature, the main fundamental principles of the CE on which CE strategies are based are "reduce", "reuse" and "recycle", which are defined as the "3Rs" (Ghisellini et al., 2016; Liu et al., 2017). But since the food supply chain plays a vital role in increasing economic, environmental, and social sustainability issues, focusing on the 3Rs is no longer enough in the context of the CE (Vlajic et al., 2021), and over time they have evolved to the framework of 10R strategies (Table 1), described by the authors Holzer et al. (2022) and Potting et al. (2017).

The authors analysed the strategies indicated in Table 1 in reverse order from bottom to top, because according to the authors Holzer et al. (2022) and Potting et al. (2017) studies, the strategies shown in Table 1 are based on the waste hierarchy of the waste framework directive (European Commission, 2008), which was adopted to reduce environmental impact by increasing the extent of circularity, thereby strategies that promote sustainable product production and use (e.g., a product as a service, product

sharing) are preferred over product life extension, as the need for natural resources is determined. Based on priorities set in the food waste hierarchy, prevention should be regarded as the first strategy against food waste, considering re-use or recycling of food waste only where prevention is not possible (Cicatiello et al., 2020).

Table 1 The 10R Framework (Holzer et al., 2022; Potting et al., 2017)

Strategies		Explanation
Smarter product use and manufacture	R1 Refuse	Make the product redundant by abandoning the function or by performing the same function by a radically different product
	R2 Rethink	Make product use more intensive (e.g., through products or by placing multi-functional products on the market)
	R3 Reduce	Increase efficiency in the manufacture or use of products by consuming less natural resources and materials
Extend the lifespan of the product and its parts	R4 Re-use	Re-use by another consumer of a discarded product that is still in good condition and performs the original function
	R5 Repair	Repair and maintenance of defective products so they could be used for their original function
	R6 Refurbish	Restore an old product and bring it up to date
	R7 Remanufacture	Use parts of a discarded product in a new product to perform the same function
	R8 Repurpose	Use a discarded product or its parts in a new product with different function
Useful application of materials	R9 Recycle	Process materials to have the same (high grade) or lower (low grade) quality
	R10 Recover	Incineration of materials for energy recovery

The useful applications of materials. This group's strategies for recycling and recovery are more concerned with the recycling of materials and their incineration with energy recovery; however, they can be attributed to the catering sector like recovering and recycling wasted food through donation, salvaging, processing, industrial reuse and composting (United States Environmental Protection Agency, 2016; 2023).

R10 Recover. The scenarios of this strategy are very modern and technological, but the authors believe that in the future they could also be used in school canteens because FW is a carbon-rich waste stream that could be used for the recovery of a wide range of energy and materials, from fuels/energy to chemical components to bio-plastics (Santagata et al., 2021), for example, use of microbial fuel cells (MFCs) due to their ideal approach in the generation of electricity and parallel treatment of organic food wastes. The MFCs are significant as an innovative approach using microorganisms and oxidizing organic food wastes into bioelectricity

(Kumar et al., 2022a). The so-generated commodities show various benefits such as reduced environmental impacts, deriving from the avoided disposal and the avoided extraction of natural resources, and the reduced economic cost of FW as a feedstock (Santagata et al., 2021).

R9 Recycle. This includes options such as recycling food wastes for animal feed (Ali, 2020), using a traditional technology (composting) and a radical innovative one (insects as feed) (Borrello et al., 2017). The recycling of food by-products, which can also be used in animal and human nutrition, is also mentioned in the context of this strategy (Jackowski et al., 2020).

Extend the lifespan of the product and its parts. The purpose of this group's strategies is to retain goods and their parts in the economy as long as possible, while at the same time maintaining or improving their value (Morseletto, 2020). The European Parliament (2016) underlines that the longer life of products means that it is necessary to take appropriate measures to combat planned obsolescence and increase consumer rights by improving product information. The authors believe that to effectively implement these strategies, it is required to strengthen the waste management policy of school canteens, where FW is not thrown away, but collected and transferred to implement other strategies.

R8 Repurpose. This strategy can be applied using food waste and by-products as a resource (Kumar et al., 2022b), for example, by using tallow for biodiesel production, capturing methane produced in the onsite wastewater treatment system for electricity generation, using tallow to generate the remaining electricity needs and using biomass for thermal energy generation (Colley et al., 2020), or using food waste to produce building blocks for use in bioplastic production (Visco et al., 2022).

R7 Remanufacture. This strategy is intimately linked with the revalorization of by-products for the generation of high-revenue bioactive compounds (Montone et al., 2021).

R6 Refurbish. Literally restoring spoiled food and bringing it up to date is impossible, but this strategy can be applied as the management of food products that have not been served for various causes and are thus destined to be discarded and moved to landfill, thereby representing only a cost (Giuseppe et al., 2014).

R5 Repair. Food repair is a relational practice that links an eating body with organic matters, producers and farmers, soils, supermarkets, modes of preservation and packaging, as well as kitchen technologies, food preparation, cooks, and other eaters (Abrahamsson, 2019). The author Abrahamsson (2019) articulates the various, different skills and resources that are used when food gets repaired with the following examples: individuals collecting and eating discarded food from dumpsters; collective dinners to eat foods that have expired their due date; and people growing

and eating food in communal gardens in a city. In the context of school canteens, this strategy could be applied by donating uneaten food, or food that has expired but has not yet been spoiled.

R4 Re-use. In scientific literature, this strategy is mentioned in context of food management practices such as "food freezing" or "reuse leftovers for new recipes" (Principato et al., 2022), also valorise food losses into animal feed to contribute to a reduced environmental and climate footprint of animal products and food waste avoidance (Pinotti et al., 2021).

Smarter product use and manufacture. From the CE point of view, these are the most circular strategies. The food industry is under growing pressure to produce high-quality and minimally processed foods by using sustainable approaches and ingredients, as well as increasing demands to replace animal products with plant-based products (Mahony & van Sinderen, 2022). Besides, the challenge of persuading people to change their eating habits to more environmentally friendly food consumption patterns become more and more relevant (Vermeir et al., 2020); therefore, it is necessary to improve the availability and price of sustainable food, as well as to promote a healthy and sustainable diet among consumers. The key elements are improving consumer information, strengthening sustainable food procurement, and promoting the introduction of fiscal measures supporting sustainable food consumption (European Commission, 2023).

R3 Reduce. Strategic opportunities to reduce food loss and waste, sustainable use of resources in the food supply chain (Iagăru et al., 2023; Lemaire & Limbourg, 2019; Reynolds et al., 2019) and reduction in the carbon footprint throughout the chain of food supply (Bhatia et al., 2023).

R2 Rethink. Rethink is mainly focused on rethinking the behaviour and perception of the CE by consumers and organizations (Sitadewi et al., 2021). Rethink comes first as individuals consider and question their habits (Mak et al., 2021). It has been studied that educational, skills-based school interventions to decrease food waste by encouraging schoolchildren to be more involved at home in choosing and/or preparing food to take to school can lead to food waste behaviour change to the good side (Boulet et al., 2022).

R1 Refuse. This strategy can be applied by excluding from the menu recipes that children do not like (Pagliarino et al., 2021). Most of the establishments do not have menu alternatives, consumers can only decide whether to order the food offered. In order to increase the amount of food actually eaten, it would be desirable to remove less-liked dishes from school catering menus (Tóth et al., 2023), and it is also highly recommended to periodically review the menus and not include in them the foods that schoolchildren do not want (Ellison et al., 2019), because school menus

should be based not only on the requirements of the relevant legislation but also on modern students' understanding of nutrition (Lonska et al., 2022).

The results show that "R strategies" in transition to a CE are the most widely described strategies in the scientific literature (Khan & Haleem, 2021), and they can be widely used in various industries, including the food sector (Morseletto, 2020; Khaw-ngern et al., 2021).

Conclusions and suggestions

As the transition to a CE and the reduction of food waste is a priority strategic objective in policy planning on the global and EU scale, and food waste in catering has become a major sustainability issue, school catering businesses could implement responsible practices by introducing preventive measures and recycling practices to reduce food losses and wastes, and the impact on the environment.

The systematic literature review results show CE "R strategies" implementation approaches to reducing food wastes at school canteens.

The results of the research could serve as a basis for school and canteen administration to implement CE policies and waste management practices that will promote responsible food consumption and support sustainable food consumption and waste reduction strategies, and create added value for school canteens, the environment and society in general.

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V Raksts

Reducing Plate Waste in Latvian Schools: Evaluating Interventions to Promote Sustainable Food Consumption Practices

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Abstract: Food waste (FW) threatens food security, environmental sustainability, and economic efficiency, with about one-third of global food production lost or wasted. Schools play a crucial role in addressing FW, representing lost resources and missed educational opportunities. The present research assessed three interventions to reduce plate waste (PW) in Rezekne City schools, namely (S1) a plate waste tracker, (S2) an awareness and educational campaign, and (S3) organizational changes, including larger plates, extended lunch breaks, and teacher supervision. Implemented in three schools with a fourth as a control, PW was measured at three intervals, at pre-intervention, short-term, and long-term post-intervention. The PW data analysis utilized two models (day view and class view) and a Wilcoxon signed-rank test. While the plate waste tracker initially reduced PW, sustained impact required continuous reinforcement. The awareness and educational campaign alone proved insufficient, highlighting the need for complex strategies. The organizational changes unexpectedly increased PW, underscoring FW's complexity. The research has concluded that reducing FW requires tailored and multi-faceted approaches. According to the MOA framework, the school catering model in Rezekne City lacks essential "Opportunities" for effective FW reduction, as students have limited flexibility in portion sizes and food choices, which hinders the interventions' effectiveness. Future research should explore adaptable FW-reducing interventions suited to specific school contexts.

Keywords: food waste; plate waste; school catering; food waste-reducing interventions

1. Introduction

High FW levels are attracting global attention, and FW reduction is one of the targets within the sustainable development framework developed by the United Nations [1]. Over the last ten years, food loss (FL) and FW have become a global problem. FW is not only an ethical and economic issue but also an environmental one; environmentally, FW contributes to the unnecessary use of resources such as water, energy, and land, which harms our soil, air, and water quality; economically, it represents a significant loss, driving up costs and reducing efficiency in the food supply chain; socially, FW increases food insecurity, as good food is thrown away while many people go hungry [2–5]. The European policy report on food loss and waste [6] calls for a more unified approach to address these issues. It suggests that reducing FW can play a key role in making our food system more sustainable. This

would improve food security and public health, help to restore the environment, protect biodiversity, and maintain the value and quality of food.

Globally, approximately a third of all food produced for human consumption is lost or wasted [2]. According to the UNEP Food Waste Index (2024) [7], around 1.05 billion tons of FW were wasted across three sectors in 2022 (or 132 kg per capita)—60% of which came from households (79 kg per capita), 28% from food services (36 kg per capita, including ISIC 85 sector "Education", specifically canteens and other places for the preparation and consumption of food associated with educational settings), and 12% from retail (17 kg per capita). This amounts to one-fifth (19%) of food available to consumers being wasted at the retail, food service, and household levels. In high-income countries, the composition of FW varies slightly, at 81 kg per capita in households, 21 kg per capita in food service, and 13 kg per capita in retail.

In the EU, over 58 million tons of FW are generated annually [8], with associated costs estimated at EUR 132 billion [9]. According to the latest EU data, 70% of total FW arises at consumption and retail, with households generating more than half of the total FW in the EU (54%) [8]. Addressing consumer FW is crucial to achieving Sustainable Development Goal 12, Target 12.3, of halving per capita global FW at the retail and consumer level by 2030 [1].

The recent EU strategies [10–13] include some measures to reduce FW. The European Commission intends to set legally binding FW reduction goals throughout the EU as well as to incorporate food loss and waste prevention targets into other EU policies [12].

Reducing FW requires all food system actors to work together—this is where educational institutions have an important role to play in raising students' awareness of the importance of preventing and reducing FW. Schools play a crucial role in providing information on healthy and sustainable food consumption, which can help to shape the habits of the new generation, including those related to FW. Some foreign researchers [14] point out that the school catering sector is one of the largest sources of FW at the food service stage, and at the same time, this also provides an opportunity to improve the dietary habits of the population and educate the public about sustainable resource consumption and development, thereby affecting the food system in the future.

The present research focuses on managing the school catering process in four selected schools in Rezekne City (Latvia) that provide free lunches for students. The purpose of this pilot study is to assess the impacts of interventions aimed at reducing the amount of PW in three schools with a fourth as a control. The subject of the research includes both individual PW and discarded served food from common containers after free lunches. The research explores the hypothesis that implementing targeted interventions to reduce PW can effectively decrease the quantity of uneaten food, thereby promoting more sustainable food consumption practices. During the research, multiple pre-intervention and post-intervention PW quantifications were made to statistically test the impacts of interventions on reducing the amount of PW.

This study provides a significant contribution to the field of FW research by focusing on interventions to reduce PW in school canteens—a largely underexplored area in Latvia. Unlike previous studies conducted in countries with buffet-style catering systems, this research addresses the challenges of a partly pre-portioned catering model, which is widely used in Latvian schools. By experimentally testing three targeted interventions—a plate waste tracker, an awareness campaign, and organizational changes—this study highlights the processes of transferring, adapting, and evaluating international best practices within a Latvian context. The findings underscore the importance of tailoring interventions to specific organizational settings, offering practical insights for policymakers and school administrators aiming to reduce FW and foster sustainable consumption habits among

students. Moreover, the application of the Motivation–Opportunities–Abilities (MOA) framework provides a structured approach to understanding the behavioral prerequisites of FW, making this research a valuable reference for both academic and practitioner communities seeking scalable solutions to FW challenges in schools.

The structure of this paper is as follows: Section 2 provides an in-depth review of the relevant literature on existing FW-reducing interventions at the FSC consumption level, particularly in school catering. Section 3 outlines the materials and methods employed by the research, focusing on the interventions applied in Rezekne City schools to reduce PW. Section 4 presents a data analysis and the results, detailing the short- and long-term impacts of the interventions across the participating schools. This section also includes statistical tests, including a Wilcoxon signed-rank test used to assess intervention effectiveness. Finally, Section 5 offers a discussion of the findings, while Section 6 concludes the research, addressing potential implications for policy and recommendations for future research on sustainable FW reduction in schools.

2. Theoretical Background and a Literature Review

2.1. Food Waste at the Consumption Stage

Academics categorize FW based on the stages of waste generation, such as pre- and post-consumer FW [15]. Pre-consumer waste occurs at the food supply chain (FSC) primary production and distribution levels, and pre-consumer FW is often called food loss, while post-consumption waste occurs at the consumption level [16]. This research focuses on an analysis of FW and measures to reduce it at the consumption level (see Figure 1).
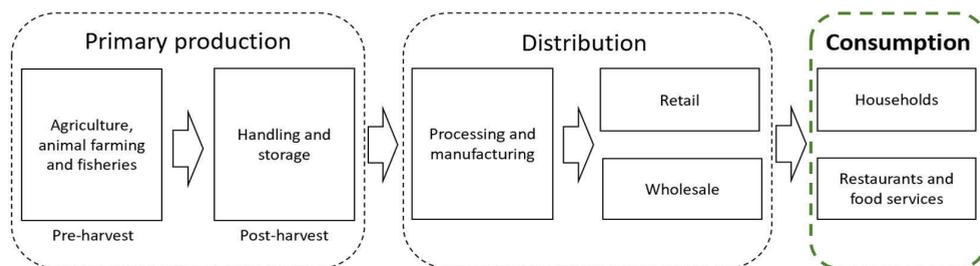
Figure 1. Stages in the FSC at which food might be lost or discarded (based on [17]).

Consumers are the primary contributors to FW across the food supply chain in high-income countries, accounting for an estimated 53% [18]. Given that a significant portion of this waste could be avoided, it is evident that there is an urgent need to change consumer behavior [19].

The European Commission, through its Farm to Fork strategy [12] and its broader European Green Deal policy [20], commits to ambitious food systems objectives, which can be achieved by driving a step-wise, learning-focused policy transformation at the global, EU, national, regional, and local levels [21]. Some of the barriers to the reduction in FW are referred to, such as (1) food operators and consumers do not have adequate information on how much they waste (consumers often underestimate the amount of food they waste), nor on the possible options to reduce FW and (2) a lack of willingness of actors to adopt FW-reducing innovations among consumers [22]. As one of the enablers of change, the following solution is mentioned: (1) to improve action design, monitoring, evaluation, and knowledge sharing regarding FW prevention interventions and (2) to integrate FW reduction in school education and professional training, both in the public and private

sectors, thus promoting the value of food and working to shift social norms so that wasting food is no longer acceptable, etc. [22].

In addition, the UN Environment Program notes that accurate, traceable, and comparable FW measurement is a key starting point for national FW strategies and policies to deliver the 50% reduction in consumer FW targeted in the 12th SDG Target 12.3 [23]. It is necessary to measure FW as accurately as possible; therefore, weight measurements are considered the gold standard in FW measurements [24].

According to the Latvian Waste Prevention Plan developed by the European Environment Agency, in 2018, the total amount of FW generated in Latvia reached 319 thousand tons, with primary production accounting for 5% (16 thousand tons); processing and manufacturing 37% (117 thousand tons); and trade < 1% (two thousand tons). Most of the FW, i.e., 57% or 185 thousand tons, ended up in municipal solid waste, and a part was mainly discharged by households and food services. As not all producers of FW and surpluses are obliged to report the amount of waste generated, the information summarized above is indicative [25]. Arina et al. [26] estimated that in 2020 in Latvia, 157 thousand tons (or 83 kg per capita) of FW was generated by the household sector, while 11 thousand tons (or almost 6 kg per capita) by restaurants and food services [26].

In 2021 in Latvia, according to Eurostat, the total FW per capita averaged 130 kg, close to the EU average of 131 kg per capita [8]. Table 1 presents the amounts of FW reported by the EU Member States (average amount) and Latvia for the reference year 2021, measured in tons of fresh mass and as a % share of the total amount by sector of activities.

Table 1. FW in the EU and Latvia by sector of activities, 2021 (based on [8]).

Sectors of Activities		Total FW	Primary Production	Processing and Manufacturing	Retail and Other Distribution of Food	Restaurants and Food Services	Households
EU [1]	tons	58,400,000	5,100,000	12,400,000	4,200,000	5,400,000	31,000,000
	%	100	8.7	21.2	7.2	9.2	53.1
	kg per capita	131	11.4	27.8	9.4	12.1	69.6
Latvia [2]	tons	245,442	30,592	32,518	16,765	28,617	136,950
	%	100	12.5	13.2	6.8	11.7	55.6
	kg per capita	130	16.3	17.2	8.8	15.2	72.3

[1] 2020 data presented; [2] definition differs for some figures.

As shown in Table 1, most of the FW is generated at the food consumption stage both in the EU as a whole and in Latvia, i.e., by restaurants and food services, as well as households: in the EU, on average, it is 62.3% or 81.7 kg per capita, while in Latvia, it is 67.3% or 87.8 kg per capita. It could be concluded that the amount of FW reported by Latvia is 6.1 kg higher than the EU average at the food consumption stage. The data clearly point to the need to actively promote FW reduction at the consumer level.

2.2. Complexity of School Food Consumption Behavior

Consumer behavior related to FW generated in schools is influenced by a combination of internal and external factors, making it essential to understand the various influences that drive individual decision-making. While Lonska et al. [27] emphasize the role of both exogenous and endogenous factors in shaping school food consumers' behaviors, it is equally important to explore how these factors interact within broader behavioral frameworks. At the FSC consumption stage, this interplay becomes particularly relevant, as interventions targeting FW reduction must account for these complexities through robust theoretical approaches.

One of the earliest and most frequently applied frameworks is the theory of planned behavior (TPB). However, the TPB primarily focuses on cognitive drivers, treating FW as an

intended behavior, which limits its scope [28,29]. To address this limitation, the Motivation–Opportunities–Abilities (MOA) framework has been suggested as a more comprehensive approach to classify the drivers, levers, and interventions related to consumer FW [30,31], which has been used in FW research in both academic and practitioner settings. The MOA framework broadens the analysis beyond cognitive aspects by incorporating the Motivation element, which includes attitudes, intentions, and norms as outlined in the TPB, and adding Opportunities and Abilities elements, which extend the framework beyond cognitive boundaries. Unlike the TPB, the MOA framework views FW not as a solely intended behavior but as an unintended consequence of a series of decisions and behaviors associated with food management practices both inside and outside the home. These practices are influenced by both internal (individual) and external (social and societal) factors [29,32–35].

Motivation to prevent FW refers to an individual's willingness to take actions that minimize the occurrence or quantity of FW. Key factors influencing motivation include attitude, awareness, and social norms. Opportunities to prevent FW involve the availability and accessibility of the necessary materials and resources to reduce FW, for instance, time management or a daily schedule, available food infrastructure and technologies, and food policies. Abilities involve the skills and knowledge required to carry out a behavior successfully. The MOA framework emphasizes that in order for consumers to successfully act on a FW reduction, there must not only be a strong motivation to do so but also an absence of barriers that might obstruct their efforts. These barriers often include factors that lead consumers to believe they are incapable of reducing FW. Even if someone is motivated to reduce FW, without the necessary skills or knowledge—such as understanding proper food storage techniques—they might find it difficult to achieve their goals [33,34].

According to the MOA framework, effective behavior change, such as reducing FW, occurs when these three elements—motivation, opportunities, and abilities—are aligned. When all three are present, simple interventions such as informational reminders might be enough to sustain the desired consumer behavior. However, if any of these elements are lacking, more targeted interventions are required. For instance, if motivation is low, strategies such as regulatory incentives, nudging, competition, or social influence campaigns might be necessary. If abilities are lacking, educational campaigns providing practical tips can help. And if opportunities are limited, introducing new products or services could create the necessary prerequisites for behavior change. The MOA framework highlights that achieving and maintaining behavioral change, such as reducing FW, requires addressing all three components. Without a balanced approach, individuals are likely to revert to their previous behaviors once the interventions are removed [32].

The MOA framework allows us to analyze in-home and out-of-home consumer food management. It is important for the present research to apply the MOA framework to analyze consumer food management in school canteens (see Figure 2).

As shown in Figure 2, motivation, abilities, and opportunities to engage in FW prevention affect the amount of consumer FW generated. Under the out-of-home consumer food management model, food is being moved from provisioning to consumption, passing (all) intermediate stages. In the case of school catering, students as food consumers can only affect the amount of FW at the ordering/serving and consuming stages, i.e., the differentiation of portion sizes, the choice of a food type, and the eating behavior of students are important at these stages.
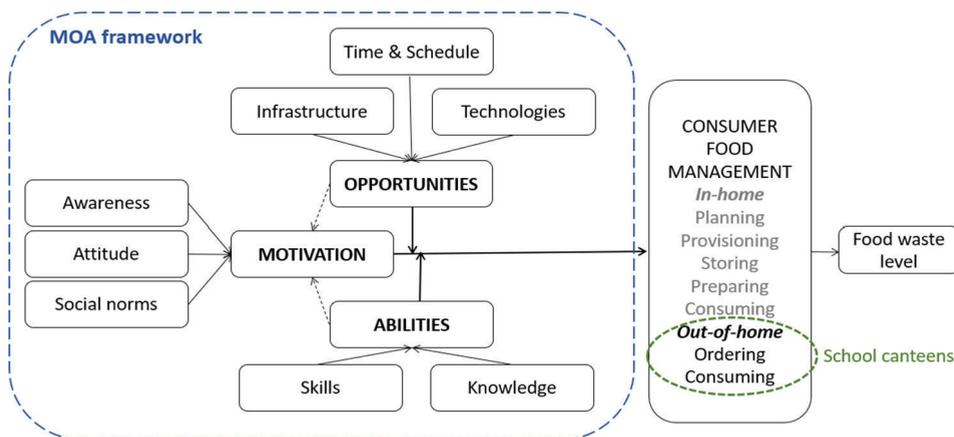
Figure 2. MOA framework and the consumer food management model for in-home and out-of-home consumption (authors' modification based on [29]).

2.3. Overview of Interventions to Reduce Consumer Food Waste

In European countries, various initiatives or interventions aimed at reducing consumer FW have been launched over the last 10–15 years. Next, a number of EU-level and project reports are reviewed to identify and classify the most commonly implemented interventions to deal with consumer FW in Europe.

Wunder et al. [36], in the policy report on consumer FW "REFRESH: Consumers and Food Waste", highlight the complexity of consumer FW, influenced by the consumers' desire for convenience, taste preferences, and cost-saving behaviors such as bulk buying and promotions. It should be noted that the report also covered FW mitigation interventions that can influence food consumer behavior at the retail stage, which, as shown in Figure 1, belong to the FSC distribution level. The authors categorize policy instruments into information campaigns, regulation, economic measures, nudging, and voluntary agreements (see Table 2).

The report concludes that informational and awareness-raising campaigns alone are often ineffective in significantly reducing FW but prompts, skill training, social norm campaigns, and feedback mechanisms show more promise. A systematic, integrated approach involving collaboration with the retail and hospitality sectors and a thorough assessment of the effectiveness of interventions is essential for impactful FW reduction [36].

The European Commission has developed a series of action plans and regulatory measures to deal with FW in the EU. One of the most important steps was the implementation of the ECFWF (European Consumer Food Waste Forum) project [37], which provided practical tools and recommendations to reduce FW at the consumer level. The ECFWF evaluated 78 consumer-level FW measures, revealing the varying effectiveness of different approaches. The interventions evaluated were classified as follows (Table 3):

Table 2. Interventions to reduce consumer FW (based on [36]).

Category	Policy Option	Description
Information	Information and awareness-raising campaigns	Public campaigns to educate consumers about the impacts of FW and encourage behavior changes
	Social norm campaigns	Campaigns that leverage social norms to influence consumer behavior by showcasing what others are practicing to reduce FW
	Education/skill training	Programs to enhance consumers' skills in meal planning, food storage, and creative cooking to reduce FW. This includes school programs and public workshops
	Prompts	Visual or verbal reminders placed in strategic locations (e.g., refrigerators, shopping lists) to encourage behaviors that reduce FW
	Feedback	Providing consumers with information about the amount of food they waste, potentially through apps or smart bins, to increase awareness and drive behavior change
	Commitment	Encouraging consumers to make public pledges or commitments to reduce FW, enhancing accountability and consistency in behavior
	Apps and ICT tools	Digital tools that provide information, tips, and incentives to reduce FW, such as apps offering recipes for leftovers or tracking food inventory
Regulation	Regulation on date marking	Standardizing and clarifying date labels (e.g., "use by" vs. "best before") to reduce consumer confusion and unnecessary waste
	Promotions, product presentation, and packaging	Regulating promotional activities (e.g., banning "Buy One Get One Free" offers) and requiring appropriate portion sizes and packaging that reduce overbuying and waste
	Influencing consumer behavior through regulation targeted at other actors	Adopting regulations that indirectly affect consumers, such as relaxing marketing standards for cosmetically imperfect produce, increasing the availability of surplus food products, and prohibiting supermarkets from discarding edible food
Economic Instruments	Fees and taxes	Implementing pay-as-you-throw schemes that charge households based on the amount of waste they produce, incentivizing FW reduction
	Subsidies	Providing financial incentives for activities that reduce FW, such as subsidies for food donation programs
	Penalties for supermarkets wasting food	Imposing fines on supermarkets that discard edible food, encouraging better food management practices
	Financial incentives for donating food	Offering tax breaks or other financial benefits to businesses that donate surplus food
Nudging and Choice Architecture	Altering food placement in stores and dining facilities	Strategically placing food items in stores (e.g., at eye level) and adjusting serving sizes in dining facilities to encourage the purchase and consumption of appropriate amounts
	Changing serving sizes and portion control	Introducing smaller portion sizes by restaurants and canteens to reduce the likelihood of food leftovers and waste
Voluntary Agreements	Public–private partnerships	Collaborative efforts between the government and private sector stakeholders to implement FW reduction practices
	Industry-led initiatives	Voluntary commitments by businesses to adopt practices that reduce FW, such as improved inventory management and offering surplus food for sale
	Non-binding guidelines and strategies	Developing and promoting best practice guidelines for reducing FW, which businesses and organizations can choose to adopt

It is evident that in the EU, FW reduction interventions are being implemented at the macro (local and national government), meso (trade associations, producer groups, NGOs), and micro (entrepreneur and consumer) levels, e.g., by schools or restaurants. The key findings made by the ECFWF highlight that the interventions tailored to local contexts and involving community and stakeholder collaboration are more successful. Disruptions to daily routines promise to reduce household FW, and highly personalized interventions yield positive outcomes, especially if consumers participate voluntarily. However, no single intervention proves universally effective, indicating that a multifaceted strategy combining various interventions is necessary to significantly reduce consumer FW [38].

Table 3. Types, subtypes, descriptions, and examples of the consumer FW prevention interventions (based on [38]).

Type	Subtype	Description	Examples
Nudges	Tools and prompts for food storage and preparation	Interventions, including digital tools, physical aids, and informational campaigns, designed to help individuals manage food more effectively, reduce FW, and promote sustainable consumption	Food trainer app test (United Kingdom) [39]
			Use It Up Tape—a visual prompt for leftover consumption (Australia) [40]
	Other nudges for household FW	Interventions that use strategies like social influence, feedback, awareness campaigns, and innovative tools to raise awareness and encourage behavior change, aiming to reduce FW at the household level across various stages	FW calculator (Finland) [41]
			Study on eco-feedback device (Canada) [42]
	Labeling and visual cues on food packaging	Interventions aimed at reducing FW by improving consumer understanding of expiration dates and promoting better food handling through stickers, time temperature indicators, and storage advice	Day-on-date label (United Kingdom) [43]
			Evaluation of date labeling campaign encouraging consumers to look–smell–taste (Canada) [44]
	Nudges out of the home	Interventions targeting FW reduction and sustainable behaviors in public spaces like schools, restaurants, and hotels; primarily target serving and consumption stages, aiming to influence behaviors like portion control and food storage	Nudging strategies in school canteens (Spain) [45]
			Posters displaying social norms (France) [46]
Education and training	School programs	Interventions engaging students, teachers, and parents in activities like food preparation, creative projects, and using teaching materials to reduce FW and promote sustainable practices in schools and households	Food and nutrition education program (Netherlands) [47]
			Green Chef—a youth-targeted competition (Portugal) [48]
	Training for food business personnel	Interventions educating food industry employees to reduce FW, improve food management practices, and promote sustainability through tailored strategies like menu design, storage optimization, and consumer education	PENNY apprenticeship program (Germany) [49]
			Zero-waste restaurant (Portugal) [50]
	Coaching for households	Interventions aiming to reduce FW in households by improving food management skills through workshops, thematic challenges, personalized guidance, and community networks, focusing on planning, shopping, cooking, and storage practices	Cooking classes and workshops (Germany) [51]
			Tailored intervention with personalized coaching (USA) [52]
Awareness raising	Local initiatives	Community-focused interventions aiming to reduce FW through door-to-door visits, cooking workshops, awareness campaigns, and school or business engagement, emphasizing in-person interaction and collaboration with local stakeholders	Reduce FW, save money (Canada) [53]
			West London FW prevention campaign (United Kingdom) [54]
	Large-scale initiatives	Interventions take the form of broad awareness campaigns aimed at reducing FW by promoting behavior change through tools such as media outreach, exhibitions, and partnerships with retailers	FW-free week (Netherlands) [55]
			Great taste, no waste (United Kingdom) [56]

Table 3. *Cont.*

Type	Subtype	Description	Examples
National programs		Large-scale interventions raising awareness of FW through media campaigns, educational materials, and stakeholder collaboration, promoting sustainable practices and systemic impacts by fostering partnerships and regional initiatives	Project Wasteless (Hungary) [57]
			Life FOODprint (Cyprus) [58]
Interventions uncovering new drivers		Interventions identifying new drivers of FW and testing innovative approaches, focusing on behaviors like overprovision during special occasions and poor planning, highlighting cultural contexts and social interactions	Education and leveraging social influence in school environments (Italy) [59]
			Study on domestic food practices (Italy) [60]
Out of scope	Measurement	Interventions aim to track and reduce surplus food through measurement or redistribute it to consumers and charities, minimizing FW via apps or food banks	Gladsaxe measurement (Denmark) [61]
			Copenhagen municipality (Denmark) [62]
	Redistribution		Olio app (51 countries globally) [63,64]
			Munch app (Hungary, Czech Republic, Slovakia, Romania) [65]

A literature review conducted by Caldeira et al. [66] showed that there was a notable lack of studies dealing specifically with the evaluation of FW prevention actions. In this report, 91 actions were collected through a survey and individually assessed to test the evaluation framework developed. Most (58) were implemented at the FSC food service and household stages. The classification is presented in Table 4.

Table 4. Classification of FW prevention actions implemented by food services and households (based on [66]).

Type	Sub-Type	Description
FOOD SERVICES		
Supply chain efficiency	Process innovation	Innovating processes within food service establishments to increase efficiency and reduce waste. This includes implementing new technologies and improving current practices related to food handling and storage
	Training and guidelines	Providing training and guidelines for food service personnel to reduce FW, focusing on areas such as inventory management, portion control, and food preparation. This includes internal personnel training sessions and the development of best practice guides
	Public procurement	Integrating FW prevention criteria into public procurement processes for food services. This can include specifying requirements for waste reduction practices, such as sourcing locally to reduce transport losses and adopting sustainable food service practices
Consumer behavior change	Awareness/ educational campaigns	Implementing campaigns to educate and raise awareness among consumers and personnel about the importance of reducing FW. This includes digital tools, school programs, and public campaigns aimed at changing FW behaviors
Food redistribution	Surplus food redistribution	Redistributing surplus food to charities or other organizations to ensure it is consumed rather than wasted. This includes collaboration with local food banks and other non-profits to handle excess food.
FW prevention governance	Voluntary agreement	Establishing voluntary agreements among stakeholders within the food service industry to commit to reducing FW. The agreements often involve setting shared goals, monitoring progress, and reporting on outcomes to ensure collective action toward FW reduction
	Regulatory framework/policy	Developing and implementing regulatory frameworks or policies that mandate FW reduction practices within the food service industry. This includes requirements for waste tracking, targets for waste reduction, and incentives for compliance
	National FW prevention program	Coordinating national programs that involve multiple stakeholders from the food service industry, the government, and non-profits to implement comprehensive strategies for FW prevention. This includes public awareness campaigns, support for innovation, and funding for waste reduction initiatives
HOUSEHOLDS		
Consumer behavior change	Awareness/educational campaigns	Launching educational initiatives to inform consumers about FW and provide practical tips for reducing waste at the household level. This includes workshops, digital tools, and media campaigns focused on planning food purchases, proper storage, and utilizing leftovers
	School programs	Implementing educational programs in schools to teach students about FW and encourage waste reduction behaviors that they can practice at home. The programs aim to build a culture of waste reduction from a young age
	Digital tools for behavioral change	Developing and promoting apps and online platforms that provide consumers with tips and strategies for reducing FW, tracking their food consumption, and planning meals more effectively. This includes mobile apps that remind users of expiration dates and suggest recipes based on available ingredients
	Innovation of products—date marking	Implementing initiatives to improve date marking on food products to help consumers better understand "best before" and "use by" dates. Examples include the introduction of labels such as "Best before … often good after" to encourage consumers to use their judgment before discarding food

Table 4. *Cont.*

Type	Sub-Type	Description
		HOUSEHOLDS
Supply chain efficiency	Innovation of products—packaging	Innovating packaging solutions to extend the shelf life of food products, thus reducing the likelihood of food spoilage and waste at the household level. This includes creating more effective and sustainable packaging materials and technologies
FW prevention governance	Voluntary agreement	Establishing voluntary agreements among various stakeholders, including consumers, retailers, and local authorities to commit to reducing FW. The agreements involve setting targets, monitoring progress, and reporting outcomes to ensure collective action toward FW reduction
	National FW prevention program	Coordinating national programs that involve multiple stakeholders from households, the government, and non-profits to implement comprehensive strategies for FW prevention. The programs typically include public awareness campaigns, support for innovation, and funding for waste reduction initiatives

This report highlights that effective FW prevention relies on a multifaceted approach at the food consumption stage. The assessment of FW prevention actions revealed that most of the initiatives focused on consumer behavior change, food redistribution, and improving supply chain efficiency. These actions demonstrated varying levels of success, with some effectively reducing FW through awareness campaigns and redistribution efforts, while others highlighted the need for better design and implementation strategies. The analysis underscored the importance of setting clear objectives, monitoring progress, and adapting approaches to local contexts to enhance the effectiveness and sustainability of FW prevention measures at the food consumption stage [66].

Cooperation between all food system actors is essential to reduce FW, with educational institutions playing a key role. By providing information on healthy and sustainable diets, schools can shape the habits of the next generation and affect the future food system, as school meals are one of the largest sources of FW. It is undeniable that responsible food consumption in schools can contribute to reducing FW at the FSC consumption stage; therefore, it is important to identify and classify FW-preventing interventions addressing students' behavioral change, which could be implemented in schools (see Table 5). FW prevention in school and school canteens could set a positive example for children and young people and inspire them to do the same at home. Understanding the nature of various interventions aimed at reducing FW in schools, policymakers and school administrators could develop and adapt food resource efficiency strategies.

Table 5 presents various effective interventions to reduce FW in schools through behavioral and attitudinal changes among students. Visual nudging interventions, such as posters and signs, can raise students' awareness of FW problems. Participatory nudging interventions involve students in activities such as FW audits and cooking workshops. Educational nudging interventions integrate food sustainability topics into the curriculum, which can have a positive impact on the students' food consumption habits. Food choice architecture involves designing and presenting food options to effectively influence students to make more efficient consumption choices, using strategic placement and presentation to reduce waste. Altering the dining environment, e.g., extended lunch breaks or modifying the dining setting and conditions to encourage students to make sustainable food choices and practice responsible consumption, are aimed at creating a more pleasant and quiet dining experience. Feedback ensures continuous improvement. The mentioned multifaceted interventions, tailored to the local context, can significantly reduce FW in schools and promote a culture of sustainability.

Table 5. FW-preventing interventions addressing students' behavioral change.

Type of Intervention	Category and Description	Examples
Visual nudging interventions	Awareness raising: Implementing campaigns and visual tools to raise students' awareness about FW issues and providing tips to adopt less wasteful behavior. The interventions often involve visual aids and the strategic placement of information to influence students' decisions.	• Using posters and signage to provide students with detailed information about the negative environmental, economic, and social impacts of FW [14,15,67–71] • Displaying strategically placed posters and signs that encourage students to take only the food they intend to eat [72] • Displaying posters that evoke negative social emotions associated with wasting food to discourage wasteful behavior [73] • Placing visual reminders such as table talkers in dining areas to inform students about healthy food choices and/or the negative impact of FW [74,75] • Utilizing posters highlighting social norms and peer behaviors regarding FW reduction to influence student choices [76]
Participatory nudging interventions	Interactive activities: Engaging students in hands-on, practical, or interactive experiences and competitive events focused on reducing FW. The activities encourage active participation and often involve a peer-driven approach to behavior change.	• Involving students in FW audits to assess the amount of waste generated and identify key areas for improvement [14,77] • Involving students in menu planning to make them more likely to adopt and advocate for waste-reducing behaviors [78,79] • Organizing interactive activities where students participate in FW reduction challenges or competitions, making them more conscious about the amount of food they waste [14,80,81] • Encouraging students to lead campaigns and create content (e.g., videos, posters) about FW, fostering a peer-driven approach to behavior change [71] • Organizing food cooking workshops in school canteens to gain students' practical skills and a better understanding of how their choices impact FW, promoting more sustainable behaviors [14,82] • Installing digital bulletin boards with interactive content that educates students about FW and encourages them to take quizzes or participate in games related to food sustainability [83] • Introducing mobile apps that allow students to track their FW and receive personalized tips and goals for reducing waste [83] • Involving students in "food rescue programs" where leftover untouched food is collected and donated to local shelters or food banks, teaching them about food redistribution and community support [84,85] • Installing interactive digital displays and touch-screen kiosks with quizzes and games related to food sustainability [86] • Using color-coded waste bins with clear signage to guide students in sorting their waste correctly, making them more aware of how much food is being wasted [87]

<p style="text-align:center;">**Table 5.** *Cont.*</p>

Type of Intervention	Category and Description	Examples
Educational nudging interventions	Educational activities: Promoting responsible food consumption through various pedagogical approaches designed to foster long-term behavior change among students. The interventions focus on integrating food sustainability education into the curriculum and extra-curricular activities.	• Educating students about the entire food system, from production to consumption, and deepening their understanding of and personal commitment to reducing FW [14,88–90] • Developing a comprehensive curriculum that includes lessons, discussions, and assessments focused on FW and sustainability, ensuring that students encounter the topics across various subjects [14,68,90,91] • Inviting guest speakers such as local farmers, chefs, or environmentalists to talk about food sustainability and waste reduction, providing real-world insights and inspiration [81] • Organizing field trips to farms, food processing facilities, or waste management centers to give students a first-hand understanding of the food production and waste process [92,93]
Food choice architecture	Designing food choices: Designing and presenting food choices in a way that subtly influences students to select and consume their food more efficiently. This can involve the strategic placement and presentation of food items to promote healthier and less wasteful choices.	• Allowing students to choose their food items rather than being served pre-determined portions ensures they take only what they plan to eat [14,94,95] • Positioning items that are commonly wasted in more prominent locations, for example, placing vegetables at the beginning of the serving line so students are more likely to take and consume them [96–100] • Offering fruits and vegetables in pre-sliced, ready-to-eat portions to encourage students to finish their servings, as these are more convenient and appealing than whole items [98,100] • Using attractive names and presentations for healthier food options to make them more enticing [98,100,101] • Introducing themed food days that focus on specific types of food (e.g., "Veggie Day") to highlight and promote the consumption of particular food groups, reducing waste of those items [102–104] • Organizing taste test events where students can sample small portions of different foods (e.g., "tasting spoons") before deciding on their meal, reducing the likelihood of taking larger portions they might not finish [74,82]
Environment altering	Dining environment changes: Altering the dining environment and its conditions to encourage students to make sustainable food choices and practice responsible food consumption. The changes aim to create a more pleasant and quiet dining experience.	• Extending the duration of lunch breaks to provide more time for students to eat slowly, thereby reducing FW and fostering responsible consumption [105–107] • Changing plate sizes and shapes: when students serve themselves, offering smaller plates and different shapes can promote serving smaller portion sizes, thereby reducing the likelihood of plate waste; however, if the food is pre-served, using larger size plates is beneficial, as it allows students to clearly see and understand the ingredients of the food being served (more engaging for younger students) [27,108,109] • Altering dining spaces by improving lighting, reducing noise levels, adding comfortable seating, and creating a pleasant atmosphere can make the dining experience more enjoyable, thereby encouraging students to appreciate and finish their meals [101,110] • Establishing school gardens where students can grow their own fruits and vegetables and then use these in the school canteen, thus creating a direct connection between growing and consuming food [111,112]

Table 5. *Cont.*

Type of Intervention	Category and Description	Examples
Continuous improvement through feedback	Feedback and iteration: Regularly gathering feedback and insights from students on their food-wasting behavior and food preferences to refine and improve the interventions. This approach involves iterative processes to continuously enhance strategies based on collected data.	• Implementing feedback systems where students can report on their FW habits and suggest improvements, potentially using digital tools to collect this feedback and iterating on strategies based on the data collected [42,113] • Providing real-time feedback on FW levels in the canteen, such as through charts or digital displays, to raise students' awareness about the environmental impact of their FW and to set goals to reduce it, thus allowing students to track progress and adjust their behavior accordingly [74,114–116] • Regularly conducting surveys and polls to gather student opinions on menu items and dining experiences, using these data to make informed adjustments to the menu and dining environment [77,117,118]

It is clear that there is a need for a multi-faceted approach to reducing FW at the FSC consumption stage, especially in schools. The variety of interventions aimed at reducing FW, ranging from visual and participatory nudging to educational activities and environmental change, highlight the complexity and multidimensional nature of effectively addressing FW. By implementing these actions toward sustainability, schools can influence students' food consumption habits, thus contributing to a culture of responsible consumption among the younger generation.

3. Materials and Methods

3.1. Scope of Research

This pilot study aimed to evaluate the impacts of interventions designed to reduce PW in three schools with a fourth as a control in Rezekne City, Latvia, to promote smart and responsible food consumption. The underlying hypothesis was that targeted interventions in these schools could effectively lower PW levels, thereby fostering sustainable food consumption practices. To assess the impacts of the interventions, PW quantities were measured multiple times before and after the implementation to provide a statistical basis for evaluating PW reduction.

The total measured weight of PW included uneaten food left on individual plates and discarded food in common bowls and pots following the free lunches provided to students in grades 1–7 in the observed schools (see Section 3.4).

The novelty of our pilot study lies in the fact that no national-level research has previously been conducted in Latvia to verify the effectiveness of interventions made by foreign researchers aimed at reducing FW in the Latvian school ecosystem. This is particularly important, considering that the management of catering services in Latvian schools is significantly different from foreign practices.

Within our previous research study, a comprehensive literature review was performed, and a large number of research studies on factors contributing to PW in schools were reviewed [27]. An experiment by the Swedish University of Agricultural Sciences with the aim of testing interventions related to reducing FW in school catering could be mentioned as the most relevant research on the research problem [74]. The following interventions were examined during the Swedish experiment: (1) tasting spoons; (2) an awareness campaign; (3) a plate waste tracker; (4) a forecasting system; and (5) a reference group. However, the management of catering in Swedish schools and the level of public awareness of responsible food consumption, as well as the socio-economic culture, are significantly different from

those in Latvia. For example, in Latvia, self-service (buffet-style) catering is rarely practiced in schools for those schoolchildren whose catering expenses are covered by state/municipal funding, and it is not possible to choose the type of food, as the food is already served following all the dietary guidelines regarding the amount of food served, calories, and nutrients. This means that schoolchildren cannot choose the size of the portion themselves (smaller or larger, depending on the feeling of hunger or age). We can also observe similar differences in many other research studies conducted outside Latvia [14,119–123].

Consequently, a natural question arises as follows: can foreign experience be effectively transferred to Latvia? Based on the fact that no scientific research in this field has been conducted in Latvia to date, we decided to assess how effectively certain interventions examined by the Swedish University of Agricultural Sciences (awareness campaign and plate waste tracker) worked in Latvia. However, given the specifics of the management of catering in Rezekne City schools (there is no buffet-style catering), it was not possible to transfer all interventions proposed by the Swedish colleagues; therefore, the 3rd intervention component (using larger diameter plates for serving food, holding longer lunch breaks, and ensuring the presence of a supervising teacher during the lunch break) was chosen based on the recommendations we proposed in our previously implemented "E-mentor" project [124] after analyzing global best practices. All the interventions proposed were coordinated with the administrations of the selected schools, receiving their support. We also contacted colleagues from the Swedish University of Agricultural Sciences about the possibility of using their plate waste tracker in our research and localizing its functionality for the region of Latvia. After summarizing the above, it could be found that the novelty of our project involves experimentally testing foreign best practices aimed at PW reduction in Latvia, as well as making cross-cultural comparisons of the results, which is essential when continuing to implement interventions in the long term.

3.2. Research Methodology

The research intends to use the scientific findings made in our previous research, thereby resulting in the development of a set of recommendations (interventions) for stakeholders to be implemented to reduce the amount of PW in Rezekne City schools [27]. PW accounts for the majority of FW in schools [125]. It should be noted that most of the researchers working on FW analysis focus specifically on PW analysis [121,125–133]. Derqui and Fernandez [91] have found that approximately 80% of research in this field directly relates to PW analysis without auditing FW at the whole stage of food consumption, i.e., not considering the FW generated during cooking in the kitchen or the FW from serving lines.

Of the 6 schools in Rezekne City offering free lunches to students in grades 1–7, 4 were selected based on the willingness of school principals to collaborate, ensuring smooth coordination and effective implementation of the interventions. All schools operate under a similar catering model with partly pre-served meals, providing a uniform context for evaluation. The schools represent urban Latvian schools, where free lunches are provided to students in grades 1–7 through state and municipal funding. The student populations in grades 1–7 across the schools are similar, ensuring comparable sample sizes and demographics. While limited to Rezekne City, the findings offer valuable insights for similar school settings across Latvia with analogous catering systems.

During our previous research, we found that there was a need for interventions that could reduce the amount of PW in Rezekne City schools. Thus, we decided to implement several of the proposed interventions in three schools (a test group). One more school participated as a reference group for PW quantification, yet no special interventions aimed at reducing PW were planned. Malefors et al. [74] used the reference group to examine

whether the test interventions reduced FW or whether reductions were due to other trends and ambitions that would have happened in any case.

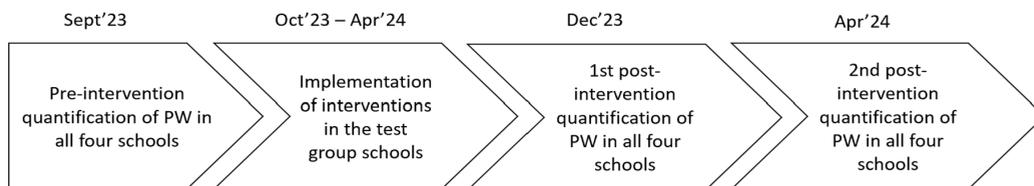The research comprised the following main steps (see Figure 3):

Sept'23	Oct'23 – Apr'24	Dec'23	Apr'24
Pre-intervention quantification of PW in all four schools	Implementation of interventions in the test group schools	1st post-intervention quantification of PW in all four schools	2nd post-intervention quantification of PW in all four schools

Figure 3. Timeline of the pilot research.

Statistical analysis was applied to verify the impact of our interventions. The null hypothesis "PW is equal in the pre- and post-intervention periods" was tested. The following laboratory conditions were organized in all four schools: (1) similar classes participated in the survey and (2) a unified menu design was applied in pre- and post-intervention PW measurement weeks. The unified menu for the field study was developed for one working week within our previous research (for details, see Lonska et al. [27]). As a result, the paired method was applied for statistical analysis; for Model 1 (class view), the average PW g/student data were calculated per class. In schools, classes were divided into sections A, B, and C. Therefore, each school had 15–20 pairs for comparison depending on the school, and for Model 2 (day view), the average PW g/student data per day were calculated for each school. Additionally, a comparison between 5 days for PW and g/student for each school was performed to exclude the impact of the menu. A Wilcoxon signed-rank test was performed to test each intervention within both models.

3.3. Description of the Implemented Interventions

The following interventions aimed at a reduction in PW were tested: School 1 (S1)—a plate waste tracker; School 2 (S2)—an awareness and educational campaign; and School 3 (S3)—a set of organizational changes, including larger diameter plates used in the canteen, longer lunch breaks, and the presence of the supervising teacher during the lunch break. The interventions were implemented from 1 October 2023 to 30 April 2024. The capability of the interventions to reduce PW in school canteens was tested against both the baseline before implementation and a reference School 4 (S4), in which no intervention was implemented. The objective was to identify the interventions that could be scaled up so that school canteens can achieve larger-scale reductions in PW necessary for a sustainable food system.

3.3.1. Plate Waste Tracker

As part of the research study in S1, a plate waste tracker was installed (Matomatic AB, Uppsala, Sweden) [134]. The plate waste tracker is a kitchen scale connected to a tablet computer running dedicated software that interacts with canteen visitors, showing them how much food they are wasting and the impact of this waste. The tablet computer allows the canteen visitors to respond to why they wasted food, with some predefined alternatives, such as "I did not have enough time to eat", "The portion size was too large", "I did not like it", and "I am full" [74]. The device was adapted for use in Latvia by installing the Latvian language. However, because only one device was installed at the school, we encountered a situation where long lines of students formed during the lunch break, as they had to dispose of their PW on the tracker scales. Additionally, this process was slowed down by the fact that some primary schoolchildren did not yet read quickly; therefore, providing

their feedback took extra time. At the beginning of the intervention, we observed that some students lacked the time to throw away their PW during the lunch break. We solved this problem by hanging the possible reasons for PW, as provided by the tracker, on the wall right next to the tracker. The students could then tell the school personnel operating the device why they did not eat all the food, and the personnel would enter the students' answers into the tracker (see Figure 4).
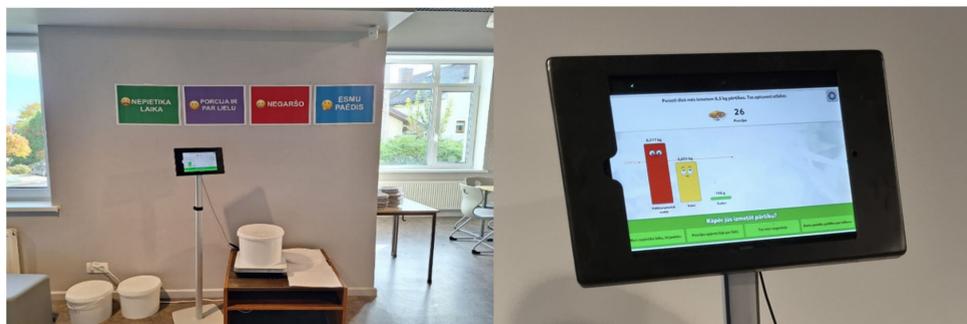

Figure 4. Plate waste tracker installed in the S1 canteen.

3.3.2. Awareness and Educational Campaign

In S2, an intervention to reduce PW was implemented through a combination of awareness and educational campaigns [14,68,71,120,135–137]. Preventive measures aimed at reducing FW during the FSC consumption phase emphasize several key approaches to educate consumers and alter behaviors to minimize waste. The approaches include public awareness efforts, educational programs in schools, and waste reduction initiatives in cafeterias and restaurants [138]. Such educational interventions typically highlight the significance of reducing FW and offer practical tips, such as portion control and proper food storage techniques. The initiative was based on the idea that increasing awareness and education about FW issues would lead to less waste. School environments play a vital role in raising awareness and imparting knowledge about food to younger generations. Incorporating FW into specific curricula offers long-term benefits and can be integrated with other food-related subjects [139]. The awareness campaign utilized one-way communication methods, such as posters and table talkers, to inform canteen visitors about the negative aspects of FW and to nudge students to consume food more responsibly. The school conducted educational class lessons for its students, focusing on the ecological consequences of FW, its environmental impact, the scarcity of food resources, and the importance of responsible food consumption. This comprehensive approach aims to raise students' awareness and positively influence their eating habits [14,120,136].

This process was implemented in the form of class lessons (at least 2 h per academic year in each class from 1st to 7th grade). At the same time, 16 (12 + 4) informative posters were placed in the school canteen, indirectly nudging students toward the responsible consumption of school food. In the school canteen, table talkers were changed every 2 weeks with interesting facts about various school food products (see Figures 5 and 6).

Figure 5. Informative posters were placed in the S2 canteen with slogans like "STOP wasting food!", "Save the world", "Be responsible—say no to food waste".

Figure 6. Table talkers were placed in the S2 canteen, featuring nutritional information and interesting historical facts about the origins of food products such as apples, eggs, and carrots.

Additionally, to intensify the impact of the awareness and educational campaign, a creative poster competition was organized in the school for 1st- to 9th-grade students on the following topics: "I am what I eat"; "Eat responsibly: think before throwing away"; "I am a healthy eating agent"; and "Spare the planet, do not waste food!". Participatory nudging interventions for FW reduction encourage students to lead campaigns and create content (e.g., videos, posters) about FW, fostering a peer-driven approach to behavior change. As a result of the competition, four drawings were selected and used to create informative posters, which were then placed in the school canteen.

3.3.3. A Set of Organizational Changes

In S3, the implementation of organizational changes in the provision of catering services included the use of larger diameter plates for serving food, longer lunch breaks, and the presence of a supervising teacher during the lunch break. The chosen interventions were based on the results of our previously implemented research, as it was observed that

a school selected used plates of an insufficient diameter, which did not allow students to place the food ingredients in such a way that they did not mix (for example, meat sauce was placed on top of pasta along with vegetables), resulting in spoiling the visual appearance of the food on the plate, which could be one of the factors contributing to PW, especially in primary school. Researcher observations have shown that often the food is mixed during serving, and the schoolchildren refuse it because they do not understand the ingredients of the food. Schoolchildren could refuse to eat or not finish eating the food offered to them if they are not satisfied with the appearance, taste, texture, color, and temperature of the food [123,140–142]. Larger diameter plates would allow food to be placed more transparently and be more visually appealing to the schoolchildren, thereby encouraging the acceptance of food by them. The use of larger plates in the intervention relates to school catering in Rezekne City, as the main course is served to each student before the lunch break, and they cannot choose the type and quantity of food.

Regarding the extension of the lunch break, several research studies have concluded that an insufficient lunch break length might be a factor contributing to PW, as a short lunch break does not give the schoolchildren enough time to eat a full meal [136,143–145]. Based on the analysis performed within our previous research using artificial intelligence, it was concluded that an optimal lunch break reduces the amount of PW by 20% [106]. Extending the lunch break to at least 30 min and reviewing the school timetable, avoiding the lunch break too early (i.e., until 11:00 a.m.), could contribute to a reduction in PW.

The decision on the presence of the supervising teacher during the lunch break was taken into consideration because the non-involvement of supervisory or support personnel in the catering process (e.g., a teacher or canteen personnel), which could otherwise promote the schoolchildren's healthy attitudes toward food and new tastes and help to reduce PW, is referred to as one of the factors in PW [123,136,140]. The intervention we proposed is the presence of a class teacher during the lunch break to help and encourage children to eat and try new foods, as well as to stimulate teachers to act as role models, teach the children how to behave in the canteen, and discuss food and nutrition during meals.

3.4. Description of the Catering Management and Unified Menu

In all Rezekne City schools, the catering process is organized in closed-type canteens (referred to hereafter as school canteens), supervised by the municipal school board, ensuring compliance with hygiene and healthy nutrition standards, and funded by the local government of Rezekne City. School canteens are equipped to follow safe food handling regulations, and specialized workstations are provided for canteen staff.

In all the school canteens included in the field study, food was partially pre-served on tables designated for each class. Just before the lunch break, canteen staff placed individual portions of the main dish (consisting of staple foods and meats) on plates at the assigned tables. In S4, vegetables with the main dish were served on the same individual plate for each student, while in S1, S2, and S3, vegetables were served in common dishes on the tables for each class separately. In all the schools, the soup was served in common soup pans on the tables for each class, with the amount calculated based on the number of students in each class using standardized measures and serving cups. Slices of bread were placed on tables in common containers according to the number of students in each class. Beverages were served in separate glasses for each student. Fruits (usually whole unpeeled apples, pears, or bananas) were placed on tables in common containers according to the number of students in each class. Similarly, glazed curd cheese was served in its packaging in common containers according to the number of students in each class.

This means that for those students whose catering expenses were covered by the state/municipal budgets, it was not possible to choose the type of food, as the food was

already served following all the guidelines regarding the amount of food served, calories, and nutrients. In addition, students could not choose the size of the portion themselves (smaller or larger, depending on their feeling of hunger or age). In all the schools of Rezekne City, catering is provided free of charge for the following students: grades 1–4, for whom free lunches are funded by the national government and grades 5–7, for whom free lunches are funded by the local government of Rezekne City.

Only students in grades 1–7 were included in the field study sample, i.e., those who were entitled to free lunch. During the PW measurement weeks, students in all the schools were fed according to a unified lunch menu, designed for the PW measurement week that would eliminate differences in food availability and ensure laboratory conditions, thereby reducing the influence of external factors on the students' individual food preferences (see Table 6). The development of the unified menu was based on the results of the previous project, including dishes that students generally liked, disliked, or had a neutral attitude toward. During the PW measurement weeks, the schools ensured that the menus were repeated and the food offered to the students was the same in all the schools. The development process of the unified menu is described in detail in our previous study [27].

3.5. Data Collection

Measuring FW is a crucial component of a strategic intervention to reduce FW. It helps to assess the effectiveness of interventions and tracks progress in reducing FW. Additionally, measurement provides consumers with tangible information about the quantity, composition, and cost of the food [38].

In total, PW measurements were taken three times during the school year and performed simultaneously in all four schools, and the students were fed according to a unified menu.

The pre-intervention quantification of PW took place on 25–29 September 2023 in all four school canteens to establish a baseline level of PW. The aforementioned interventions for PW reduction were introduced in three schools after the pre-intervention measurements were taken. On 11–15 December 2023, the first post-intervention quantification of PW was performed to track the effects of the interventions in the short run. It should be noted that PW quantification was also carried out in a control group in S4, where no interventions were implemented. This allowed us to examine whether the test interventions reduced PW or the reductions were due to other trends and factors that would have occurred regardless. The second post-intervention quantification of PW in all four schools was performed on 15–19 April 2024 to track the long-term effects of the interventions.

Each school had a different lunch break schedule. The average lunchtime for grades 1–4 was from 9:30 to 11:30, and for grades 5–7, it was from 11:30 to 13:00. The researchers arrived at the schools at about 9:00 in the morning and finished their work at about 14:00 (depending on the school) for 5 consecutive days of the measurements.

Before the meal, the researchers identified the expected number of students based on the number of main dishes served on the table. During lunch, they registered the actual number of students who participated in the lunch.

The research employed the following methods: observation, photography, and direct manual weighing of PW by food category and by grade of students.

During the PW measurement, the students of the same age group were observed across all schools (grades 1–7), and the amount of PW was identified separately for each class. All the observed schools are located within the same geographical region, specifically in Rezekne City, indicating that the children belonged to the same ethnic group. Pre- and post-intervention PW measurements in all the schools were conducted simultaneously three times over one week (five working days).

Table 6. A unified menu designed for the field study.

	Placed Portion Planned Weight in Grams	Weight of Food Served on a Plate, Grams		Placed Portion Planned Weight, Grams	Weight of Food Served on a Plate, Grams
	Monday			Thursday	
Pasta	130	130	Borscht (beet soup) with fresh cabbage and sour cream	200/5 *	205
Pork goulash	50/50	100	Chicken cutlet	80	80
Pickled cucumber	25	25	Stewed rice with carrots and corn	100/5	105
Cinnamon roll	1 piece	60	Fresh cucumber	30	30
Bread	25	25	Bread	25	25
	Tuesday			Friday	
Rice soup with chicken meat and sour cream	150/22/5 *	177	Fish in breadcrumbs	60–65	63
Pork cutlet	50	50	Mashed potatoes	130	130
Mashed potatoes	130	130			
Fresh tomato salad with oil	50	50	Carrot salad with sunflower seeds	50	50
Bread (optional)	25	25	Glazed curd cheese	1 piece	46
Banana	1 piece	175 **	Bread	25	25
	Wednesday				
Pork chop	60	60			
Mashed potatoes	130	130			
Fresh cabbage salad with carrots	50	50			
Bread	25	25			
Cupcake	50	50			
Apple	1 piece	140 **			

* Note: 5 g of sour cream is put in a common pot of soup, providing 5 g per 1 child. The weight of soup in each plate is 250 g. ** Note: average weight of 1 piece of banana and apple.

During the PW measurements, the students were asked to leave their dirty plates on the tables (usually, the students had to bring them to a special table near the canteen's dishwashing room). When the students finished their lunch, the researchers gathered the PW into buckets, dividing it into the following categories: soup, staple food, meat/fish, salad/vegetables, bread, fruit, and curd products (glazed curd cheese). The PW measurements were taken separately for each class.

Individually served portions of a main dish (staple food and meats/fish on an individual plate) were not weighed before the lunch break. To calculate the number of main dishes served, the researchers relied on the meal weight indicated in the menu per student (see Table 6). A different approach was applied to measure the amount of soups, salads, and bread served in common bowls and pots for each class separately. In S1, S2, and S3, the researchers recorded the weight of each pot/bowl with soup/salad/bread before the lunch break (gross amount) and the weight of an empty pot/bowl to calculate the net amount of served soup/salad/bread for students. If any soup/salad/bread was left in the common pot/bowl after the lunch break, the pot/bowl was replenished for the next

class. The remaining soup/salad/bread in common pots/bowls was discarded only after the final lunch break (see Figure 7). According to the legislation of the Republic of Latvia, school meals are not intended for reheating or reuse the next day. It should be noted that primary school students often took leftover bread to class to consume later.
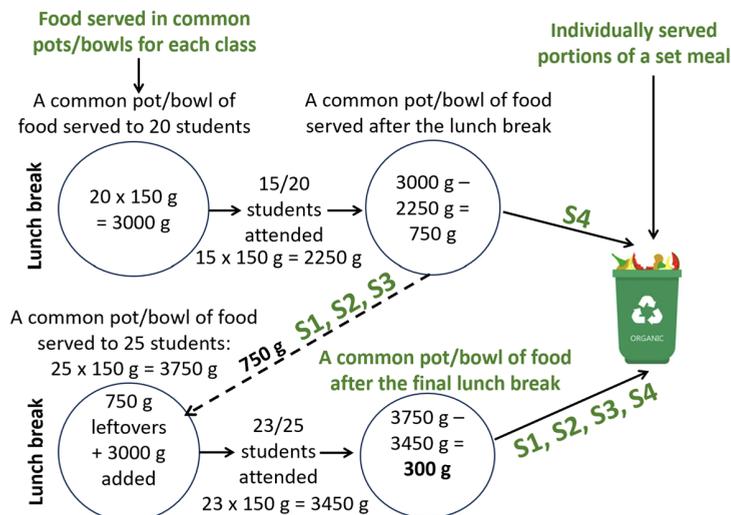

Figure 7. Scheme of the PW generation process in S1, S2, S3, and S4 (an example).

The situation regarding serving soup in common pots was different in S4. The common soup pots in this school were not replenished for the next classes. Instead, the remaining soup in the pots was discarded immediately at the end of each lunch break, as per the decision of the canteen manager due to hygiene concerns (see Figure 7). The situation was similar with leftover bread in common containers; however, in this school as well, primary school students often took bread with them to class. As mentioned, salad in this school was served to each student individually on main dish plates.

Considering the specifics of catering management in the schools observed, in this study, we define PW as the amount of food served to students that remains uneaten on their individual plates, as well as discarded food leftovers in common bowls and pots. The total measured weight of PW includes uneaten food left on individual plates and discarded food in common bowls and pots following the free lunches provided to students in grades 1–7 in the Rezekne City schools observed.

After each lunch break, all buckets with the PW were weighed, and the data were entered into a waste registration protocol. The following measurement tools were used to quantify the PW: two kinds of high-density polymer buckets (a large bucket with a capacity of 2 L, weight 61 g, and a small bucket with a capacity of 1 L, weight 35 g; each bucket was marked with the food category and the number of the class for which it was intended and electronic kitchen scales were used (model—Clatronic KW3412, art. No. 271680, measuring range—up to 5 kg, units of measurement—grams, producer Clatronic International GmbH, Kempen, Germany).

4. Data Analysis and Results

All of the data analyses were performed using the statistical software R and MS Excel. The research employed a statistical analysis method, the Wilcoxon signed-rank test, using

the R method "wilcox.test" to test the null hypothesis and verify sufficient differences between two paired groups, namely pre-intervention and post-intervention groups.

In total, 17,144 plates (number of samples) were surveyed in three PW measurements, with 5772 in September 2023, 5751 in December 2023, and 5621 in April 2024. The distribution of the number of surveyed samples by school is shown in Figure 8.
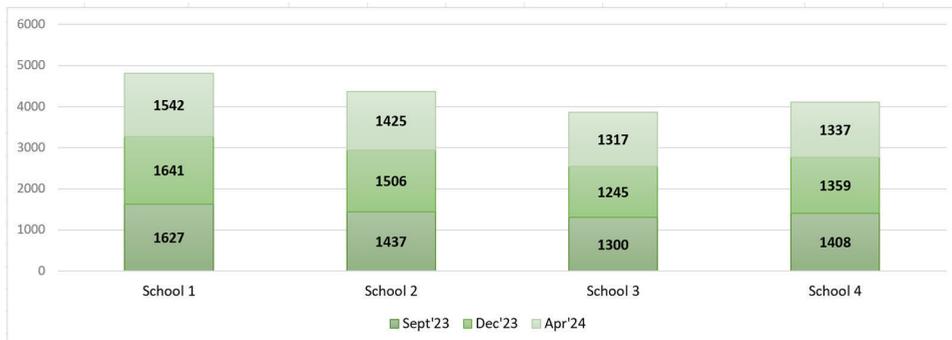

Figure 8. Distribution of the number of samples by school at each PW measurement (i.e., the actual number of students who participated in lunch breaks).

4.1. Data on Total Food Served and PW

Initially, the total amount of PW was calculated as a ratio of the food served, expressed as a percentage, including soup, salad, and bread served in common pots/bowls (see Table 7 and Figure 9).

Table 7. Data on the amount of food served and total PW registered.

School	September 2023				December 2023				April 2024			
	Food Served, Total g	PW, Total g	PW, g per Stud. *	PW, % of the Food Served	Food Served, Total g	PW, Total g	PW, g per Stud.	PW, % of the Food Served	Food Served, Total g	PW, Total g	PW, g per Stud.	PW, % of the Food Served
S1	639,522	150,959	93	23.6	619,794	130,261	79	21.0	590,944	121,851	79	20.6
S2	587,279	129,006	90	22.0	577,767	117,347	78	20.3	593,915	117,555	82	19.8
S3	525,541	76,427	59	14.5	507,082	73,643	59	14.5	543,887	78,057	59	14.4
S4	653,534	152,481	108	23.3	627,717	109,991	81	17.5	615,617	131,764	99	21.4
Total	2,405,876	508,873	88	21.2	2,332,359	431,242	75	18.5	2,344,363	449,227	80	19.2

* Based on the actual number of students who participated in lunch breaks.

An analysis of pre- and post-intervention total PW as a % of the food served did not allow us to draw conclusions on the impact of the interventions, as the total amount of food served in the communal dishes varied significantly from week to week, especially that of soup. It was therefore important to express PW in grams per student so that the values were comparable (see Figure 10).
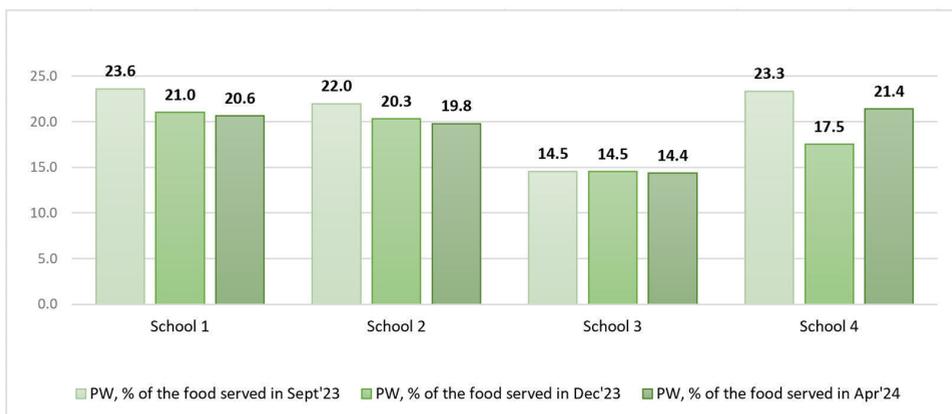
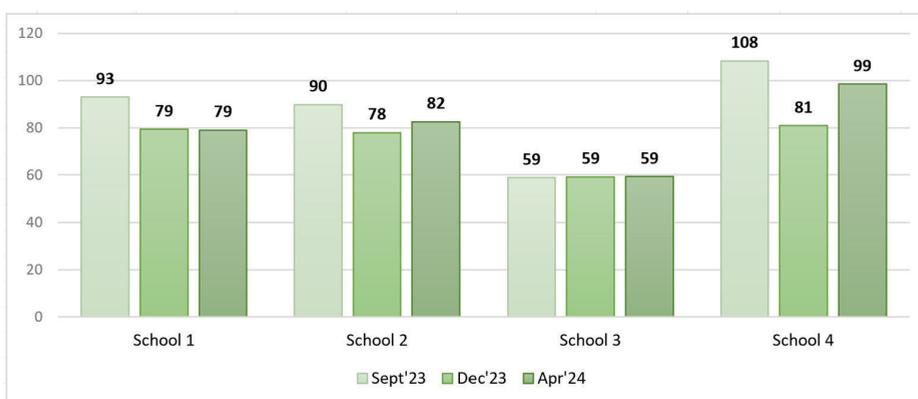**Figure 9.** Total PW as a % of the food served.

Figure 10. Total PW, g/student (based on the actual number of students who participated in lunch breaks).

An analysis of the obtained PW results in grams per student revealed that the highest PW was registered in S4. This could be justified by the fact that the way of serving soup and salads in S1, S2, and S3 differed from that in S4 (see Figure 7), i.e., in S1, S2, and S3, the common soup pot/salad bowl was replenished after each lunch break for the next classes, while in S4, the remaining soup in the pots was discarded immediately at the end of each lunch break and the common soup pots were filled again for the next classes; additionally, in S4, salad was served on the individual plates to each student.

However, a more detailed analysis of the data on the amount of food served—particularly soup in common pots—revealed that the quantity served in some schools (notably S1 and S2) often differed significantly from the amount specified in the menu per student. In some cases, the difference between classes during the same lunch break was as much as double. This imprecision in food serving can significantly affect the relative amounts of PW (as a % of the food served). Conversely, in S4, no measurements were made of the soup served in common pots, as in this school, the serving waste was discarded after each lunch break.

4.2. Data Filtering

To eliminate the impact of different approaches to serving food in common pots/bowls, data analysis was conducted using data filtering. This involved excluding soup, salad, and bread waste, as well as intact discarded portions from the statistical analysis and including only PW data on the main dish (staple food with meat/fish), fruits, pastry items, and glazed curd cheese.

It is also important to note that in all the schools, some portions of food served remained intact on the tables, and some of the intact portions were eventually discarded. This was mainly owing to inaccurately planning the expected number of students, as information from parents about their children's absences did not always reach the canteen administration in time. As a result, surplus portions were prepared and served based on an incorrect estimate of the expected number of students. Some children might not have liked the food and might not have touched their portions. The surplus portions were sometimes partially eaten by classmates, sold to senior students, or discarded, especially toward the end of the day. We excluded such intact discarded portions from both the amount of food served and the amount of PW to ensure the accuracy of the data analyzed. The PW data obtained were then expressed in grams per student by dividing the total amount of PW by the actual number of students who participated in lunch breaks (or the number of samples).

By filtering the PW data, we focus on the more consistent and comparable elements of the meal, providing a clearer picture of waste patterns. Measuring soups can be complicated due to their varying properties, such as significant differences in viscosity, ingredient composition, and portion sizes, which make accurate comparisons across different meals and schools challenging. It should also be taken into account that soup consumption could be highly variable among students due to personal preferences [146–148].

The filtered data on food served and PW after excluding soup, salad, bread, and intact and thrown-away portions from the analysis are available in Table 8 and Figures 11 and 12.

Table 8. Filtered data on food served and PW.

School	September 2023				December 2023				April 2024			
	Food Served, Total g	PW, Total g	PW, % of the Food Served	PW, g per Stud.	Food Served, Total g	PW, Total g	PW, % of the Food Served	PW, g per Stud.	Food Served, Total g	PW, Total g	PW, % of the Food Served	PW, g per Stud.
S1	475,057	90,922	19.1	56	475,666	76,428	16.1	47	450,681	80,395	17.8	52
S2	458,281	82,240	17.9	57	452,556	79,467	17.6	53	465,013	80,052	17.2	56
S3	363,520	43,679	12.0	34	356,514	53,644	15.0	43	377,378	57,233	15.2	43
S4	426,388	62,883	14.7	45	415,085	52,770	12.7	39	402,718	57,723	14.3	43
Total	1,723,245	279,723	16.2	48	1,699,821	262,309	15.4	46	1,695,790	275,403	16.2	49

An analysis of the filtered PW data in grams per student revealed that in S1, S2, and S3, the PW decreased in the short run, whereas in the long run, a slight increase was observed. In contrast, in S3, we could observe a PW increase in the short run that remained unchanged in the long run.

Part of the reason for the long-run result was that in S2 and S4, a significant problem arose with catering management related to serving the exact number of portions according to the expected number of students who were going to participate in the lunch break on a given day. It should be noted that no digital tools were used in any school to collect information about the expected number of students and pass it to the canteen. Usually, the key persons receiving and passing the information were the class teachers who were informed about the schoolchildren's absences by the parents, and then the class teacher

either directly informed the canteen personnel early in the morning or the school nurse collected this information and then passed it to the canteen personnel.
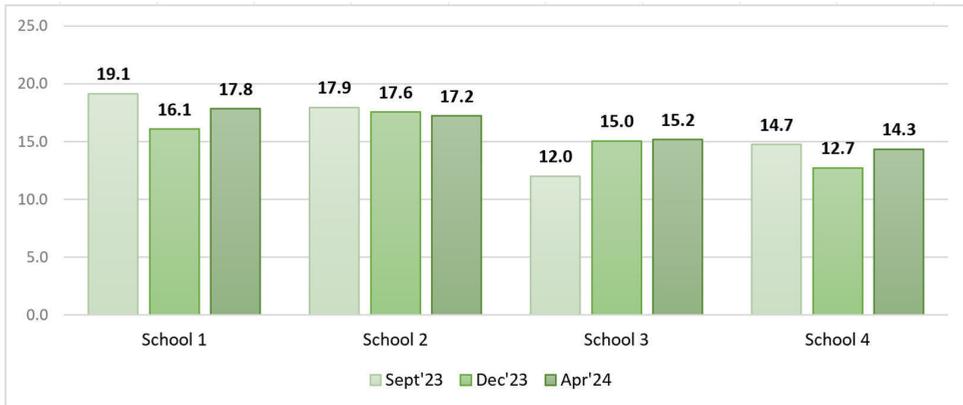

Figure 11. Filtered PW data as a % of the food served.
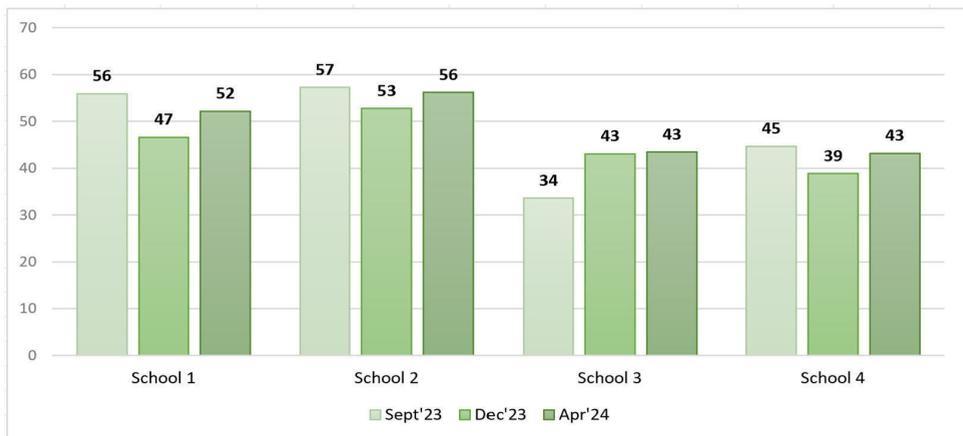
Figure 12. Filtered PW data, g/student.

If the information about the expected number of students is incorrect, then surplus portions that exceed the actual number of students are served on the tables. Usually, surplus portions are (partially) eaten by classmates, most often eating only the meat dish, and leaving the side dish on the plate, which goes to waste. If such surplus portions are intact, they can be given to senior students or sold to students/school personnel. Some of the surplus portions also end up in the garbage. Considering the number of surplus portions recorded in S2 and S4 (see Table 9), it obviously affected the PW fluctuations.

Table 9. Data on surplus portions served.

	S1	S2	S3	S4
September 2023	1	133	0	103
December 2023	0	60	0	97
April 2024	0	182	0	78
Total	1	375	0	278

4.3. Class View and Day View Analysis Models

To draw unambiguous conclusions on the results of interventions, the filtering of PW data allowed us to apply two analysis models, namely Model 1 (class view), to analyze the pre- and post-intervention filtered PW data per student for each school and each class over a total of five days and Model 2 (day view), to analyze the pre- and post-intervention filtered PW data per student per day for each school for all classes combined.

Model 1 (class view) allows us to analyze the pre- and post-intervention filtered PW data, g/student, for each class in the short run (September 2023–December 2023) and in the long run (September 2023–April 2024). For each class, the filtered PW data, g/student, make a statistical pair, with September 2023–December 2023 and September 2023–April 2024.

There were 15 pairs for S1, 17 for S2, 16 for S3, and 15 for S4. To identify the impact of the interventions, the null hypothesis "pre- and post-intervention filtered PW data, g/student, remain unchanged" was tested. The rows represent classes (1a, 1b, 2a, etc.), while the columns represent filtered PW g/student datasets (September 2023–December 2023 and September 2023–April 2024) (see Tables 10 and 11). The hypothesis was tested individually for each school. A Wilcoxon signed-rank test with a confidence level of 95% was performed.

Table 10. Data on filtered PW in the short run, g/student, September 2023–December 2023 (class view).

Grades	S1		S2		S3		S4	
	Sept.	Dec.	Sept.	Dec.	Sept.	Dec.	Sept.	Dec.
1a	59	51	53	64	29	50	64	45
1b	63	53	61	63	33	33	33	39
1c	x	x	84	72	x	x	x	x
2a	67	53	63	68	32	49	42	31
2b	62	57	56	58	58	56	59	45
2c	x	x	65	56	x	x	x	x
3a	48	38	47	56	32	52	57	49
3b	75	56	44	44	38	37	52	39
3c	x	x	53	54	x	x	x	x
4a	53	49	64	45	22	38	39	39
4b	55	46	54	56	52	39	44	49
4c	x	x	x	x	58	56	x	x
5a	59	35	57	28	32	54	56	38
5b	63	55	73	62	12	23	35	20
5c	39	32	x	x	x	x	46	49
6a	49	38	62	51	36	41	30	32
6b	53	40	58	57	42	52	38	40
7a	42	45	50	44	28	40	49	25
7b	45	40	26	22	15	44	25	36
7c	x	x	x	x	19	22	x	x
	p-value = 0.000		*p*-value = 0.159		*p*-value = 0.011		*p*-value = 0.095	

Table 11. Data on filtered PW in the long run, g/student, September 2023–April 2024 (class view).

Grades	S1		S2		S3		S4	
	Sept.	Apr.	Sept.	Apr.	Sept.	Apr.	Sept.	Apr.
1a	59	52	53	53	29	39	64	56
1b	63	74	61	66	33	25	33	23
1c	x	x	84	91	x	x	x	x
2a	67	58	63	76	32	48	42	34
2b	62	67	56	51	58	52	59	54
2c	x	x	65	69	x	x	x	x
3a	48	56	47	67	32	46	57	56
3b	75	51	44	55	38	43	52	61
3c	x	x	53	51	x	x	x	x
4a	53	54	64	44	22	31	39	30
4b	55	52	54	68	52	64	44	39
4c	x	x	x	x	58	74	x	x
5a	59	50	57	34	32	43	56	32
5b	63	52	73	59	12	34	35	32
5c	39	28	x	x	x	x	46	69
6a	49	40	62	43	36	38	30	40
6b	53	41	58	71	42	63	38	46
7a	42	52	50	48	28	39	49	34
7b	45	39	26	27	15	36	25	40
7c	x	x	x	x	19	9	x	x
	p-value = 0.107		*p*-value = 0.890		*p*-value = 0.004		*p*-value = 0.639	

Model 1 (class view) results: In the short run for S1, a Wilcoxon signed-rank test with a *p*-value = 0.000 < 0.001 indicated that there was a statistically significant difference in the filtered PW data, g/student, between September 2023 and December 2023, thereby indicating a significant change in PW in the case of the plate waste tracker intervention. Figure 13 shows that the plate waste tracker intervention reduced PW in the short run. Statistically significant differences in PW were also found for S3 (*p*-value = 0.011 < 0.05), where several organizational changes in the catering process were introduced; yet, in this school, the opposite was observed, i.e., an increase in PW (filtered data, g/student) in the short run (see Figure 13). In the cases of S2 (*p*-value = 0.159) and S4 (*p*-value = 0.095), there was not enough evidence to reject the null hypothesis, and it was assumed that for these schools, the permanent difference in PW was not statistically significant in the short run.

In the long run (September 2023–April 2024), however, the Wilcoxon signed-rank test showed that in the cases of S1 (*p*-value = 0.107 > 0.05), S2 (*p*-value = 0.890 > 0.05), and S4 (*p*-value = 0.639 > 0.05), there was no statistically significant difference in PW (filtered data, g/student), which means that the plate waste tracker intervention in S1 and the awareness and educational campaign intervention in S2 did not have a significant effect. S4 was the control, with no interventions implemented, thereby having no significant effect of external factors on the result (e.g., seasonality). In contrast, in the case of S3, a significant difference in PW (filtered data, g/student) (*p*-value = 0.004 < 0.01) was found, with the PW increasing (see Figure 14). The results for S2, S3, and S4 were consistent with the short-run results, while in the case of S1, the result changed. The intervention in S1 showed a decrease in PW (filtered data) in the short run but not in the long run, as the result was statistically insignificant (*p*-value = 0.107 > 0.05).
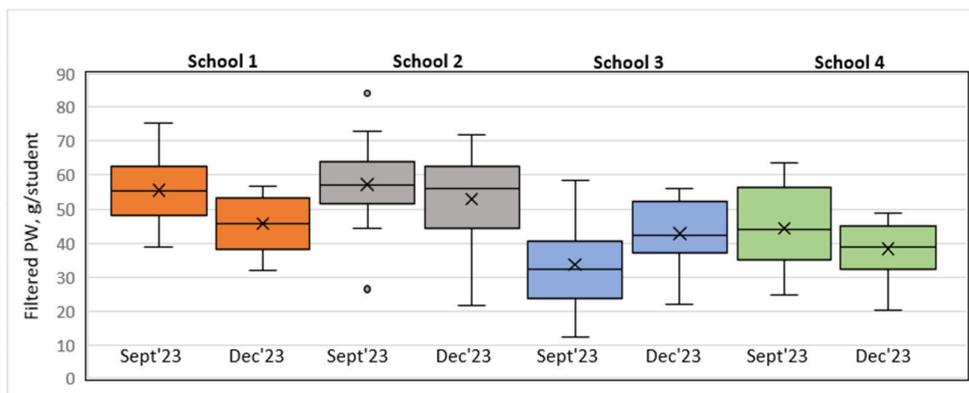
Figure 13. Analysis of filtered PW data in the short run, g/student, September 2023–December 2023 (class view).
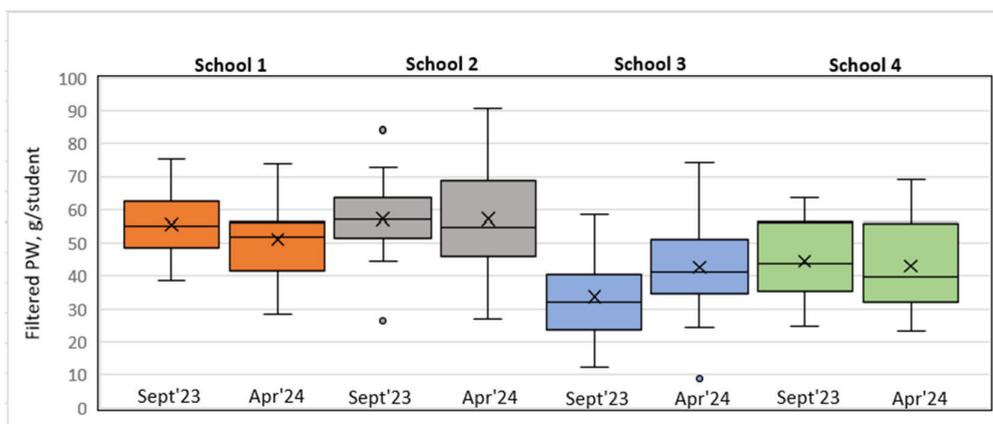

Figure 14. Analysis of filtered PW data in the long run, g/student, September 2023–April 2024 (class view).

Model 2 (day view) analyzed the pre- and post-intervention filtered PW data per day for each school for all classes combined. In this case, the rows represent the days of the week (Monday–Friday) and the average PW, g/student, at all the schools. For each school, there were five data pairs in the short run (September 2023–December 2023) (see Table 12) and in the long run (September 2023–April 2024) (see Table 13). The null hypothesis was the same: "pre- and post-intervention filtered PW data per student remain unchanged". A Wilcoxon signed-rank test with a confidence level of 95% was performed.

Model 2 (day view) results: In the short run, as well as in the long run, the Wilcoxon signed-rank test indicated that there were no statistically significant differences in PW (filtered data, g/student) between all the schools, meaning that the interventions implemented did not have a significant effect on changes in PW. However, it is important to note that in the case of S3 in the long run, the p-value = 0.063, which was close to the threshold of 0.05, meaning that there was probably some PW difference, but the evidence was not strong enough. As shown in the boxplot short run diagram (see Figure 15), the post-intervention case in S3 indicates a tendency toward increasing PW. A similar situation

is seen in the long-run diagram (see Figure 16); however, the S3 long-run *p*-value = 0.063 is more significant than the short-run *p*-value = 0.188.

Table 12. Data on filtered PW in the short run, g/student, September 2023–December 2023 (day view).

	S1		S2		S3		S4	
	Sept.	Dec.	Sept.	Dec.	Sept.	Dec.	Sept.	Dec.
Monday	49.83	47.49	47.24	39.94	21.35	35.22	29.08	37.43
Tuesday	31.97	39.92	50.94	43.64	24.26	31.18	40.49	34.56
Wednesday	49.19	44.76	55.59	48.74	33.65	33.92	49.36	44.80
Thursday	94.50	60.29	84.97	72.67	51.21	79.22	53.59	42.70
Friday	53.62	40.36	52.79	58.19	36.98	32.98	50.04	35.20
	p-value = 0.313		*p*-value = 0.125		*p*-value = 0.188		*p*-value = 0.313	

Table 13. Data on filtered PW in the long run, g/student, 23 September–24 April (day view).

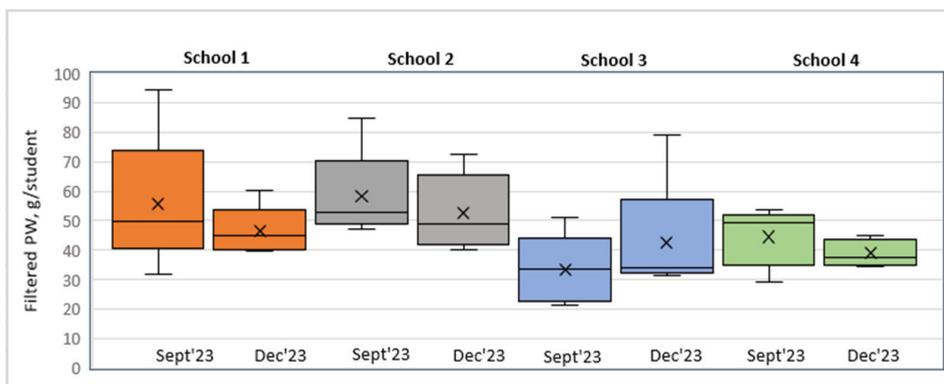|	S1		S2		S3		S4	
	Sept.	Apr.	Sept.	Apr.	Sept.	Apr.	Sept.	Apr.
Monday	49.83	41.06	47.24	47.93	21.35	34.65	29.08	39.22
Tuesday	31.97	55.52	50.94	63.32	24.26	45.83	40.49	41.12
Wednesday	49.19	51.80	55.59	56.02	33.65	36.10	49.36	44.85
Thursday	94.50	66.70	84.97	62.32	51.21	62.03	53.59	49.71
Friday	53.62	46.53	52.79	52.27	36.98	38.10	50.04	41.05
	p-value = 0.813		*p*-value = 1.000		*p*-value = 0.063		*p*-value = 0.813	

Figure 15. Analysis of filtered PW data in the short run, g/student, September 2023–December 2023 (day view).
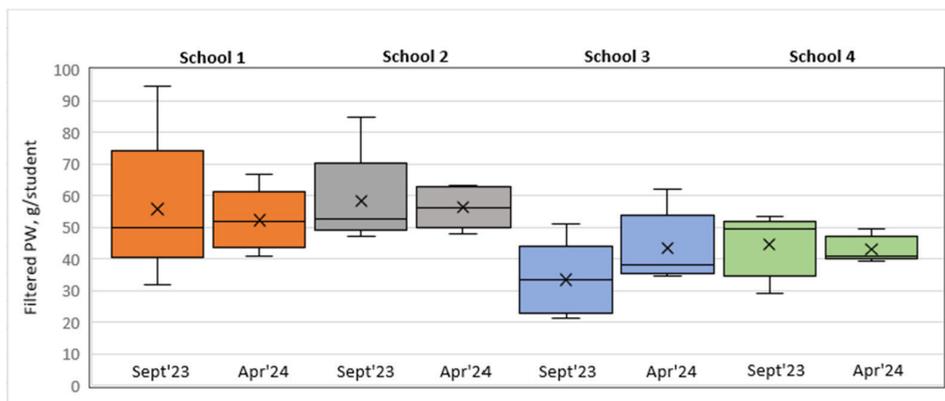
Figure 16. Analysis of filtered PW data in the long run, g/student, September 2023–April 2024 (day view).

5. Discussion

In the short run (September 2023–December 2023), Model 1 (class view) revealed that the PW reduction intervention was effective in S1, where a plate waste tracker was installed, as the amount of PW (consisting of the main dish (staple food with meat/fish), fruits, pastry items, and glazed curd cheese) (filtered data, g/student) significantly decreased. In the case of S3, a significant difference in PW (filtered data, g/student) was also found; however, it cannot be concluded that the intervention had a positive effect because the PW, g/student, increased. In this case, the impact of external factors such as competitive food cannot be excluded because with the extension of the lunch break, students who do not like free lunches have enough time to buy and eat other food in the school canteen that is available for money outside the free lunch menu, meaning that in this case, the free lunches served are more likely to be thrown away. No in-depth analysis of the S3 situation was performed to unequivocally conclude the factors in the increase in PW (filtered data). It should be noted that the earlier 20 min lunch break was restored in S3 after the end of the field study in the study year 2024/2025. The statistical analysis showed no statistically significant change in PW (filtered data, g/student) after the awareness and education campaign intervention in S2. S4 was the control, and no effect of external factors was observed there.

In the long run (September 2023–April 2024), the statistical analysis did not show statistically significant changes in PW (filtered data, g/student) after the interventions in S1 and S2. The exception was S3, where according to Model 1, the opposite effect was observed, i.e., an increase in PW (filtered data, g/student). S4 was the control, indicating the absence of relevant external factors that could have influenced the experimental results.

Model 2 (day view) showed no statistically significant differences in the amount of PW (filtered data, g/student) for all the schools in the short run and the long run (see Tables 12 and 13).

After summarizing the results provided by Model 1 and Model 2, it should be noted that a significant difference between Model 1 and Model 2 was the number of statistical pairs to be analyzed, which tended to affect the accuracy of the analysis results (the higher the number of pairs, the higher the accuracy). In the case of Model 1 for S3 in the long run, the *p*-value = 0.004 was more accurate, and if corrected for accuracy under Model 2, the *p*-value = 0.063 for S3, which was close to 0.05, suggesting that there was still a statistically significant difference between the pre- and post-intervention PW (filtered data, g/student)

in the long run. In the case of S1, a similar correction is doubtful, since in the short run for S1, the *p*-value = 0.000 under Model 1 and the *p*-value = 0.313 under Model 2.

What is the semantic difference between Model 1 and Model 2? Under Model 1 (class view), a particular class was the subject of observation, which was therefore more precise in terms of both data and methodology. In contrast, Model 2 (day view) considered the statistically average student deciding to eat or not to eat the school food served according to the free lunch menu. Analyzing the responses of 13,584 students (which, according to approximate calculations, account for 30% of the total number of students who participated in lunch breaks during the intervention period) provided through the plate waste tracker regarding the reasons for PW, the most frequently mentioned reason was "I am full" (44.3%), followed by "I did not like it" (38.8%), "I did not have enough time to eat" (9.6%), and "The portion size was too large" (7.3%). Combining the responses "I am full" and "The portion size was too large"; it is evident that the primary reason for PW (in 51.6% of cases) is directly related to the quantity of food served. The second significant reason for PW is students' preferences and dislike of the menu (38.8%). Given that Model 2 dealt with a menu that changed daily, it can be concluded that in the case of S1 in the short run, there was a high probability of being affected by factors arising from students' food preferences. Most likely, the short-term reduction in PW was driven by the installation of the plate waste tracker and its associated psychological effects on students and their desire to reduce PW. However, in the long run, the inability to choose the size and type of food supported the hypothesis about the absence of a sustained impact of the plate waste tracker intervention.

In the case of S3 under Model 2, if corrected for accuracy and assuming that there was still a change in the amount of PW (filtered data, g/student) in the long run, it could be concluded that there was a probability of an effect of the student food preference factor on the result. It could be assumed that during the S3 intervention, with the longer lunch break of 30 min, if a student did not like the free lunch, they had enough time to purchase other foods outside the free lunch menu, which might explain the S3 anomaly with higher amounts of PW (filtered data, g/student) in the short run as well as in the long run. For example, a previous research study found that 41.6% of the students decided to reject food if they did not like it. However, competitive food in schools affects students' satiation in 21–42% of cases, and they eat at best 1/3 of the portion served [106]. The effect of external factors such as food seasonality was unlikely, as no significant difference was observed for S4; therefore, it was more likely that the increase in PW (filtered data, g/student) in S3 was due to an in-school factor.

The results obtained in the study should be interpreted through the prism of the MOA framework (Figure 2) to better understand the prerequisites of students' FW behavior. In the out-of-home catering model, FW is primarily determined by activities related to ordering/serving and consuming. In school catering, students' impact is limited to these stages, where factors such as portion size differentiation, the choice of a food type, and eating behavior significantly influence the amount of FW produced. It is important to provide students with opportunities to consume school meals responsibly, which involves tailoring portion sizes to their needs based on appetite level and physiology, food choice options, and a takeaway option for uneaten food. By projecting this model onto the catering organization in Rezekne City schools, we can conclude that in this case, the model lacks the Opportunities element, because first- to seventh-grade students are served free lunches according to the same menu without the option of choosing the type of food, without differentiating the size of the portions depending on their age and appetite, as well as without providing the possibility to take away uneaten food. Even though the student is motivated to consume food responsibly, and they can do it by having appropriate

knowledge and skills (in-home circumstances), they do not have opportunities to act responsibly with food in the school canteen.

This conclusion also represents the result observed in the schools surveyed. The interventions implemented in S1 and S2 could not produce a full effect, as the catering model in Rezekne City schools was not adaptable to students' food preferences, age, appetite, physiology, etc. However, many authors point out that it is important to take into account children's food preferences through the implementation of new menus that have been designed based on the results of student food satisfaction/food preference questionnaire surveys [149]. PW in school canteens is influenced by students' menu preferences, shaped by individual and contextual factors [140]; therefore, more proactive menu management by developing more appealing menus can be an effective strategy to boost food consumption and reduce PW [99,150,151]. For instance, the present research found that the amount of waste consistently spiked on Thursday, with the average amount of PW (filtered data, g/student) being 37% higher than the average for all three measurements. This increase was largely due to a side dish "stewed rice with carrots and corn" that was not preferred by the students because of the vegetables added to the rice. A FW analysis by component can help to identify foods with the highest PW, allowing for their improvement or modification in menus [89,151,152].

Several studies on the reasons for PW in schools with a similar pre-served meals catering model confirm that the amount and type of food served are among the main contributors to PW. For instance, Sehnem et al. [153], analyzing FW in seven schools in Brazil with a pre-served set meals catering model, found that approximately one-fifth (20%) of the food remained uneaten on plates. Boschini et al. [119], in their analysis of 78 primary schools across three regions in Italy with pre-served set meals, found that PW increased with larger portion sizes. They identified a threshold of 370 g/day per capita for served portions, above which PW grew significantly. Also, Favuzzi et al. [154] found that the weight of the food served influences FW. It should be noted that in the study by Favuzzi, as in our study, all children were served a standard portion size using a standardized graduated ladle [154].

If catering is organized in the form of pre-serving or pre-portioning (as was the case mainly in the schools surveyed), it is important to adapt the amount of food served to the physiology of students; if it is not possible to serve food according to their appetite level, at least their age needs to be considered. Currently, any school menu is designed for students of all grades entitled to free lunch and the weight of the food is the same for all, regardless of age. The present research did not analyze differences in PW, g/student, between students of different ages; however, even without any further statistical analysis, a difference in PW (filtered data, g/student) between primary and upper secondary school students could be identified. The latter had a lower average amount of PW, g/student, which we plan to analyze in the future. Some researchers note that the sex of the child also tends to influence the amount of FW, e.g., Favuzzi et al. [154] found that meal judgment is not the only factor contributing to FW, identifying larger amounts of FW, particularly among females in primary school, even when they expressed a positive opinion about the meal, and they concluded that the increase in FW could be attributed to the surplus portions served to female students.

Steen et al. [155] found a positive correlation between the amount of FW (both plate and serving waste) and the portion size regardless of gender, especially when older students take more food on their plates than they can eat. Often, this is the case of food overproduction (and therefore also overserving) due to the lack of information about the daily number of diners [155]. Our research observed that in S2 and S4, the expected number

of students was often larger than the actual one; therefore, surplus portions were served, and some of them were discarded, leading to higher PW amounts.

Referring to the implementation of FW interventions in schools, it should be noted that in our case, the interventions did not work for several reasons. First, two schools tried single interventions, namely the plate waste tracker in S1 and an awareness and educational campaign in S2.

Malefors et al. [74,114] found that the plate waste tracker intervention in Swedish schools was effective in significantly reducing both PW and serving waste. This tool provided real-time feedback to students on the amount of food they wasted, which not only decreased PW by 37% but also led to a substantial 62% reduction in serving waste as a spillover effect, demonstrating its impact on overall waste reduction in school canteens [74,114]. The installation of the plate waste tracker in 12 schools in Sweden and Germany, featuring a buffet serving style, effectively reduced PW by 17%, significantly lowering environmental impacts and nutrient losses while demonstrating long-term sustainability and cost-efficiency [156]. Undeniably, the research studies by Swedish colleagues clearly revealed the plate waste tracker as a disruption in daily routine [38] and the effect of nudging on the food consumption behavior of students, as the students had such an opportunity because it was self-service catering (buffet meals) in the schools observed. In our research, the effectiveness of the plate waste tracker was short-lived, largely due to the unadaptable catering organization model in S1. This lack of flexibility significantly limits the potential of the plate waste tracker to influence student behavior in the long term. While the initial introduction of the tool may have created a psychological impact, encouraging students to reduce PW temporarily, the inability to align portions with individual needs ultimately undermined its sustained effectiveness. This limitation highlights the importance of integrating adaptable catering practices, such as allowing portion customization or offering self-service options, to fully leverage the benefits of interventions like the plate waste tracker. If this obstacle is overcome, further actions to enhance the tracker's effectiveness include installing multiple devices in canteens to avoid bottlenecks, reducing queues, and ensuring younger children can interact with the tracker without feeling rushed. Simplifying the interface with child-friendly visuals can make feedback more engaging and accessible. Gamified elements, such as class competitions rewarding waste reduction, could further motivate participation. Regular monitoring and feedback loops are essential, while integrating tracker insights into lessons on sustainability and healthy eating can deepen students' understanding and foster mindful food consumption.

Favuzzi et al. [154] did not identify a strong impact of educational intervention on the amount of waste generated in school canteens, indicating that a single educational effort, regardless of its complexity, is insufficient to produce significant changes because after just one educational intervention, both parents and children tend to revert to their habits afterward, which might explain the slight and insignificant difference in waste observed before and after the intervention.

A comparison of two interventions to reduce PW in university canteens by Visschers et al. [137] revealed that providing information about FW alone did not lead to any reduction in waste. However, when smaller servings were offered alongside the informational campaign, PW was reduced by 20%. This suggests that portion control, combined with awareness efforts, is more effective in minimizing FW.

In turn, Liz Martins et al. [157], analyzing PW changes after a 6 h children's nutrition education intervention in three primary schools in Portugal with a pre-served catering model, observed a significant reduction in PW in the short term (one week after the intervention), particularly for soups and main dishes. However, the effect diminished in the medium term (three months after the intervention), highlighting the need for ongoing reinforcement.

In our case, due to the specifics of the research project, it was not possible to implement an intensive educational campaign in S2; therefore, only two lessons were delivered per school year in each class from first to seventh grade, which was insufficient. For instance, in Italy, three classes spent four hours per week for five weeks on a comprehensive awareness program, creating posters on FW, and exploring related topics such as climate change and biodiversity through follow-up activities [158]. In Bari, for the educational intervention targeting children, a flipped classroom method was employed during one month. In total, 361 students in 12 schools first engaged in autonomous learning at home, followed by applying their new knowledge in the classroom under teacher guidance [154]. In our study, the allocation of only two hours of teaching per school year represents a significant research limitation. Such limited exposure was likely insufficient to foster sustained behavioral change, as highlighted by the existing literature that underscores the necessity of comprehensive and continuous educational efforts to effectively influence food waste reduction behaviors. The short duration of the intervention may have made it harder for students to absorb the key messages, which is important for building long-term habits. This limitation likely contributed to the lack of statistically significant reductions in PW in S2, emphasizing the need for more intensive and recurrent educational initiatives to achieve meaningful and lasting outcomes in future interventions.

However, 16 posters with slogans for responsible food consumption and reducing FW were displayed in the S2 canteen as a nudging intervention. Whitehair et al. [159], in their study of 19,046 trays in a university dining operation, concluded that a simple to-the-point prompt-type message reduced FW by 15%. It should be noted that unlike students in our research, university students were able to adjust the amount of food they put on their plate, so they could change their food consumption behavior influenced by nudging. In our research, the students did not have this possibility; therefore, we expected that they would simply start eating better under nudging, but this did not happen because it was impossible to force a child to eat all the food offered if they did not like it, had no appetite, or the portion was too large. Another nuance that should be noted is FW messaging on posters. Nisa et al. [160] assessed FW messaging for households and found that more forceful messages (e.g., "stop waste" or "don't waste") on posters might be ineffective and potentially counterproductive, as they were more likely to trigger psychological resistance compared to softer persuasive messages like "reduce waste", which were perceived as less controlling and authoritative. Of the 16 posters displayed in S2, six had the following slogans: "Be responsible—say no to food waste"; "Use food responsibly! Don't throw it in the garbage!"; "School food is healthy and tasty. Say no to food waste"; "Don't waste, respect food, respect nature, save money"; "STOP wasting food"; and "Respect food. Say no to food waste!". We assume that in this case, there might be a trigger effect on the students.

The organizational changes implemented in S3, including the use of larger plates, extended lunch breaks, and the presence of a supervising teacher during meals, did not yield the expected results; on the contrary, filtered PW g/student amount increased. We are inclined to associate the anomaly of PW increase with the S3 lunch break extension to 30 min, which may have allowed students to buy other food outside the school's free lunch menu, which caused the free lunches served to end up in the garbage.

Despite the fact that one of the widely used FW reduction interventions in out-of-home catering is smaller plates so that food consumers can put less food on their plates [33,161], it should be noted that it is useful under the self-service catering organizational model. However, in Rezekne City schools, including in S3, students are given pre-served main dishes; therefore, using larger plates is beneficial, as it allows students to see clearly and understand the ingredients of the food being served (more engaging for younger students) [27,108,109].

It was difficult for researchers to assess the impact of supervising teachers during mealtimes in S3. The SKOOL report emphasizes that those who supervise students during meals are key to reducing waste, making it essential to provide them with the necessary skills. While it might seem simple, motivating all personnel to participate is challenging. Supervisors need the knowledge and resources to guide students in reducing waste while understanding their preferences and encouraging them to try new foods [158]. School principals, canteen supervisors, and teachers play a crucial role in facilitating, designing, and implementing waste minimization interventions, with the human factor emerging as the most significant element in reducing FW. The lower FW amounts were observed in areas where students had greater awareness, driven by two key factors, namely the integration of sustainable eating behaviors into their routines and the strong focus on sustainability by school managers and teachers [14]. In Liz Martines' study [157], an intervention focused on educating teachers about FW and encouraging their active presence during lunch, implemented in a Portuguese school with a pre-served catering model, demonstrated a better impact in the medium term. It led to a slight but consistent reduction in PW over time, indicating that teacher-focused interventions had more sustained effects in the medium term. During the three months following the start of the intervention, teachers were encouraged to be present during lunchtime as much as possible and to promote waste reduction among students actively.

In our study, the supervising teachers during lunch were class teachers who had not received any prior training on the issue of FW. This could also be regarded as a limitation of our research, which may have limited the effectiveness of the intervention, as the class teachers were not equipped with strategies to reduce FW or encourage sustainable eating habits. Without proper guidance, they may have missed opportunities to influence student behavior, such as promoting the acceptance of new foods or reducing waste. This highlights the need for targeted training and clear protocols for supervisors in future interventions to ensure consistency and maximize impact.

The International Food Waste Coalition report "School Kitchen Organization Optimization Learning (SKOOL report)" has admitted that collaborative efforts are more effective in reducing FW than single ones. For instance, educating students about FW and teaching them simple ways to reduce it in the canteen will yield limited results if meal organization, portion sizes, and recipes remain unchanged [158].

Complex FW-reducing interventions are often seen as more effective than single ones, as FW is influenced by various factors. However, evidence is mixed, with some studies showing positive results from combined messages but lacking clarity on which specific element was effective [33]. To drive significant FW change, a combination of targeted interventions, informed by models such as the MOA framework, should be employed to address specific consumers' behaviors [35].

6. Conclusions

The interventions tested in the present research provide valuable insights into strategies for reducing PW in school canteens, particularly within the Latvian context. The findings demonstrate that specific targeted actions can lead to meaningful reductions in FW, though the effectiveness of the interventions can vary depending on the type of intervention and specific conditions under which they are implemented.

The plate waste tracker intervention in S1 resulted in a statistically significant reduction in PW in the short run, highlighting the potential of technology-driven solutions as a means of nudging students' food consumption behavior through disruptions in their daily routines. The short-term effect can be attributed to the initial curiosity sparked by the installation of the device in the school canteen, which motivated students to try not to leave

uneaten food on their plates. However, the long-term data indicate that this reduction is not sustained, suggesting that while such tools can create immediate impacts, their effectiveness might diminish over time without continuous reinforcement or additional complementary measures.

In S2, the awareness and educational campaign showed mixed results. While this intervention is crucial for fostering long-term behavioral change and raising awareness about the importance of reducing FW, the lack of a statistically significant reduction in PW in both the short and long run suggests that awareness educational efforts alone might not be enough. This finding aligns with previous studies indicating that awareness-raising activities need to be part of a broader, more intensive, and complex approach to be effective.

The intervention implemented in S3, stemming from the specific catering organization model used in Rezekne City schools, included organizational changes such as using larger plates, extending lunch breaks, and involving supervising teachers. However, these changes did not yield the expected reductions in PW. On the contrary, an increase in PW was observed in both the short and long run, and the significance of this difference increased over time, as noted in the cases of both Model 1 and Model 2. This outcome underscores the complexity of FW behaviors and suggests that while changes to the dining environment and schedule are important, they must be carefully designed and monitored to avoid unintended consequences.

We cannot conclusively state that the increase in PW in S3 was caused by the implemented intervention, as this is an internal factor, and the experiment would need to be replicated in other schools to generalize the effect to other schools in Latvia that have a similar free school meal catering model. A similar situation applies to the plate waste tracker intervention in S1, which had a positive impact in the short run, but the experiment should be replicated in several other schools with similar catering models before widely implementing this device.

Reducing PW in Rezekne City schools requires a combination of targeted interventions and structural adjustments. Flexible approaches to portion sizes are essential, as rigid, pre-determined servings often result in increased waste. Customizable portioning practices that account for students' age and appetite can help address this issue. Transitioning to self-service or semi-self-service catering models could reduce the mismatch between servings and consumption by giving students greater autonomy in portion selection. Digital tools for meal planning could enhance efficiency by allowing students or parents to pre-select meals, helping canteens better anticipate demand and minimize surplus food. Comprehensive educational campaigns—such as interactive workshops, farm-to-table programs, and competitions—can foster sustainability awareness and encourage responsible consumption among students. The active involvement of teachers and staff is crucial. Training programs can equip them with strategies to promote sustainable eating habits and model responsible behavior during meals. Enhanced monitoring and feedback systems can track trends in PW, guide menu adjustments, and reinforce waste reduction efforts through regular communication with stakeholders.

Overall, the research has confirmed that reducing FW in schools is a multifaceted challenge that requires a combination of interventions tailored to specific contexts. The variability in results across the schools suggests that a one-size-fits-all approach is unlikely to be effective. The research also highlights the need for further studies to explore the long-term sustainability of the interventions and their adaptability to different cultural and operational contexts. By continuing to refine and test the approaches, stakeholders can develop more effective strategies for reducing FW in schools, thereby contributing to broader efforts to promote sustainable food consumption and achieve the global sustainability goals.

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VI Raksts

Article

Insights into Awareness and Perceptions of Food Waste and School Catering Practices: A Student-Centered Study in Rezekne City, Latvia

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Abstract: A fundamental step to foster a sustainable future is enhancing students' awareness of responsible food consumption. The present research study assessed students' awareness of food waste (FW) issues, attitudes towards school catering and lunch management, and the reasons for plate waste (PW) in Rezekne city schools, Latvia. A survey was conducted in April 2024 involving 944 students in grades 2 to 7 across four selected schools (S1, S2, S3, and S4), provided with state and municipality-funded free lunches. Statistical analysis methods (Mean ± SD, Kruskal–Wallis H test, Mann–Whitney U post hoc test, and Spearman's correlation analysis) were used to analyze the results. The findings revealed limited awareness and knowledge of students about FW issues, and generally indifferent attitude towards FW and school meals. In addition, significant dissatisfaction with the sensory qualities of meals was observed, yet sensory satisfaction did not correlate with FW levels, pointing to broader issues within the catering model. The restrictive pre-served portion system was found ineffective in reducing FW and fostering responsible consumption. A sustainable catering model should empower students to independently choose the type and quantity of food, combining their abilities and motivation with practical actions. These findings provide a basis for strategies aimed at reducing FW and promoting responsible and sustainable food consumption in Latvian schools.

Keywords: student awareness; responsible food consumption; consumer behaviour; food waste; plate waste; student survey; school catering; sustainability

1. Introduction

FW is a global problem having major implications for environmental sustainability, economic efficiency, and social equality [1,2], thereby exacerbating hunger, overexploiting natural resources, and contributing to greenhouse gas emissions [3]. According to the World Food Programme (WFP) [4], approximately a third (1.3 billion tonnes) of food produced annually for human consumption, with a monetary value of USD 1 trillion, is lost or wasted in the food supply chain (FSC). This quantity of food could potentially feed 2 billion people, which is twice the current number of undernourished people worldwide. In addition, FW is a major contributor to carbon dioxide emissions [4].

Food loss and FW in the FSC are distinguished based on the stage at which they occur. Food loss occurs during the first three stages of the FSC—production, handling

and storage, and processing—due to infrastructure limitations, environmental factors, and quality or safety standards, resulting in a reduction in the weight of edible food. In contrast, FW occurs in the final two stages—distribution and consumption—when food originally intended for human consumption is discarded, whether still edible or spoiled at the time of disposal [5–8].

The amount of FW in the FSC varies from country to country and is affected by factors such as income levels, urbanization, and economic growth [7,9]. In developing countries, FW is a major problem at the production and distribution stages [10,11], whereas in developed countries it is produced mostly at the consumption stage, including households and food service providers [7,11–14]. The European Union (EU) produces almost 57 million tonnes of FW annually, representing an economic loss of EUR 130 billion annually [15,16]. Research findings for the period 2019–2021 showed that 46% of FW in the EU was produced at the consumption stage [17–19]. In 2021 in the EU, according to Eurostat [16], FW per capita was 131 kg, with households (70 kg/capita) and food service providers (12 kg/capita) accounting for the largest share, totalling 63% of the total FW in the entire FSC [16]. In 2022 in the EU, FW from households accounted for 54% (32 million tonnes of fresh mass), while from restaurants and food service providers—11% (below 7 million tonnes of fresh mass) [16], which indicates the need to focus waste reduction efforts on the consumption stage.

To foster sustainable food systems, in 2015 the United Nations (UN) set the Sustainable Development Goals (SDGs) for 2030, of which Goal 12 focuses on responsible production and consumption, with Target 12.3 aimed at halving per capita FW at the retailer and consumer stages by 2030, while reducing food losses at the production and supply stages. This initiative is expected to increase food security and contribute to a more resource-efficient economy [20,21]. FW is perceived very seriously in the EU, and the EU Member States are committed to achieving UN Goal 12 [22]; however, the progress has been hampered by the lingering effects and devastating impacts of the COVID-19 pandemic, environmental pressures from the climate crisis and geopolitical tensions, so that the world is seriously off track in its efforts to halve FW and food losses per capita by 2030 [23].

Encouraging responsible consumption practices is key to sustainable development (SD) [23], which indicates the need to develop such practices in individuals from an early age, and, in this respect, educational initiatives play a key role in reducing FW in the EU [24,25]. In this sense, schools are catalysts for shaping the habits and behaviours of future generations [26]. The schools are a place not only to provide nutrition education and promote healthy eating habits but also to lead by example through school meals [27,28].

Schools have the potential to deal with societal challenges by educating students who can act as agents of change at home and in society [29,30]. Raising awareness about FW and promoting sustainable consumption practices can help to change consumer behaviour [31]. In recent years, FW at school has received much attention, with current research focusing mainly on quantifying the amount of FW, e.g., measuring PW [32–34], assessing environmental impacts, and identifying nutrient losses in school meals [35], analyzing factors influencing food and PW in schools [33,36,37], testing interventions and prevention strategies of FW and PW [34,38,39], developing and testing various tools to prevent FW and PW [40–42] and, while common, there is more research on students' knowledge and perceptions of FW issues and how they influence their behaviour [43–45]. However, while problems with FW and its reduction and the role of consumers in tackling them have been widely researched and documented globally, the authors believe that there is a lack of relevant national research. Tackling a global problem, e.g., FW, requires a deep understanding of its aspects in different contexts, including geographical locations and consumption patterns. Such research is important to gain a deeper understanding of

the particular context so that patterns and actions can be identified which can ultimately contribute to tackling the problem on a broader, global scale.

As an EU Member State, Latvia is involved in EU-scale initiatives to reduce FW in all industries and, just like the EU, under Sustainable Development Goal (SDG) 12, Target 12.3, is committed to halving per capita FW by 2030 [46]. In this respect, a number of activities have been implemented at the national level so far, including the adoption by the Government of the Action Plan for the Transition to a Circular Economy by 2027 [47], the mandatory sorting of organic waste as of 1 January 2024 [48] as well as global education or education for SD have been set as an important aspect of development and cooperation policy of Latvia, thereby supporting activities that promote public awareness of sustainability, including responsible consumption [46].

In addition, Latvia is also implementing a number of initiatives to reduce FW, including raising public awareness about reducing FW, e.g., the international Eco-school Programme implemented by the Environmental Education Foundation, which has successfully implemented FW reduction initiatives in many Latvian educational institutions, as well as the association Green Liberty, which launches and participates in various waste reduction projects (both food and industrial) and develops initiatives to improve the environment and the quality of life [49], research is performed on FW and PW in schools [38,40,50], as well as ICT solutions are being developed to tackle the FW problem in schools [40,41], etc.; however, no specific research has been conducted in Latvia to assess students' understanding and knowledge of FW issues. Existing research in Latvia primarily focuses on broader institutional or household levels [51–53], leaving a gap in understanding students' role in FW reduction. Studies from other countries have explored student perspectives on FW, including survey-based assessments of awareness and behaviour among university students in China [43] and Indonesia [54], attitudes and self-reported food waste habits among Polish students [55], and factors influencing FW behaviours in educational settings [45,56]. However, the extent to which Latvian students are aware of and knowledgeable about FW remains unexplored. Such research is important to establish the foundational baseline for addressing the issue, as children play a key role in shaping future attitudes and habits towards food consumption and sustainability. Assessing their awareness and knowledge can help to develop more effective initiatives and strategies that can promote responsible food consumption behaviour from childhood, contributing to long-term FW reduction in schools and beyond.

The present study aims to identify and assess students' knowledge and awareness of FW issues, their attitudes towards school catering and lunch management, as well as identify the reasons for PW in city schools in Rezekne, Latvia. The study put forward the following hypotheses: H1. Students from Rezekne city schools have insufficient knowledge and understanding of FW and its impact on sustainability; H2. The current catering model in Rezekne city schools is unsustainable and does not promote responsible food consumption by students.

The structure of the manuscript is as follows. Section 2 presents a literature review, outlining key theoretical and empirical insights into school catering management, FW in schools, students' awareness of FW, and the role of behavioural economics in food consumption. Section 3 details the materials and methods, focusing on catering management in Rezekne city schools and the student survey. Section 4 presents the results, structured across four dimensions of the questionnaire. Section 5 discusses the findings of the existing literature and policy implications. Finally, Section 6 concludes the study by summarising key insights and offering recommendations for improving FW management in school catering.

2. Literature Review

2.1. Management of Catering in Schools

According to a UN report, more than 1 billion people worldwide suffer from obesity: 650 million adults, 340 million adolescents and 39 million children [57], while 828 million people suffer from hunger [58], and more than 42 million people in the EU cannot afford a quality meal every day [15,16,59].

School catering plays a crucial role in contributing to the health, education and overall development of children, especially in vulnerable and marginalised communities [60]. According to a WFP report [61], which compiled data from 176 countries, 418 million children received school meals in 2022, an increase of 30 million compared with 2020, whereas 153 million children, unfortunately, struggled with hunger in 79 countries; in low-income countries, the number of children receiving school meals decreased by 4% [61]. In some countries, school meals not only reduce unequal access to food but also help to fight hunger [62], and in the context of current global crises, governments around the world have made school catering programmes a top priority, as they are considered a highly effective and affordable solution to prevent hunger among children and ensure access to education, health and nutrition for them, especially for those from vulnerable families [60].

The management of school catering varies considerably between countries, as each country has its own set of regulatory frameworks and policy documents to ensure that school catering meets health standards and cultural expectations while also addressing food safety problems [63,64]. Therefore, the process of management of school catering tends to vary, as some components of catering might vary, e.g., the way food is served, the menu, food placement on the plate, portion size, nutritional value of the meal and even the time of the lunch break. The dominant approaches to managing the catering process in schools are self-service and pre-portioned meals. The self-service approach, which is common in countries such as Sweden and Finland, allows students to choose the ingredients and portion size of the meal according to their preferences [34,65,66]. It has been found that if giving students choice, this approach reduces the amount of PW and satisfies their diverse nutritional needs, preferences, and appetites [33,67–69]. However, this approach also requires close supervision by teachers or kitchen personnel to ensure that students consume a balanced diet and appropriate portion sizes. The pre-proportioned meal approach, which, like in Latvia, is common in countries such as Brazil, Italy and France, ensures that each student is served a certain portion before the lunch break [70–73]. This approach ensures that meals meet the strict nutritional requirements and are the same for all students [67]; however, it limits the students' autonomy in choosing the type and quantity of food, which affects their overall satisfaction with the meal and thus increases PW [12,74].

Funding models for school catering also vary across European countries—some countries provide free meals for all students, while others combine public support and parental contributions [75]. Some countries implement income-adjusted support programmes, e.g., the Education and Participation Package in Germany [76,77]. Similarly to Latvia, some countries, such as Sweden and Finland, have introduced a national free lunch programme [78]. In Norway, in contrast, school catering is not regulated, and it is common for students to eat food brought from home, with bread being the key component; however, like Latvia, Norway has a state-funded support scheme for fruit, vegetables, and school milk in primary and secondary schools [66,78]. Dutch schools are still transitioning from eating lunch at home to eating lunch at school to provide an opportunity to increase the quality of nutrition for children [79,80].

Several research studies confirmed that the role of school catering goes beyond simply providing nutrition and is crucial in promoting healthy behaviours and shaping long-term

habits, as the children spend a lot of their time at school [69,81]. Some research studies have found that if students eat meals together with their peers and teachers, it develops and strengthens their socialisation skills, builds their experience in table culture, and reinforces their positive behaviours throughout the day [82].

2.2. Food Waste in Schools

Although school catering provides significant support for the educational process, thereby contributing to healthy nutrition and fighting hunger, its effectiveness is undermined by FW. While free and quality meals are provided in schools in many parts of the world, not all students consume them responsibly, thus producing significant amount of FW [78]. School canteens are part of the last stage of the FSC, i.e., food consumption [7,12–14,83–85], which involves households, restaurants, and food services (including school canteens) and which produces the most FW.

The problem of FW in schools is receiving more attention worldwide [25,33–35,38,43,86]. In the last decade, school canteens have also gained significant public and research interest as a unique setting where education and catering come together, as food is served, consumed, and wasted, thereby revealing consumer behaviour and resource management [13,87]. Schools are recognized as a significant source of FW [74,88,89]. Several research studies have found that schools produce a large amount of FW, with the largest source of waste being PW [12,33,34,90,91]. The research conducted has confirmed that solutions are needed to reduce FW in schools, which would result in economic, social, and environmental benefits, as responsible food consumption and waste reduction are the social responsibility of every educational institution [92,93].

School catering programmes play an important role in the global food system [94]; therefore, combating FW in schools can provide multiple benefits in overall efforts towards SD and the achievement of the SDGs [95].

From the SD environmental perspective, decreasing FW in schools can reduce the consumption of resources such as water, electricity, and land that are needed to produce, transport, and dispose of food and reduce the total ecological footprint [27,96,97]. Therefore, reducing FW in schools contributes to achieving SDG 12 (Ensure sustainable consumption and production patterns) and SDG 13 (Take urgent action to combat climate change and its impacts) [21], while decreasing the environmental burden caused by food systems as well as preserving biodiversity and natural resources [98].

From the economic perspective, FW in schools causes significant economic losses for all FSC actors [7], resulting in inefficient use of state and local government funding that covers free school lunches. Several research studies have found that relatively large economic losses arise from wasting school lunches, e.g., in the Swedish catering industry, approximately 20% of the food served ends up in waste [34], in Italian schools, 20–29% or $1/3$ of the food served is wasted, and FW accounts for 6–11% of the total cost [13]. In Latvia, a study conducted in 2020 revealed that 29% of the total amount of food served in schools in Rezekne city ended up in waste, which in monetary terms was approximately EUR 84,000 per year [33], thereby negatively affecting the economic aspect of sustainability. By reducing the amount of waste, the saved resources could be used to increase the quality of meals or support other initiatives.

FW also significantly impacts the social aspects of SD, as a large amount of food is wasted worldwide, including in schools. Accordingly, reducing FW can improve food security, promote social equity, and develop sustainable and healthy consumption practices [95].

The problem of FW in educational institutions is multifaceted, yet schools play a vital role in addressing the complex relationship between FW and nutrition by offering essential

nutrition through school meals, educating young consumers and influencing future habits regarding healthy eating and sustainability [99].

2.3. Students' Awareness of Food Waste

Some research studies have found that students lack understanding and knowledge of FW issues, which is the cause of a lack of responsible food consumption, thereby not contributing to the reduction in FW [15,100–102]. Based on an extensive literature review, Lonska et al. [33] have established that students skip meals because they are unaware of the environmental damage caused by FW, as well as the associated ethical and socioeconomic consequences, and this behaviour might be facilitated by a lack of knowledge about the origin of food and food production [33]. In this respect, schools as educational institutions are the primary place where students can develop sustainable habits and behaviours from an early age, thus increasing their awareness of FW and the need to reduce it. By educating students about healthy and sustainable food practices, schools can serve as an important tool in creating and reinforcing values that promote responsible consumption and inspire the students to apply the practices beyond schools, thus also influencing their families and the wider community [12,103].

It has been found that various initiatives aimed at reducing FW and PW can increase students' awareness and knowledge of the FW problem. For example, education and awareness campaigns like the "Food Education and Sustainability Training (FEAST) Programme", which was designed to promote sustainable food practices and nutrition education in schools, focusing on increasing fruit and vegetable consumption by children, while improving their food-related knowledge, behaviour and skills, including their awareness of FW [104], the "Clean dish, clean conscience!", which was a cheap and simple campaign to increase consumer awareness about PW, highlighting the link between FW and personal behaviour [105], the "Clean Your Plate", which is widespread in Chinese universities, with the aim of motivating students to eat as much as possible and suggesting that wasting food is bad [43], etc. Interventions aimed at reducing FW have been found to be particularly effective in primary and secondary schools, and if integrated, for example, into lessons on the SDGs [106]. However, some research studies have found that interventions aimed at reducing FW in primary and secondary schools can be effective in the short term, thereby increasing the students' awareness and changing their behaviour immediately after the intervention, yet the interventions need to be regularly reviewed and integrated into the learning environment to maintain the long-term effect [25,38]. Limited resources, e.g., funding and expertise, which need to be considered when designing educational initiatives, can also be an obstacle to the successful implementation thereof [106]. Awareness and understanding of FW issues is an emerging area of research with significant potential for shaping future consumption patterns and promoting sustainability because educating students and the public has a much broader impact, as consumers have an opportunity to evaluate and review their consumption habits and make more sustainable choices after becoming aware of the problem of FW [107].

2.4. Behavioural Economics: Understanding Food Consumption

Consumer behaviour has been researched and analyzed for over 50 years. Research on responsible food consumption at schools is based on a variety of theoretical frameworks that give unique insights into the factors and causes that influence FW behaviour. The earliest foundational theories include the Norm Activation Model (NAM), developed by Schwartz [108] with the aim of examining how personal moral norms activate awareness of consequences and a sense of responsibility [108], and the Theory of Planned Behaviour (TPB), developed by Ajzen [109,110], which initially aimed to understand and predict

behaviour in various areas, while later to explain how beliefs, attitudes, and behavioural intentions influence an individual's actions [109,110]. Over time, theoretical frameworks have evolved, thereby revealing an increasingly complex and nuanced understanding of the various interrelated factors that influence individual behaviour, e.g., the Nudge Theory, introduced by Thaler and Sunstein [111], that focuses on how to influence individuals' behaviour in a predictable way without restricting their freedom of choice [111]. Similarly, the Motivation–Opportunity–Ability (MOA) framework, introduced by Ölander and Thøgersen [112], reveals that individuals' food consumption behaviour is influenced not only by their motivations but also by their abilities as well as opportunities available in their environments, and used appropriately [112]. This framework suggests a comprehensive approach to understanding behaviour by examining the interaction of three main components (motivation, opportunity, ability) [113,114]; as concerns consumer FW, motivation refers to an individual's willingness to take actions that reduce FW, which is influenced by internal factors such as awareness and attitude and external factors like social norms, while opportunity involves the availability and accessibility of resources and materials necessary for FW prevention, including infrastructure, technologies, time, schedule, etc. And ability represents the skills and knowledge required to perform actions related to FW prevention [113]. Both models are widely used nowadays, thereby giving valuable insights into behavioural changes.

Behavioural economics is a valuable tool for understanding food consumption behaviour, because unlike traditional economic models that recognise rational consumer behaviour, behavioural economics emphasises the role of psychological, cognitive, social, and emotional influences in decision-making [115–117]. Ogaki and Tanaka [117] believe that behavioural economics goes beyond the traditional structure by incorporating insights from related subfields, including neuroeconomics, cultural and identity economics, and the economics of happiness, thus allowing for a deeper understanding of how environmental, cultural, and psychological factors shape economic decisions [117]. In the context of food consumption, one of the main priorities is to promote responsible and sustainable consumption behaviour and change habits to reduce FW [12,118,119]. However, to influence and change the behaviour of consumers, including students, it is first necessary to understand the factors and reasons that influence their decisions, including those leading to FW. In this regard, a student survey is one of the tools providing critical insights into students' perceptions, attitudes, and habits related to school meals.

Some research studies on responsible food consumption highlight the complexity of FW behaviour [54,120–123], and, according to Mganga et al. [54] and Quested et al. [121], there is no framework or system that can fully explain this concept as a unified system [54,121], as it is affected by several factors, including the environment in which a particular behaviour occurs, individuals' knowledge about FW, personal attitudes, habits, societal norms, ability to control one's actions, etc. [54,121,124]. Either way, the amount of FW in schools relates to consumer (student) behaviour and habits [125,126] and is primarily considered a behavioural problem, determined by several interrelated and often contradictory factors significantly affecting behavioural outcomes [120,122,123].

Based on theories on individual behaviour, consumers can change many of their habits that contribute to FW, e.g., making smaller meals [103], yet changing consumer behaviour is challenging, especially in the field of food consumption where established routines, habits and cultural norms play a key role [25]; in addition, the ability to reduce FW is also affected by various external factors, including policy frameworks and lifestyles [103]. FW is, therefore, the final result of a complex decision-making process centred on individual resource consumption [127]. For the above reasons, interventions during school years when values and habits are still being shaped are likely to be more effective than in

later adulthood, thus highlighting the important role of education [25,128]. Therefore, reducing FW requires cooperation between all actors in the food system, with educational institutions playing a central role in promoting responsible consumption behaviour from a young age [94,103].

3. Materials and Methods

3.1. Case Study Background

3.1.1. Food Waste Research Projects in Rezekne, Latvia

Since 2021, the RTA research team has been addressing the issue of FW in school catering. The research project "E-mentor as a Transformation Tool for Ensuring Zero-Waste Food Consumption in Educational Institutions" (No. lzp-2020/2-0115) (E-mentor), funded by the Latvian Council of Science, analyzed PW in seven schools in Rezekne. The findings led to recommendations for stakeholders on how to reduce this waste. Notably, prior research in Latvia had not specifically focused on zero-waste food consumption in educational institutions, particularly in relation to PW. This was the first attempt to understand how much PW is generated by Rezekne city schools. The research study revealed that a significant amount of PW was generated in the surveyed schools: an average of 178 g per student per day, or 28.75% of the food served (including beverages) [33]. After the E-mentor project, it became clear that research in this area needs to be continued, and future research studies should focus on practical activities aimed at reducing FW.

At the beginning of 2023, a second research project "Testing Interventions and Developing a Knowledge-based Recommendation System to Reduce Plate Waste in School Catering in Latvia" (No. lzp-2022/1-0492), funded by the Latvian Council of Science, was launched. The primary aim of this project was to implement and evaluate interventions designed to reduce PW in Rezekne city schools. Three interventions were implemented: S1—a PW tracker, S2—an awareness and educational campaign, and S3—organizational changes (larger plates, extended lunch breaks, and teacher supervision during the lunch breaks). S4 served as a control school. PW was measured at three intervals: pre-intervention, short-term post-intervention, and long-term post-intervention [38]. In parallel, a survey was conducted among 2nd–7th grade students (excluding 1st graders due to their insufficient reading skills) to explore the subjective causes of PW, investigate students' eating habits, and collect feedback on the school catering process. The survey was designed to offer valuable insights into students' perspectives, helping to understand better the factors contributing to PW in schools. The general research steps can be seen in Figure 1.

Sept'23	Oct'23 – Apr'24	Dec'23	Apr'24
Pre-intervention survey; Pre-intervention quantification of PW in all four schools	Implementation of interventions in the test group schools	1st post-intervention quantification of PW in all four schools	2nd post-intervention quantification of PW in all four schools; **Post-intervention survey**
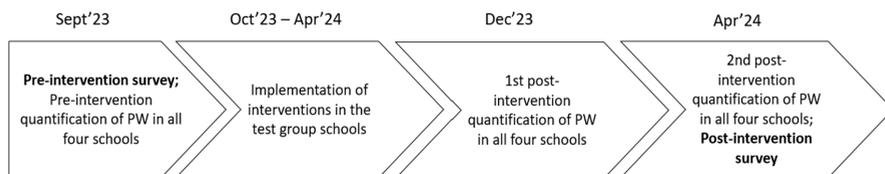
Figure 1. Overview of the research steps (compiled by the authors).

3.1.2. Management of the Catering Process in Rezekne City Schools

Following legal norms, such as the Cabinet regulation No. 614 Procedure for Calculating, Allocating, and Utilizing State Budget Funding for Student Meals [129], along with the annual directive from the Rezekne City Council's Education Board on student catering, students in grades 1–7 in Rezekne city schools (Latvia) receive free lunches funded by the state (grades 1–4) and the local municipality (grades 5–7).

In the school canteens in Rezekne, the distribution of free lunches is partially self-service. Shortly before lunch, school canteen personnel prepare tables for each class with portioned meals according to the expected number of students. This includes placing main courses (a combination of staple foods and meat) on individual plates and drinks in separate glasses for each student. In some schools, vegetables are served on individual plates, while in others, they are provided in shared dishes for each class. Soups are served in common pots at the tables, with portions determined based on the number of students using standardized serving sizes. Bread and glazed cottage cheese are also provided in shared containers, portioned according to the number of students [33,38,41].

3.2. Survey Questionnaire

A structured survey was conducted among students in grades 2–7 in the four schools involved in the project to identify and assess their knowledge about the negative impact of FW, attitudes towards healthy eating habits, opinions on the sensory qualities of food served in the school canteens, and evaluations of the management of catering in the school canteens, as well as to receive feedback for improving the catering process.

The survey method is considered the backbone of social science research, as it is one of the most commonly used methods in all fields of social science research [130]. This method allows a large number of respondents to be questioned simultaneously, as well as to obtain information in a format that makes it easy to make statistical aggregations and calculations [131].

A questionnaire was designed by the project researchers, which included questions covering four dimensions:

I   The demographic profile of respondents.
II The environmental dimension—basic knowledge about school food, FW and its negative impacts;
III The personal dimension—students' individual attitudes toward FW and their personal food consumption habits;
IV The organizational dimension—students' opinions on the sensory quality of food (taste, smell, appearance, temperature) and their assessment of the organization and management of the school canteen.

The questionnaire included both open-ended questions, allowing respondents to give free-form answers, and structured closed-ended questions with multiple-choice answers.

To assess the appropriateness of the questions and answer options, the questionnaire was validated by face-to-face interviews with 28 students (7 per school from each grade) in May 2023. Each question was discussed with the students to identify whether the target respondents understood the questions and answer options and determine the time required to complete a questionnaire. As a result of these interviews, some questions were slightly paraphrased for clarity, but no significant structural changes were made. Additionally, it was decided to exclude 1st grade students from the study, as their reading and writing skills were not yet sufficiently developed. This required extensive explanations for each question, which significantly increased response time and resource usage.

A pre-intervention survey of students was conducted at the end of September 2023. Students in grades 2–4 completed paper questionnaires, while those in grades 5–7 completed digital ones. Access to the e-survey was provided via the project website by entering a password. This approach was selected considering the digital skills of younger students as well as the availability of computer labs in the schools. A post-intervention survey was conducted in April 2024. To avoid potential data errors, e.g., inconsistencies between digital and paper formats, identical and detailed instructions for questionnaire completion were given to all the participants, regardless of the format of the questionnaire, and the structures

of the digital and paper questionnaires were designed exactly the same, including the order, format, and answer options of the questions. This approach ensured that the data from both groups were comparable and reliable, no notable differences in response rates or answer completeness were observed between the two questionnaire formats.

The pre-intervention survey data, collected at the beginning of the school year, were not included in the main analysis because the students, particularly those in lower grades, lacked sufficient experience with school meals after the summer holidays and were unable to provide informed evaluations. While conducting the surveys, researchers observed that many students expressed uncertainty and hesitated in their responses, often stating that they were unsure how to answer certain questions. The post-intervention survey data, collected during the second half of the study year, provided more reliable insights, as the students had gained sufficient experience with school catering during the study year. However, pre-intervention survey data were included in the correlation analysis to meet the sample size requirement for Spearman's correlation.

3.2.1. Sample Selection

The survey sample consisted of students aged 7–16 in grades 2–7 from four selected schools in Rezekne city. The selection of schools was based on data on the school catering ecosystem and the amount of PW identified by the E-mentor project [67]—the selected schools were of equivalent quality to ensure the quality of the experiment, i.e., all the schools operated under a similar catering model with partly pre-served meals, providing a uniform context for evaluation, as well as the willingness of school administrations to cooperate was taken into account. The selection of classes was based on the fact that in Rezekne city, free lunches for grades 1–7 were funded by the state and the municipality. As mentioned above, the survey did not include 1st graders because it was found that during the validation of the questionnaire, their reading and writing skills were not yet good enough, and they needed a long time to understand each question.

All the students completed the questionnaires in the presence of their teachers and project representatives so that they could explain the nature of the questions, if necessary, especially for primary school students.

3.2.2. Ethical Considerations

The heads of the schools involved in the project informed parents of the students about the project and their anonymous and voluntary participation in the experiment and survey via the online school management system "E-class". Due to the fact that no personal data from the students were collected and processed during the project and their participation was completely anonymous, the students were not exposed to any physical or emotional risk during the experiment, and due to the fact that the school administrations agreed to participate in the project and gave permission for the implementation of the project activities, no written consent was required from the parents for their children's participation in the project activities. All ethical aspects of the research study were reviewed and approved by the Scientific Council of the Research Institute for Business and Social Processes at the Rezekne Academy of Technologies (excerpt from the minutes of meeting No. 9, dated 25 April 2023).

3.2.3. Data Analysis

Microsoft Excel and IBM SPSS v.29, a predictive analytics and statistical analysis software package, were used to process the survey data and results. Descriptive statistics and statistical analysis were employed to analyze the survey results.

To assess whether there were significant differences in opinions on the different issues between the different student groups, the answers were measured on a 5-point Likert

scale, and both a descriptive statistics test (Mean ± SD) and a Kruskal–Wallis H test were conducted. The descriptive statistics test provided an overview of the central tendency and variability in student answers, while the Kruskal–Wallis H test evaluated the significance of differences between the groups. This nonparametric test is appropriate in cases where data do not meet normality assumptions and comparing more than two groups is necessary. A Kruskal–Wallis H test operates on ranked data rather than raw scores, which means that all responses are first ordered from lowest to highest across groups, with ranks assigned accordingly. By summing the ranks within each group, the Kruskal–Wallis test determines if observed differences are statistically significant [132], making it well-suited for Likert scale responses. For the groups that showed significant differences in the Kruskal–Wallis test ($p < 0.05$), a Mann–Whitney U post hoc test was additionally performed to make pairwise comparisons and identify specific pairs of groups with significant differences [132]. By examining the pairwise differences, it was possible to better understand which groups of students had different opinions on the issues. To maintain the statistical accuracy and control of the overall Type I error rate, significance values were adjusted by the Bonferroni correction for multiple tests.

Spearman's correlation analysis was used to determine a relationship between FW and students' satisfaction with meal sensory properties. This test was performed because the data analyzed represented PW in grams per student, and student Likert scale (1–5) answers were expressed in mean value (Appendix A, Table A1). The PW data were filtered by excluding waste data on soup, salad, and bread served in common containers, as well as untouched meal portions due to differences in catering management (S1, S2, S3 differed from S4, see Figure 2).
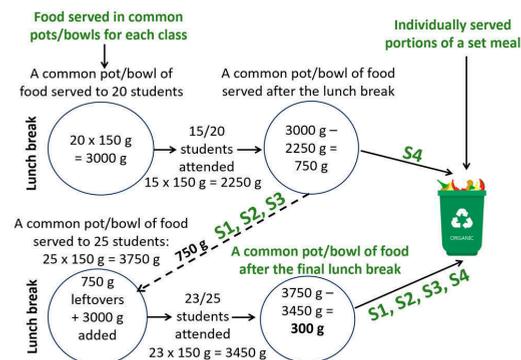
Figure 2. Example of PW generation in S1, S2, S3, and S4 (developed by the authors [38]).

The respondents' answers to the questions were grouped by school and by grade. Each answer was given a rating: Always—5, Often—4, Sometimes—3, Rarely—2, and Never—1. Next, the mean rating was calculated. Since the Likert scale data represented ranked categories rather than continuous measurements and might not follow a normal distribution, Spearman's correlation was more suitable for analyzing non-parametric relationships [132,133]. This method allowed authors to examine the association between the students' perceptions of meal sensory characteristics and the amount of PW. Correlation analysis involves hypothesis testing to identify a relationship between two variables. The initial assumption or null hypothesis indicates that there is no significant relationship between the variables [132,133]. The strength of a correlation is indicated by the correlation coefficient (r), which is between −1 and 1, and although the value expressed might vary slightly, depending on the test coefficient, it is generally accepted that r ≥ 0.5 or r ≤ −0.5

indicates a strong relationship, between ±0.3 and ±0.5 a medium relationship, and between ±0.1 and ±0.3 it shows a weak relationship [132]. Statistical significance (*p*-value) was also determined. If the *p*-value is below the significance level ($p < 0.05$), the null hypothesis is rejected and the variables are correlated [133,134].

4. Results

4.1. I Dimension. The Demographic Profile of the Respondents

On 1 September 2024, the total number of students in grades 2 to 7 in the four Rezekne city schools was 1150. A total of 944 students took part in the survey, which represented approximately 82% of the general population, which meant that the results could be confidently generalized to the entire population of grades 2 to 7 students in the schools. The demographic profile of the respondents is presented in Table 1.

Table 1. Distribution of the total respondent sample, n and %, (n = 944) (compiled by the authors).

Category	Group	Number of Respondents	% of Respondents
Gender	Female	453	48%
	Male	491	52%
Grade	2	172	18%
	3	158	17%
	4	150	16%
	5	176	19%
	6	134	14%
	7	154	16%
Age	7	5	0.5%
	8	117	12.4%
	9	173	18.3%
	10	154	16.3%
	11	151	16.0%
	12	162	17.2%
	13	137	14.5%
	14	38	4.0%
	15	6	0.6%
	16	1	0.1%
School	School 1	293	31%
	School 2	239	25%
	School 3	196	21%
	School 4	216	23%

Table 1 data show that the distribution of the respondents was fairly balanced across all the categories and groups, thereby ensuring that the sample was representative and that the survey results were not disproportionately affected by the disproportionate dominance of any group.

4.2. II Dimension. Knowledge and Awareness (Environmental Dimension)

To identify students' awareness and knowledge about school food, FW, and its negative impacts, the following questions were included in the questionnaire (see Table 2).

Table 2. Survey questions and answer options about food waste and school food (compiled by the authors).

Question No.	Question	Answer Options
Q1	What do you think food waste is? (it was possible to mark multiple answers)	(1) Food packaging (2) Food that has spoiled (3) Peels, bones (4) Food that remains uneaten on the plate
Q2	Do you agree that school food is healthy?	(1) Yes (2) Rather yes (3) I don't know (4) Rather no (5) No
Q3	Do you agree that food waste has a negative impact on the environment?	
Q4	Do you agree that school lunches cost money? If you don't eat them, the money is "thrown away"?	
Q5	Where do you think the plate waste goes? (it was possible to mark multiple answers)	(1) The canteen personnel take it home (2) It is thrown in the trash or down the drain (3) It is fed to pets (4) It is fed to ducks by the Rezekne River (5) It is used to produce bioenergy (6) I don't know

An analysis of the respondents' answers to Q1 "What do you think food waste is?" is available in Figure 3.
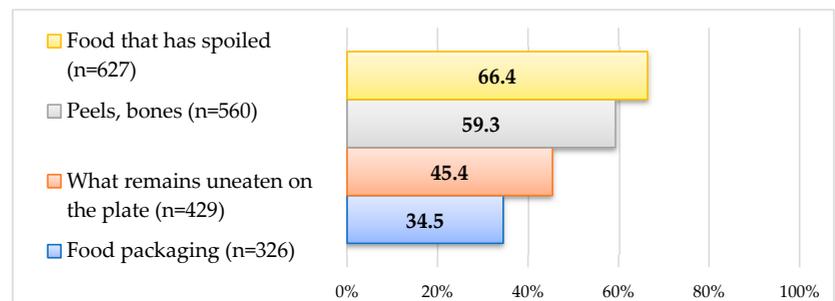
Figure 3. Distribution of respondent answers to Q1 "What do you think food waste is?", % (n = 944) (compiled by the authors).

As shown in Figure 3, the students mainly associated FW with food that had spoiled (66.4%) and inedible food parts such as peels and bones (59.3%), almost half (45.4%) of the students associated uneaten food that remained on their plates with FW, and about $^1/_3$ associated FW with food packaging.

An analysis of the respondents' answers to Q2 "Do you agree that school food is healthy?" is available in Table 3.

The data in Table 3 show that more than half of the respondents (61.3%, Yes + Rather yes) believed that school food was healthy, a quarter could not answer this question, and a small proportion (14.6%) believed that school food was unhealthy.

A descriptive statistics test (Mean $\pm$ SD) and a Kruskal–Wallis H test were performed to test whether there were significant differences in opinions on whether school food was healthy between different groups of students. The results revealed that there was a significant difference between boys and girls; the boys had a higher belief that school food was healthy and that there were statistically significant differences ($p < 0.001$) in answers

between classes. Therefore, an additional Mann–Whitney U test was performed to identify pairs with significant differences (Figure 4).

Table 3. Analysis of the respondents' answers to Q2 "Do you agree that school food is healthy?", (n = 944) (compiled by the authors).

Question	Multiple Choice Answers	Values	Distribution of Respondent Answers, % (n = 944)
Do you agree that school food is healthy?	Yes Rather yes I don't know Rather no No	5 4 3 2 1	5 — 27.1 4 — 34.2 3 — 24.1 2 — 8.7 1 — 5.9

Variables		Mean ± SD	Kruskal–Wallis H test *p*-value	Statistical significance
School	School 1 School 2 School 3 School 4	3.67 ± 1.12 3.79 ± 1.08 3.59 ± 1.24 3.64 ± 1.14	0.396	$p > 0.05$ Group results are not statistically significantly different
Grade	2 3 4 5 6 7	4.19 ± 1.02 3.94 ± 0.98 3.75 ± 1.13 3.63 ± 1.13 3.07 ± 1.05 3.35 ± 1.15	<0.001	$p < 0.05$ Group results are statistically significantly different
Gender	Male Female	3.79 ± 1.17 3.56 ± 1.08	<0.001	$p < 0.05$ Group results are statistically significantly different

Figure 4. Pairwise comparisons of the responses to question Q2 "Do you agree that school food is healthy?" in a group of grades using Mann–Whitney U test results (compiled by the authors). Each node shows the grade and sample average rank of grade.

The Mann–Whitney U test results (Figure 4) revealed several pairs of classes with statistically significant differences. It should be noted that the answers of students in grades 2 and 3 were significantly different from those of students in grades 6 and 7. The younger

grades were more confident that school food was healthy, while the older grades were more sceptical.

An analysis of the respondents' answers to question Q3 "Do you agree that food waste has a negative impact on the environment?" is available in Table 4.

Table 4. Analysis of the respondents' answers to question Q3 "Do you agree that food waste has a negative impact on the environment?", (n = 944) (compiled by the authors).

Question	Multiple Choice Answers	Values	Distribution of Answers of the Respondents, % (n = 944)
Do you agree that food waste has a negative impact on the environment?	Yes Rather yes I don't know Rather no No	5 4 3 2 1	

Variables		Mean ± SD	Kruskal–Wallis H test *p*-value	Statistical significance
School	School 1 School 2 School 3 School 4	3.35 ± 1.21 3.53 ± 1.29 3.41 ± 1.24 3.43 ± 1.23	0.285	*p* > 0.05 Group results are not statistically significantly different
Grade	2 3 4 5 6 7	3.49 ± 1.34 3.67 ± 1.14 3.56 ± 1.29 3.49 ± 1.21 3.28 ± 1.11 3.02 ± 1.21	<0.001	*p* < 0.05 Group results are statistically significantly different
Gender	Male Female	3.42 ± 1.27 3.43 ± 1.21	0.990	*p* > 0.05 Group results are not statistically significantly different

The data in Table 4 show that although almost half of the respondents (47.8%, Yes + Rather yes) agreed that FW had a negative impact on the environment, a significant proportion (21.7%) disagreed, and an even larger proportion (30.5%) could not answer this question. This indicated the different levels of awareness and knowledge of the respondents about the environmental impacts of FW.

A descriptive statistics test (Mean ± SD) and a Kruskal–Wallis H test were performed to test whether there were significant differences in opinions between different groups of students on whether FW had a negative impact on the environment. The results showed that there were no statistically significant differences in opinions on the negative environmental impact of FW between the schools and between the genders. However, the opinions differed significantly between classes (*p* < 0.001); therefore, an additional Mann–Whitney U test was performed to identify pairs of classes with statistically significant differences (Figure 5).
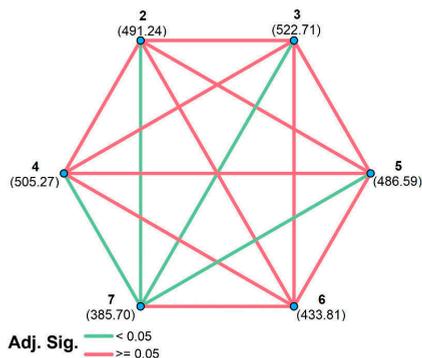
Figure 5. Pairwise comparisons of the responses to survey question Q3 "Do you agree that food waste has a negative impact on the environment?" in a group of grades using Mann–Whitney U test results (compiled by the authors). Each node shows the grade and sample average rank of grade.

As shown in Figure 5, the answers of grade 7 students to Q3 were statistically significantly different from those of grades 2, 3, 4, and 5. The data in Table 4 show that the students in younger grades overwhelmingly answered in the affirmative to this question compared with those in grade 7.

An analysis of the respondents' answers to question Q4 "Do you agree that school lunches cost money? If you don't eat them, the money is "thrown away"?" is available in Table 5.

Table 5. Analysis of the respondents' answers to question Q4 "Do you agree that school lunches cost money? If you don't eat them, the money is "thrown away"?", (n = 944) (compiled by the authors).

Question	Multiple Choice Answers	Values	Distribution of Answers of the Respondents, % (n = 944)
Do you agree that school lunches cost money? If you don't eat them, the money is "thrown away"?	Yes Rather yes I don't know Rather no No	5 4 3 2 1	5 → 37.0; 4 → 26.9; 3 → 17.4; 2 → 8.4; 1 → 10.4

Variables		Mean ± SD	Kruskal–Wallis H test p-value	Statistical significance
School	School 1 School 2 School 3 School 4	3.79 ± 1.31 3.85 ± 1.28 3.47 ± 1.45 3.69 ± 1.21	0.02	$p < 0.05$ Group results are statistically significantly different
Grade	2 3 4 5 6 7	3.94 ± 1.43 3.79 ± 1.42 3.58 ± 1.37 3.89 ± 1.16 3.58 ± 1.14 3.45 ± 1.27	<0.001	$p < 0.05$ Group results are statistically significantly different
Gender	Male Female	3.72 ± 1.36 3.71 ± 1.27	0.449	$p > 0.05$ Group results are not statistically significantly different

The data in Table 5 show that most of the students (63.9%, Yes + Rather yes) believed that their uneaten school lunch was "wasting money"; however, a small proportion of the students (18.7%) (No + Rather no) disagreed, while 17.4% could not answer this question.

A descriptive statistics test and a Kruskal–Wallis H test were performed to test whether there were significant differences in opinions between different groups of students regarding *Q4*. The results revealed that there were statistically significant differences in answers broken down by school ($p = 0.02$) and by class ($p < 0.001$); therefore, an additional Mann–Whitney U test was performed (Figure 6).
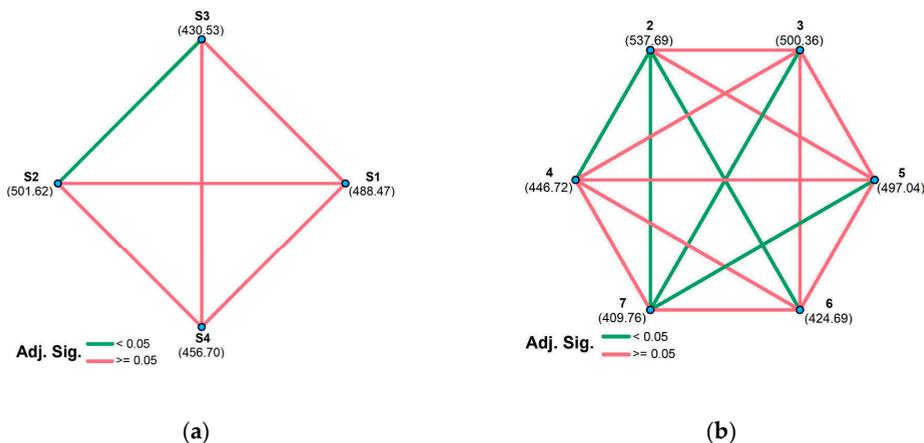

(**a**)   (**b**)

Figure 6. Pairwise comparisons of the responses to survey question Q4 "Do you agree that school lunches cost money? If you don't eat them, the money is "thrown away"?" using Mann–Whitney U test results: (**a**) in a group of schools (each node shows the school and sample average rank of school); (**b**) in a group of grades (compiled by the authors) (each node shows the grade and sample average rank of grade).

Figure 6 data reveal a pair of schools with statistically significant differences in answers (S2 and S3). S2 students' answers were more affirmative, indicating greater agreement with the statement in Q4, while S3 students gave fewer affirmative answers and were inclined to give neutral or negative answers. The results broken down by grade revealed several pairs of grades with statistically significant differences in answers: between grade 7 and grades 2, 3, and 5 and between grade 2 and grades 4, 6, and 7. The answers of students in grade 7 were predominantly negative, compared with those in grades 2, 3, and 5 who were mostly affirmative for the statement in Q4. Grade 2 students tended to agree with the statement included in Q4, compared with those in grades 4, 6, and 7, who mostly answered in the negative.

An analysis of the respondents' answers to question Q5 "Where do you think the plate waste goes?" is available in Figure 7.

The data in Figure 7 show that most of the respondents believed that PW ended up in the trash, almost as many students believed that PW was fed to pets, 1/3 noted that they did not know what happened to PW. The remaining students indicated that PW was used to produce bioenergy, PW was fed to ducks by the Rezekne River or the canteen personnel took it home.
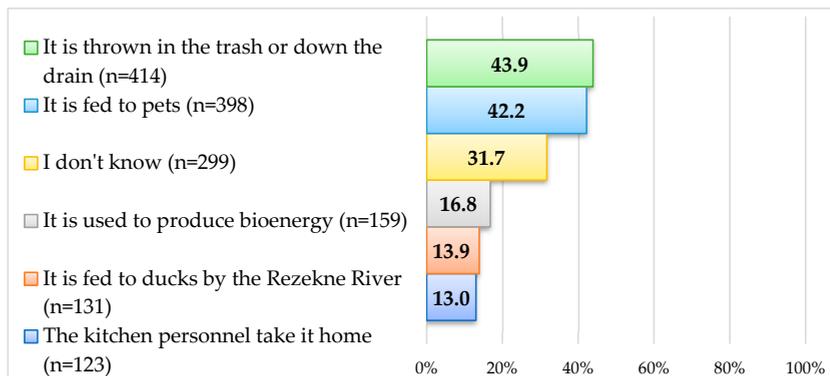
Figure 7. Distribution of the respondents' answers to question Q5 "Where do you think the plate waste goes?", % (n = 944) (compiled by the authors).

4.3. III Dimension. Attitude (Personal Dimension)

This section of the questionnaire identified the students' attitudes towards FW and the food served at school. The questionnaire included the following questions (see Table 6).

Table 6. Survey questions and answer options about food consumption patterns and reasons for plate waste during school lunches (compiled by the authors).

No.	Question	Answer Options
Q6	Are you worried about food being thrown away?	(1) Yes (2) No
Q7	How much of the SOUP served at lunch do you usually eat?	(1) I do not eat at all (2) I eat quite a bit (3) I eat half of the food (4) I eat almost all the food (5) I eat all the food
Q8	How much of the MAIN COURSE served at lunch do you usually eat?	
Q9	How much of the DESSERT served at lunch do you usually eat?	
Q10	How much of the BREAD served at lunch do you usually eat?	
Q11	How much of the SALAD served at lunch do you usually eat?	
Q12	The main reasons why you don't complete the SOUP? (it was possible to mark multiple answers)	(1) The portion is too big (2) The food doesn't taste good (3) I do not have enough time to eat it (4) Lunch is served too early, I do not want to eat yet (5) Because others do it
Q13	The main reasons why you don't complete the MAIN COURSE? (it was possible to mark multiple answers)	
Q14	The main reasons why you don't complete the DESSERT? (it was possible to mark multiple answers)	
Q15	The main reasons why you don't complete the BREAD? (it was possible to mark multiple answers)	
Q16	The main reasons why you don't complete the SALAD? (it was possible to mark multiple answers)	
Q17	What do you do with the food you don't eat during school lunch?	(1) I left it on the plate (2) I give it to a classmate to eat (3) I take with me what I can (fruit, bread, etc.) and eat it later or at home

An analysis of the respondents' answers to question Q6 "Are you worried about food being thrown away?" revealed that most of the students (65.4% out of 944) in Rezekne city schools were not concerned about the food being thrown away, while about 1/3 (34,.6%) confirmed that they were concerned about this problem.

An analysis of the respondents' answers to questions about how much of the food served at lunch was usually eaten is available in Figure 8.
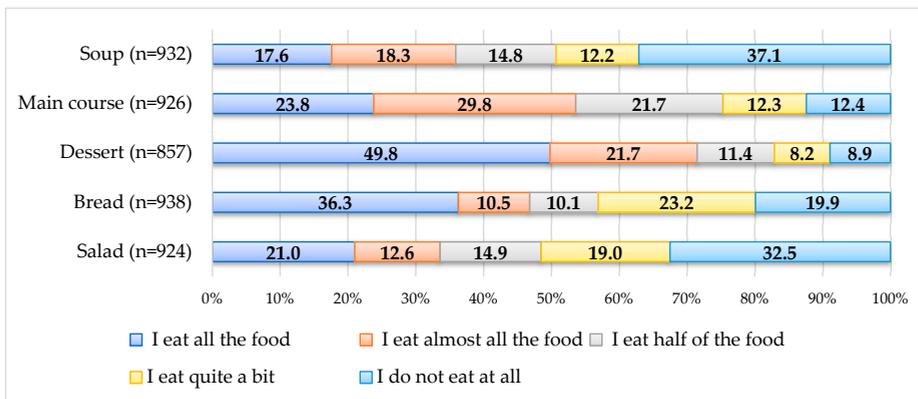
Figure 8. Distribution of the respondents' answers to questions about how much of the food served at lunch was usually eaten, % (compiled by the authors).

The data in Figure 8 show that the consumption of various dishes during lunch varied significantly. The consumption of dessert (Q9) (according to the school menu, it is most often a muffin or cottage cheese product—glazed curd cheese, pre-packaged yoghurt, pre-packaged curd snack) was the highest, 71.5% indicated that they ate up the dessert completely or almost completely. This was followed by the main course (Q8)—53.6% of the respondents noted that they ate up the main course completely or almost completely. Bread (Q10) was consumed by almost half of the respondents—46.8% (all + almost all). The consumption of salad (including vegetables) (Q11) was lower—33.6% (all + almost all), while 32.5% of the respondents noted that they did not eat it at all. The dish that the students most often refused was soup (Q7)—37.1% of the students noted that they did not eat it at all.

An analysis of the respondents' answers to questions about the main reasons, why they don't complete the served food is available in Figure 9.
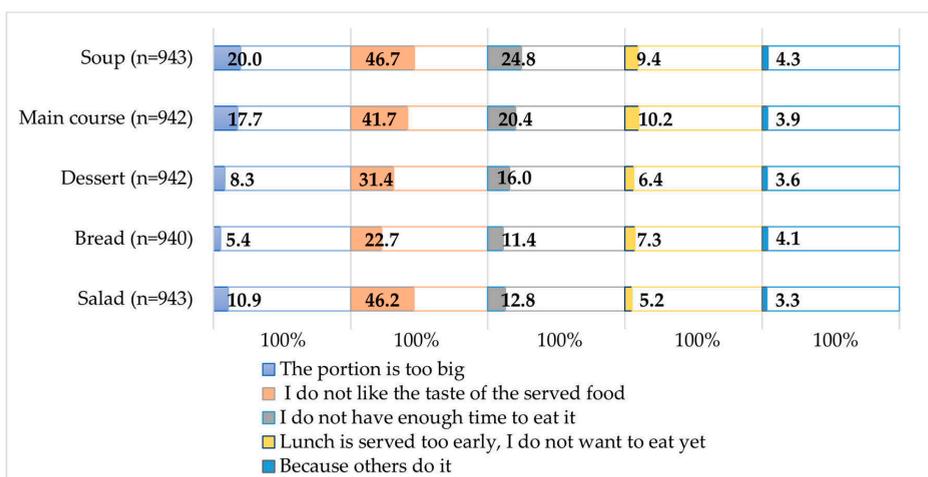

Figure 9. Distribution of the respondents' answers to the questions about the main reasons, why they did not eat the food served, % (compiled by the authors).

The data in Figure 9 show that the primary reason why the respondents did not complete the food served at lunch was they did not like the taste of the food. The most frequently noted dishes were soup (46.7%) (Q12) and salad (46.2%) (Q16), indicating a strong dislike of the dishes among the students. The second most frequent reasons were not having enough time to eat: soup (24.8%) (Q12) and the main course (20.4%) (Q13). The third most frequent reason given was too large a portion size, especially for soup (20%) (Q12) and main course (17.7%) (Q13).

An analysis of the respondents' answers to question Q17 "What do you do with the food you don't eat during school lunch?" is available in Figure 10.
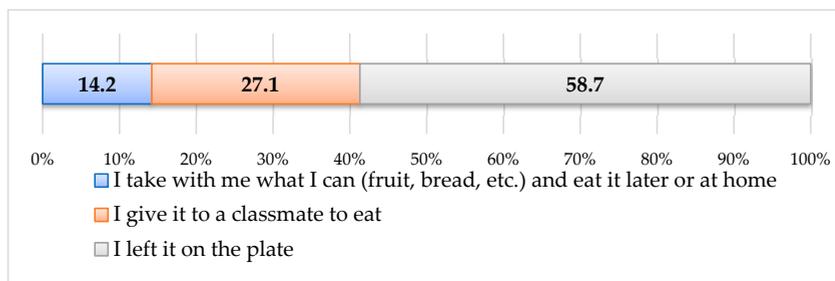
Figure 10. Distribution of the respondents' answers to question Q17 "What do you do with the food you don't eat during school lunch?", % (n = 942) (compiled by the authors).

The data in Figure 10 show that most of the respondents (58.7%) left their uneaten food on their plates at lunch, 27.1% gave it to their classmates, 14.2% took the uneaten food (usually whole fruit or bread) with them and eat it later.

4.4. IV Dimension. Opinion/Evaluation (Organizational Dimension)

This section of the questionnaire includes questions to identify students' opinions on the sensory qualities of the food, i.e., appearance, taste, temperature, and portion size, etc., and the organization and management of the canteen.

4.4.1. Students' Satisfaction with School Meal Sensory Properties

To identify students' opinions on the sensory qualities of school food, the survey included the following questions (see Table 7).

Table 7. Survey questions and answer options about the students' satisfaction with the sensory characteristics of school food (compiled by the authors).

No.	Question	Response Options
Q18	Are you satisfied with the appearance of the food served at school?	(1) Always (2) Often (3) Sometimes (4) Rarely (5) Never
Q19	Do you like the taste of the food served at school?	
Q20	Are you satisfied with the smell of the food served at school?	
Q21	Are you satisfied with the temperature of the food served at school?	

An analysis of the respondents' answers to questions about the sensory characteristics of the food served is available in Figure 11.
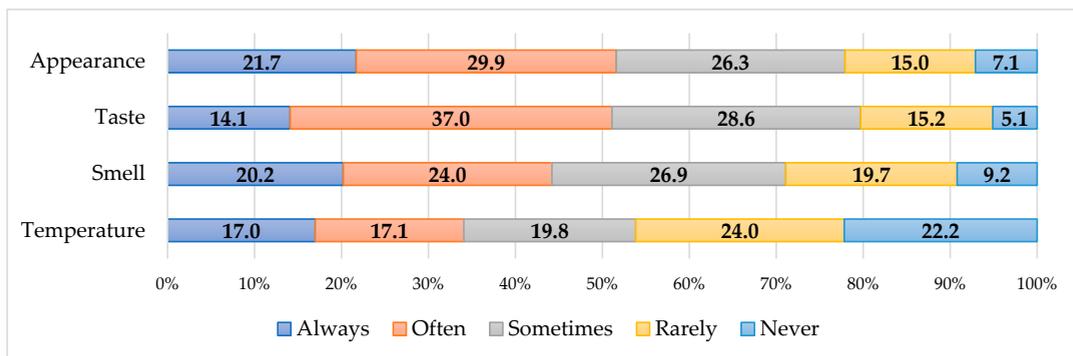
Figure 11. Distribution of the respondents' answers to questions about satisfaction with sensory characteristics of the food served at school, % (n = 944) (compiled by the authors).

The data in Figure 11 show that only a small proportion of the students were always satisfied with the sensory qualities of school food. An analysis of the combined responses "Always" and "Often" revealed that the students were most satisfied with the appearance (51.6%) and taste (51.1%) of school food, but least satisfied with the temperature of school food, as shown by the responses "Rarely" (24.0%) and "Never" (22.2%). Overall, the results showed that the students were often dissatisfied with the sensory qualities of school food.

To test whether there were statistically significant differences in the opinions of different groups of students on the appearance, taste, smell, and temperature of school food, a descriptive statistics test and a Kruskal–Wallis H test were performed (see Tables 8–11).

Table 8. Analysis of the respondents' answers to question Q18 "Are you satisfied with the appearance of the food served at school?", (n = 943) (compiled by the authors).

Question	Multiple Choice Answers	Values
Are you satisfied with the appearance of the food served at school?	Always Often Sometimes Rarely Never	5 4 3 2 1

| Variables		Mean ± SD	Kruskal–Wallis H test *p*-value	Statistical significance
School	School 1 School 2 School 3 School 4	3.28 ± 1.23 3.54 ± 1.17 3.63 ± 1.17 3.39 ± 1.14	0.007	$p < 0.05$ Group results are statistically significantly different
Grade	2 3 4 5 6 7	3.65 ± 1.25 3.56 ± 1.21 3.53 ± 1.18 3.51 ± 1.06 3.14 ± 1.14 3.18 ± 1.20	<0.001	$p < 0.05$ Group results are statistically significantly different
Gender	Male Female	3.61 ± 1.21 3.26 ± 1.14	<0.001	$p < 0.05$ Group results are statistically significantly different

Table 9. Analysis of the respondents' answers to question Q19 "Do you taste the food served at school?", (n = 943) (compiled by the authors).

Question		Multiple Choice Answers	Values
Do you taste the food served at school?		Always	5
		Often	4
		Sometimes	3
		Rarely	2
		Never	1

Variables		Mean ± SD	Kruskal–Wallis H test *p*-value	Statistical significance
School	School 1	3.27 ± 1.00	0.013	$p < 0.05$ Group results are statistically significantly different
	School 2	3.50 ± 1.07		
	School 3	3.51 ± 1.12		
	School 4	3.35 ± 1.08		
Grade	2	3.55 ± 1.14	<0.001	$p < 0.05$ Group results are statistically significantly different
	3	3.58 ± 1.01		
	4	3.46 ± 1.12		
	5	3.39 ± 1.02		
	6	3.13 ± 0.97		
	7	3.23 ± 1.05		
Gender	Male	3.55 ± 1.09	<0.001	$p < 0.05$ Group results are statistically significantly different
	Female	3.24 ± 1.02		

Table 10. Analysis of the respondents' answers to question Q20 "Are you satisfied with the smell of the food served at school?", (n = 942) (compiled by the authors).

Question		Multiple Choice Answers	Values
Are you satisfied with the smell of the food served at school?		Always	5
		Often	4
		Sometimes	3
		Rarely	2
		Never	1

Variables		Mean ± SD	Kruskal–Wallis H test *p*-value	Statistical significance
School	School 1	3.14 ± 1.21	0.034	Sig. < 0.05 Group results are statistically significantly different
	School 2	3.40 ± 1.28		
	School 3	3.37 ± 1.26		
	School 4	3.18 ± 1.22		
Grade	2	3.42 ± 1.31	<0.001	$p < 0.05$ Group results are statistically significantly different
	3	3.51 ± 1.23		
	4	3.39 ± 1.20		
	5	3.26 ± 1.20		
	6	2.93 ± 1.17		
	7	3.00 ± 1.24		
Gender	Male	3.39 ± 1.29	<0.001	$p < 0.05$ Group results are statistically significantly different
	Female	3.12 ± 1.18		

Table 11. Analysis of the respondents' answers to question Q21 "Are you satisfied with the temperature of the food served at school?", (n = 944) (compiled by the authors).

Question		Multiple Choice Answers	Values
Are you satisfied with the temperature of the food served at school?		Always	5
		Often	4
		Sometimes	3
		Rarely	2
		Never	1
Variables		**Mean ± SD**	**Kruskal–Wallis H test** *p*-value	**Statistical significance**
School	School 1	2.44 ± 1.27	<0.001	*p* < 0.05 Group results are statistically significantly different
	School 2	3.19 ± 1.39		
	School 3	3.30 ± 1.39		
	School 4	2.52 ± 1.34		
Grade	2	3.30 ± 1.46	<0.001	*p* < 0.05 Group results are statistically significantly different
	3	3.11 ± 1.41		
	4	2.77 ± 1.39		
	5	2.73 ± 1.32		
	6	2.47 ± 1.36		
	7	2.49 ± 1.23		
Gender	Male	3.03 ± 1.44	<0.001	*p* < 0.05 Group results are statistically significantly different
	Female	2.61 ± 1.31		

The results in Table 8 show that there were statistically significant differences between the answers given by boys and girls: the boys were more satisfied than the girls with the appearance of school food. There were also statistically significant differences in the students' answers broken down by school (*p* = 0.007) and by class (*p* < 0.001); therefore, an additional Mann–Whitney U test was performed (Figure 12).

(a)

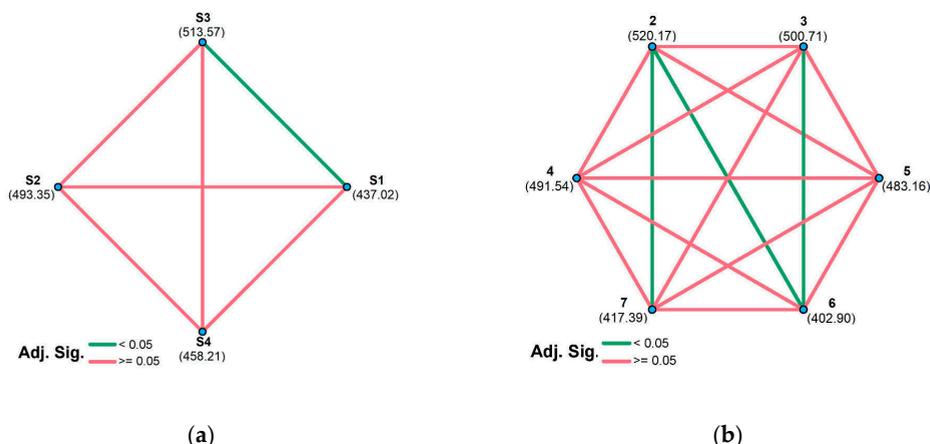
(b)

Figure 12. Pairwise comparisons of the responses to survey question Q18 "Are you satisfied with the appearance of the food served at school?" using Mann–Whitney U test results: (**a**) in a group of schools (each node shows the school and sample average rank of school); (**b**) in a group of grades (compiled by the authors) (each node shows the grade and sample average rank of grade).

Figure 12 data reveal one pair of schools with statistically significant differences in the students' answers—S3 vs. S1: S3 school students' answers were mostly affirmative, indicating that they were satisfied with the appearance of school food, while S1 school students' answers were mostly neutral with a tendency towards negative. The results revealed several pairs of classes with statistically significant differences in answers: between grades 2 and 7, grades 2 and 6 and grades 3 and 6, meaning that younger students were more satisfied with the appearance of school food than older ones.

As shown in Table 9, there were statistically significant differences in answers to Q19 between boys and girls—the boys were more satisfied with the taste of school food. There were statistically significant differences in the students' answers broken down by school ($p = 0.013$) and by class ($p < 0.001$); therefore, an additional Mann–Whitney U test was performed (Figure 13).
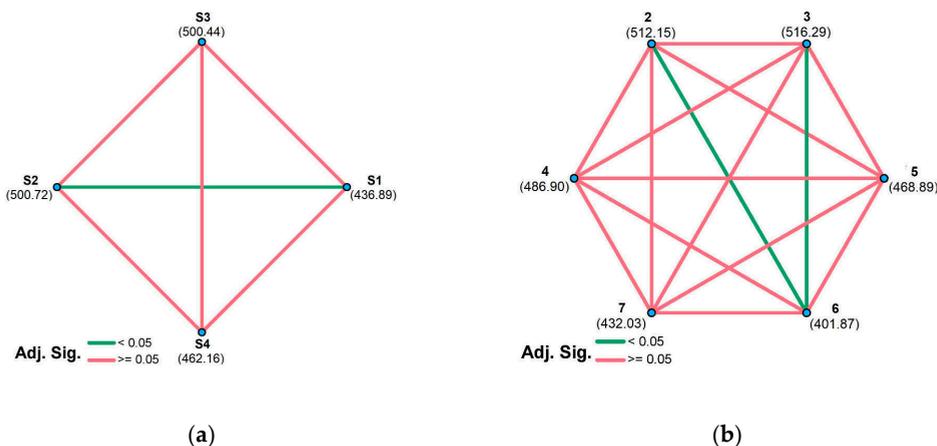

(**a**)   (**b**)

Figure 13. Pairwise comparisons of the answers to survey question Q19 "Do you taste the food served at school?" using Mann–Whitney U test results: (**a**) in a group of schools (each node shows the school and sample average rank of school); (**b**) in a group of grades (compiled by the authors) (each node shows the grade and sample average rank of grade).

Figure 13 data reveal one pair of schools with statistically significant differences in the students' answers—S2 vs. S1: S2 students' answers were mostly affirmative, indicating a higher rating of the taste of food at school, while S1 students' answers were mostly negative. The results revealed several pairs of classes with statistically significant differences in answers between grades 6 and 2 and between grades 6 and 3. Table 9 data indicate that younger students were more satisfied with the taste of school food than older ones.

As regards Q20, as shown in Table 10, there were statistically significant differences in answers between boys and girls, as the boys were more satisfied with the smell of school food than the girls. There were statistically significant differences in answers broken down by school ($p = 0.034$) and by class ($p < 0.001$). In addition, a Mann–Whitney U test was performed (Figure 14).

Figure 14 shows that pairwise comparisons using the Mann–Whitney U test did not show any statistically significant differences in answers across the schools. This indicates that although the answers varied between the schools, the differences between particular pairs of schools were not statistically significant. The results revealed several pairs of classes with statistically significant differences in the students' answers: between younger classes (grades 2 and 3) and older classes (grades 6 and 7), as well as between grades 4 and

6. Table 10 shows that the students in younger grades (2, 3 and 4) were more satisfied with the smell of the food served at school compared with those in grades 6 and 7.
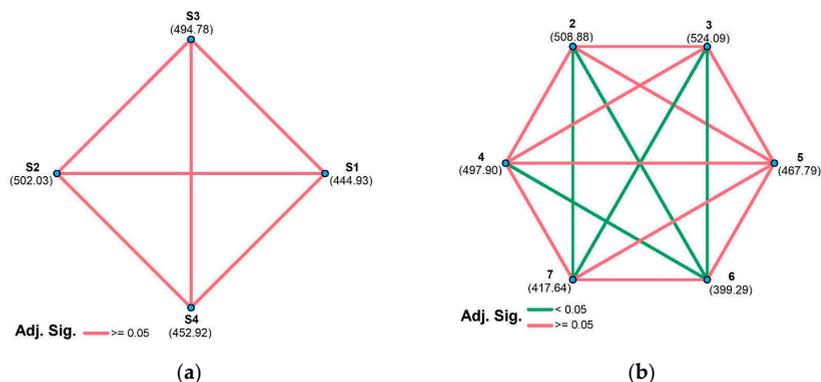

(**a**)   (**b**)

Figure 14. Pairwise comparisons of the answers to survey question Q20 "Are you satisfied with the smell of the food served at school?" using Mann–Whitney U test results: (**a**) in a group of schools, (each node shows the school and sample average rank of school); (**b**) in a group of grades (compiled by the authors) (each node shows the grade and sample average rank of grade).

Regarding Q21 (Table 11), there were statistically significant differences in answers between boys and girls, as the boys were more satisfied with the temperature of school food than the girls, as well as if broken down by school ($p < 0.001$) and by class ($p < 0.001$). A Mann–Whitney U test was performed as well (Figure 15).

(**a**)   (**b**)
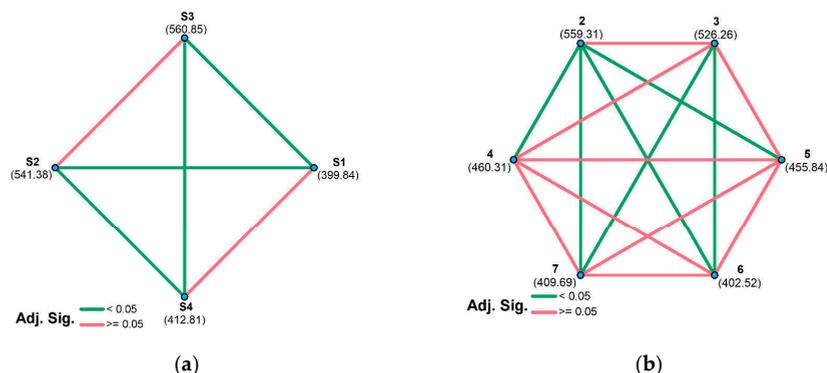
Figure 15. Pairwise comparisons of the responses to survey question Q21 "Are you satisfied with the temperature of the food served at school?" using Mann–Whitney U test results: (**a**) in a group of schools (each node shows the school and sample average rank of school); (**b**) in a group of grades (compiled by the authors) (each node shows the grade and sample average rank of grade).

Figure 15 shows that a Mann–Whitney U test results revealed 4 pairs of schools with statistically significant differences in the students' answers: S1 vs. S2 and S3, S2 vs. S1 and S4, S3 vs. S1 and S4, S4 vs. S2 and S3. S3 and S2 students were satisfied with the temperature of school food, while S1 and S4 students were not satisfied with the temperature of school food.

The results also revealed several pairs of classes with statistically significant differences in the students' responses between grades 2 and 4, 5, 6, 7, as well as between grades 3 and

6, 7. As shown in Table 11, the students in grades 2 and 3 were more satisfied with the temperature of school food than older ones.

Since the students' answers on the sensory qualities of school food were statistically different between the different student groups, the authors decided to identify whether there was a relationship between the students' satisfaction with the sensory qualities of school food and PW by performing a correlation analysis. The data from the analysis are available in Appendix A (Table A1).

Based on Table A1 data, Spearman's rho and a significance coefficient (*p*-value) were calculated. The results are presented in Table 12.

Table 12. Spearman's correlation between the sensory characteristics of food served at school and plate waste (compiled by the authors).

	Satisfaction with Appearance	Satisfaction with Taste	Satisfaction with Smell	Satisfaction with Temperature
Spearman's rho *	0.113	0.130	0.193	0.236
p-value **	0.444	0.378	0.190	0.106

* Spearman's rho < 0.3—the weak relationship between paired data; ** $p > 0.05$ group results are not statistically significantly different.

The data in Table 12 show that the correlation between PW per student and the mean satisfaction scores for all food sensory properties indicated a weak relationship between the paired data. However, the results were not statistically significant, suggesting that there was no link between the students' satisfaction with school food sensory properties and PW.

4.4.2. Students' Ratings of the Organization and Management of Canteen Work

To identify the students' opinions on the organization and management of their canteens, the following questions were included in the survey (see Table 13).

Table 13. Survey questions and answer options about the organization and management of canteen work (compiled by the authors).

No.	Question	Response Options
Q22	Are you satisfied with the time at which lunch is served?	(1) Yes (2) I would like lunch to be served sooner (3) I would like lunch to be served later
Q23	Do you have enough time for lunch to eat?	(1) Yes (2) I need more time so that I can eat without rushing (3) Yes, and there is still free time for other activities
Q24	Do you like that the food is already served on the table when you arrive for lunch?	(1) Yes (2) No (3) It would be better to choose yourself from the offer of the school canteen (buffet)
Q25	The canteen staff are kind and helpful.	(1) Always (2) Often (3) Sometimes (4) Rarely (5) Never
Q26	The teacher helps us during lunch (pours soup, offers to taste food, etc.).	
Q27	The teacher eats lunch with us at our table.	

An analysis of the respondents' answers to questions Q22, Q23 and Q24 is available in Figure 16.

The data in Figure 16 show that most of the respondents (55.2%) were satisfied with the time at which lunch was served; however, 37.9% would like to have lunch earlier and a relatively small proportion (6.9%)—later.

Most of the respondents (56.8%) were satisfied with the length of the lunch break; however, 28.9% would need more time to eat, while 14.3% still had time for other activities during the lunch break.
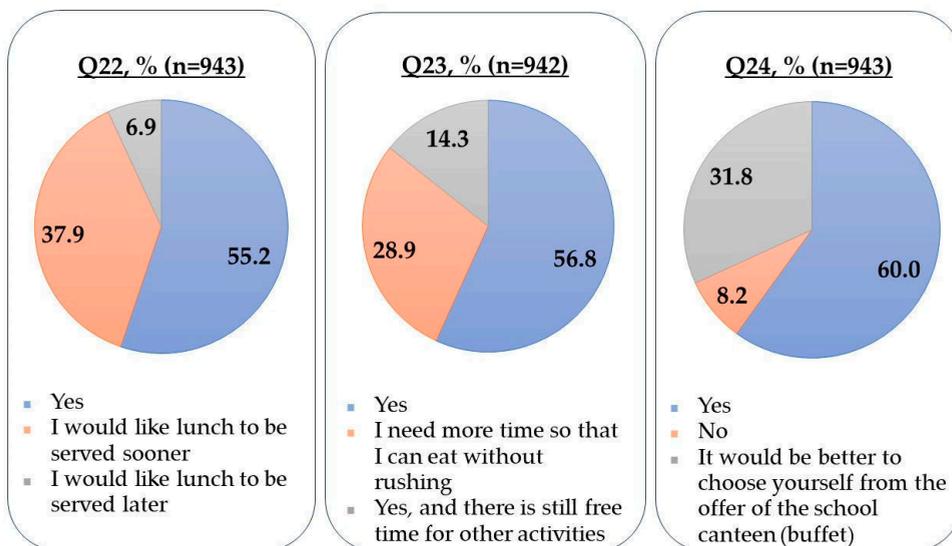
Figure 16. Distribution of the respondents' answers to questions Q22, Q23, and Q24 (compiled by the authors).

Most of the respondents (60%) liked that the food was already served on the table, 8.2% noted that they did not like it, while 31.8% would like to have an opportunity to choose their dishes and portion sizes.

An analysis of the respondents' answers to questions Q25, Q26 and Q27 is available in Figure 17.
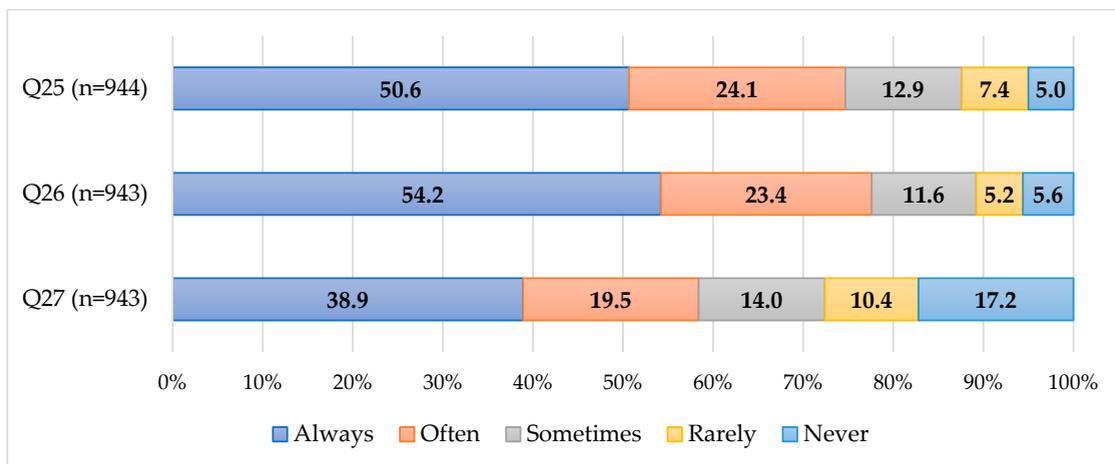

Figure 17. Distribution of the respondents' answers to questions Q25, Q26, and Q27, % (compiled by the authors).

The data in Figure 17 show that most of the respondents (74.7%) answered that canteen personnel were always or often kind and helpful, 12.9% noted that they were kind and helpful only sometimes, while 12.4% indicated that the canteen personnel were kind and helpful rarely or never.

Most of the respondents (77.6%) noted that their teachers always or often helped during lunch, 11.6% indicated that this happened sometimes, and 10.8% that the teachers helped rarely or never.

In addition, most of the respondents (58.4%) noted that their teachers had lunch with them at the same table, 14% admitted that this happened sometimes and 27.6%—rarely or never.

5. Discussion

5.1. Students' Awareness and Knowledge About School Food, FW, and Its Negative Impact

The results of the survey on students' understanding and knowledge of school food, FW and their impact on the economy and the environment revealed that although the students were aware of the problems to some extent, they lacked in-depth understanding and knowledge of some specific aspects.

Most of the students associated FW with spoiled food or inedible parts of food, slightly less than half of them believed PW was FW (Figure 3). The results are consistent with findings made by Coşkun and Filimonau [135] that consumers tend to justify their wasteful behaviour with various external factors; therefore, they do not fully associate PW with general FW. As a result, although they can acknowledge FW at a broader societal level, they are often unaware of their role in contributing to FW through PW [135]. Similar observations were made by Matzembacher et al. [136], who found through interviews that consumers did not perceive FW left on their plates, as they considered the waste produced during the observation day to be an exceptional occurrence rather than an ongoing behaviour [136], thus highlighting the gap between general perceptions of FW and personal responsibility for PW. The findings suggest that while students are generally aware of the problem of FW in general, they often do not associate PW with the problem of FW, thereby indicating the need for targeted interventions or strategies to address misconceptions and promote individual responsibility among the students.

Although more than half of the respondents answered that school food was healthy (Yes + Rather Yes), a small proportion of the students disagreed and around a quarter could not answer this question (Table 3), thereby indicating a lack of information, knowledge, awareness or education on this problem. It has been established that students sometimes associate the healthiness of a food with other characteristics of the food, e.g., taste or appearance [137]. Noble et al. [138] also found that students had different perceptions of the healthiness of food, as some of them associated it with the absence of fat, while others focused on the presence of vitamins. Moreover, the children's perceptions of the healthiness of food often did not match their preferences [138]. In addition, students' perceptions of the healthiness of school food might be influenced by their parents' opinions and attitudes towards school lunches. Several research studies found that positive parental perceptions of school meals were associated with higher student participation in school meal programmes [139,140]. The results of a statistical analysis revealed that students in younger grades, i.e., grades 2 and 3, were more confident that school food was healthy, whereas those in older grades, i.e., grades 6 and 7, were more sceptical about it (Table 3 and Figure 4). This could be due to the fact that younger students tend to believe their parents, teachers, etc., whom they perceive as authorities [141] and do not question their opinions on the healthiness of school food, whereas older students start to develop critical thinking [142], and are more likely to listen to information from different sources (peers,

social sites, etc.), which might lead them to have doubts about the healthiness of school food. Gender differences were also observed, with girls displaying greater scepticism about meal healthiness, which is consistent with other observations that females tend to be more health-conscious and are often more critical of food quality and nutrition [143–145]. The results point to the need for targeted educational initiatives to increase students' nutritional awareness and knowledge and explain the nutritional value of school food through age-appropriate communication and potentially parental involvement.

While nearly half acknowledged the negative environmental impact of FW, some respondents disagreed, while a third could not answer the question at all (Table 4). While more than half agreed or rather agreed that their uneaten school lunch was "wasting money", approximately a third disagreed or did not know the answer (Table 5), thereby indicating a gap in understanding and education. Previous research studies have shown that most typical consumers view FW primarily as a social problem rather than recognizing it as an environmental or economic concern [56,146]. Inayah et al. [44] also found that even with environmental education, students often fail to understand FW as an environmental issue, while financial aspects are better understood [44]. Similar findings were found by Mganga et al. [54], where students who were more aware of the financial consequences of FW were more motivated to avoid it; in contrast, their awareness of the environmental and social consequences did not significantly motivate them to reduce FW [54], suggesting that while environmental education is important, it might not be as effective in changing their consumption behaviour, while the financial aspect, which could seem more direct and tangible, could encourage more active action to reduce waste. It has been established that a lack of awareness or misconception of the economic, social and environmental impacts of FW is one of the main factors contributing to FW [15]. The results of the statistical tests revealed differences in the students' answers to the questions, depending on grades and schools (Tables 4 and 5, Figures 5 and 6). The tendency in the students' answers was the same as for the answers on the healthiness of school lunches: those in younger grades were more likely to answer in the affirmative compared with those in older grades, and those in grade 7 in particular were more sceptical, which the authors attribute to the same behavioural changes during adolescence. The results suggest the need for educational initiatives aimed at strengthening students' awareness of FW as an environmental problem.

About a third of the students surveyed did not know what happened to PW after school lunch, almost half of the respondents noted that PW ended up in the trash and about the same number of them noted that PW were fed to pets (Figure 7). Students' perceptions of FW are often based on subjective factors related to the environment, culture, etc. [147]. In a 2021 research study of schools in Rezekne, Lonska et al. [33] found that some solid FW (mostly meat) was disposed of by canteen personnel for feeding pets, some food was disposed of in common household waste containers, and liquid waste, e.g., drinks and soups, was usually disposed of in the sewer [33]. The authors attribute the high proportion of answers—PW was fed to pets—to the Latvian way of life: many have backyards or farms with pets or livestock that can be fed uneaten food. Although, based on the FW management hierarchy, feeding pets is not the optimal solution compared with prevention or redistribution to people [19,148], it is still an environmentally preferable option in managing FW, provided the food is safe for animals. This approach is a practical and sustainable solution to FW management, but it might limit students' understanding of the wider FW problem. Tailored education programmes could contribute to a more comprehensive understanding of FW and FW management, recycling options and other more sustainable solutions to the problem of FW.

Overall, the survey results regarding dimension II revealed gaps in the students' understanding and knowledge of FW, the economic and environmental impacts of FW, as

well as the disposal of FW and the healthiness of school food. These findings are consistent with wider-scope research findings that a lack of awareness and knowledge of FW, its negative impact and prevention are the key drivers of FW [15,93]. Moreover, a lack of knowledge about the drivers and sources of FW further exacerbates the problem [90,149]. A clear understanding of the underlying problem is important for students to effectively reduce FW [90] and understanding consumer awareness levels, perspectives and practices concerning FW is essential for developing evidence-based initiatives and strategies that promote sustainable food systems [150]. However, several research studies have confirmed that awareness and knowledge of FW problems do not necessarily result in changes in behaviour or habits [45,55,151,152], as increased interest in sustainable food consumption practices alone is not sufficient to encourage students to adopt more sustainable food consumption habits [151]. Raising awareness and knowledge alone has been found to have limited impacts causing short-term changes in consumer behaviour [127], hence the need to reinforce the changes through interesting practical activities promoting long-term behavioural changes in students.

5.2. Students' Attitudes Towards FW and School Food

The results of the survey provide important insights into students' attitudes towards school food and highlight trends in food consumption and FW among the students in Rezekne city. The data show significant differences in the consumption of various foods, which points to actions that can promote responsible consumption of school food, as well as changes in school menus based on students' preferences.

More than half of the students were not concerned about the food being thrown away. The survey results are consistent with previous findings suggesting that a lack of awareness and knowledge are probably the main reasons why most of the students are not concerned about food being thrown away. A research study by Qi and Roe [153] has found that sometimes, even if consumers are aware of the FW problem, they are too busy to consider it because they are essentially unmotivated to deal with the problem [153]. Accordingly, if students lack a comprehensive understanding of the wider impacts of FW, e.g., their role in environmental degradation, resource waste and economic loss, they might assume that FW is insignificant.

This was also reflected in the answers to the question "How much of the food served at lunch was usually eaten?" (Figure 8), with a relatively small proportion of the students indicating that they ate all the food (main course—23.8%, soup—17.6%, salad—21%). This pattern of consumption is worrying not only because a large proportion of food is left on the plate, which is defined by the authors as PW, but also because school lunches play an important role in ensuring a complete daily diet for children [61,81,154]. The foods that the students consumed the least were soups and salads, the main ingredient of which is vegetables that are an essential source of vitamins, minerals and fibre in ensuring a healthy diet for students [155,156]. It is undeniable that the consumption of vegetables provides significant health benefits, which relate not only to the nutritional composition but also to the synergistic effects of the biologically active compounds they contain [157–159]. Similarly, the consumption of plant-based foods is more sustainable compared with meat-based diets [160–162], and ethical, environmental and cost advantages should also be taken into account in this case [163,164]. However, despite all the benefits, several research studies have found that vegetables are one of the most wasted kinds of food [156,157,165], and, although, for example, in the United Kingdom vegetable consumption has increased in recent years, children continue to consume only a small portion of the vegetables provided to them [166]. This suggests that comprehensive transformations are needed in school menus that would simultaneously promote the consumption of vegetables and other

foods, thereby ensuring that the meals meet both students' preferences and nutritional requirements, which could result in reducing the amount of FW and PW and strengthening healthier eating habits.

The findings highlight the ongoing challenge of changing consumer behaviour towards a more responsible and sustainable pattern because, as mentioned above, while awareness and knowledge are essential foundations, there are many other factors that lead to wasteful behaviour. The survey responses to the question "The main reasons, why they did not complete the food served" (Figure 9) reveal that FW was primarily related to students' preferences. The majority indicated that they did not like the dishes served, particularly soup (46.7%), salad (46.2%), and the main course (41.7%). These findings are consistent with many other ones, with taste preferences being mentioned as the primary reason for meal refusal [167–169]. Similarly, Lonska et al. [33] found that students were more likely to leave food unfinished if they did not like the food served or any of its ingredients. The second most important reason for FW indicated by students was a lack of time to eat—the lunch break in the Rezekne city schools included in the survey ranged from 20 to 30 min. Based on the authors' previous research, using an artificial intelligence prediction tool, it was concluded that students should spend at least 20 min at the table (excluding getting to and from the canteen) [40]. Other research studies have also confirmed that sufficient time for meals could help to reduce PW [36,170–172], and, conversely, a lack of time and a sense of urgency contribute to FW [173,174]. However, it should be noted here that one intervention aimed at reducing PW in S3 was the extension of the lunch break from 20 to 30 min. On the contrary, as a result of the experiment, an increase in PW was observed in both the short and the long term, and the researchers associated with the complexity of FW behaviours and the need for carefully designed interventions [38]. Large portions were the third most popular reason for PW noted by the students from Rezekne city schools. In the scientific literature, this FW factor is also referred to as one of the most common [36,72,175,176], especially in the case of school catering in Rezekne city schools, with portions being served in advance, without adjusting them to students' physiological parameters, e.g., age and appetite; as a result, the students are often simply unable to eat the entire portion [33,67]. In this regard, organizational changes in the school catering system could contribute to reducing PW, so that students can choose the kind and quantity of school food according to their physiology and preferences.

The shortcomings of this catering model were also revealed by the respondents' answers to a question "What do you do with the food you don't eat during school lunch?" (Figure 10). More than half of the respondents noted that they left uneaten food on their plates. This behaviour was affected by the current catering model in Rezekne city schools, which did not provide for the possibility for students to take their uneaten food with them, for example, in lunch boxes, or other alternatives to using PW; consequently, the uneaten food was simply thrown away. It has been established that similar restrictive catering models prohibiting students from sharing food or taking uneaten food with them significantly contribute to FW [36,177,178]. Almost a third of the respondents indicated that they tended to share their uneaten food with their classmates. During the PW measurements, the project researchers were able to observe that the students shared with their classmates, for example, a meat dish (cutlets or chops) in case they did not want to eat it themselves. This is essentially a good informal approach to prevent PW; however, this practice does not solve the main problem, as students are not initially given the opportunity to choose the kind and quantity of school food. Unlike the situation in Latvia, various practices are in place around the world to prevent uneaten food from going to waste, for example, "take-away" options, "sharing tables", and students can leave untouched food, thus reducing FW and providing food to those who are hungry [179,180]. In some EU Member States, food

donation movements are widely spread, and some school food is donated to vulnerable social groups [71,179,181]. If, however, the leftover food is no longer usable, sorting and composting FW has been recognized as an effective way to use FW [182]. Implementing similar strategies in schools in Latvia could be a more sustainable alternative to leaving food on the plate, thereby reducing FW.

5.3. Students' Opinions on School Food and the Organization and Management of a Canteen

An analysis of student satisfaction with food sensory properties, such as appearance, taste, smell, and temperature, revealed that satisfaction levels varied significantly across schools, grades, and genders, yet overall, the student satisfaction with the sensory properties of food served in Rezekne city school canteens was relatively low, especially the temperature and smell (Figure 11).

Several research studies have confirmed that the sensory properties of school food directly affect students' desire to eat and, consequently, the amount of PW [37,147,175,183]. This problem is challenging because students' attitudes towards the sensory properties of food are shaped by both individual characteristics and factors such as the cooking skills of kitchen personnel, technical cooking equipment, etc. [33,67]. The authors have observed that the students' great dissatisfaction with the temperature of school food stemmed from the way the catering was managed, with the portions being served in advance, and during this period the food tended to cool down, as the schools did not have special heat-retaining containers (e.g., marmites). It has been established that the temperature of food also affects other food properties [184]; therefore, it is possible that students do not find cooled food particularly fragrant and tasty.

The survey results revealed differences in the sensory preferences of food between younger and older students (Tables 8–11 and Figures 12–15). The younger students were more satisfied with school food appearance, taste, smell, and temperature than older ones. Similar findings have been made by other research studies, e.g., Piochi et al. [183] have found that younger children (6–7 years old) in grades 1 and 2 have the most positive attitude towards the school canteen, and they often express positive emotions about meals and are distinguished by a low level of FW [183]. Tuorila et al. [185] pointed out that third graders had a positive attitude towards school meals compared with students in higher grades [185]. Steen et al. [186] found that as children get older, PW increases as well [186]. This could be due to the fact that as they grow older, children become increasingly aware of their desires and become more critical in their choices [142].

The survey results also showed differences in the students' answers, depending on gender (Tables 8–11). Boys rated all sensory properties of food higher (more positively) than girls. Favuzzi et al. [71] found in their study that boys had a higher tolerance to changes in the quality and appearance of school food, while girls were more selective and showed increased sensitivity to the sensory properties of food, and it was also found that boys wasted less food if they positively rated aspects such as smell, taste and appearance, while girls wasted more if their rating of the factors was negative [71], confirming that there are gender differences in behaviour that are not affected by external factors, e.g., only social pressure. This aspect should be considered when tackling the problem of FW and increasing satisfaction with meals in schools.

Despite several research studies showing that food aversion contributes to FW, the findings indicated only a weak correlation between sensory satisfaction and PW (Table 12), suggesting that factors beyond meal appearance, taste, smell and temperature, such as meal options and portion control, played a more substantial role in determining FW levels in schools in Rezekne. And this confirms that the school catering model in Rezekne is not

sustainable. Even if students do not like the food served, hunger takes over, and there is nothing left to do but eat the food served.

The results of the survey on the organization and management of school canteens showed that the students generally had a positive opinion of school catering. However, the findings also indicated areas where improvements were needed.

Regarding the time and duration of the lunch break (Figure 16), most of the students were satisfied with the time and duration of the lunch break; however, a significant proportion of them would like the lunch break to start earlier and be longer. In Rezekne schools, lunch schedules vary, with younger students eating earlier (9:30–11:30) and older students later (11:30–13:00), and break durations ranging from 20 to 30 min. This variation in schedules might be the main reason for the students' satisfaction, as their wishes and needs were very individual and depended on several factors [33,36]. Several findings suggest that a thoughtful adjustment of lunch time and a longer lunch break could improve students' eating experiences and help the reduce PW [33,36,40,170–172].

As regards the way lunch is served (Figure 16), more than half of the students appreciated the fact that lunch was already served on the tables, which indicates that this arrangement is convenient and acceptable for students. However, about a third indicated that they would prefer to choose their dishes and portion sizes. Some research studies have found that providing students with more flexibility, such as buffet-style meals, could potentially reduce FW by allowing students to choose their food and portion it according to their preferences and needs, thus promoting more responsible food consumption and promoting co-responsibility in reducing FW [33,67]. Other research studies also confirmed the effectiveness of buffet-style meals [68], indicating that schools that supply "prepared meals", limit students' options for choosing what food and how much they could consume [70]. However, implementing a buffet-style system in schools presents regulatory challenges in Latvia, as inspectors from the Food and Veterinary Service have raised concerns about allowing students to choose their own meals and portion sizes. They argue that this flexibility may conflict with strict legal requirements mandating specific nutrient quantities per meal to ensure balanced nutrition for each child. Despite these concerns, the official stance of the National Food and Veterinary Service of Latvia is acceptable for buffet type self-service as long as the overall nutritional standards are met on average for each student [33,187]. It is undoubtedly important to follow nutritional guidelines in student meal programmes, yet they should be combined with student preferences. Schools could apply a combined approach, supplying healthy meals within controlled parameters to meet both regulatory requirements and student preferences.

Overall, the students appreciated the attitude of canteen personnel, with about three-quarters reporting that the personnel were always or often kind and helpful (Figure 17). In addition, slightly more than three-quarters of the students reported that their teachers always or often helped during lunch (Figure 17), and half stated that their teachers ate lunch with them at the same table (Figure 17). Several research studies have confirmed that the role of supervising personnel during lunch is important for the efficient functioning of the dining process [74,188–190], as their presence, support and involvement can help to maintain order, make a positive atmosphere and solve any immediate needs or problems that arise among students during lunch. It has been established that the presence of a teacher during lunch can reduce PW and encourage healthy eating habits [37,189]. In addition, several research studies have highlighted the role of the teacher serving as an example when eating at the same table with students [90,189,191,192], as teacher behaviour plays a major role in influencing food consumption by students and shaping their future eating habits [193]. The researchers observed that in the Rezekne city schools, the involvement of both kitchen personnel and teachers in the dining process differed significantly across schools and

classes. The teachers mostly ate at the same table with younger students (grades 1–4) and, accordingly, also helped during lunch (pouring soup, serving salads, etc.). In Latvia, teacher involvement during lunchtime is voluntary and not included in the established working hours, while in other countries, e.g., Sweden, school lunches are integrated into the general curriculum as "pedagogical meals", thus encouraging the teachers to eat with their students, serving as a role model and including food-related discussions that are consistent with the school curriculum, thereby emphasizing the educational value of lunch [191,194,195]. Applying a similar approach in Latvia would increase the educational value of lunchtime, encourage positive and responsible consumption behaviour among students, and consequently reduce FW.

An analysis of the survey results through the MOA framework [112–114] revealed that the Rezekne city students had a certain ability level, including basic understanding and knowledge of school food, FW and its negative impacts. In addition, the answers to several questions showed that some students would be motivated to engage in more sustainable nutrition practices, for example, expressing preferences for customized portion sizes or more flexible meal options. However, actual behavioural changes were limited by the school catering model, which did not provide an opportunity for the students to choose the kind and quantity of food themselves, which is important in out-of-home food services, thus limiting their responsible food consumption behaviour, thereby leading to PW. It is obvious, that organizational changes to the catering process, for example, a buffet-style system or involving students in menu planning, are essential to address the missing "opportunity" element, so that they can turn their motivation and ability into sustainable consumption behaviour, thus providing them with the autonomy to make responsible choices regarding the kind and quantity of food consumed.

5.4. Limitations and Further Research

The present research study had some limitations that should be stressed. Although research studies of this focus have not been conducted in Latvia before, and this is a first step to identifying students' understanding and knowledge of FW issues, the authors acknowledge that the generalizability of the findings restricts the limited survey sample, which included only four schools in Rezekne city. Future research studies would need to expand the sample to include schools from other regions of Latvia with different catering models to conduct a more comprehensive analysis and comparison in different contexts.

The authors assume that the students' answers to the survey questions might have been influenced by their ability to concentrate and maintain attention during the survey, as the survey was quite long, which could have contributed to fatigue and loss of interest, especially for younger students. The researchers also observed a tendency for the students, especially younger ones, to copy answers from their classmates during the survey, which might have related to the above-mentioned ability to concentrate and maintain attention, and copying answers from classmates might have been an easier alternative for some students, allowing them to avoid the effort of independently thinking through the survey questions. Future research studies should consider developing more interactive surveys, especially for younger students, and completing the questionnaires in a more controlled environment to avoid such limitations.

The students' perceptions of survey questions and answers might also have been influenced by the survey format (paper versus digital). For example, digital questionnaires are easy to use, so they can be completed quicker, while paper questionnaires might produce more thoughtful answers because they can be reviewed and corrected, unlike digital questionnaires, which cannot be corrected once submitted. Additionally, while the completion of questionnaires was supervised—through the controlled distribution

of paper surveys and restricted access to the digital survey via a password-protected website—the possibility that a student may have completed the digital questionnaire more than once cannot be entirely ruled out. However, this risk is minimized by the significant time required to complete the questionnaire (30–45 min) and the voluntary nature of participation. Given these factors and the structured survey administration process, it is unlikely that this had a meaningful impact on the overall results.

Another limitation of the present research is that the survey questions focused on school catering, reflecting students' attitudes, knowledge and behaviour in the context of school catering, and therefore the students' answers did not reflect their overall food consumption habits and responsibility for FW at home or elsewhere outside school. Future research studies could expand the scope of the survey to include questions that would reveal students' food consumption practices at home and elsewhere outside school, thus providing a broader understanding of their attitudes, knowledge and behaviour related to food consumption and waste. This could help to develop policy recommendations, interventions and strategies for successfully reducing FW and PW and encouraging responsible food consumption not only at school but also in the wider community.

Although the survey was anonymous, it cannot be excluded that the students might have marked socially desirable answers that they perceived as expected or correct, rather than those that reflected their true thoughts and behaviour. This aspect cannot be completely excluded, yet the survey could be combined with other methods, e.g., focus group discussions or interviews, which would complement the survey data and provide a deeper insight into students' attitudes, knowledge and behaviour regarding FW and allow for a better understanding of the factors influencing their answers.

6. Conclusions

The present research study provides a broad insight into students' knowledge and awareness, their attitudes towards school food, catering and lunch management, as well as their food consumption behaviour and broader challenges related to FW and catering in Rezekne city schools.

The students demonstrated a lack of awareness and knowledge regarding FW issues, which was reflected in their answers, and revealed that many students failed to fully understand the broader understanding of FW, including its financial and environmental impacts and disposal methods. These findings support the proposed hypothesis H1, confirming that students from Rezekne city schools have insufficient knowledge and understanding of FW and its impact on sustainability. The gaps highlight the need to improve student awareness and knowledge, which is a crucial step in addressing FW. However, the research study found that awareness and knowledge alone are not enough to create lasting changes in students' food consumption behaviour; therefore, to effectively combat FW and promote responsible and sustainable consumption practices, it is important to combine educational measures with practical, complex and interesting activities that empower the students to make informed and responsible choices, thereby promoting long-term behavioural changes. In addition, indifference towards FW among the students was likely due to their limited awareness and knowledge regarding FW issues. The fact that more than half of the students showed little concern about food being wasted indicates that a lack of understanding of the consequences of FW reduces personal responsibility and motivation to tackle this problem.

Most of the students were not satisfied with the sensory qualities of the food served, indicating that school meals often did not meet their expectations. Younger students were generally more satisfied with the sensory qualities of school food than older ones, who were found to be more likely to openly express their dissatisfaction. Gender differences revealed

that boys rated all food sensory qualities more positively, while girls were more selective. These findings emphasize the crucial role of sensory characteristics in influencing students' willingness to eat and reduce PW and highlight the need for organizational improvements in Rezekne school catering.

However, weak positive correlations between the generated amount of PW and the students' satisfaction with sensory characteristics indicate that these factors play a secondary role in the generation of PW, suggesting that other factors, including meal choice and portion size control, have a greater influence. This confirms the unsustainability of the current school catering model in Rezekne city, as it does not foster responsible food consumption behaviour or help to reduce PW. Students, even if dissatisfied with the food served, have no choice but to eat what is provided. Addressing these restrictions is essential to promote a more sustainable and student-cantered approach to school catering.

The survey results clearly reveal that the current organizational model of school catering in the city of Rezekne is fundamentally wrong and not focused on sustainability and FW reduction, as it deprives students of the important element of "opportunity" needed to promote responsible and sustainable food consumption behaviour concerning out-of-home catering. The current restrictive system, with pre-served portions, not only hinders changes in consumption behaviour but also fails to address FW issues. These findings confirm the proposed hypothesis H2, demonstrating that the current catering model in Rezekne city schools is unsustainable and does not promote responsible food consumption by students. In order to create a more sustainable and learner-centred catering model, it is imperative to provide opportunities that allow learners to combine their ability and motivation with practical action, to make autonomous decisions on the type and quantity of food consumed and thus engage in responsible and sustainable food consumption.

Abbreviations

The following abbreviations are used in this manuscript:

FW	Food waste
PW	Plate waste
FSC	Food supply chain
EU	European Union
WFP	World Food Programme
SDGs	Sustainable Development Goals
SDG	Sustainable Development Goal
SD	Sustainable Development
UN	United Nations
NAM	Norm Activation Model
TPB	Theory of Planned Behaviour
MOA	Motivation–Opportunity–Ability
E-Mentor	The research project "E-mentor as a Transformation Tool for Ensuring Zero-Waste Food Consumption in Educational Institutions" (No. lzp-2020/2-0115)

Appendix A

Table A1. Correlation between plate waste per student and mean scores (based on the Likert scale) of sensory characteristics by schools and grades before and after interventions (compiled by the authors).

School	Grade	PW (g)	Appearance (Mean, L)	Taste (Mean, L)	Smell (Mean, L)	Temperature (Mean, L)
S1—Pre	2	64.12	4.16	4.39	4.05	3.91
	3	62.93	3.16	3.56	3.48	3.28
	4	54.07	3.73	3.40	3.64	2.71
	5	53.29	3.75	3.73	3.73	3.10
	6	51.49	3.05	3.11	2.97	2.32
	7	43.42	3.37	3.48	3.21	2.60
S1—Post	2	62.61	3.71	3.52	3.50	3.27
	3	53.27	3.22	3.44	3.16	2.72
	4	53.07	3.27	3.16	3.22	2.29
	5	42.92	3.52	3.29	3.17	2.28
	6	40.97	2.78	2.86	2.47	1.86
	7	46.00	3.00	3.23	3.13	2.08
S2—Pre	2	61.60	3.15	3.44	3.28	3.64
	3	48.20	3.75	3.82	3.33	3.44
	4	59.27	4.13	3.63	3.41	3.63
	5	65.00	3.41	3.41	3.28	3.49
	6	59.85	3.26	3.42	3.24	2.79
	7	37.67	3.46	3.63	3.42	3.42
S2—Post	2	67.20	3.66	3.47	3.30	3.36
	3	56.79	3.80	3.78	4.02	3.63
	4	55.80	3.70	3.73	3.73	3.47
	5	46.03	3.53	3.56	3.24	3.11
	6	55.50	3.11	3.05	2.87	2.50
	7	36.69	3.31	3.38	3.07	2.93

Table A1. *Cont.*

School	Grade	PW (g)	Appearance (Mean, L)	Taste (Mean, L)	Smell (Mean, L)	Temperature (Mean, L)
S3—Pre	2	45.02	3.77	3.75	3.82	3.32
	3	34.76	3.96	4.07	3.50	3.64
	4	42.84	3.92	3.92	3.83	3.81
	5	23.04	4.09	3.86	3.91	4.11
	6	38.74	3.44	3.42	3.12	3.30
	7	21.43	3.66	3.76	3.51	3.34
S3—Post	2	50.17	3.60	3.63	3.37	3.37
	3	44.68	3.80	3.40	3.28	3.32
	4	53.41	3.67	3.59	3.46	3.03
	5	38.78	3.65	3.49	3.54	3.32
	6	51.47	3.60	3.53	3.43	3.77
	7	31.83	3.49	3.40	3.09	3.09
S4—Pre	2	51.73	3.55	3.82	3.88	3.73
	3	55.02	4.18	3.76	3.42	3.79
	4	40.83	3.60	3.60	3.63	3.40
	5	47.39	3.36	3.26	3.05	2.51
	6	32.89	3.49	3.44	3.20	2.61
	7	34.25	3.13	3.16	3.52	2.26
S4—Post	2	46.91	3.60	3.62	3.50	3.21
	3	58.09	3.56	3.65	3.44	2.79
	4	33.55	3.58	3.47	3.22	2.50
	5	42.76	3.33	3.22	3.11	2.39
	6	42.41	3.17	3.17	3.07	1.87
	7	37.85	3.11	3.00	2.73	2.19

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VII Raksts

Article

Knowledge-Based Recommendation System for Plate Waste Reduction in Latvian Schools

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Abstract: Food waste indicates ineffective and irresponsible consumption of resources, particularly during the food consumption stage. The aim of our research study is to optimize the catering management process at Latvian schools by reducing the amount of plate waste. The experts developed a set of recommendations aimed at improving the catering management process at schools. The recommendations developed were supported by measurable parameters, which must be monitored by school staff. The capability-driven development approach was applied to model the recommendation system. A plate waste predictive module and a large language model classifier were integrated into the system to support sustainable decision-making. The large language model classifier was trained to filter questions and recommendations. Three training methods were compared: training from scratch and finetuning by using datasets DBPedia and News Category Dataset. As a result, we present the list of recommendations based on the literature review, and the prototype of the knowledge-based recommendation system was developed to audit the school catering management process and promote sustainable school management and decision-making. The recommendation system aims to reduce plate waste due to deficiencies in the implementation of the catering process and to promote responsible food consumption at schools.

Keywords: expert system; food waste; large language model; recommendation system; smart school; sustainability

1. Introduction

Worldwide demand for food is changing as a result of demographic trends, urbanization, economic prosperity, and changing consumer preferences. The growing global population leads to an increase in the demand for food, while a higher level of prosperity constantly causes an increase in the consumption of animal proteins, which means that it is necessary to increase the output of grain for livestock production. The migration of the population from rural areas to cities requires seeking new food production and delivery models [1]. Over time, undoubtedly, the demand for food is going to increase, which makes us consider the environmental and social capacity of the current food system.

There is increasing discussion about the need to transform the current food system into a sustainable food system [2–5]. A sustainable food system (SFS) refers to a food system that operates within the planet's boundaries—limits set by Earth's capacity to sustain life, which includes thresholds for critical environmental processes like climate change, biodiversity loss, and nutrient cycles. By functioning within these boundaries, an SFS delivers and promotes the consumption of safe, nutritious, and healthy food with minimal environmental impact. This includes minimizing climate impact and addressing issues like food loss and waste, which are key factors in staying within planetary boundaries. A SFS ensures that food is available to everyone in a way that protects and revitalizes the natural

environment and its ecosystem services. Additionally, it is resilient, economically vibrant, equitable, socially acceptable, and inclusive, meeting the needs of both current and future generations [6].

The EU Commission has recognized that under the Farm to Fork strategy, the EU food system is not sustainable either in the environmental dimension or in the social dimension [7]. To bring the EU food system within planetary boundaries, one of the solutions is to reduce the amount of food waste (FW) by half, but preferably by $2/3$ [8].

In the pursuit of achieving an SFS, addressing FW is a critical aspect. Increasing the sustainability of the global food system and reducing the amount of FW is not easy to achieve, as it requires a complex of targeted actions at the macro (local and national government), meso (trade associations, producer groups, NGOs) and micro (entrepreneurs and consumers) levels. Sustainable Development Goal (SDG) 12 seeks to "ensure sustainable consumption and production patterns"; the third target under this goal (Target 12.3) calls for cutting in half per capita global FW at the retail and consumer level and reducing food losses along production and supply chains (including post-harvest losses) by 2030 [9].

According to the statistical data on FW related to Target 12.3, on average, each person in the world wastes 120 kg of food per year [10]. However, according to the FAO, $1/3$ of the edible parts of food produced for human consumption get lost or wasted globally [11], having economic, social, and environmental impacts. Food loss and waste (FLW) cause about \$940 billion annually in economic losses. It exacerbates food insecurity and malnutrition. FLW consumes about a quarter of all water used by agriculture, requires land area the size of China, and is responsible for an estimated 8 percent of global greenhouse gas emissions [10]. Wasting less means feeding more: the lost and wasted food could feed 1.26 billion people every year [12].

The benefits of reducing FW are threefold: environmental, economic, and social impacts (less demand for foods and the associated environmental resource use and pollution, labor cost, and energy cost efficiency, increase in non-agri-food demand and thus GDP, reduced greenhouse gas emissions, improvement of nutritional status and energy intake, improved access to food and food affordability due to food price reduction, increase in employment in non-agri-food sectors, etc.) [12–18].

When there are only six years left to attain Target 12.3, broader systemic changes are needed in both food production and consumption regarding an SFS [19,20]. In this sense, school canteens have a considerable impact on global FW generation, and at the same time, school canteens can be a significant contributor to reducing the amount of global FW.

In this paper, we present our original knowledge-based recommendation system developed to minimize plate waste (PW) in Latvian schools. Referring to the previously mentioned classification, our system was primarily oriented to provide clear and precise recommendations and guides to school staff. However, the system includes the elements of the digital twin, a decision support system, and an expert system.

The research study aims to develop a knowledge-based recommendation system to reduce PW in Latvian schools.

The objectives of the study:

1. To model the recommendation system to reduce PW in Latvian schools;
2. To digitize expert knowledge as practical recommendations;
3. To develop an audit system and environmental criteria to identify the most suitable recommendations;
4. To train a large language model to improve user experience by providing microservices to filter recommendations and audit criteria using natural language queries.

2. Literature Review

Various initiatives and activities aimed at reducing FW and implemented either by school management or academic staff are increasingly implemented by educational institutions. However, the basis for reducing FW is to start measuring. Derqui et al. [21], by measuring FW from over 10,000 pupils' trays, found that avoidable FW at primary

schools was from 36.3 up to 93.3 g per pupil/day, while at secondary schools—from 62.3 up to 119.3 g per pupil, and PW was found to be the main source of avoidable waste [21]. Eriksson et al. [22], by analyzing data collected by the schools' kitchen staff through direct measurements, found that the average amount of FW at schools was 79 g per portion, which accounted for 23% of the food served [22]. In Sweden, based on FW data collected from 415 primary and upper secondary schools by municipalities between 2013 and 2020, the average of varying means Wastes Per Portion (in grams) in primary schools and upper secondary schools were 64 g and 96 g, respectively. In 2020, the Waste per Portion median at primary schools was 40 g (the lower value—48 g, and the upper—53 g), the Waste per Portion median at upper secondary school was 79 g (the lower value—73 g, and the upper—85 g) [23]. Malefors et al. [24], based on FW data from 391 primary and upper secondary schools collected by kitchen staff or taken from previously published studies, found that the amount of FW (both PW and serving waste) made up 19.7% of the food served at primary schools and 17.8% at upper secondary schools (in both cases mainly in Sweden, yet schools from Finland and Germany were also observed) [24]. A research study on Italian schools conducted by Garcia-Herrero et al. [13], which included observations of 137,972 meals and direct FW weighting across 7 primary schools, found that the average weight of FW per primary school pupil was 136 g [13]. In an audit of FW in four Spanish schools, Derqui et al. [21], by directly measuring FW from over 10,000 pupils' trays, found that the largest amount of FW came from PW, i.e., ranging from 21 g to 47 g per pupil at primary schools and from 23.7 g to 88.0 g per student at secondary schools [21]. Martins et al. [25] found the mean PW at Portuguese primary school canteens was 49.5 g per portion, or 27.5% of the food served according to the weighing method [25]. Boschini et al. (2018) [26], through direct waste measurements, found that FW at Italian primary schools totaled 27% of the food served [26]. The average amount of PW generated by school students in Beijing in 2014 was 130 g/cap/meal, accounting for 21% of the total food served, based on physical weighing [27]. In 2022, Lonska et al. [16], based on direct measurements of PW, found the average weight of PW per schoolchild in Latvia reached 178 g, and the total weight of PW accounted for 28.75% of the food served (including beverages). A relatively high proportion of PW found by the present research resulted directly from the way school catering was managed, as the canteen personnel served portions of a set meal on the tables reserved for each class, and the schoolchildren could not choose the kind and amount of food themselves [16].

Digital transformation has entered all industries, improving operational processes and work efficiency and generally helping companies to achieve their goals, and digitalization solutions are also being integrated into FW reduction strategies. Various technological and digital solutions are used to support schools in reducing FW. For instance, Malefors et al. [28,29] tested the Plate Waste Tracker at school canteens to reduce FW by giving real-time feedback to students. It consists of a kitchen scale and a tablet that shows the amount of waste and its impact, encouraging students to waste less. The system also collects data on why food is wasted, helping canteen staff improve meal planning and portion sizes. This digital tool supports schools in minimizing FW and promoting sustainable practices [28,29]

To reduce FW at schools, a recommendation system is essential for several reasons [16,30–33]:

1. Education and awareness building. The presence of a recommendation system builds awareness of FW itself. If a school starts to monitor and think about FW, it will grow social awareness and have an educational impact. Any school is an ideal place to inform students about the negative environmental impacts of FW with the aim of encouraging responsible food consumption. The school system, based on particular recommendations, can significantly improve students and teachers' understanding and awareness of the FW problem. Folliard et al. [30] emphasize that it is recommended for schools to systematically conduct a FW audit, which allows for an unbiased assessment of the amount and specificity of FW and is fundamental in educating students and school employees about the need to reduce the amount of FW, thereby contributing to more efficient management of resources [30].

2. Food use efficiency. A recommendation system can help schools plan food supply and consumption more effectively, thereby reducing avoidable FW. The recommendation system could also include best practices in food storage and preparation. After analyzing FW reduction initiatives in elementary schools, Antón-Peset et al. [31] emphasized the role of education and awareness building in the fight against FW. The didactic intervention, which included informing both teachers and students and involving them in FW reduction activities, led to positive changes in the level of their knowledge of and attitudes to FW, as well as reducing the amount of FW generated during lunch breaks. In addition, the research study emphasized the possibility of increasing the efficiency of food consumption by using a system that helps schools to more accurately plan the supply and consumption of food, which resulted in the reduction of FW. By following the system's recommendations for improving the catering process in schools, it is possible to promote better student consumption of school meals, thereby ensuring they receive the necessary nutrients according to dietary guidelines. This approach not only reduces FW but also supports sustainable and responsible consumption, fostering healthy eating habits and long-term environmental sustainability. The implementation of such a system could also include better approaches to food storage and preparation. The research study revealed that educating students and building their awareness can have a significant impact on reducing FW at educational institutions, thereby contributing to sustainable and responsible consumption and efficient resource management [31].

3. Improving FW monitoring. With the recommendation system, schools can monitor FW more effectively, thereby identifying the main sources of waste and developing targeted measures to reduce it. This could include auditing FW and setting waste reduction targets. The research study Plate Waste Forecasting Using the Monte Carlo Method for Effective Decision Making in Latvian Schools, conducted by Kodors et al. [33], applied the Monte Carlo method for monitoring and forecasting FW produced by schools in Latvia. This method makes it possible to effectively identify the main sources of FW and develop targeted measures to reduce it. The method was based on mathematical modeling and simulation, which gave an opportunity to better understand causal associations between the parameters examined through data visualization, and the application of this knowledge allows managers to make effective decisions. The system developed is multidisciplinary in application, thus promoting education and decision-making aimed at reducing FW and contributing to public health and school food management [33].

4. Public involvement. The recommendation system can promote wider public involvement by educating students and their families about the FW problem and involving them in solving it. It can also help to build sustainable food consumption habits both at school and at home. The research study by Lonska et al. [16] emphasizes the role of education in schools to build sustainable attitudes towards food consumption, which could also affect families and the wider public [16].

5. Waste reduction strategies. The recommendation system can help schools design and implement strategies aimed at reducing FW, e.g., through launching food-sharing initiatives or using food leftovers for other purposes. FW reduction initiatives launched at schools can promote sustainable food consumption and educate the younger generation about responsible resource consumption. The research study by Kodors et al. [33] discussed strategies for reducing FW, including a decision-making system for schools based on mathematical modeling and simulations to optimize food consumption and reduce FW. To achieve the research aim, the research developed a mathematical model and a simulator that can be integrated into a decision-making system for effective food management at schools. The present research aims to develop a tool based on three basic principles: knowledge and education, monitoring and forecasting, as well as data updating, and accurate decision-making [33].

At this moment, various solutions have been developed to minimize FW worldwide. However, the basis of an effective FW minimization program is the capability to quantify and monitor FW. Caldeira et al. [34] presented an evaluation framework to assess the

performance of FW prevention actions and classified FW prevention actions into five groups: (1) redistribution; (2) food valorization; (3) consumer behavior change; (4) supply chain efficiency; (5) FW prevention governance [34]. Considering the mentioned classification system, our research focuses on the group "supply chain efficiency" and the category "Digital tools for supply chain efficiency" because its focus involves providing guidelines through recommendation systems to achieve FW reduction at the production/ processing/ distribution stages at schools.

In our case, the recommendation system is aimed at knowledge sharing by transferring the best practices to school staff. According to Schwartz [35], knowledge sharing is an exchange of knowledge between two persons: one who communicates knowledge and one who absorbs it [35]. Knowledge becomes an essential and valuable asset in every organization [36]. However, the modern knowledge-based society generated and collected so much data and information that only digital solutions and artificial intelligence provide a possibility to overcome big data problems. The recommendation systems represent not only one digital solution that can share knowledge. There are different digital solutions; however, conceptually, they are similar, and all are aimed at sharing precise knowledge required for decision-making at the current moment. Let us explore some of them: decision support systems, digital twins, expert systems, and recommendation systems.

Regarding decision support solutions, there are two different definitions, which have similar titles and different contexts: "data support frameworks" and "data support systems". Data support frameworks are economic evaluation models to calculate a product's impact on a solid waste amount, while data support systems are software that is developed to assist people in the decision-making process [37]. However, decision-support systems must be based on some business model to provide the appropriate functionality, and decision-support frameworks can play this role.

For example, Karmperis et al. [37] and Goulart Coelho et al. [38] identified the most widely used decision support frameworks in the field of solid waste management: life cycle assessment (LCA), cost-benefit analysis (CBA), and multi-criteria decision-making (MCDM) [37,38]. LCA assesses the inputs, outputs, and environmental impacts of the product life cycle [39]. CBA calculates the cost of solution implementation and estimates the result benefits. However, MCDM encompasses a broad range of methods to support decision-making to reach a compromise solution when there are multiple criteria [40].

A review of decision support systems for solid waste management was presented by Zhai et al. [41]. The main purpose of the mentioned systems is to optimize logistics, namely minimize CO_2 outputs and improve food safety. The systems are based on an optimization algorithm and specialized for a specific business. Other solutions are based on the usage of the IoT, UAV, and satellite, which provide monitoring data and related information [41]. So, it can be concluded that the trending synonym for a decision support system is a "digital twin". A comprehensive review and a classification of digital twins are presented in a review by Verdouw et al. [42], who refers to "prescriptive digital twins", which can evaluate the current situation and predict the future to support decision-making [42]. If a system clearly provides guidelines or presents important information, which is interpreted by a specialist with the following action plan, all the same, the gist remains similar. The third similar definitions are a "recommendation system" and a "recommender system". For example, Shi et al. [43] trained a neural network to predict volunteers to pick up and deliver food for food rescue tasks [43], while Rodrigues et al. [44] developed a recipe recommendation system, which was based on convolution neural networks for the recognition of available food products to advise a recipe for a dish [44]. Another related group is expert systems. The expert systems are based on expert knowledge digitization. The most popular method is ontology development. For example, Pruvost et al. [45] developed an expert system for building energy waste minimization, which was based on the ifcOWL ontology, expert rules in the Semantic Web Rule Language (SWRL), and the reasoner Pellet [45]. Mhlongo et al. [46] applied an ES-builder tool to design a knowledge and rule-based expert system for the rehabilitation of abandoned mines in South Africa. One of the expert system

subjects was mine waste. The proposed rule-based solution was based on the IF-THEN decision tree [46]. However, Yun et al. [47] applied Dung's argumentation framework to develop an expert system for choosing environment-friendly food packaging [47].

It can be concluded that each definition simply distinguishes some feature of a decision support tool in the result solution (see Figure 1). For example, recommendation systems are primarily oriented on the presentation of guides to users, whereas expert systems focus on expert knowledge digitalization in semantic ontologies and rule-based solutions to process the data. Decision support systems are mainly based on specialized algorithms, which were developed for specific tasks. But digital twins are based on environment monitoring and optimization put together. Considering our objective to primarily provide clear and precise guides to school staff, we call our decision support tool "a recommendation system" within the scope of this article. We focus on the development of recommendations, their digitalization, and the usability of the recommendation system.
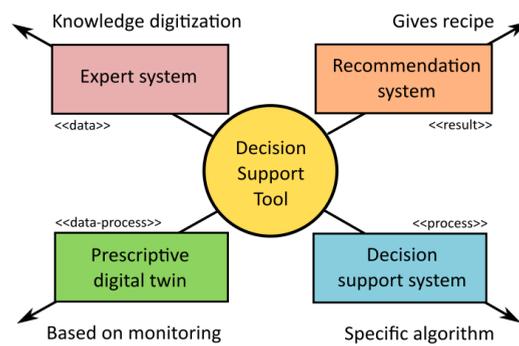

Figure 1. Comparison of each type of decision support tool.

There are different software development methodologies; we need a specialized methodology for expert knowledge digitalization with a business-oriented approach. One of the methodologies to model recommendation systems is the capability-driven development (CDD) approach [48]. The CDD approach was developed to design enterprise models that consider business processes, risks, and possibilities of information technologies (IT) to overcome changes in the ecosystem. The core element of the CDD approach is a capability, in other words, an ability or a capacity that enables an enterprise to achieve a business goal in a certain context. However, the context presents the state of the ecosystem, which can be expressed by measurable properties related to possible risks or contextual situations, which require adapting the business with the goal of obtaining optimal business results [49]. The CDD approach strongly relates to the concept that modern business management is risk management.

Recent advancements in Large Language Models (LLMs) have sparked researchers' interest in improving recommendation systems using LLMs. The main challenge is to provide better collaborative filtering information through LLMs. One solution is to directly prompt LLMs to generate recommendations using natural language queries; another is training or finetuning LLMs to serve recommendation data [50]. Another approach is SPARQL or SQL query generation based on a natural language query [51]. Zhao et al. [52] completed a comprehensive review of recommendation systems in the era of LLMs [52]. They reviewed pre-training, fine-tuning, and prompting LLMs applied for the recommendation systems. The main application domains of LLMs are e-commerce, news recommendation, and social media to provide personalized recommendations to users based on textual data, such as product descriptions, reviews, or news articles [52,53]. The LLMs can be applied to classify text; this approach can be used to search and filter data considering user needs. This approach is useful for large knowledge-based recommendation systems, which have many self-evaluation questions and recommendations.

3. Materials and Methods

3.1. Recommendation System Modeling

The framework of our system was based on expert knowledge collected in project lzp-2020/2-0115, "E-mentor as a Transformation Tool for Ensuring Zero-Waste Food Consumption in Educational Institutions", which was reported in 2021 [32]. This knowledge was preprocessed to obtain measurable properties (criteria) and their key performance indicators (KPIs) and relate them to appropriate recommendations. As a result, the obtained material was integrated into the design of the knowledge-based recommendation system. The conceptual model of our knowledge-based recommendation system is depicted in Figure 2.
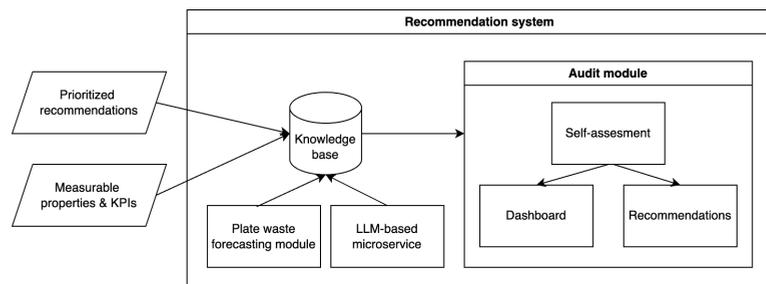
Figure 2. Knowledge-based recommendation system.

The recommendation system consists of several components:

- Audit module, which provides a roadmap for school staff to self-assess the school catering ecosystem. The results of the self-assessment are displayed on the dashboard and included in the recommendation list;
- Knowledge base, which contains digitized expert knowledge: self-evaluation questions and recommendations.
- Plate waste forecasting module—the simulator proposed by Kodors et al. [33] was integrated. The simulator is based on school parameters and a pupil survey, which must be completed annually;
- LLM-based microservice—nowadays, it is very common to integrate large language models (LLMs) to search/filter information to allow users to describe their problem/question in free form using their natural language. LLMs were trained for classification tasks to identify related audit properties and recommendations.

Figure 3 depicts the objects and processes of the recommendation system to provide its functionality.
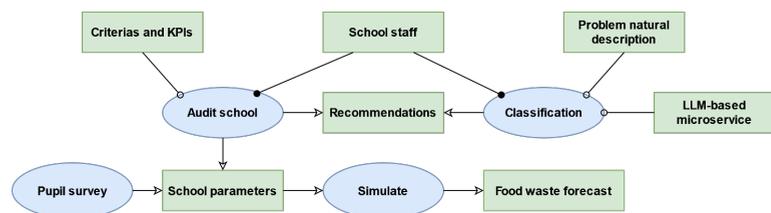
Figure 3. Object-process diagram of the recommendation system.

The original idea of the system concept was developed using the CDD approach. Figure 4 presents the CDD metamodel simplified and commented to highlight the elements of the recommendation system. The PW forecasting and LLM-based microservice were added later to extend system functionality.

Figure 4. Recommendation system based on the CDD approach.

3.2. Development of Data-Based Recommendations

The recommendations aimed at reducing PW presented in Table 1 and the audit criteria presented in Table 2 were developed based on the type of catering management at the schools of Rezekne City (Latvia), as well as on world experience, which was analyzed as part of the "E-mentor" project. The report of the project and the policy recommendations [32] were developed based on the comprehensive review of the FW factors. However, the original recommendations presented in the project report were not suitable for the recommendation system because 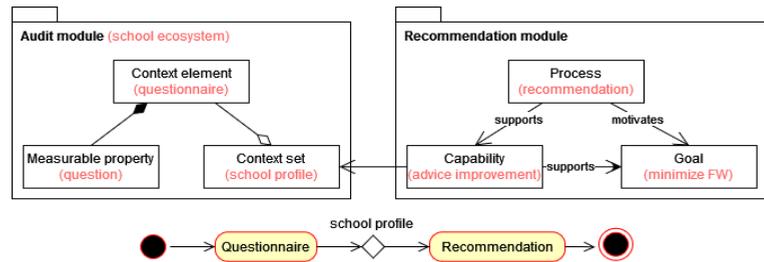the CDD approach requires data-based recommendations with measurable properties. Therefore, we had to involve the experts to digitize recommendations considering the CDD metamodel presented in Figure 4. To simplify the traceability of the literature sources, which were a framework of the digitized FW-reducing recommendations, the literature sources were presented in Table 2. Each recommendation is connected to measurable property (impact factor of FW) considering CDD metamodel. The connections between the FW factors and the recommendations are presented in Appendix A.

A group of four experts participated in developing recommendations aimed at reducing PW; the selection of experts was considered a critical factor in the quality of recommendations and the evaluation process. The experts were selected considering the following criteria: (1) previous experience: the need for previous experience in FW reduction projects implemented by a school, which included research or practical work; (2) analytical thinking: an ability to develop and critically analyze recommendations and evaluate their potential impact on FW reduction; (3) knowledge of the school environment: an understanding of the school environment and the specifics that affect the generation of FW.

After the data-based recommendations were developed considering the CDD approach, they were evaluated by an independent expert to make unbiased and comprehensive findings. The independent expert was selected based on the following criteria: (1) an ability to critically analyze and evaluate the potential impact of the recommendations; (2) an understanding and knowledge of the school environment and its impact on the generation of FW; (3) an ability to give constructive feedback and come up with suggestions.

The evaluation of the 26 recommendations developed by the present research was performed by applying the pairwise comparison method [54,55]. The evaluation was carried out by the previously established group of four experts, based on their scientific experience from analyzing various sources on FW factors, as well as their practical experience in observing catering processes in school canteens and conducting FW measurements. The pairwise comparison method is a systematic approach that allows an evaluation of a set of two or more options by comparing them in pairs to determine which one is preferable. The experts individually compared all the recommendations for reducing PW at school canteens in pairs to identify their relative values. This process allowed the experts to create a ranked list of recommendations based on their relative priorities, applying the systematic pairwise comparison approach. The principles of this approach are based on comparing each alternative with others in pairs and choosing which alternative is superior or equally good. This approach has been widely used in decision-making, voting, and researching human preferences, thus providing a structured and unbiased process of evaluating alternatives [54,55].

Table 1. Systematization and prioritization of FW reduction recommendations (based on the expert structured survey and a pairwise analysis).

ID	Priority 1 Recommendations: The Frequency of Responses ≥ 60 up to 85	Total Score
R1	Provide students with an opportunity to participate in designing their menu by offering a choice between dishes meeting the nutritional standards and school nutrition recommendations (e.g., to choose the main dish for a particular day of the next week a few days in advance, with two main dish options being available for each day)	85
R2	Ensure that the menu is not only in compliance with the healthy nutrition requirements and school catering legislation but also considers changes in the taste of modern children, allowing the children to choose the ingredients of the main meal themselves (buffet-style catering)	83
R3	Ensure that the lunch break begins no earlier than 10:30	82
R4	Improve communication and the information flow between school personnel and canteen personnel by introducing a digital system or tool that provides timely and accurate information on the number of students per meal.	75
R5	Ensure that the temperature of the dishes served meets the requirements	72
R6	Serve the dishes upon the arrival of students at the canteen	68
R7	Ensure that the lunch break is not shorter than 30 min (provided that at least 20 min are spent by the students at the lunch table)	67
R8	Offer pre-portioned, pre-packaged and cut fruits and vegetables as part of a daily meal kit (e.g., baby carrots, tomatoes, cucumber straws, apple slices etc.), with a deposit take-away system being in place	64
R9	To ensure the temperature of the dishes served complies with the relevant legislation, school canteens must use thermoses for soups and main dishes, the volumes of which correspond to the required number of servings, as well as marmites, which can be conveniently placed on the common dining table intended for one class	61
	Priority 2 recommendations: the frequency of responses ≥ 30 up to 59	**Total score**
R10	To provide an optimal arrangement of food, the canteen must use proper size plates (the plates intended for a main course should be 21–25 cm in diameter)	59
R11	With the deposit take-away system in place, if necessary, provide students with takeaway packages for the food served, so that the students who did not manage to finish the meal during the lunch break can do so later in the classroom or at home	56
R12	For students to finish their meal without rushing, no sports class must be before/after the lunch break	54
R13	Students need to be educated about a zero-waste lifestyle, thereby increasing their awareness of the ecological role of FW and the negative environmental impact	49
R14	Applying the competence approach to the curriculum, it is necessary to integrate nutrition education into the curriculum to increase the students' awareness of healthy food	48
R15	Assess the performance of the canteen in cooking and serving the food, so that side dishes or vegetables are easy to eat (e.g., the size of vegetables/thickness of slices)	47
R16	Design a school menu in a creative way (e.g., involve students in coming up with funny or attention-grabbing names for "complex" dishes)	47
R17	Deliver practicals about food processing (e.g., "pedagogical lunch") to teach the students how to properly peel fruits/vegetables and try new flavors, familiarize them with kitchen work or hold study trips to food production facilities, thereby increasing the students' understanding of the role of food	47
R18	Involve a school personnel member (teacher or canteen employee) during the lunch break, thereby motivating students to eat or taste the food, explaining matters related to the food served and helping the students to replenish their lunch plates	46
R19	Raise the awareness of students, teachers and school personnel about the problem of FW (e.g., by applying a healthy food awareness strategy that involves one-way communication tools, communication campaigns "Zero FW week", "Week/day without FW" and "Vegetable month", as well as a "Zero FW competition" between classes etc.)	43
R20	Create a schedule for technological equipment depreciation and plan the purchase of equipment that meets the modern requirements and use modern food preparation technologies to diversify the range of food served, thereby preparing the food by newer and nutrient-friendly techniques while considering the taste and wishes of students and complying with the requirements of healthy nutrition and the relevant school food legislation.	35
R21	Design a training plan for school kitchen personnel to acquire, improve or expand their skills and knowledge necessary for this profession (position)	33
	Priority 3 recommendations: the frequency of responses ≥ 12 up to 29	**Total score**
R22	Provide enough table space per student in the dining hall	25
R23	Ensure the permissible number of students in the dining hall	20
R24	Ensure canteen furniture (tables, chairs) are comfortable for students	18
R25	At lunchtime, students must be offered drinking water as an alternative to cold drinks	15
R26	Provide an opportunity for student parents/guardians to familiarize themselves with the recipes of the dishes served at schools, thus encouraging the preparation of the same dishes in the families and the acceptance and recognition of the dishes by the students at the school	12

The experts were asked to compare each pair of recommendations and choose the one that had a greater impact on reducing FW at school canteens. In total, each expert

compared 325 pairs of recommendations. After that, all the recommendations having the greatest impact on reducing PW at school canteens were aggregated, ranking a total of 26 recommendations from the most influential (according to the experts) to the least influential. The impact of each recommendation was identified by calculating the number of times it was ticked by the experts as the most relevant. The data were processed to get the overall result, which is presented in Table 1. The overall result indicates comparable results that more accurately and objectively reflect the expert opinions on the impact of each recommendation on reducing FW at school canteens. As a result, the recommendation, which was rated as having the greatest impact on reducing PW at schools, was ticked 85 times. In contrast, the recommendation with the least impact on reducing PW was ticked only 12 times.

All the recommendations were divided into three priority categories depending on their impact on reducing PW and the total number of recommendations ticked by the experts (see Table 1).

Each recommendation offered by the system is based on specific audit criteria used to evaluate the school ecosystem, reflecting the real situation in the school. Following the audit conducted by the school administrative staff, the recommendation system provides tailored recommendations for each school aimed at reducing PW, ranked from the most to the least influential. The evaluation criteria for the school ecosystem are summarized in Table 2.

Table 2. Criteria for the recommendation system and the characteristics and values divided by subtopic (authors' own compilation).

Context Element	ID	Measurable Properties	Target Value	Context Range	Impact on PW Reduction
Canteen	Q1	Noise in the dining hall makes students leave the hall earlier	1	Likert scale 1–5	An increased noise level can make students want to leave the dining hall earlier, thereby not eating all the food served [56–59]
	Q2	The canteen environment puts psychological pressure on students, forcing them to leave the dining hall earlier	1	Likert scale 1–5	An uncomfortable and unpleasant canteen environment can make students want to leave the dining hall earlier, thereby not eating all the food served [60]
	Q3	The size of the dining hall meets the requirements specified in the guidelines for establishing school canteens	$\geq 0.8 \, \text{m}^2/\text{student}$	[0; inf+)	Overcrowding can cause psychological stress for students, some of them might leave the dining hall earlier; as a result, the food served might not be eaten [21,59]. According to Cabinet regulation No. 693 [61], the minimum area per student in the canteen in Latvian school must be 0.8 m^2
	Q4	Canteen tables and chairs must meet ergonomic requirements	5	Likert scale 1–5	Tables and chairs in school canteens that are not adapted to the age of students can negatively affect the students' subjective opinion of the comfort of the furniture, which in turn can reduce the time they spend at the table, thereby increasing the likelihood of FW [32]
	Q5	Dining table space per student, cm	≥ 50 cm	[0; inf+)	Not enough table space per student can make eating difficult and reduce the time the student spends at the table, thereby increasing the likelihood of FW [32]
	Q6	Students participate in arranging the dining hall, creating one-way communication tools for responsible food consumption	Yes	Bool	One-way communication tools, e.g., posters, placards and informative table talkers, provide information about food, responsible consumption and FW, thereby positively influencing food consumption by students and reducing the likelihood of FW [16,28,31,62–64]

Table 2. *Cont.*

Context Element	ID	Measurable Properties	Target Value	Context Range	Impact on PW Reduction
Lunch break	Q7	Beginning of the first lunch break (time)	11:00–14:30	[00:00; 23:59]	An early lunch break (e.g., before 11:00) might make students reluctant to eat lunch due to insufficient hunger, thereby increasing the likelihood of FW [65,66]. Cabinet Regulation No. 610 [67] stipulates that lunch should be held in schools no earlier than 11:00, however, given the fact that in Latvian schools classes begin mainly at 8:00, lunch breaks are used to set based on the needs of younger students
	Q8	Duration of the lunch break	≥30 min	[0; inf+)	It is essential to provide an opportunity for students to spend at least 20 min at the lunch table, so that they can eat without rushing, thereby reducing the likelihood of FW [33,64,65,68–72]. Cabinet Regulation No. 610 [67] stipulates that lunch should be held in Latvian schools no earlier than 11:00, with a break of at least 30 min
Schedule of sports classes and lunch breaks	Q9	Sports classes are scheduled to begin right after lunch	No	Bool	It is important to allow enough time for lunch so that students can eat without rushing, thereby reducing the likelihood of FW. If sports classes are scheduled to begin right after lunch, it could reduce the time students spend at the table, as they need enough time to change their clothes for the sports classes during the lunch break [32,65,70–74]
	Q10	Sports classes are scheduled to begin right before lunch	No	Bool	It is important to allow enough time for lunch so that students can eat without rushing, thereby reducing the likelihood of FW. If sports classes are scheduled to begin right before lunch, it could reduce the time students spend at the table, as they need enough time to change their clothes after the sports classes during the break [32,65,70–74]
School personnel	Q11	School personnel (teachers/kitchen personnel) are helpful and kind to students in the dining hall during lunch	5	Likert scale 1–5	Students are not afraid to turn to school personnel if they need help, e.g., serving food, which can reduce the likelihood of FW [75–77]
	Q12	School personnel (teachers/kitchen personnel) pay individual attention to students in the dining hall during lunch	5	Likert scale 1–5	School personnel actively participate in the catering process, providing students with the necessary help in serving food or communicating with the students and explaining questions related to the food served, thereby reducing the likelihood of FW [21,22,58,68,77–79]
	Q13	Students feel trust in school and kitchen personnel	5	Likert scale 1–5	Students enjoy visiting the canteen, they are not afraid to turn to school personnel if they need help, e.g., in serving food, which can reduce the likelihood of FW [75,80]
Serving food	Q14	Diameter of a plate for the main course	≥21 cm	[0; inf+)	The size of the plate should correspond to the size of the portion. Dinner plates with a diameter of 21–25 cm provide an optimal arrangement of food, with the textures and ingredients of the food being visible and not overlapping. It promotes the visual appeal of the food and stimulates the appetite, thereby reducing the likelihood of FW [16,81–84]
	Q15	Catering system in the form of a buffet	Yes	Bool	The catering system in the form of a buffet allows students to choose what they want, thereby reducing the likelihood of FW [16,27]
	Q16	Time food is served on tables before the beginning of the lunch break	≤5 min	[0; inf+)	In case the meal is portioned on tables for each student individually, the meal should be served shortly before the beginning of the lunch break to ensure the optimal temperature thereof, thereby reducing the likelihood of FW [64,85]

Table 2. *Cont.*

Context Element	ID	Measurable Properties	Target Value	Context Range	Impact on PW Reduction
Sensory evaluation of food	Q17	Students are satisfied with the temperature of the food served	5	Likert scale 1–5	Students are overall satisfied with the temperature of the food served, which contributes to their appetite and reduces the likelihood of FW [64,85]
	Q18	Average temperature of the soup served	70–80 degrees	[0; inf+)	The temperature varies, depending on the type of food: soup—70–80 degrees, main course—60–65 degrees, salad—12–14 degrees [86,87]
	Q19	Average temperature of the main course served	60–65 degrees	[0; inf+)	The temperature varies, depending on the type of food: soup—70–80 degrees, main course—60–65 degrees, salad—12–14 degrees [86,87]
	Q20	Average temperature of the salad served	12–14 degrees	[0; inf+)	The temperature varies, depending on the type of food: soup—70–80 degrees, main course—60–65 degrees, salad—12–14 degrees [86,87]
	Q21	Students are satisfied with the complex menu	5	Likert scale 1–5	Students are overall satisfied with the taste, smell, texture, and visual appeal of the food served, which contributes to their appetite and reduces the likelihood of FW [88–90]
Menu	Q22	Students have an opportunity to order food in advance	Yes	Bool	Students can choose meals from the menu according to their preferences and order them a day/week before, which can reduce the likelihood of FW [32,91,92]
	Q23	Students have an opportunity to choose the ingredients of the main course themselves	Yes	Bool	Students can choose meal ingredients from the menu (e.g., make a salad from various vegetables), which can reduce the likelihood of FW [16,27,93]
	Q24	The centrally planned menu is adapted to the wishes of students	Yes	Bool	The centrally planned menu is designed considering student preferences, e.g., through surveys of students, kitchen personnel, teachers, and nutritionists based on school catering guidelines, which can reduce the likelihood of FW [16,32,65,94–96]
	Q25	The weight of portions is differentiated according to the age of students	Yes	Bool	The meal is portioned in proper amounts depending on the age of students, which can reduce the likelihood of FW [97–100]
	Q26	Students have access to drinking water at lunchtime	Yes	Bool	Along with other drinks, students are also offered drinking water at lunchtime [101–103]
	Q27	Students are involved in suggesting creative menu item names	Yes	Bool	Involvement of students in suggesting creative menu item names stimulates their interest in school meals, which in turn can contribute to their appetite and reduce the likelihood of FW [104–106]
Ways of serving fresh fruits/ vegetables	Q28	Fruits/vegetables are peeled	Yes	Bool	Peeled fruits/vegetables contribute to responsible food consumption (this does not apply to bananas) [21,107–109]
	Q29	Fruits/vegetables are cut	Yes	Bool	Peeled fruits/vegetables contribute to responsible food consumption [21,107–109]
	Q30	The fruit/vegetable pieces cut are "one bite" size	Yes	Bool	Fruits/vegetables should be cut in such a way that it is more convenient for students to eat them, considering that primary school students might be at the transition stage of teeth, which makes it difficult for them to eat solid food products; therefore, the students might refuse harder fruits/vegetables (this does not apply to bananas) [110–114]
	Q31	Fruits/vegetables are cut and portioned in shared containers	Yes	Bool	By offering fruits/vegetables in shared containers, students can choose their fruits/vegetables, e.g., for salad, which can reduce the likelihood of FW [32,115–117]
	Q32	Fruits/vegetables are cut and portioned in takeaway containers	Yes	Bool	Offering fruit/vegetables in takeaway containers can promote healthy eating habits and responsible food consumption [16,114,118]

Table 2. *Cont.*

Context Element	ID	Measurable Properties	Target Value	Context Range	Impact on PW Reduction
Kitchen work management	Q33	Kitchen equipment allows the application of various cooking techniques	5	Likert scale 1–5	Choosing a proper food cooking technique can improve the sensory properties of meals and consequently increase food consumption [16,21,32]
	Q34	Kitchen personnel are skillful in choosing a proper technique for food preparation	5	Likert scale 1–5	Choosing a proper food cooking technique can improve the sensory properties of meals and consequently increase food consumption [21,85,119,120]
	Q35	Kitchen personnel have adequate cooking skills and skills to work with various technological equipment	5	Likert scale 1–5	Choosing the right food cooking equipment can enhance the sensory properties of meals, thereby increasing food consumption [21,85,119,120]
Sustainable school administration	Q36	The school administration is focused on total waste reduction, incl. FW, at the school	5	Likert scale 1–5	The school administration should effectively involve school personnel in achieving zero-waste catering, which can reduce the likelihood of FW [120,121]
	Q37	The school administration is oriented towards a sustainable management policy	5	Likert scale 1–5	The school administration can contribute to responsible consumption of resources, which also involves achieving zero-waste catering [21,81,122]
	Q38	The school implements various kinds of activities to draw students' attention to waste, incl. to the problem of FW	Yes	Bool	The implementation of activities aimed at reducing FW at the school contributes to responsible consumption of resources (including food) by students [123–126]
	Q39	Students' awareness of healthy nutrition is sufficient	5	Likert scale 1–5	A sufficient level of awareness among students about healthy eating contributes to responsible food consumption, reducing the likelihood of FW [127–129]
	Q40	Students' awareness of the negative impacts of FW is sufficient	5	Likert scale 1–5	A sufficient level of awareness of students about the negative impacts of FW contributes to responsible food consumption [21,97,127,130–133]
	Q41	Topics on FW, the importance of healthy food consumption and nutrition are included in the school curriculum	Yes	Bool	Incorporating the topics of FW, healthy food consumption and the role of nutrition into the school curriculum contributes to responsible food consumption, thereby reducing the likelihood of FW [32,81,134–137]
	Q42	More than half of the students have healthy eating habits	Yes	Bool	Students' healthy eating habits resulted in responsible food consumption [131,138,139]
	Q43	Students are provided with an opportunity to take their uneaten food or drink with them	Yes	Bool	Uneaten food or drink taken by students at lunchtime can be eaten/drinked later, thereby reducing FW [32,72,140]
	Q44	Students are provided with an opportunity to submit feedback on school food	Yes	Bool	Knowing students' feedback about school meals, e.g., in the form of surveys, comment books, or online applications, allows kitchen personnel to plan the menu based on the students' preferences, thereby reducing the likelihood of FW [141–144]
	Q45	Teachers are informed about the benefits and healthy properties of school meals with the aim of increasing students' awareness	5	Likert scale 1–5	Teachers can raise students' awareness of school meals and the benefits thereof, thereby contributing to responsible consumption of food at the school [16,21,57,145,146]
	Q46	Parents of students are informed about the benefits and healthy properties of school meals with the aim of increasing the students' awareness	5	Likert scale 1–5	Parents can increase their children's awareness of school meals and the benefits thereof, thereby contributing to responsible consumption of food at school [147–149]
	Q47	The school provides timely and accurate information on changes in the number of students	5	Likert scale 1–5	The school provides an opportunity to report on changes in the number of students in time for the accurate preparation of the amount of food, which reduces FW [32,150,151]

3.3. Study Site

In the Rezekne city schools, the catering process is managed within closed-type canteens, meaning that catering services are provided only to specific groups—namely, those who study, work, or reside in the institutions where these facilities operate. According to legal provisions, including Cabinet Regulation No. 614, "Procedures for Calculating, Allocating, and Using Funding Provided from the State Budget for Catering to Learners" [152] and the annual directive of the Rezekne City Council's Education Board, 'free lunches' are provided to certain student groups in Rezekne city schools: grades 1–4 receive 'free lunches' funded by the national government, while grades 5–7 receive 'free lunches' funded by the local Rezekne city government [16].

In these school canteens, serving 'free lunches' often involves partial self-service. Just before the lunch break, canteen staff prepare tables for each class by setting out portions of a main dish (including staple foods and meats on a single plate) and placing beverages in individual glasses. In some schools, vegetables are served directly on the main dish plates, while in others, they are provided in shared bowls on each table. Soups are served in common pots, with the quantity determined by the number of students in each class using standardized measures and serving cups. Bread slices and pieces of glazed curd cheese are placed in shared containers on the tables following the expected number of students. In most schools, if any soup, salad, or bread remains in the common pot or bowl after the lunch break, it is replenished for the next class. The leftover soup, salad, or bread in these shared containers is discarded only after the final lunch break. However, in one school, the common soup pots are not replenished for subsequent classes. Instead, the leftover soup is discarded immediately after each lunch break, based on the canteen manager's decision due to hygiene concerns.

In this research, plate waste is defined as the amount of food served to students that remains uneaten on their plates and is subsequently discarded, including any served food remnants left in shared bowls and pots. Given the catering management system at Rezekne city schools, PW constitutes the majority of FW. To address this issue, a prototype recommendation system has been developed based on audit criteria derived from the current catering management practices, with the goal of reducing PW.

3.4. Expert Knowledge Digitalization

Knowledge digitalization is traditionally based on knowledge graph (semantic network) application. Different visual notations have been developed: knowledge maps, mind maps, concept maps, etc. However, the most popular expert instruments are semantic ontologies and the tool WebProtege. Leveraging ontologies within the Semantic Web framework allows for the definition of expert knowledge in a model-driven manner. When considering the Web Ontology Language (OWL) for this purpose, the decision-making facilities of the expert system must be defined elsewhere because OWL is not fully suitable for the definition of IF-THEN rules. Although OWL has several types of conditions, they are very constrained and insufficient for application in the recommendation system developed. To circumvent this shortcoming, we have developed a metamodel (see Figure 5) that defines a structure and rules to combine expert knowledge definition and rule-based decision-making logic considering CDD metamodel (see Figure 4).

The metamodel consists of two packages:

- The audit package defines the concept of an audit question. An audit question consists of the question text, an answer data type, an answer value, and a predefined expected answer value.
- The decision support package defines the recommendation concept. Each recommendation has its priority defined as an integer, a short name for use in recommendation graph visualization, recommendation text, and one or more linked questions. The function "isActive" determines whether the question answer meets the recommendation criteria or not.
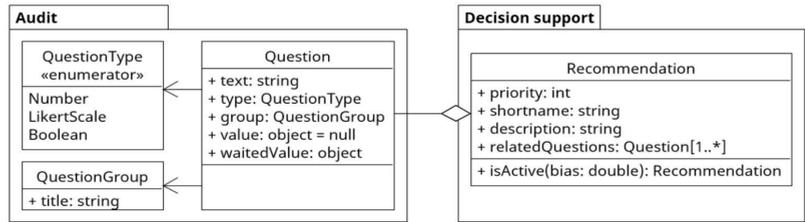
Figure 5. Metamodel of the recommendation system (* UML visual notation).

Recommendations and audit questions have a one-to-many relationship, allowing for multiple questions that lead to the same recommendation.

When it comes to building an expert system, some of the common approaches include the application of rule-based systems and decision trees. Based on the expert-prepared audit question and recommendation data, the rule-based approach was selected. The developed recommendation system incorporates user self-assessment to input data for the rule-based decision-making process. During the self-assessment, users audit their school's catering management process by answering a series of questions. Once answers for at least one category of questions have been submitted, the system can provide recommendations if recommendation criteria are met. All recommendations are grouped by their priority—the higher the priority, the more important it is for the school to take it into consideration.

3.5. LLM Training

We trained LLM classifiers because there is a finite number of recommendations, and the recommendation system does not have a classical database with multiple user records, which must be processed for data analysis. The user inputs a natural language query (NLQ), and then the system returns related recommendations. Considering the metamodel (Figure 5), audit questions can be filtered by the same LLM because the recommendations have connections with the self-assessment questions.

The length and number of items in the questionnaire play a crucial role. If respondents lose interest due to the long length of the questionnaire, they provide unconsidered and unreliable answers or stop to answer the questions. Consider the article "How short or long should a questionnaire be for any research? Researchers' dilemma in deciding the appropriate questionnaire length" [153], the recommended length should be 25 to 30 questions and should be able to be administered within 30 min. Our system contains 26 recommendations and 53 questions, which exceed the recommended length. Looking to the future, when the recommendation system is extended with additional questions and recommendations, the user must have some function to filter these questions and recommendations up to their main focus of interest. The LLM classifier can play exactly this role. The greater the number of questions and recommendations in the recommendation system, the more useful LLM classification for its users (see Figure 6).
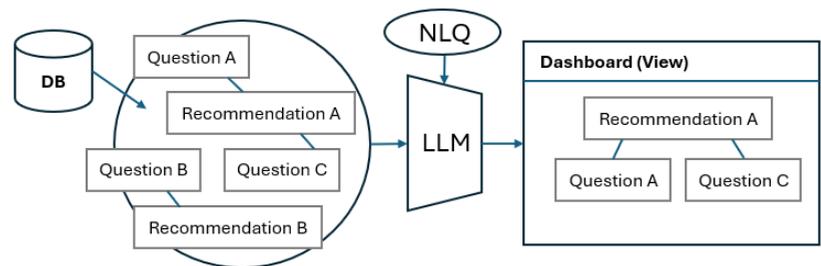

Figure 6. LLM filters for questions and recommendations, considering a user query.

We decided to train an LLM classifier from scratch and to apply finetuning with LLMs pre-trained on two popular text-classification datasets (DBPedia [154] and News Category Dataset [155]). The pretraining allows LLMs to understand linguistic aspects, including grammar, syntax, semantics, and even common sense reasoning [52]. LLM architecture is based on the paper "Attention Is All You Need" [156]. We only excluded the decoder part and the position encoding layer (Figure 7).
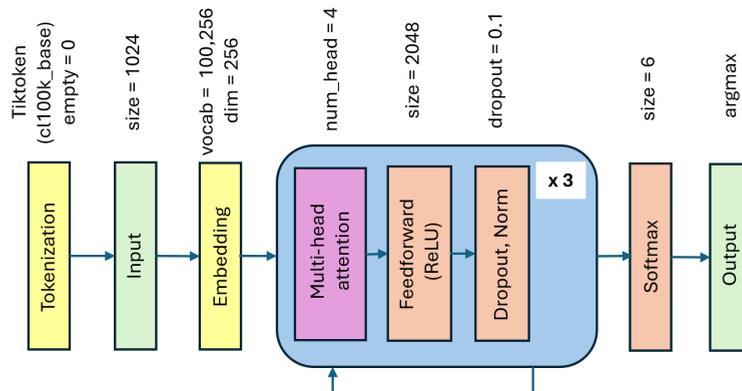

Figure 7. LLM architecture was applied in our experiment.

We used the PyTorch framework for LLM development and training. PyTorch has the class nn.TransformerEncoderLayer provides prebuilt Transformer functionality with multi-head attention, a feedforward layer, a dropout, and a normalization layer with an option to configure them through parameters. The Python tokenization package "Tiktoken" was applied to establish standardized input because we plan to make finetuning. The Adam optimization algorithm, the CrossEntropyLoss function, and the Nvidia RTX4060 GPU were used in the training process.

The Softmax layer has 6 outputs because we grouped 26 recommendations into 6 categories (see Figure 7). The following six categories were identified by ChatGPT: (1) Dining Hall Capacity and Comfort; (2) Lunch Break Timing and Duration; (3) Staff Involvement and Communication; (4) Food Serving and Presentation; (5) Menu Design and Participation; (6) Education and Healthy Habits. It should be done to simplify the task by changing a multi-label problem to a multi-class task. The groups were defined by ChatGPT 4 using the prompt with a recommendation list and a request to group them into contextually independent categories. As a result, the training dataset contained only 748 samples, which included 20% of the validation samples. The training dataset was generated using expert materials. The augmentation was completed using ChatGPT. It generated samples with keywords, key phrases, questions, and problem descriptions, which users could input. One hundred samples were prepared manually for the test: 50 samples by the developers and 50 samples by the experts.

In the beginning, we pre-trained LLMs on the DBPedia and News Categories dataset (see Figure 8). DBPedia provided 9 categories, but the News Categories dataset—42 categories (see Figure 9). We wanted to obtain a TinyML model and achieve comparable results using the same model in all experiments. Therefore, we decided to pre-train LLMs ourselves. Additionally, we need to train LLMs in the future, which will support the Latvian language. There is a limited number of category datasets that support the Latvian language. The DBPedia and News Categories datasets provide common categories that are accessible and can be obtained from local sources. English datasets play a role in the pilot experiment to understand: "Is it useful to prepare pre-training datasets in our case?". The LLM pre-training was repeated 5 times; the best models were selected for the next part of the experiment.

Then, we completed the main part of our experiment. LLMs were trained on our dataset from scratch, and we completed fine-tuning using pre-trained LLMs (see Figure 10). The experiment was repeated 5 times to compare three methods (see Figure 11). The experiment showed that the finetuning method with the DBPedia and News Categories datasets provided comparable training accuracy with the scratch method in a shorter time period (see Figure 10). However, the validation accuracy of the finetuning method was smaller than in the case of the scratch method (see Figure 11).

Figure 8. Accuracy of LLMs trained on the DBPedia and News Categories datasets.

Figure 9. Sample distribution and categories of two datasets: the DBPedia and News Categories datasets.

The final test was completed using manually written queries and the best LLMs from the previous stage (see Table 3). In this case, we tested the accuracy of LLMs on samples that were used at the training stage. Additionally, we measured user satisfaction with the outputs of LLMs. The satisfaction was measured by two methods: (1) Do you like the answer? (Yes/No); (2) the average on the LikertScale5: 5—a very good answer, 1—a very bad answer. The LLM trained from scratch showed the best result at the validation stage.

The News Categories dataset showed the second-best results. Additionally, we can see that the satisfaction levels of the experts and developers were different. However, the results were sufficiently acceptable for integration into the recommendation system.
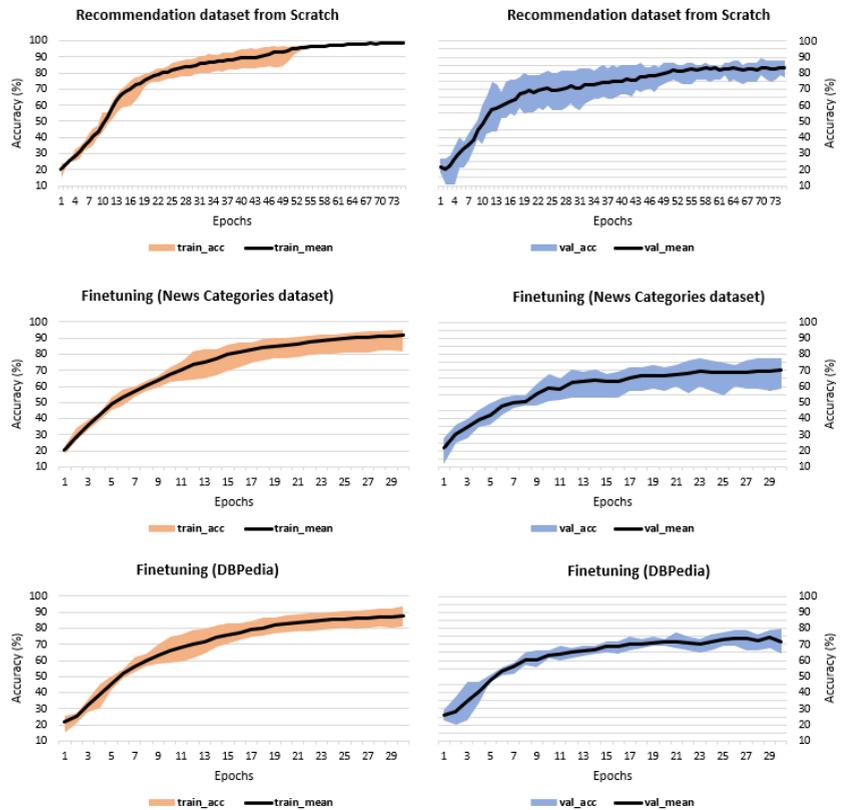

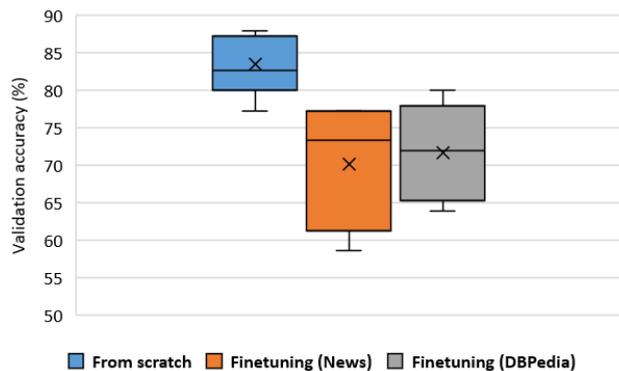**Figure 10.** Training of LLMs on our dataset.

Figure 11. Box plot diagram to compare three methods, where ×—mean value.

Table 3. Test results for LLMs.

LLMs	Together (100)	Experts (50)	Developers (50)
From scratch	Like: 79% Satisfaction: 3.87	Like: 64% Satisfaction: 3.33	Like: 94% Satisfaction: 4.39
Finetuning (News)	Like: 74% Satisfaction: 3.72	Like: 54% Satisfaction: 3.02	Like: 94% Satisfaction: 4.39
Finetuning (DBPedia)	Like: 67% Satisfaction: 3.59	Like: 50% Satisfaction: 2.92	Like: 84% Satisfaction: 4.24

4. Results

As a result, we present our original knowledge-based recommendation system developed to minimize PW in Latvian schools. The first task was to implement an audit system. Each audit theme was based on a context element (see Table 2). The example of a questionnaire implemented into the recommendation system is depicted in Figure 12.

Figure 12. Example of the audit module user interface.

The answers received were saved and used to calculate the compliance level to determine recommendations that would be relevant to the situation described by the user. The calculation was done on request when the corresponding systems interface was opened, for example, the dashboard (see Figure 13), where results are shown in condensed form. Users can obtain the following data:

- compliance level with each recommendation (match);
- compliance level for each context element;
- average compliance level for all user answers in the audit system;
- predicted the total amount of PW (in one week) using the PW forecasting algorithm described in the paper by S. Kodors et al. [33].
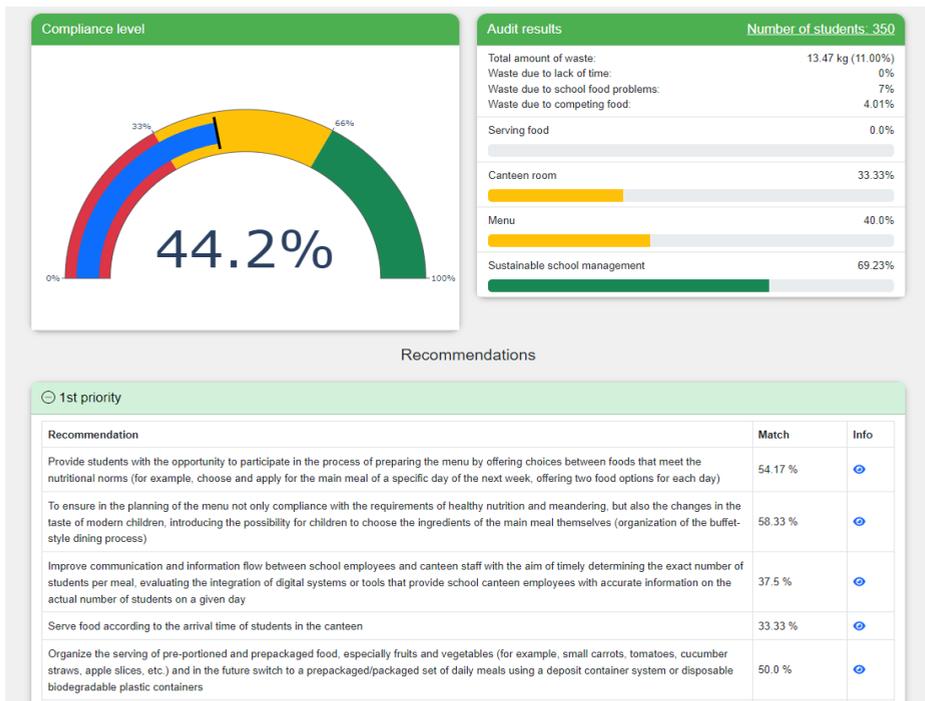
Figure 13. Dashboard of the recommendation system.

As a result, the dashboard provides recommendations and compliance with the context elements, which identify problems and assist in effective decision-making. The total amount of PW (in one week) is predicted by an algorithm described in the paper by S. Kodors et al. [33]. The use of input parameters is one of the questions in the audit system. The trained LLM provides a similar dashboard (see Figure 13), and only the recommendations, compliance levels, and context elements are filtered based on the natural language query. We integrated a geospatial analysis map and a school summary table with export options to support our experts with regional data for future analyses of the PW situation in Latvia (see Figure 14).

Figure 14. Analytical tools.

One of the key advantages of the system is its ability to adapt recommendations based on the unique ecosystem parameters of each school. By integrating expert knowledge with contextual data, the system ensures that the recommendations it gives are not only relevant but also practical, which is essential for enhancing the sustainability of the school environment.

5. Discussion

The recommendation system involves its users, i.e., both school personnel and students, collecting information about the parameters of the school ecosystem, thereby building up a sense of responsibility and increasing awareness of the importance of reducing FW. By involving the school community, the system helps to develop a culture of responsible consumption, thus promoting long-term sustainability.

With advanced technologies, e.g., the integration of LLMs and PW forecasting modules into the recommendation system, it is possible to increase the usability of the system and the possibilities of data-based decision-making. Such technologies enable the system to process natural language queries and provide more accurate and relevant recommendations, thereby allowing the users to make informed decisions.

Another important feature of the system is its capability to continuously improve itself by incorporating user feedback and new research findings, adapting to the various kinds of school catering and the changing needs of the school catering environment. This is important to maintain the adequacy and effectiveness of the system over time.

In addition to its practical advantages, the recommendation system also serves an educational purpose. Implementing the recommendations given for schools allows students to understand the FW problem, thereby fostering long-term changes in their behaviors, even after their school years.

The recommendations given by the system for enhancing school catering management are based on system audit criteria after performing an evaluation of the canteen infrastructure, menus, food serving practices, and waste management. Each audit criterion is associated with certain measurable parameters of the school ecosystem, which allows for an unbiased evaluation. This quantitative approach is essential for identifying areas for improvement as well as tracking the progress over time. Besides, the school ecosystem parameters help to prioritize recommendations based on their potential impact, thus ensuring that the most effective recommendations are selected and implemented first.

The recommendation system is developed with the objective of providing a user-friendly audit system, which allows responsible school staff to easily undergo minimal training. Developers focused their attention on the intuitive interface and clear guidelines to make it accessible to a wide range of users. School administrators can use audit results to make data-based decisions about necessary improvements in the food system, thus ensuring that the resources are used effectively to reduce FW. At this moment, the system has been evaluated by experts and students, and it is prepared for testing in the Living Lab.

Typically, language models as text encoders are integrated into recommendation systems to generate user-item matching scores. Two main lines of research are in this area: (1) language models represent textual items; (2) language models are applied as user encoders or recommendation backbones [53]. However, there is another growing trend—small language models (SLMs)—which are not powerful enough to solve common problems, but they can be sufficiently effective to process specific tasks. For example, the Phi-1 model was presented, which has 1.3B parameters (model size) and showed 50.6% accuracy on the HumanEval dataset. For comparison, GPT-3.5 has 175B parameters and showed 47% accuracy on the HumanEval dataset. The Phi-1 authors stated: "The central ingredient of our model relies on textbook-quality training data". They underlined the importance of high-quality data, which are key elements to training SLMs, and called the paper "Textbooks Are All You Need" [157]. SLM Phi-3 was presented in 2024, which already presents multimodal option reasoning with both visual and text input capabilities [158]. So, our research study is in agreement with other research studies. We must focus more on specialized tasks.

Considering the LLM training results, the difference between the experts' and developers' test datasets (see Table 3) is normal for neural networks. A similar effect is known in computer vision, where convolution neural networks trained on laboratory datasets show dramatically smaller accuracy than natural datasets. Regarding LLMs, Razeghi et al. [159] experimentally proved that the term frequency impacted LLM accuracy [159].

The developers' test dataset and training dataset were prepared by the same people. Therefore, they have a high term frequency of common words and similar stereotypes. We did not apply position encoding (PE) in our LLM architecture, which was presented in the paper "Attention is all you need" [156]. When processing sequences like text, audio, and video, the ordering information is clearly critical [160]. However, Kazemnejad et al. [161] experimentally proved that no positional encoding (NoPE) outperformed other explicit positional encoding methods while requiring no additional computation. They provide theoretical proof that NoPE can learn absolute positional encoding and relative positional encoding. Their experiment showed that NoPE learned to use relative PE in practice [161]. In the future, we plan to train LLMs to process queries written in Latvian. The Latvian language involves conjugations of words. Therefore, it is preferred that LLM architectures be compared with NoPE and PE in our case. Another discussion object is dataset size. According to Hoffmann et al. [162], an efficient computational frontier can be described by a power-law relationship between the compute budget, model size, and the number of training tokens. They discovered that the larger models underperform compared with what could be achieved with the same computing budget. They suggest focusing on dataset scaling, not training larger and larger models [162]. Therefore, improvements in accuracy and satisfaction can be achieved by involving more people to extend our training dataset while minimizing the model size.

6. Conclusions

The development of a prototype of a knowledge-based recommendation system for reducing PW at schools in Rezekne is an important step towards sustainable food consumption. We presented the next original solutions in our paper: (1) a list of measurable properties and recommendations to reduce PW; (2) an LLM solution to filter/search data and recommendations by using natural language queries, which were integrated into the recommendation system. In the chapter "Results", we presented the prototype of the knowledge-based recommendation system.

We applied the CDD approach to model our recommendation system and to develop data-based recommendations to reduce PW in Latvian schools.

The CDD approach requires digitizing expert knowledge in a special form, where the recommendations are connected to measurable properties, to satisfy the data-based approach. By tailoring recommendations to the unique parameters of each school's ecosystem, this system provides a practical approach to improving the efficiency of school catering management. The audit-based recommendations not only address the immediate issues related to PW but also contribute to long-term sustainability by fostering responsible food consumption habits among students.

The findings from our study indicate that the recommendation system can be effectively implemented in schools to systematically reduce FW by guiding staff through data-driven recommendations. These recommendations are prioritized based on their impact, ensuring that the most suitable recommendations are applied first. Moreover, the system's integration of expert knowledge and its adaptability to different school environments make it a versatile tool that can be customized for broader use in various educational settings. In practical terms, schools can implement this system with minimal training due to its user-friendly interface. By continuously incorporating feedback and new data, the system remains relevant and effective over time, making it a sustainable solution for managing FW in schools.

Considering the LLM training objective, the best LLM training method, in our case, was training from scratch: the validation showed 88% accuracy, while the test showed 79% accuracy. It must be mentioned that trained LLMs were focused on developers' lexicon and stereotypes, who prepared the training dataset. The experiment showed that the best LLM showed a test accuracy of 94% on the developers' samples and only 64% on the experts' samples. The satisfaction level showed results between "normal" and "good": 4.39 for the developers, 3.33 for the experts, on average—3.87. To improve the obtained results, we

must extend the training dataset by involving different people to generate new training samples. Considering the finetuning, our LLM architecture does not contain a Position Encoding layer; therefore, it would be preferred to repeat the experiment to identify the impact on transfer learning results. In addition, a "neutral" category like "There are no suitable recommendations!" must be added for queries with irrelevant content. In the future, we plan to prepare a dataset with samples in the Latvian language and train LLMs in both languages. The Latvian language has conjugations of words.

Appendix A

Table A1. The connections between the FW factors and the recommendations.

Recommendation ID	Measurable Property ID
R1	Q22; Q23; Q24; Q36; Q37; Q43;
R2	Q15; Q21; Q23; Q24; Q25; Q26; Q33; Q34; Q35; Q36; Q41; Q42; Q44;
R3	Q7;
R4	Q22; Q36; Q37; Q47;
R5	Q17; Q18; Q19; Q20;
R6	Q10; Q15; Q16; Q18; Q19; Q20; Q21; Q43;
R7	Q8;
R8	Q15; Q32; Q39; Q42;
R9	Q15; Q16; Q18; Q19; Q20; Q21; Q36; Q37; Q44;
R10	Q14;
R11	Q32; Q36; Q37; Q38; Q40; Q41; Q43;
R12	Q9; Q10;
R13	Q6; Q36; Q37; Q38; Q40; Q41;
R14	Q6; Q36; Q37; Q39; Q41; Q42; Q45; Q46;
R15	Q28; Q29; Q30; Q31; Q33; Q34; Q35;
R16	Q6; Q27; Q36; Q37; Q38; Q44;
R17	Q37; Q36; Q38; Q40; Q39; Q45; Q46; Q41; Q42; Q13;
R18	Q11; Q12; Q13; Q36;
R19	Q6; Q27; Q37; Q36; Q38; Q39; Q40; Q41; Q42; Q44; Q45; Q46;
R20	Q18; Q19; Q20; Q21; Q33; Q36; Q37; Q44;
R21	Q18; Q19; Q20; Q21; Q33; Q34; Q35; Q44;
R22	Q5;
R23	Q1; Q2; Q3;
R24	Q4;
R25	Q26;
R26	Q39; Q41; Q42; Q45; Q46;

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VIII Raksts

Review

Shaping Sustainability Through Food Consumption: A Conceptual Perspective

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Abstract

The food consumption stage, the final step in the food supply chain (FSC), where food has already undergone resource-intensive processes, plays a central role in the transition to a sustainable food system. Consumers' food choices and consumption practices directly influence food demand, production methods, and resource use across the FSC. These factors affect global challenges such as overconsumption, malnutrition, hunger, and food waste (FW)—issues integral to the UN Sustainable Development Goals (SDGs). Therefore, this study aims to identify key aspects of the food consumption stage that influence the shift toward sustainability and to develop a conceptual framework to guide this transition. To achieve this, an integrative literature review (ILR), supported by bibliometric analysis and narrative review elements, was conducted to strengthen the conceptual foundation. The results reveal four central aspects: FW and its reduction, the need for dietary shifts, changes in consumer behaviour, and policy reform, highlighting the consumer and their behaviour as the central connecting element. Based on the findings, a framework was developed linking the identified problems with targeted solutions, which can be implemented through various tools that also act as drivers of change, enhancing sustainable food consumption, food system sustainability, and the achievement of global SDGs.

Keywords: sustainable food system; responsible food consumption; food supply chain; consumer behaviour; food waste; sustainability

1. Introduction

Human existence is based on interaction with nature, as humanity depends on the planet's resources. In addition to air and water, food is one of the most essential resources, serving as a foundation of human life by providing the energy and nutrients necessary for survival. In this context, food is a vital link between humanity and the planet. Therefore, the global food system plays a central role in ensuring the sustainability of both people and the planet.

Over time, the global food system has evolved and become increasingly complex. As a result of market globalization, the diversity of food products has expanded, and the distances between producers and consumers have increased [1]. The advancement of agricultural mechanization has boosted productivity, which in turn has driven the development of related sectors such as logistics, trade, and waste management [2,3]. This progress

has positively influenced the costs of various crops, production value, income levels, and overall returns [4]. However, there are also negative consequences, including excessive fossil fuel consumption and soil degradation [5]. Additionally, mechanization has contributed to a decline in food prices, which, coupled with the gradual rise in living standards in developed countries, has fuelled global FW at all stages of production and distribution [2,3].

Over the past decades, the global food system has demonstrated resilience and the ability to adapt to various challenges [6]. However, it continues to struggle with several pressing issues, including population growth and the corresponding increase in food demand, hunger, food loss and waste (FLW), unsustainable consumption patterns, climate change, food crises, unsustainable agricultural practices, global conflicts, food insecurity, and resource depletion, such as water scarcity, among others. These challenges pose significant threats to environmental, economic, and social sustainability [7–11]. Current resource consumption practices have pushed the planet to a critical threshold, jeopardizing human health and environmental sustainability [12,13]. According to the Planetary Health Check Report 2024 [12], six of nine planetary boundaries have already been exceeded. The global food system is a major driver of these transgressions and a fundamental pillar of both human health and environmental sustainability [12,13]. Therefore, transforming the global food system into a sustainable food system is an urgent necessity to ensure the well-being of humanity and the planet in the future.

In the context of sustainable development, driven by major global organizations such as the United Nations (UN), including its General Assembly (UNGA), the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the European Commission, and others, food systems have been identified as a key domain of sustainable development and policy interventions due to their crucial role in addressing multiple interconnected global challenges [14–17]. A sustainable food system ensures that everyone has access to sufficient and nutritious food while preserving the economic, social, and environmental foundations necessary to maintain these benefits for future generations [7]. Achieving sustainable development is a complex task, but it is based on a simple principle: fostering economic growth that delivers equitable outcomes for all people while ensuring responsible resource use that does not exceed the planet's limits. Ensuring food system (FS) sustainability requires improving existing economic practices and addressing imbalances within the FS—primarily by adopting more sustainable production and consumption models [18]. However, this remains a challenging task due to the complex nature of the FS, which involves numerous and diverse stakeholders and their interrelationships within the FSC, including production, distribution, and consumption (Figure 1). Moreover, the timeframe for implementing change is constrained, and the human tendency to preserve established practices further complicates the transition [19].

One of the most pressing inefficiencies within the global food system is FLW. It poses a significant threat to environmental sustainability, food security, and economic efficiency, making it a key focus area in the transition toward more sustainable food systems. FLW occurs at all stages of the FSC, from production to consumption, and addressing it is essential for advancing sustainability goals [7,20].

Figure 1 provides a schematic representation of the FSC and illustrates the distribution of FLW across its various stages.

Figure 1. Schematic representation of the food supply chain stages and the distribution of food loss and waste (compiled by the authors based on [20,21]).

This study focuses on the final stage of the FSC—food consumption—as it is the largest source of FW in developed countries [20,22–26]. This stage contributes approximately 35% to global FLW [26,27], whereas households account for around 60% of global FW [28]. In 2022, FW in the European Union (EU) was estimated at 132 kg per capita, with households (72 kg per capita) and food service providers (15 kg per capita) together making up 65% of total FW within the FSC [29]. Such inefficiencies impose a substantial environmental burden and lead to considerable economic losses, as by the time food reaches the consumption stage, it has already passed through all FSC stages, utilizing substantial resources [20,26,30]. Nevertheless, despite the initially grim outlook, it is important to emphasize that, since the adoption of the 2030 Agenda for Sustainable Development in 2015 [31], FW has received increasing global attention, resulting in notable progress in addressing the issue. Key advances include the EU's Farm to Fork Strategy [15], the promotion of circular economy (CE) practices [32,33], and the implementation of targeted national policies have all contributed to reducing FW across various sectors. For example, several countries have introduced mandatory food donation laws, awareness-raising campaigns, and improved measurement frameworks [34–36]. Moreover, research shows that multi-level interventions combining education, behavioural nudges, and systemic adjustments have resulted in measurable reductions in consumer FW, both in households and public institutions [36–39]. Thus, understanding the impact of the food consumption stage within the global food system is essential for facilitating the transition to a sustainable food system. In this regard, the study seeks to answer the following research question: What are the key aspects at the food consumption stage that shape the transition toward a sustainable food system? Therefore, this study aims to identify these aspects through a bibliometric analysis and an ILR, and to develop a conceptual framework to guide this transition.

2. Conceptual Background and Literature Review

2.1. Definition and Framework of Food System

The term "food system" is relatively new in the English language. Brock [40], using Google's N-gram search tool, which scans digitized English texts, found that FS has been used since the 1930s. Initially, it referred to restricted diets and specific supply chains. However, since the 1970s, and especially from the 1990s onward, it has come to describe large, dynamic systems encompassing interconnected social and ecological dimensions [40].

The FS comprises numerous elements, including the environment, individuals, resources, procedures, institutions, and activities related to food production, processing, distribution, preparation, consumption, disposal, and the resulting socio-economic and environmental impacts [7]. Based on definitions provided by several authors, the FS is a

comprehensive and dynamic system, and a complex network of interactions that encompasses the full spectrum of food-related elements and activities—from production to consumption and waste management—ultimately influencing social, economic, and environmental outcomes [41–53]. A simplified FS model can be framed around three key components: the FSC, the food environment, and consumer behaviour (Figure 2) [54–56].
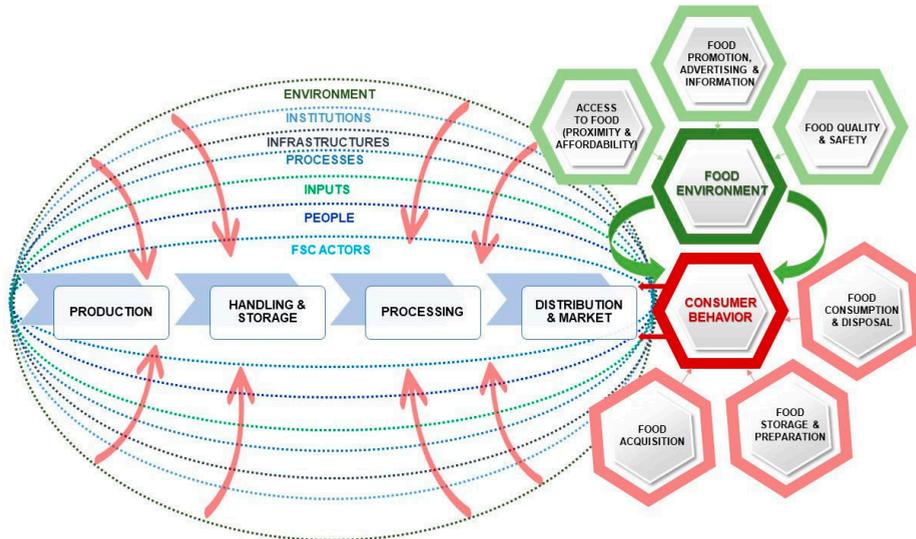
Figure 2. The food consumption stage within the food system framework (compiled by the authors based on [41–43,57]).

The food supply chain refers to the complex system of actors, activities, and resources involved in food production, processing, transportation, distribution, and consumption [58–60]. It is characterized by a multi-layered structure that forms an interconnected network by interacting across hierarchical levels and throughout the entire FS [61].

The food environment (FE) refers to the physical, economic, political, and socio-cultural conditions that shape consumers' food-related decisions [62–64]. It includes access to food (both physical proximity and affordability), availability, marketing, labelling, food quality, safety, and the broader sociocultural context in which consumers interact with food [55]. These factors directly affect food acceptability and dietary patterns [65], and are considered key intervention points for improving the sustainability and equity of the FS [66].

Meanwhile, consumer behaviour encompasses individuals' and households' food-related actions and decisions from food selection, purchase, and preparation to consumption and waste disposal. It is shaped by personal choices, motivations, cultural habits, and the surrounding FE [55,65,67]. To sum up, consumer behaviour is not only a consequence of system dynamics but also a powerful driver of change, influencing demand and, consequently, the structure and sustainability of FS [55].

These three components are deeply interlinked. While the FSC and FE provide the structural and contextual foundations, it is ultimately consumer behaviour that influences and shapes food-related practices throughout the entire FSC. Its central position in the visual model (Figure 2) underscores its strategic importance as a leverage point for fostering a more sustainable and resilient FS.

2.2. Evolution and Transformation of the Food System

Throughout human history, food systems have undergone profound transformations, reflecting fundamental changes in the ways societies produce, distribute, and consume food.

The post-World War II era marked the most rapid and intensive phase in the evolution of the FS, characterized by the onset of industrialization, globalization, urbanization, and a general increase in societal well-being [44,68,69]. While these transformations led to a significant rise in food production, they also gave rise to new challenges, including environmental degradation, biodiversity loss, and growing social inequality [44–48]. One of the most notable changes has been the dramatic rise in the consumption of resource-intensive foods, especially meat and dairy products [70,71]. Between 1961 and 2011, average global meat consumption increased by 75% per capita [72,73], and this trend is projected to continue, with livestock product demand expected to grow by 70% by 2050 [45]. While such diets have become common in many regions, they are also linked to higher greenhouse gas emissions and greater pressure on land and water resources [53,74].

At the same time, technological advancements have transformed food production and supply chains, enabling higher yields and greater efficiency [44–46]. However, these developments have contributed to an increasingly complex and often unsustainable FS [44,45]. Industrial agricultural practices, including the intensive use of fertilizers, land expansion, and deforestation, have led to increased emissions and ecosystem degradation [47].

The interaction between food systems and climate change is cyclical [45]—food production contributes significantly to global emissions, while climate change threatens food security by disrupting production and supply chains [45,48]. However, recent shifts in consumer preferences, such as the rise in plant-based diets, reflect a broader movement toward dietary patterns that are better aligned with environmental sustainability goals [49,53].

There is a scientific consensus on the negative impacts of the current FS, including its contributions to climate change, biodiversity loss, environmental degradation, and social inequality [19,50,51]. Transformative change has become imperative to combat hunger, which remains a persistent and pressing problem [52,54], to reduce the hidden social, economic, and environmental costs, estimated at USD 12 trillion, and to safeguard sustainable development and the progress achieved through decades of global efforts to transform the FS [55,56].

Growing awareness of the negative externalities and the unsustainable trajectory of the FS has highlighted the need for fundamental, systemic paradigm change. In this context, the concept of a sustainable food system has emerged as a key framework for transforming food production and consumption practices. A sustainable food system is defined as one that ensures food security and nutrition for the present generation while preserving the environmental, social, and economic foundations necessary to sustain these benefits for future generations [7,50,58]. This definition emphasizes the importance of intergenerational equity and highlights the ability of the FS to maintain or improve its functions over time for the long-term well-being of society [59–62].

The performance of food systems is closely linked to the achievement of all 17 SDGs [63–65]. Adopting a food systems approach requires addressing not only SDG 2 (Zero Hunger) and SDG 12 (Responsible Consumption and Production), but also the full range of SDG targets. This underscores the need for integrated food policies and system-level thinking [66], making food policy a crucial component in the implementation of the SDGs [13,67,75,76]. Pioneering work by Rockström and Sukhdev [77], as well as Peters [78], has illustrated how food systems lie at the intersection of the biosphere, society, and economy,

emphasizing the systemic and cross-cutting role of food systems in achieving sustainable development.

Within this context, the European Union's "Farm to Fork" Strategy [15], developed as part of the European Green Deal, provides a comprehensive roadmap for creating a sustainable food system by addressing environmental, health, and equity concerns. It promotes CE principles, supports the transition to sustainable and healthy diets, and aims to significantly reduce FLW at all stages of the FSC [15–17].

As part of this systemic transition, the CE has emerged as a key pathway for achieving FS sustainability. By promoting regenerative practices and resource loops, the CE aims to prevent or reduce FW generation, particularly at the consumption stage, which is often the most waste-intensive [32,79–82]. The application of the 10R strategies, namely, Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover, can help reduce resource use and environmental impact [83–85]. Although some strategies, such as "repair" and "refurbish," may initially appear inapplicable to food, a literature review by Deksne et al. [86] demonstrates their relevance in this context. For example, "food repair" refers to practice of saving and reusing food that would otherwise be wasted, such as cooking with expired but safe products or using leftovers, emphasizing care rather than discarding [87]. "Refurbish" can be interpreted as the recovery and redistribution of food products nearing expiry or left unsold, thereby minimizing food losses and generating economic benefits [88]. However, reducing and valorising FW, along with shifting diets toward more plant-based products, remain key practical and impactful strategies for both consumers and policymakers [19,32].

While the CE provides important tools, it is not a complete solution [80,89–92]. Recent scholarship emphasizes the need for a more holistic sustainable circular economy approach that integrates environmental, economic, and social dimensions [90–92]. This broader framework encompasses not only resource efficiency and closed-loop systems, but also key aspects of social responsibility and environmental sustainability [90].

In summary, the evolution of the FS has reached a critical point where systemic transformation based on sustainability and circularity is essential to ensure long-term social equity, economic resilience, environmental protection, and overall planetary well-being.

2.3. Existing Perspectives on Food System Transformation

The transformation of the food system has increasingly gained scholarly attention over the past decade. Numerous studies have addressed pathways to achieving sustainable FS [22,39,51,58,61,67,75,89,93]. However, most of them adopt a broad systems perspective, focusing on areas such as health [93], technological solutions [51], or the implementation of the CE [89,94].

Relatively few studies have positioned the consumption stage—where food-related choices are translated into everyday action—as a strategic entry point for system transformation. Nichifor et al. [95], for example, provide a valuable overview of drivers, barriers, and technological innovations in sustainable food consumption, and yet, their analysis focuses primarily on personal motivation and behaviour, rather than on the broader structural and transformative role of the consumption stage within the FS. Other studies have examined FW as a key sustainability issue. For instance, Vittuari et al. [96] explore behavioural drivers and levers to reduce FW, though they limit their scope to household-level actions. Similarly, Phan [97] proposes a behavioural framework that dissects micro-level mechanisms of food acquisition, usage, and disposal. In addition, Tsai et al. [98] apply the TPB theory to model FW behaviour among emerging adults, emphasizing the role of environmental concern and personal attitudes. Likewise, da Rocha Ramos et al. [99] explored sustainable food consumption barriers through a campus-based case study and proposed an exploratory framework focusing on the gap between intention and action,

but their analysis remains focused on individual-level patterns. Consequently, these studies provide important insights into individual-level behaviour but fall short in defining consumption as a systemic driver of the sustainability transition.

Some studies have made efforts to bridge the gap between behavioural and systemic dimensions. For example, Buczacki et al. [100] propose a systemic view of FW reduction in the HoReCa sector, indicating the need for alignment between micro- and macro-level actors in achieving SDGs. Similarly, Kechagias et al. [101] introduce a holistic framework to address FLW across the FSC, incorporating the environmental, economic, and social pillars of sustainability. Macura et al. [36], in turn, assess the effectiveness of public policy tools for sustainable food consumption through an evidence gap map. While their work highlights important policy tools, it treats consumption primarily as a target of intervention rather than as a strategic platform for integrated action.

A number of conceptual frameworks have attempted to explain sustainable food systems from a systems perspective. For instance, the HLPE [57] "Conceptual framework of food systems for diets and nutrition" and "The guiding principles for sustainable healthy diets" by the FAO and WHO [102] focus on improving diets and nutritional outcomes and cover the entire FSC. Likewise, the EU policy frameworks focus on specific areas, such as FW reduction [31], the transition to a CE [33], or the improvement of FW measurement and its impacts [35]. These models and strategies do not highlight the consumption stage. Moreover, in many of these models, consumers are seen as passive actors with limited influence on FS outcomes, rather than as active agents who shape, disrupt, or enable sustainability transitions through their everyday decisions and choices.

This fragmentation in the literature points to a notable gap: while the importance of sustainable food consumption is widely acknowledged, few studies have conceptualized the consumption stage as a driving force in system-level transformation. This research is grounded in the recognition that food consumption should not be seen as the final step in the FSC, but rather as a pivotal leverage point where structural conditions and individual behaviours intersect. In this context, the following section explores the role of consumer behaviour.

2.4. Consumer Behaviour in the Context of Sustainable Food System

Any transition requires human involvement, but the complexity of consumer behaviour poses a barrier to the transition towards a sustainable FS.

In the scientific literature, consumer behaviour is studied through behavioural theories. For example, Wang et al. [103] used the Norm Activation Model (NAM) to explain consumers' behavioural intentions to reduce FW when dining out, incorporating self-efficacy as an explanatory variable. Their findings revealed that self-efficacy, through personal norms related to FW, directly or indirectly impacts behaviour. Therefore, it is possible to influence consumer behaviour by enhancing their belief that responsible food consumption is more beneficial to the environment [103]. The Theory of Planned Behaviour (TPB) assumes that behavioural intentions are shaped by attitudes, subjective norms, and perceived behavioural control [104,105]. However, TPB primarily focuses on conscious and deliberate actions, which limits its ability to account for unintentional or habitual behaviours. It also tends to underestimate the role of external conditions, such as infrastructure or access, which can significantly influence behavioural outcomes [105–107]. The Motivation–Opportunity–Ability (MOA) framework is also widely used, demonstrating how to combine motivation with abilities and contextual factors—opportunities—to explain consumer behaviour [39,108]. For example, Vittuari et al. [96] used an adapted MOA framework, supplemented with micro, meso, and macro situational factors, to analyze consumer FW behaviour [96]. Schulze et al. [109] have argued that existing sustainability transition models primarily address problems at the macro level and are not sufficiently

grounded in evidence or theories that reflect the complexity of individual consumer behaviour. Similarly, Buczacki et al. [100] highlight that current approaches to SDGs implementation often lack integration between micro-level behavioural change and macro-level policy frameworks, thereby undermining the coherence of sustainability strategies across scales. However, it is the personal decisions and actions of each consumer that form the basis of change. In this sense, consumers themselves face a difficult task: they are encouraged to change their diets by reducing consumption of processed meat, animal-based protein, and dairy products in favour of more plant-based options, purchasing organic and sustainable food, preferably from local producers, and changing habits to reduce FW [109,110]. Yet, food consumption is based on deeply rooted habits that are difficult to change [109]. Therefore, it is crucial to understand consumers, their motivations, and the factors influencing their decisions, choices, and actions [111] to guide them toward more sustainable food choices and consumption.

Given the diversity and complexity of factors influencing food-related choices, this study adopts the MOA framework as its analytical foundation, because it brings together individual capabilities, personal motivations, and structural opportunities within a single explanatory model. According to MOA theory, consumer behaviour is influenced by the interaction of motivation, opportunity, and ability. Motivation refers to personal attitudes and social norms regarding sustainable food choices, opportunity involves the availability of resources and materials that facilitate or constrain action, and ability encompasses knowledge and skills. These factors depend on various internal (individual) and external (social and societal) conditions [108,112,113]. In addition, at the consumption level, consumer behaviour should be analyzed from a three-level perspective. At the micro level, the consumer acts as an individual and is the primary decision-maker. At the meso level, the consumer is part of a social unit (e.g., a household), where decisions and activities are made collectively. At the macro level, the consumer is part of a wider society beyond the home, where regulations, cultural norms, and market conditions shape food consumption patterns [96].

As this study aims to develop a conceptual framework to guide the transition of FS through the consumption stage, the MOA framework is particularly well-suited for structuring the analysis. It offers a comprehensive lens that captures both individual-level and structural aspects, thereby bridging the gap between micro-level consumer behaviour and macro-level systemic change. It has also been widely used to analyze both in-home and out-of-home consumer food management [112,114–117]. The MOA theory allows for a holistic understanding of the need to align all three elements to achieve behaviour change. This makes it particularly suitable for conceptualizing the consumption stage as a dynamic platform for the systemic transformation of the FS.

3. Materials and Methods

3.1. Methodological Approach

This study adopts an ILR as the primary research method, supplemented by narrative and bibliometric elements to ensure conceptual depth and thematic clarity. According to Torraco [118], the integrative review is a form of scholarly inquiry that "reviews, critiques, and synthesizes representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated" [118]. Similarly, Grant and Booth [119] position the integrative review within a typology of 14 review types, noting its capacity to combine empirical, theoretical, and policy-based literature to advance conceptual understanding [119]. The narrative approach offers an overview of a research field, synthesizes existing knowledge, and formulates recommendations for future inquiry [120]. Meanwhile, bibliometric analysis has gained considerable popularity in recent

years, especially with the rise in digital databases and analytical tools, enabling researchers to visualize patterns and thematic structures within the literature [121,122].

Although bibliometric analysis typically relies on author keywords derived from metadata in indexed databases, this study employed a hybrid approach by additionally analyzing keywords extracted directly from the content of selected literature. These keywords were thematically coded and later used to construct visual bibliometric maps in VOSviewer (version 1.6.20). This design enabled a meaning-based exploration of conceptual relationships, often obscured in traditional integrative and narrative reviews. While not widely adopted, the approach is replicable through the application of the same coding logic and visualization procedures to any thematically cohesive set of texts.

By combining qualitative content analysis with quantitative bibliometric mapping, this study reveals the potential and practical application of bibliometric tools within conceptual review research. It facilitates the identification and visualization of key thematic connections that may remain implicit in textual synthesis alone. This methodology is especially suited for developing conceptual frameworks that synthesize new knowledge and integrative perspectives to advance both theoretical inquiry and practical applications [118,121,122].

3.2. Study Design and Process

The research process was developed in three stages:

Narrative synthesis was used to establish the conceptual background of the study and to identify key aspects influencing the transition toward a sustainable food system. These aspects were categorized as problems and solutions and defined as analytical keywords to support the interpretation of their influence. The data were processed in Microsoft Excel for downstream analytical procedures.

Bibliometric analysis was performed using VOSviewer software (version 1.6.20) to generate visual representations of thematic trends. Co-occurrence maps were produced based on both author-generated and content-derived keywords, highlighting dominant themes and interconnections, and enabling the identification of conceptual linkages that may not be seen through textual analysis alone.

The integrative literature review served as the basis for analyzing the results of the bibliometric analysis and for further developing the conceptual framework. It involved a structured qualitative content analysis of the selected set of 69 documents to explore in depth the main aspects that emerged during both the narrative and bibliometric phases.

This hybrid analytical approach enabled a holistic, structured, and interpretative synthesis of theoretical, empirical, and policy-relevant insights, and directly supported the development of a conceptual framework grounded in the findings.

3.3. Literature Search Strategy

To ensure transparency of identification of relevant literature, the authors employed a two-step search strategy, adapting the PRISMA 2020 flow diagram for visual clarity [123]. While this study does not constitute a systematic literature review, the diagram was used to illustrate the identification, screening, and inclusion process of the literature (Figure 3). Other PRISMA principles were not applied.
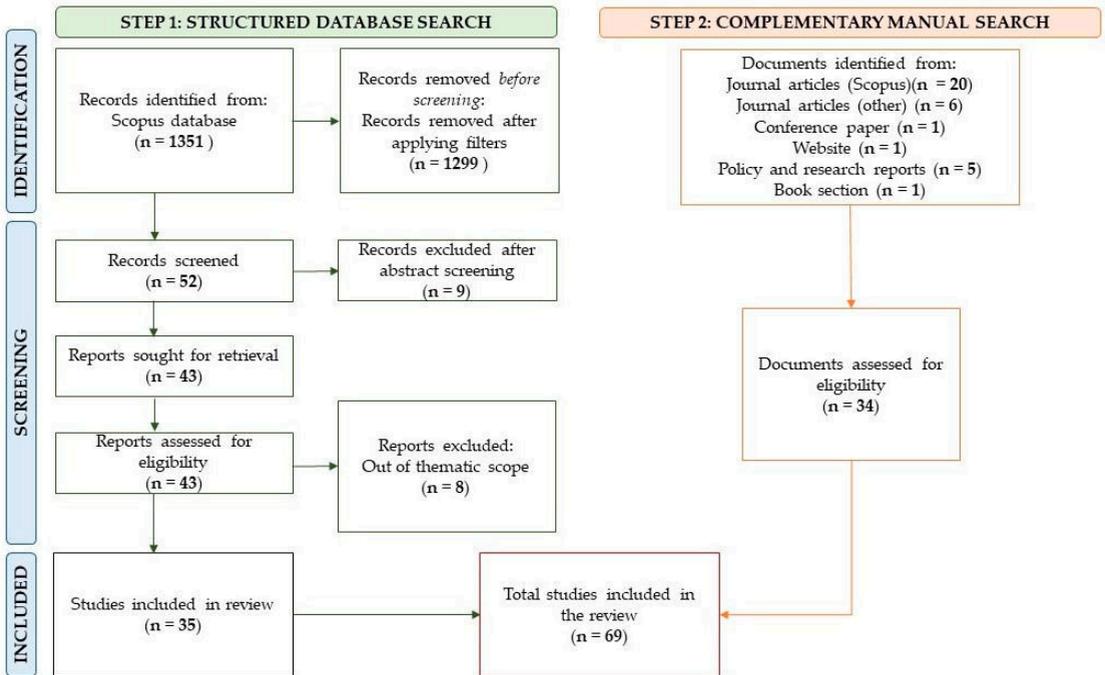
Figure 3. PRISMA-based flow diagram outlining the literature selection process (compiled by the authors based on [123]).

3.3.1. Step 1: Structured Database Search

A systematic search was conducted in the Scopus database to identify peer-reviewed journal articles addressing the food consumption stage within the context of sustainable food system transformation. The search strategy combined three core thematic keywords: "sustainable food system", "food consumption", and "food waste", which were required to appear in the title, abstract, or author keywords. The initial search yielded 1351 records, which were refined by applying the following filters:

- Publication years: 2015–2025;
- Subject area: Social Sciences;
- Document type: Peer-reviewed journal articles;
- Language: English;
- Access type: Open Access.

Additional screening based on secondary keywords related to the thematic scope of this study (i.e., food waste, consumption behaviour, food consumption, and sustainable food system) further narrowed the selection to 52 records. Abstracts were screened, and 9 records were excluded due to misalignment with the focus on the food consumption stage. The remaining 43 full texts were reviewed for eligibility, resulting in the exclusion of 8 additional documents, obtaining 35 articles for in-depth analysis.

3.3.2. Step 2: Complementary Manual Search

Following the principles of the ILR methodology [118], a flexible and inclusive approach was adopted, without applying strict inclusion or exclusion criteria. The selection included both peer-reviewed academic articles and institutional reports.

The selection process covered the period from 2016 to 2025, aiming to summarize key trends and insights related to the food consumption stage in the context of sustainable food system transition over the past decade.

Academic publications were primarily retrieved from the Scopus database, using keyword combinations such as "food consumption stage", "sustainable food consumption", "barriers and drivers of food consumption", "barriers and drivers of sustainable food consumption", "enablers of sustainable food consumption", "levers of sustainable food consumption", "drivers of sustainable food consumption", and "barriers of sustainable food consumption". To manage the high volume of results and ensure the feasibility of the selection process, searches were conducted year by year, and additional filters were applied, including language (English), access type (open access), and adjustments in the subject area to focus on relevant disciplines. This approach allowed for a more focused review of article titles and abstracts, typically reducing the number of results from several thousand to a more manageable number (approximately 50–100 per year). Articles that appeared relevant at this stage were then assessed in detail for their thematic relevance, conceptual contribution, and methodological quality. As a result, 20 articles were selected through this process.

Additional peer-reviewed articles published in journals not indexed in Scopus (e.g., national or regional journals and interdisciplinary open-access publications) were also included based on their relevance to the research focus. These sources were identified through targeted searches using Google Search and the websites of relevant journals and institutions. In addition, high-quality grey literature, such as reports from the European Commission, the World Wide Fund for Nature (WWF), and international foundations such as the Ellen MacArthur Foundation, among others, was incorporated to reflect current policy developments and practice-based perspectives. In total, this manual search process resulted in the inclusion of 14 additional documents: six journal articles, five policy and research reports, one conference paper, one book section, and one web-based conceptual analysis.

Relevant literature was chosen based on document titles, abstracts, and their thematic alignment with the study's objectives. After full-text review, 34 documents were included in the analysis, comprising a mix of academic studies and institutional reports. This ensured a well-rounded view of the topic by combining theoretical perspectives, empirical findings, and policy insights, thereby providing a comprehensive and up-to-date overview of the existing literature in this field.

The review focuses on the food consumption stage as a strategic entry point for systemic transformation toward sustainability. Therefore, instead of achieving comprehensive coverage, the review prioritized thematic saturation, seeking to uncover relevant problems and solutions through focused synthesis and interpretation.

The complete list of reviewed documents (69), as well as the categorized table of identified key aspects, is presented in Appendix A (Table A1), supporting transparency and potential replication of the review process. ChatGPT (developed by OpenAI, GPT-4o, version from 13 May 2024) was used to assist with the translation of the manuscript from Latvian to English. Its use was limited strictly to language translation.

4. Results and Discussion

4.1. Bibliometric Analysis

The study results were analyzed using 69 documents related to food consumption issues published between 2016 and 2025 (see Table A1). The most relevant articles were selected from those published in 2022 and 2023 (Figure 4).
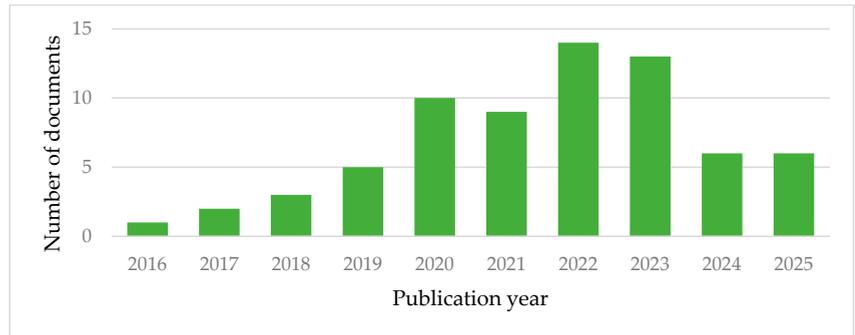
Figure 4. Distribution of selected documents by year of publication (compiled by the authors).

Based on this set of documents, a co-occurrence analysis of both author-generated and content-derived keywords was further performed.

In bibliometric maps, the size of the nodes (circles) and the font reflect the frequency of keyword occurrence, while the colours distinguish different clusters, each representing a group of closely related research topics. The thickness of the lines (link strength) between keywords indicates the strength of their co-occurrence, providing insight into how frequently certain themes are studied together [124].

4.1.1. Metadata-Derived Author Keyword Co-Occurrence Analysis

Initially, a co-occurrence analysis of the authors' keywords was performed on the selected set of documents to identify the most prominent thematic clusters within the literature. From a total of 255 keywords, 9—Portugal, South Africa, Balkans, Bosnia and Herzegovina, China, Nanjing, Poland, Slovakia, Mexico—were excluded from the analysis, as references to specific countries were not directly relevant to the thematic focus of this study. Among the remaining 246 keywords, the largest set of connected items consisted of 222 keywords, which were included in the mapping (Figure 5).

Based on the analysis results, twenty-five thematic clusters were identified, each consisting of groups of interrelated keywords, highlighting the thematic structure of the analyzed literature. Additionally, six main focal points emerged in the bibliometric map within the research topic. The most frequently occurring keywords, which serve as central points in the bibliometric map, are *food waste* (29), followed by *sustainability* (12), *consumer behaviour*, which, combining the terms *consumer behaviour* (5) and *consumer behaviour* (5), appears ten times in total, *sustainable consumption* (6), and *circular economy* (6). These keywords reflect the core research areas within the study's theme.

Among them, five central clusters dominate the map and were analyzed in greater detail:

The pink cluster focuses on *food waste* in close connection with *dietary habits*, *food behaviour*, and *food shopping*, enabling the analysis of consumption behaviour patterns related to FW generation.

The navy blue cluster focuses on *sustainability* and *food consumption* as central concepts. It incorporates themes such as *behaviour change*, *education*, *socioeconomic conditions*, and *knowledge management*, highlighting the role of food-related decisions in supporting *sustainability transition*.

The red cluster brings together *sustainable consumption* and *consumer behaviour* as its central focal points. It reflects research on the *attitude–behaviour gap*, highlighting the influence of *awareness campaigns*, *gamification*, *emotion*, *marketing*, and *interventions aimed at waste prevention*, the promotion of *sustainable choices*, and the achievement of broader sustainability goals. Additionally, the light blue cluster represents a continuation of the same

thematic area, reflecting similar content to the red cluster but framed through slightly different terminology. It focuses on *consumer behaviour* in the context of *food sustainability* and *grocery retail*. It includes keywords such as *food waste behaviour*, *food waste drivers*, *purchase decision*, and *household food waste prevention*, indicating an emphasis on individual decision-making processes and market-level factors influencing sustainable consumption at the household level.

The light green cluster focuses on the *circular economy* as its central concept. It incorporates aspects such as *consumer education issues*, *intention*, *choice parameters*, and *gender issues*, alongside themes such as *nutritional value*, *R-strategies*, and *waste-to-value food*. This combination reflects a multidimensional perspective on circular food systems, emphasizing both behavioural and systemic components of waste reduction and resource optimization.

The analysis highlights a number of recurring topics, especially *food waste*, *sustainable consumption*, *consumer behaviour*, and the *circular economy*, indicating that researchers often explore their interconnections. This overview provides a foundational perspective on the structure of the research topic.
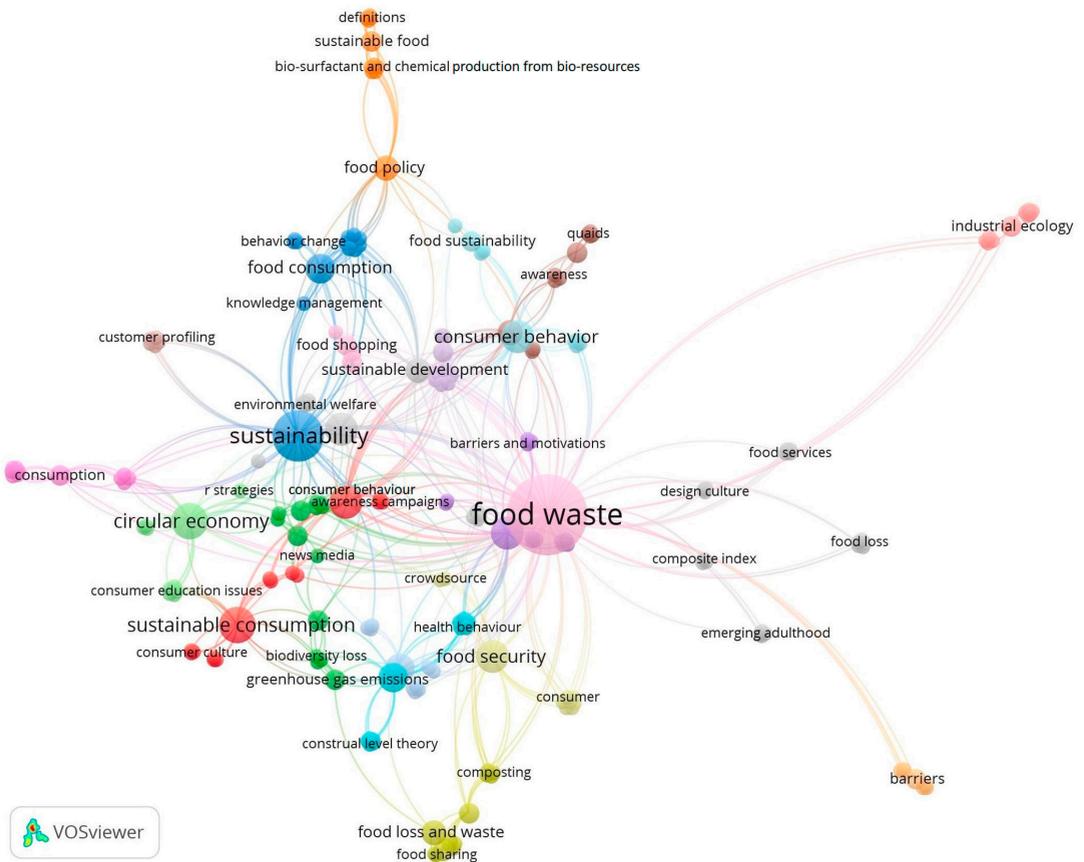
Figure 5. Bibliometric map of author keyword co-occurrence.

4.1.2. Content-Derived Analytical Keyword Co-Occurrence Analysis

In the next step, bibliometric analysis was conducted using keywords extracted directly from the content of the reviewed literature. These keywords were thematically grouped into problems and solutions with the aim of identifying the key aspects in the food consumption stage (see Table A1). Separate co-occurrence maps were generated for each group to reveal dominant themes and conceptual linkages across the literature.

Among the remaining 315 problem keywords, the largest set of connected items consisted of 304 keywords, which were included in the mapping (Figure 6).

Figure 6. Bibliometric map of the identified problems' co-occurrence.

Figure 6 represents problems within the food consumption stage, revealing five main focal points: *food waste* (43), *low awareness* (23), *meat overconsumption* (10), *consumer behaviour* (8), and *unclear labelling* (7). These concepts are the most frequently repeated and centrally positioned in the map, indicating their conceptual importance across the reviewed literature.

In total, 29 thematic clusters were generated, reflecting a broad and complex set of barriers. However, to better understand the core problems shaping the transition toward

sustainable food consumption, three thematic clusters were selected based on their direct conceptual connection to the main focal points. Rather than focusing on cluster size, this targeted selection reflects the thematic centrality and relevance of specific issues across the reviewed literature. Among them are the following:

The navy blue cluster includes three main focal points—*food waste, meat overconsumption*, and *unclear labelling*, which indicates that these concepts are interconnected and often addressed together in the literature. This cluster comprises 17 keywords that reflect how consumer choices are influenced by individual capacities (*consumer awareness, consumer competences, food literacy*), socio-cultural norms (*food culture, social norms and habits*), and the structural environment (*food environment, affordability and availability of plant-based options, limited availability of sustainable options*). Importantly, the inclusion of the *knowledge–action gap* and *unclear labelling* points to a recurring issue: consumers may be aware of sustainability concerns but lack knowledge, the practical tools or clear information to act responsibly. Overall, this cluster illustrates how individual behaviour, access to information, and external conditions interact to drive unsustainable consumption and generate FW.

The grey cluster focuses on insufficient *consumer awareness*, as indicated by keywords such as *low awareness, unsustainable consumption practices, plate waste*, and *food waste in workplace canteens*. These terms suggest that limited understanding affects not only household-level behaviour but also actions in broader social and institutional contexts. Together with *low community engagement*, this issue reflects a broader lack of knowledge and motivation, which limits active participation in sustainable food practices.

The red cluster centres on *consumer behaviour* and its interaction with broad structural, informational, and socio-economic barriers, as it is the most extensive cluster, comprising 28 keywords. It includes closely related concepts such as *consumer preferences, habits*, and *distrust*, as well as *cooking skills* and *food choices*, all of which shape everyday decision-making processes. The cluster also contains several broader contextual keywords, such as *affordability challenges, food insecurity, health inequalities, safety concerns*, and *rising living costs*, which constrain the ability to make sustainable food choices. In addition, the presence of terms like *knowledge gaps, limited information, lack of consensus,* and *inadequate data and methods* highlights persistent gaps in both consumer understanding and the systems that support them. Structural issues such as *weak food governance, low policy integration*, and *weak policy support* suggest that existing policy frameworks are not fully aligned with the behavioural changes needed to promote sustainable food consumption. This cluster thus illustrates the multifaceted nature of consumer behaviour, showing that meaningful change requires addressing not only individual habits but also the underlying social, economic, and institutional conditions that reinforce unsustainable consumption patterns.

Overall, the analysis reveals an interplay of multiple problems that hinder the transition toward sustainable food consumption. Although each cluster highlights distinct problem areas, they also demonstrate significant overlap, particularly in relation to behavioural issues, structural constraints, and informational gaps. By identifying core problem themes across the literature, the selected clusters underscore the urgent need for coordinated actions within the food consumption stage to address these interconnected issues effectively.

Among the remaining 314 solution keywords, the largest set of connected items consisted of 304 keywords, which were included in the mapping (Figure 7).
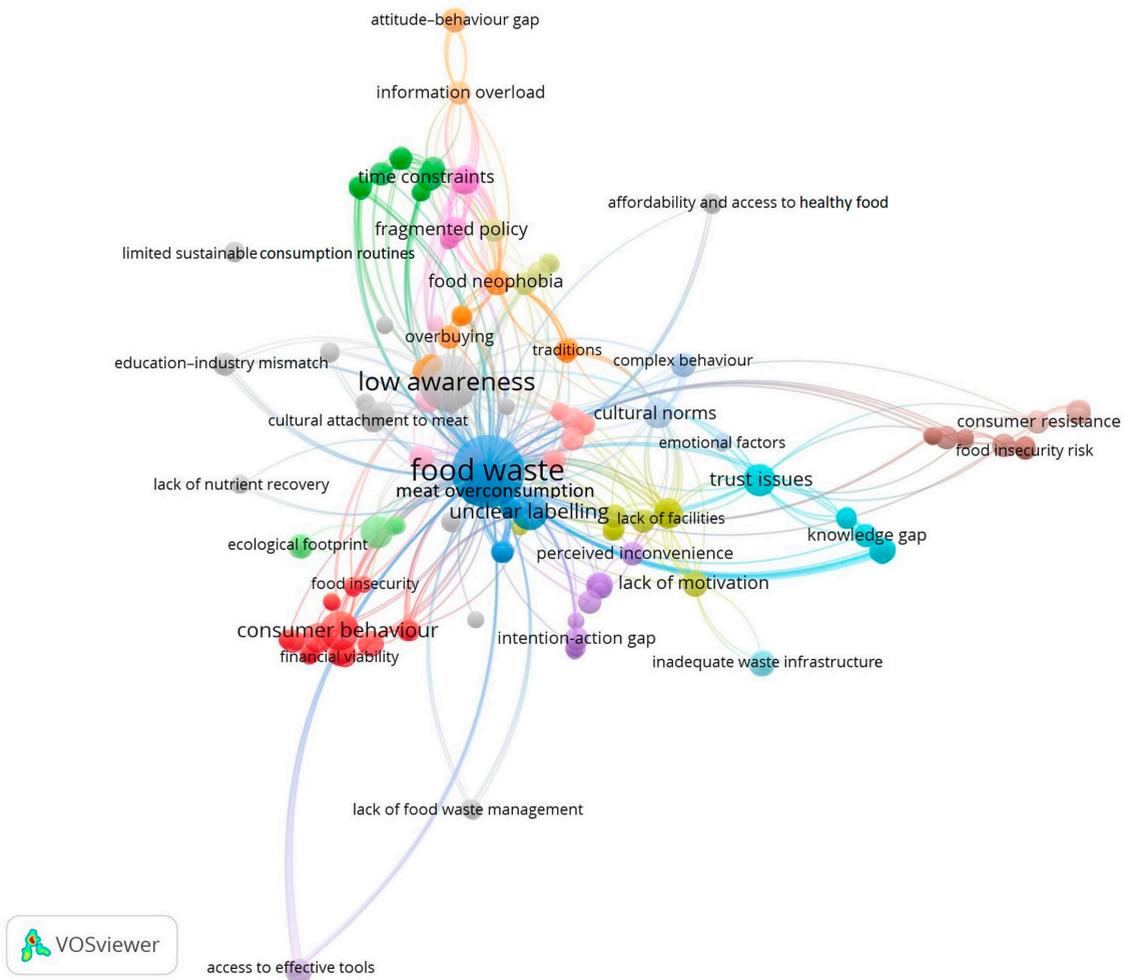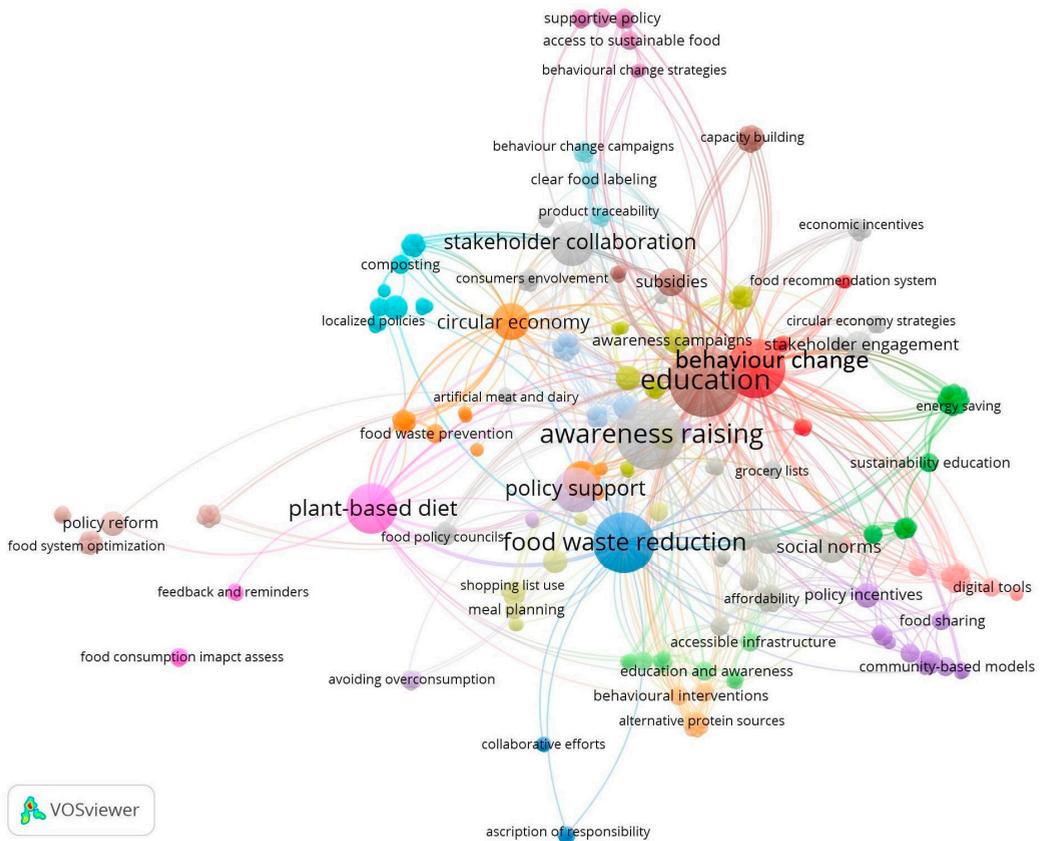
Figure 7. Bibliometric map of identified solutions' co-occurrence.

Figure 7 represents solutions within the food consumption stage and reveals four main focal points: *education* (26), *awareness raising* (24), *food waste reduction* (19), and *behaviour change* (18). Additionally, terms such as *plant-based diet* (13), *policy support* (10), *stakeholder collaboration* (10), and *circular economy* (7) also appear prominently and are strongly interconnected with the core themes.

The co-occurrence analysis of solution-oriented keywords resulted in the identification of 25 thematic clusters, indicating that the reviewed literature proposes a wide and diverse range of solutions as well. And similar to the previous analysis, seven selected clusters were interpreted in detail based on their direct conceptual relevance to the main focal points:

The brown cluster, with *education* at its centre, includes keywords such as *behavioural incentives*, *information campaigns*, *nudging*, *clearer labelling*, *marketing regulation*, and *policy tools*. It reflects solution pathways focused on improving information delivery, consumer understanding, and strategic redistribution. The cluster highlights the role of structured communication, capacity building, targeted educational measures, and *multi-actor cooperation* in supporting informed food choices and promoting responsible food consumption.

The grey cluster, centred on *awareness raising* and *stakeholder collaboration*, focuses on *sensory appeal*, *sustainable dietary patterns*, *accessibility of plant-based food*, and *innovative packaging innovations*. The inclusion of elements such as *artificial meat and dairy* and *reduced demand* suggests a forward-looking approach to shifting consumption behaviours towards more sustainable food consumption. It reflects how awareness raising initiatives,

combined with product innovation and collaborative efforts, can support transitions away from resource-intensive diets and promote informed, more sustainable choices.

The navy blue cluster, centred on *food waste reduction*, reflects an emphasis on individual-level psychological drivers of *behaviour intentions*, highlighting how *ascription of responsibility*, *personal norms*, and *self-efficacy* shape efforts to reduce FW. In addition to individual factors, the presence of terms such as *collaborative efforts*, *sustainable diets*, and *transition to a circular economy* suggests that personal motivation is embedded within broader systemic and collective action contexts. This cluster underscores the need to align internal motivators with structural enablers to effectively support FW reduction.

The red cluster focuses on *behaviour change* trough practical approaches such as *data-driven consumer tools*, *food recommendation system*, and *place-based solutions*. Alongside concepts like *sustainable food choices*, *consumption reduction*, and *healthy diet promotion*, the cluster highlights actionable strategies for supporting dietary transitions. The inclusion of *local food consumption* and the *Mediterranean diet* further emphasizes the importance of culturally adapted and geographically grounded dietary shifts.

The pink cluster with *plant-based diet* as its core combines terms such as *increased awareness*, *nudging techniques*, *municipal-level interventions*, and *feedback and reminders*. The presence of related dietary patterns—*vegan, vegetarian, and pescatarian diets*—alongside the *water–climate–food nexus*, underscores the environmental impact of food choices and their relevance within broader sustainability transitions. This cluster points to dietary shifts supported by structural measures, highlighting the need for aligned policy frameworks, behavioural nudges, and system-wide dietary transitions.

This analysis should also highlight the light lilac cluster, which centres on policy support. Combining keywords such as *awareness initiatives*, *clearer labelling*, *cross-sector collaboration*, *food banks*, and *social campaigns*, this cluster reinforces several recurring themes and points to the essential role of supportive policies in enabling and scaling sustainable food consumption practices. The inclusion of terms like *healthy eating*, *home cooking*, *avoiding overconsumption*, and *resource preserving* further emphasizes the importance of linking individual action with policy-driven efforts.

In addition, the orange cluster, with *circular economy* at its centre, integrates a wide range of CE strategies and principles. These include *food waste prevention*, *food waste valorisation*, *biogas production from food waste*, and *redistribution of surplus food*, alongside policy mechanisms like *public policy improvement*, *food labelling reform*, *revised food standards*, and *targeted interventions*. It highlights the importance of *affordability and availability of organic products*, *multi-disciplinary approaches*, *regional adaptation*, and *competence development*, emphasizing that coordinated, cross-sectoral actions are essential for food system transformation.

The analysis reveals a diverse set of solutions, with several cross-cutting themes emerging across multiple clusters, such as education, behaviour change, food waste reduction, various policy mechanisms, and the need for dietary shift. These interconnected themes align with the previously identified key problems and indicate broad opportunities for promoting sustainable food consumption.

By analyzing all three bibliometric maps, the authors discovered that *food waste* stands out as the most frequently mentioned and conceptually central theme across the datasets. This highlights the importance of *food waste prevention* as a key component in shaping sustainable food consumption. Another prominent theme is consumer *education*, *awareness raising*, and *behavioural change*, which appear both as a central problem and as an essential solution for action. In addition, issues related to *meat overconsumption* and a *plant-based diet* underscore the need for a dietary shift. Furthermore, concepts such as the *circular economy*, *policy support*, *stakeholder collaboration*, and *sustainability* reflect the systemic approaches and tools necessary to facilitate meaningful change.

To identify the key thematic directions, the authors conducted a synthesis of keywords across all three bibliometric maps and then grouped them thematically to assess recurring concepts across different levels of analysis. Several keywords appeared in two or more categories, indicating overlapping areas of concern and action.

Summarizing the results of the bibliometric analysis (see Table 1), four overarching thematic directions were identified as central to the food consumption stage: food waste and its reduction, sustainable dietary shifts, consumer awareness and behaviour, and policy and systemic transformations.

Table 1. Synthesis of keywords across bibliometric maps (compiled by the authors).

	Overarching Theme			
	Food Waste and Its Reduction	**Dietary Shifts**	**Consumer Behaviour Change**	**Policy Reform**
Most Frequent Keywords/Focal Points	**The Corresponding Keywords from Each Map**			
The author keyword co-occurrence map	food waste, sustainability, consumer behaviour, sustainable consumption, circular economy	food waste, food waste behaviour, food waste drivers, interventions aimed at waste prevention, waste-to-value food, household food waste prevention, R-strategies	dietary habits, food behaviour, sustainable choices, nutritional value, food consumption, grocery retail	consumer behaviour, consumer behaviour, attitude–behaviour gap, awareness campaigns, gamification, emotion, marketing, behaviour change, education, consumer education issues, intention, food shopping, purchase decision, choice parameters, gender issues	sustainability, sustainability transition, sustainable consumption, circular economy, socioeconomic conditions, knowledge management
The identified problems' co-occurrence map	food waste, low awareness, meat overconsumption, consumer behaviour, unclear labelling	food waste, plate waste, food waste in workplace canteens, unsustainable consumption practices, low awareness, limited information, unclear labelling	food choices, affordability and availability of plant-based options, affordability challenges, food insecurity, food literacy, food culture, social norms and habits, safety concerns, rising living costs, meat over-consumption, limited availability of sustainable options	consumer behaviour, consumer preferences, consumer awareness, low awareness, knowledge–action gap, distrust, habits, cooking skills, consumer competences, knowledge gaps, limited information, food environment, food literacy, unclear labelling, low community engagement	weak food governance, weak policy support, low policy integration, lack of consensus, inadequate data and method, low community engagement
The identified solutions' co-occurrence map	education, awareness raising, food waste reduction, behaviour change, plant-based diet, policy support, stakeholder collaboration, circular economy	education, behavioural incentives, information campaigns, nudging, clearer labelling, awareness raising, stakeholder collaboration, innovative packaging innovations, food waste reduction, transition to a circular economy, food recommendation system, consumption reduction, resource preserving, circular economy, food waste prevention, food waste valorisation, biogas production from food waste, redistribution of surplus food	education, behavioural incentives, information campaigns, nudging, clearer labelling, awareness raising, sensory appeal, sustainable dietary patterns, accessibility of plant-based food, artificial meat and dairy, reduced demand, sustainable diets, sustainable food choices, healthy diet promotion, local food consumption, the Mediterranean diet, plant-based diet, vegan, vegetarian, and pescatarian diets, water–climate–food nexus, resource preserving	education, behavioural incentives, information campaigns, nudging, clearer labelling, awareness raising, reduced demand, behaviour intentions, ascription of responsibility, personal norms, and self-efficacy, collaborative efforts, behaviour change, data-driven consumer tools, increased awareness, nudging techniques, awareness initiatives, clearer labelling, cross-sector collaboration, food banks, social campaigns, healthy eating, home cooking, avoiding overconsumption, competence development	marketing regulation, policy tools, multi-actor cooperation, transition to a circular economy, place-based solutions, municipal-level interventions, feedback and reminders, public policy improvement, food labelling reform, revised food standards, targeted interventions, affordability and availability of organic products, multi-disciplinary approaches, regional adaptation

These themes represent the key aspects addressed by this study's research question and reflect both the dominant problem areas and potential solutions for facilitating sustainable change in the food consumption stage, and they will serve as the analytical basis for the following literature review and for the development of the conceptual framework.

4.2. Integrative Literature Review

4.2.1. Food Waste and Its Reduction

One of the central issues in the food consumption stage, as highlighted by the bibliometric analysis, is FW, which primarily occurs at this stage [35,94]. The largest source of FW is households [39,96,125–127], followed by out-of-home dining, including hospitality, catering services, and school catering [22,39,86,128,129].

FW is a significant issue because it negatively affects all aspects of sustainability. First, FW is a social problem, as it undermines overall food security [93], affects nutrition security [34], and hinders social progress [93]. Second, FW has a severe environmental impact [130–132], because wasted resources [133] contribute to environmental degradation, biodiversity loss [35,93,134], and climate change [39]. Finally, FW is also an economic problem, as wasted food represents financial losses and the misallocation of resources throughout the FSC, from production to consumption [97,135].

FW reduction initiatives are incorporated into various regulatory frameworks. At the global level, FW reduction is embedded in key policy agendas such as Target 12.3 of the UN SDGs, which aims to halve per capita FW by 2030 [31]. To promote progress towards this goal, several international initiatives have been launched, such as the FAO's Save Food Initiative [26] and the UNEP Food Waste Index [30,136]. These initiatives bring together governments, businesses, and civil society actors to support coordinated action. In the EU, the Circular Economy Action Plan [33] and the EU Circular Economy Strategy [137] are considered among the most significant, as the CE is the tool to shift away from the traditional linear "take–produce–consume–discard" model toward a more complex and regenerative system, where the primary goal is to prevent waste or reuse, repair, refurbish, and recycle it, ensuring that waste serves as a raw material or resource [32,86,94,126]. However, despite policy efforts, FW at the consumer level remains a persistent and pressing issue [37].

In the hospitality and catering sector, FW primarily arises during food preparation, due to spoilage and uneaten food left on consumers' plates [39,128,129,138], but in a business setting, assessing institutional factors related to business management and the economy that contribute to FW is challenging due to the lack of comprehensive data and a limited understanding of the interaction between policy, the economy, and business behaviour [34]. Overall, as revealed by the analysis of the literature review, the primary cause of FW in the consumption stage is the consumer and their food consumption behaviour, which is influenced by a wide range of factors, including culinary and purchasing habits, misinterpretation of "use by" or "best before" dates, and inadequate meal planning [34,39,139], cultural and social norms [93,140], resistance to adapting to new regulations, self-control over food-related decisions and waste prevention [141], and limited skills in food management [39,126]. It has been shown that unprocessed foods make up the majority of household FW, with a significant proportion classified as avoidable, particularly in larger households and those with higher education levels [142]. Marketing strategies also play a crucial role in positioning products to consumers, as consumption is often driven by symbolic benefits and grounded in personal values and a sense of social belonging [101,143–145]. Additionally, limited access to technology, infrastructure, and effective food storage and management systems, as well as inadequate facilities, further exacerbate the problem [37,96,127]. Consumer behaviour is influenced by both rational and emotional factors [146]. Therefore, well-thought-out interventions, along with

monitoring and evaluation systems, are necessary to ensure progress in waste reduction [37,138,147].

The key actions required are its prevention and reduction in order to address the issue of FW [9,32,39,148]. In addition to consumer education initiatives [34,116,127,144,149] and behavioural interventions [38,39,146] that empower individuals to consume food responsibly and manage FW, CE initiatives, through the 10R strategies, play a crucial role in FW reduction [86,90,150,151]. In parallel, food donation and sharing initiatives represent an important strategy within the FW management hierarchy. For example, in Spain, food banks recover large quantities of surplus food each year and redistribute it to people in need, thereby combining environmental benefits with improved food security and enhanced social inclusion [152]. In turn, food sharing platforms in Japan have emerged as ICT-enabled solutions to redistribute surplus food, reduce FW, and promote sustainability, although they still face challenges such as consumer distrust, limited financial viability, and safety concerns [153]. Urban gardening initiatives also offer effective means to reduce household FW and strengthen local food systems [154]. In addition, technological innovations in food storage and management also can help minimize FW [37,96,116,127,129,138]. These efforts can be supported by regulatory policies, such as standardizing "use by" and "best before" labelling [34,39], applying economic incentives like tax breaks for food donations, and imposing penalties for FW [34,111,131]. Collaboration with consumers and other stakeholders involved in food consumption is also essential to achieving these goals [100,109,134].

4.2.2. Dietary Shift

Consumers' dietary patterns, including the overconsumption of meat and other animal protein-based products and the affordability and availability of sustainable food options, significantly impact the sustainability of the FS. Several studies emphasize the need to reduce meat consumption and other animal protein products, primarily to mitigate environmental impact [9,35,74,130–132,155], as an animal-based diet has a significantly greater environmental impact than a plant-based diet. This is due to the extensive use of land, forests, and freshwater resources required for the production of animal products, contributing to biodiversity loss and greenhouse gas emissions [35]. Excessive consumption of red meat, especially processed meat products with high levels of unhealthy fats, salt, and sugar, is also associated with health risks [35,111,131,156].

Research indicates that red meat consumption is primarily higher among high-income groups [9,125], urban residents, consumers with higher education levels [133], men, younger generations [131], and consumers who eat out more frequently [111]. Additionally, studies on megacities have shown that the high consumption of animal-based products in urban areas significantly amplifies the environmental footprint of food consumption [157].

Shifting to more plant-based diets is essential for human health and well-being, and for enhancing the overall sustainability of the FS. However, these changes are driven by broader social, political, and dietary factors, which interact across the entire FSC, influencing both consumer nutritional patterns and the FS [156]. Food choices are closely linked to culture. For example, in most Western societies, diets are primarily based on animal-derived foods and high-fat, high-sugar products [14,100]. Additionally, many consumers enjoy meat, making it difficult to give up [158]. However, transitioning to more sustainable diets requires consumers to change their consumption and dietary patterns [35], a shift that is necessary and rational, but difficult to achieve [156].

Another important aspect of dietary shifts is the affordability and accessibility of plant-based and sustainable food options [35,93,141]. Sustainable food options refer not only to plant-based choices but also to their sustainable production and consumption [131]. Similarly, a plant-based diet that is not entirely vegetarian can still be considered a sustainable

and healthy diet [156]. Stanley et al. [158] define sustainable diets as reducing negative environmental impacts while ensuring food and nutrition security, supporting human health, and preserving biodiversity and ecosystems. They are culturally acceptable, accessible, affordable, economically fair, nutritionally sufficient, healthy, and safe, while also efficiently utilizing natural and human resources to meet the needs of both present and future generations [158]. Still, this type of diet remains inaccessible to many. Braun et al. [134] have found that more than one-third of people worldwide cannot afford a healthy diet [134], primarily due to its high cost [141,145]. In contrast, considering red and processed meat's actual environmental costs and health impacts, these products should be significantly more expensive [35]. The European Commission [35] has emphasized that sustainable diets must be available, affordable, and accessible to all, particularly to vulnerable population groups [35]. Yet, high prices and limited market access hinder dietary shifts [141].

A significant barrier is also people's perception, knowledge, and attitude toward sustainable food options [35]. Consumers often understand the importance of sustainability and express a willingness to act, yet they do not change their behaviour [135,146] for various reasons, such as a lack of time to search for the right products and cook [141], a dislike of eating the same meal twice or using leftovers [39], and unclear or confusing product labelling [97,133,159].

The transition towards more sustainable consumption and dietary patterns is a complex challenge that requires a holistic approach, ensuring sustainable food production [131] while simultaneously addressing economic and social issues [130]. The shift towards "less and better" consumption patterns also presents a challenge for the agricultural sector [130]. To encourage dietary changes, policy incentives play a crucial role in ensuring that sustainable food options are available, affordable, and accessible to all [35]. Additionally, clear sustainability labelling can help consumers make more responsible food choices [133], while informative and awareness-raising campaigns promote plant-based and sustainable diets. Stricter regulations on school catering are also essential, primarily to reform menus toward healthier and more sustainable diets and to encourage responsible food consumption patterns. Therefore, systemic changes are needed across the entire FSC, incorporating broader social, political, and dietary factors [156].

4.2.3. Consumer Behaviour Change

As mentioned earlier, people's decisions and actions are influenced by a wide range of factors. To achieve change, it is first necessary to inform and educate consumers about FW issues [9,35]. However, research has shown that most consumers do not act upon their knowledge or understanding of the problem [38,99,126]. Some have only a superficial understanding of the issue. Moreover, consumers often underestimate their household FW and fail to recognize their personal responsibility for it, partly due to discomfort in acknowledging wasteful behaviour [139,160]. Macijewski [143] found that consumers may avoid overconsumption, focus on healthy eating, and engage in FW reduction and recycling, yet at the same time fail to consider the amount of water, electricity, and natural gas used in meal preparation [143]. Similarly, Foden et al. [161] highlight that domestic kitchen practices frequently overlook the interdependencies between water, energy, and food resources, thereby missing critical sustainability trade-offs at the household level [161]. Studies also indicate that being informed about sustainable options does not necessarily lead consumers to choose them [111]. As noted by Ali et al. [162], despite increasing sustainability awareness, acceptance of Waste-to-Value foods made from by-products remains limited due to concerns about quality and a lack of awareness [162].

Consumer behaviour can be significantly influenced, directly or indirectly, by the regulatory framework of a given country, as various policy tools, such as taxation, subsidies, labelling, and public procurement [34,36,111,130,131], can empower consumers with

information, knowledge, tools, and incentives to promote responsible and sustainable food consumption in line with policy goals and strategies. However, although some policies promote sustainable food choices, most consumers are not aware of their actual significance and instead associate them with "greening" [141]. Even among those who are aware, they do not always follow these policies due to financial constraints and the strong influence of consumerist culture [141].

Therefore, it is essential to raise awareness and introduce changes from an early age in kindergartens, continuing them through higher education institutions [130], where individual autonomy increases and long-term habits are formed. According to Tsai et al. [98], environmental concerns significantly influence attitudes and behavioural intentions towards FW reduction among university students, suggesting that tailored educational and promotional activities in higher education settings can serve as effective tools for reducing FW and fostering responsible and sustainability-oriented behaviour [98]. Educational institutions also offer an opportunity to guide food choices by providing sustainable meals [131]. Moreover, school catering involves the interaction of multiple stakeholders across the entire FSC, making it an ideal setting to promote sustainable and responsible food consumption [134].

While most behavioural interventions aim to promote structural change and long-term habit formation, studies also indicate that sudden external disruptions, such as global crises, can rapidly reshape consumer behaviour. For example, during the COVID-19 pandemic, people had to adjust their food purchasing habits, cook more frequently at home, and dedicate more time to meal planning and preparation. These changes led to increased interest in local food products, raised awareness of food safety, and encouraged the adoption of more sustainable consumption practices, resulting in reduced FW [163–165]. Similarly, geopolitical conflicts such as the war in Ukraine have influenced food choice motivations, food security, and waste management practices by exposing vulnerabilities in supply chains and shifting consumer priorities [166,167].

Based on the results of the co-occurrence analysis of solution-oriented keywords, which revealed dominant terms such as *education*, *food waste reduction*, *plant-based diet*, and *awareness raising*, it is clear that the focus should be placed on the consumer as a key element of transformative change in the food consumption stage. The results highlight consumer behaviour change through the prism of the MOA framework [108]. As emphasized in the literature, effectively changing consumer behaviour requires the implementation of consumer awareness-raising and educational campaigns [37,95,116,148,149,168,169]. These initiatives equip consumers with the necessary abilities (skills and knowledge) to make informed and responsible decisions regarding food consumption. Additionally, targeted interventions, behavioural nudges [37,39,93,125,130], and a monitoring and evaluation system [38,133] are essential for influencing motivation by changing attitudes and personal stances toward food consumption and encouraging consumers to adopt more sustainable consumption patterns. Furthermore, creating opportunities—such as access to technologies, infrastructure, appropriate food storage and management facilities [86,96,127,170] and the availability of sustainable products [95,125,158] is crucial to supporting this transformation. It is therefore essential to integrate all three components comprehensively in order to promote sustainable food consumption at the individual, household, and societal levels. Without a balanced approach, or if motivation, opportunity, or ability is lacking, consumers are likely to continue their usual behaviour [114,171]. In this context, the regulatory framework plays a significant role as the foundation for legal and institutional conditions that support activities and strategies aimed at promoting sustainable food consumption and creating opportunities that enable consumers to change their behaviour.

4.2.4. Policy Reform

Structural changes—such as pricing strategies, sustainability-focused dietary guidelines, and school programmes [111]—the development of targeted interventions [38], and various policy interventions, including administrative, market-based, informational, and behavioural measures [9,36], are essential to enable a shift toward sustainable food consumption. It is also crucial that this is not perceived as an individual responsibility but as a collective and structural transformation [9,126], which must become an integral part of everyday life [38,126].

However, implementation is challenging in reality, as national policy frameworks and strategies must be based on global goals and EU directives [131]. Moreover, within countries, responsibility for various tasks is often divided between multiple levels of government and ministries [130], or policies predominantly focus on isolated aspects such as recycling, prevention, or reuse [170], thereby contributing to implementation difficulties. The complex involvement of consumers in policy implementation also hinders progress.

Overly strict food regulations, safety standards, and low FW disposal fees contribute to increased FW [34]. In addition to taxes on red meat and subsidies for plant-based alternatives [111,131], tax breaks and fiscal incentives for food donations could help recover and redistribute food that would otherwise be discarded [34]. FW-related regulations are primarily focused on FW management rather than prevention. To transition to a more holistic policy approach, sustainable production and consumption must be integrated throughout the FSC [94]. In this sense, the CE framework, which is based on closing material loops, reducing resource extraction, and minimizing waste, provides a strategic foundation for designing policies that promote sustainable food consumption [32,94]. However, Sadhukhan et al. [150] underscore the need for clear policy frameworks and inclusive governance to support circular transitions. In addition, stakeholder acceptance, political support, and consumer involvement are seen as crucial elements for successful CE implementation [151,172]. At the same time, limited consumer understanding and low public engagement in CE initiatives remain significant barriers to progress, highlighting the need for improved communication and awareness-raising efforts [151].

Research has shown that food policy should be based on education, which is key to shaping long-term dietary habits [111,131]. Additionally, sustainable and responsible food consumption and FW issues should be integrated into curricula [111]. Coordinated multi-stakeholder engagement and efforts are also needed [36,109,116,169].

A cross-sectoral, multi-level governance approach should be adopted to strengthen the regulatory framework, incorporating CE principles, educational initiatives, and economic incentives. This approach should ensure sustainability across the economic, environmental, and social dimensions while actively engaging consumers in the transition to a sustainable food system.

4.3. Conceptual Framework Development

Based on the results of a bibliometric analysis and an ILR, the authors identified key problems and potential solutions within the food consumption stage. It was found that the identified key issues are part of the broader challenges facing the global food system [173], significantly affecting the social, economic, and environmental dimensions of sustainability and pushing beyond planetary boundaries. This highlights the urgent need for systemic changes in the food consumption stage. Drawing on these findings, the authors propose a framework for transforming the FS into a sustainable food system through the prism of the food consumption stage, in which identified problems are systematically linked to targeted solutions. These solutions can be implemented using various tools that act as drivers to promote a paradigm shift (see Figure 8).
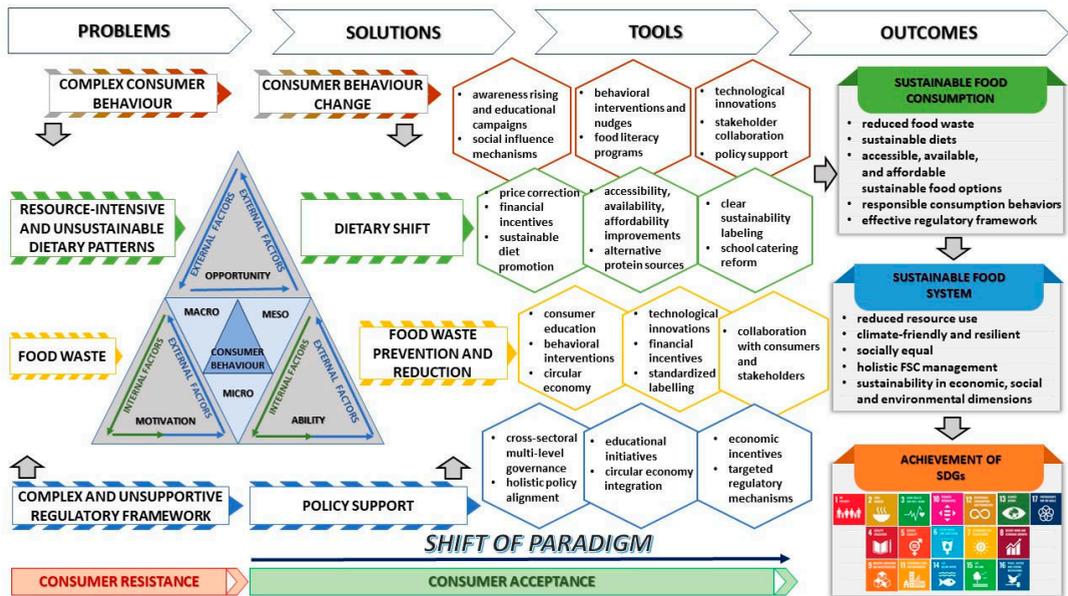
Figure 8. A framework for transforming the food system into a sustainable food system through the food consumption stage (compiled by the authors).

The framework illustrates the study's core findings, revealing that the central key aspects of the food consumption stage are FW and its reduction, the need for dietary shifts, consumer behaviour change, and policy reforms. These thematic areas encompass both major problem domains and potential solutions, providing the foundation for a structured approach to FS transformation.

While this framework provides a conceptual foundation for future interventions, it is not intended to serve as a fully prescriptive model. Rather, it should be viewed as a guiding structure, capable of adaptation to diverse FS contexts and complementary to other targeted tools. Moreover, the practical implementation of the framework may require context-specific adjustments. Its flexibility allows it to be applied across various settings, from local educational programmes to national food policy strategies, but its effectiveness depends on a range of contextual conditions.

As highlighted earlier, the consumer is the core element of change, with their behaviour serving as both a potential obstacle and a key driving force for transformation. Since consumer choices, including dietary habits, food preferences, and FW behaviours, have a direct influence on the entire FSC, affecting food demand, production practices, resource utilization, FW generation, and overall environmental impact [111,125,130,146], tools aimed at promoting change should primarily target the consumer. And building on insights from the literature review, it becomes evident that both the reviewed studies and existing conceptual models or policy strategies on food system transformation tend to be limited in scope, focusing predominantly on either micro-level behavioural factors or macro-level systemic structures. In contrast, the proposed framework addresses this identified gap by combining behavioural aspects with a three-level systemic approach through the MOA framework [108], positioning consumer behaviour as a central element and a starting point for sustainable transformation. Thereby, its novelty lies in bridging the gap between individual actions and structural change within the food system.

The proposed tools can influence one or more MOA components at different levels of action (micro, meso, or macro) [96], thus supporting a structured approach to

promoting sustainable food consumption. However, they must be applied in a coordinated and sustained manner. For example, behaviour change strategies such as educational or awareness-raising campaigns or nudging techniques may have limited long-term impact without reinforcement, continuity, or structural support [114]. This underscores the need to simultaneously address all MOA components, ensuring that consumers not only want to change, but also understand how to do so and have opportunities to act accordingly. Therefore, the framework does not promote isolated actions, but rather encourages a complementary and context-sensitive set of tools within each thematic area, enabling the removal of behavioural barriers while creating supportive environments for responsible and informed choices.

In this context, the framework emphasizes the importance of shifting from consumer resistance to acceptance. Once consumer acceptance is achieved, sustainable consumption—encompassing the adoption of sustainable diets, increased demand for plant-based, healthy, and sustainable products, responsible food purchasing and consumption, and FW reduction—can become the default choice. Only then can a paradigm shift occur.

Sustainable food consumption further drives systemic transformation by ensuring the efficient use of resources in food production and consumption, promoting equitable access to healthy and sustainable food, and integrating sustainability principles throughout the FSC. This, in turn, creates a balance between environmental, social, and economic sustainability, supports the development of a sustainable food system, and ultimately contributes to achieving the global SDGs.

4.4. Limitations and Future Research Directions

While this study provides valuable insights into the role of the consumption stage in FS transformation, several limitations should be acknowledged, which also present opportunities for future research.

The reviewed literature was based on a defined set of 69 documents, obtained through a structured Scopus search and a complementary manual search. Although the inclusion of both peer-reviewed and grey literature ensures a well-rounded perspective, it is possible that different findings might emerge with a broader or alternative selection of sources.

In future research, expanding the dataset, incorporating multilingual and non-traditional sources, and applying mixed-method approaches could further enrich the understanding of the consumption stage and its role in FS transitions.

The content-derived analytical keyword co-occurrence bibliometric analysis was based on author-assigned keywords, which may reflect a certain degree of subjectivity.

It should also be noted that, while the proposed conceptual framework offers a theoretically grounded perspective, it has not yet been empirically validated. Future studies could test its applicability through case studies, experimental designs, or policy evaluations in real-world contexts.

5. Conclusions

This study explores how the food consumption stage contributes to a systemic transformation toward more sustainable food systems. By conducting a bibliometric and integrative literature review, it was revealed that its transformation must be grounded in four key aspects: FW reduction, dietary shifts, consumer behaviour change, and policy reform.

The proposed conceptual framework offers a novel contribution by linking these thematic areas with targeted tools structured through the MOA framework and operating across micro, meso, and macro levels. Unlike existing frameworks that often focus solely on either individual behaviour or broader systemic structures, this approach integrates both, placing consumer behaviour at the core of sustainable transformation.

The framework provides a flexible and adaptable structure across different contexts—from educational programmes and community interventions to national strategies—and can assist stakeholders in identifying leverage points and the right tools to support policy planning and design interventions aimed at fostering sustainable food consumption.

The study results and the developed framework can serve as a foundation for policymakers, researchers, and other stakeholders, both for discussions on food consumption and for the development and implementation of targeted interventions and strategies to address challenges at the food consumption stage and facilitate the transition to a sustainable food system.

Future research should focus on empirically validating the proposed framework and assessing its applicability and impact across diverse real-world contexts, thereby testing its capacity and practical value in guiding the transition to sustainability.

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Abbreviations

The following abbreviations are used in this manuscript:

CE	Circular economy
EU	European Union
FAO	Food and Agriculture Organization
FE	Food environment
FLW	Food loss and waste
FS	Food system
FSC	Food supply chain
FW	Food waste
ILR	Integrative literature review
MOA	Motivation–Opportunity–Ability
NAM	Norm Activation Model
SDGs	Sustainable Development Goals

TPB	Theory of Planned Behaviour
UN	United Nations
UNGA	United Nations General Assembly
WHO	World Health Organization

Appendix A

Table A1. The list of reviewed documents, including author keywords and thematically grouped content-derived keywords identified as problems and solutions (compiled by the authors).

No.	Reference	Title	Document Type	Type of Study	Country/ Region	Author Keywords	Identified Problems (Content-Derived Keywords)	Identified Solutions (Content-Derived Keywords)	Selection Method
1.	Jurgilevich et al. [94]	Transition towards Circular Economy in the Food System	Journal article	Conceptual analysis based on experts roundtable discussion (HENVI Science Day)	Finland	circular economy; sustainability; food system; socio-technical transition	meat overconsumption; consumer awareness; food literacy; food culture; food environment; routine-based food choices; unclear labelling; consumer competences; food waste	circular economy; plant-based diet; vegetarian days in schools; food labelling reform; competence development; food waste prevention; redistribution of surplus food; revise food standards; composting waste; biogas production from food waste	Scopus database
2.	Canali et al. [34]	Food Waste Drivers in Europe, from Identification to Possible Interventions	Journal article	Literature review and policy analysis	EU	food waste; food waste drivers; food sustainability; food policy	food waste; low awareness, unclear date labels; poor planning; poor storage; oversized portions; fragmented policies; weak policy enforcement; social norms; systemic gaps;	education; clearer labellings; communication strategies; improved redistribution systems;	Manual
3.	Röös et al. [155]	Greedy or needy? Land use and climate impacts of food in 2050 under different livestock futures	Journal article	Scenario modelling study	Global	Land use; Climate; Food; Dietary change; Mitigation; Protein	resource-intensive consumption; meat overconsumption; unsustainable dietary patterns; stakeholder value conflict; insufficient demand-side focus;	plant-based diet; artificial meat and dairy; reduced demand; food waste reduction; stakeholder collaboration; awareness raising;	Scopus database
4.	Foden et al. [161]	The water–energy–food nexus at home:	Journal article	Conceptual analysis (policy-focused with expert interviews	United Kingdom	domestic practices; everyday practice; fats–oils–grease;	food waste; unsustainable kitchen practices; fragmented policy; low	behaviour change; policy interventions; awareness raising; education;	Scopus database

		New opportunities for policy interventions in household sustainability		and literature review)		household sustainability; policy interventions; water–energy–food nexus	awareness; limited knowledge;		
5.	Lindgren et al. [93]	Sustainable food systems—a health perspective	Journal article	Empirical (case study)	Sweden	food policy; food sustainability; food waste; food waste drivers	food waste; poor planning; inadequate storage; low awareness; long-term behaviour change;	nudging techniques; feedback and reminders; municipal-level interventions; increased awareness; plant-based diet;	Manual
6.	Liu et al. [140]	Placing 'sustainability' in context: narratives of sustainable consumption in Nanjing, China.	Journal article	Empirical (case study and interviews)	China	sustainable consumption; consumer culture; green lifestyle; emotion; Nanjing; China	cultural norms; policy individualism; trust issues; emotional factors	context-sensitive policy; local context strategies; awareness raising; cultural adaptation; emotional engagement	Scopus database
7.	Ellen Macarthur Foundation, [32]	Food and the circular economy—deep dive	Web page	Conceptual analysis	Global	N/A	food waste; nutrient loss; wasteful consumption patterns; lack of nutrient recovery;	transition to a circular economy; food waste reduction; collaborative efforts; sustainable diets;	Manual
8.	Falasconi et al. [160]	Such a Shame! A Study on Self-Perception of Household Food Waste	Journal article	Empirical (survey-based)	Italy	household food waste; awareness; consumer behaviour; environmental education; food waste prevention; logistic regression	food waste; low awareness; limited knowledge; unsustainable shopping habits; overbuying; lack of perceived responsibility; socioeconomic context	awareness raising; education; behaviour change; policy interventions; purchase planning; social norms	Scopus database
9.	Goryńska-Goldmann, [141]	Barriers to the Development of Consumption Sustainability: the Consumers' Perspective on the Food Markets	Conference paper	Desk research and empirical survey	Poland	Barriers; Consumers; Consumption-Sustainability; Development	food prices; lack of time for product search; lack of time for meal preparation; perceived inconvenience; need for self-discipline; household resistance; loss of consumption pleasure; limited access to sustainable food; narrow product range; poor product	institutional cooperation; education; awareness-raising campaigns; improved product communication; clear labelling; market innovation; access to sustainable food; supportive policy	Manual

						information; unclear labelling; low awareness; weak motivation;		
10.	Janssens et al. [139]	How Consumer Behavior in Daily Food Provisioning Affects Food Waste at Household Level in The Netherlands	Journal article	Empirical (survey-based)	Netherlands	food waste; food waste behaviour; consumer behavior; household food waste prevention; sustainable grocery management; grocery retail	food waste; in-store purchase behaviour; poor food planning; low awareness; low concern about food waste among young consumers; unsustainable food management	behaviour change; purchase planning; awareness raising; targeted interventions; food management education	Scopus database
11.	Sijtsema et al. [151]	Let's Talk about Circular Economy: A Qualitative Exploration of Consumer Perceptions	Journal article	Empirical (focus groups)	Netherlands	bio-economy; focus group; waste valorisation; attitudes; consumption; food packaging; circular initiatives	low consumer awareness; passive consumer engagement; lack of systems thinking; unsustainable food choices	circular economy principles; consumer involvement; communication strategies; awareness raising	Scopus database
12.	Alharbi et al. [128]	Towards Sustainable Food Services in Hospitals: Expanding the Concept of 'PlateWaste' to 'TrayWaste'	Journal article	Empirical (case study)	Saudi Arabia	sustainability; food production and consumption; sustainable food systems; sustainable menu; food catering practices in the public sector	food waste; unsustainable food service models; fragmented policy; lack of recycling; lack of waste management	sustainable food service models; waste monitoring and auditing; recycling; resource recovery; policy reform	Scopus database
13.	da Rocha Ramos et al. [99]	Needs of Sustainable Food Consumption in the Pandemic Era: First Results of Case Study	Journal article	Empirical (case study)	Italy	sustainability; food consumption; knowledge management	intention-action gap; limited access to sustainable food; low sustainability knowledge; low awareness	awareness raising; education; behavioural change strategies; access to sustainable food; student-targeted food policies	Scopus database
14.	Maciejewski, [143]	Consumers Towards Sustainable Food Consumption	Journal article	Empirical (survey-based)	Poland	consumer behaviour; sustainable consumption; food market; marketing; Poland; Slovakia	food waste; food waste behaviour; limited availability of organic products; higher costs of organic products; ineffective marketing strategies; low awareness; inefficient resource use in	awareness initiatives; avoiding overconsumption; healthy eating; clearer labelling; policy support; social campaigns; resource preserving;	Manual

No.	Author	Title	Type	Methodology	Region	Keywords	Key Themes	Interventions/Recommendations	Source
							cooking; knowledge–behaviour gap; consumers overconfidence;		
15.	Marx-Pienaar et al. [149]	The South African quick service restaurant industry and the wasteful company it keeps	Journal article	Empirical (case study)	South Africa	Consumer behaviour; developing economy; emerging context; fast foods; food waste; quick service restaurant (QSR); South Africa; supply chain	food waste; consumer behaviour; low awareness; limited information; lack of consensus	education; awareness raising; behaviour change; innovative packaging improvements; stakeholder collaboration	Scopus database
16.	Navarro Gausa et al. [169]	Creative Food Cycles: A Cultural Approach to the Food Life-Cycles in Cities	Journal article	Conceptual study	EU	resilient and sustainable cities; food waste; design culture; food cycles	food waste; low awareness; unsustainable consumption practices	awareness raising; education; self-sufficiency; reuse of food waste; stakeholder engagement; open innovation platforms	Scopus database
17.	Sadhukhan et al. [150]	Perspectives on "Game Changer" Global Challenges for Sustainable 21st Century: Plant-Based Diet, Unavoidable Food Waste Biorefining, and Circular Economy	Journal article	Conceptual study and LCA modelling	Global	biorefinery and bioeconomy; food waste and circular economy; zero hunger zero poverty; sustainable food; food policy; vegan protein; biosurfactant and chemical production from bio-resources	food waste; unsustainable dietary patterns; linear economy; policy gaps	plant-based diet; food waste valorisation; circular economy; policy support; multi-disciplinary approach;	Scopus database
18.	Soma et al. [116]	Food Waste Reduction: A Test of Three Consumer Awareness Interventions	Journal article	Empirical (intervention study)	Finland	food waste; awareness campaigns; gamification; intervention; consumer behaviour	food waste; low awareness; low community engagement	awareness raising; education; gamification; community engagement; community engagement workshops	Scopus database
19.	Spiller et al. [130]	Promoting sustainability in food consumption—Developing an integrated food policy and	Report	Conceptual analysis	Global	N/A	food waste; meat over-consumption; unhealthy choices; knowledge–action gap; social norms and habits; limited	multi-level interventions; reframing toward sustainability; behaviour change; clear labelling; supportive food	Manual

		creating fair food environments. Executive summary and synthesis report					availability of sustainable options; unclear labelling; short-term price focus;	environments; education; institutional support; policy support; plant-based diet; less meat consumption; food waste reduction;	
20.	Tsai et al. [98]	Consumer Food Waste Behavior among Emerging Adults: Evidence from China	Journal article	Empirical (survey based)	China	emerging adulthood; food waste; theory of planned behaviour; environmental concerns; structural equation modelling	food waste; low awareness; consumer behaviour	behaviour change; awareness raising; education; targeted interventions; media campaigns; environmental awareness	Scopus database
21.	Zeinstra et al. [39]	Drivers, barriers and interventions for food waste behaviour change: a food system approach	Report	Systematic literature review	Global	N/A	food neophobia; low vegetable preference; unstructured mealtime routines; lack of effective school settings; overbuying; inappropriate storing; food waste;	food waste reduction; awareness raising; education; taste education; structured interventions in school and home; perceived behavioural control; food waste reduction;	Manual
22.	Aguirre Sánchez et al. [38]	What influences the sustainable food consumption behaviours of university students? A systematic review	Journal article	Systematic literature review	Global	sustainable food consumption; sustainable diets; pro-environmental behaviour; health behaviour; university students; young adults; young people; systematic review	food waste; misplaced priorities; cultural habits; affordability and availability of sustainable options; limited knowledge; short-term behavioural focus; insufficient systemic alignment; individual-level burden; limited policy involvement; unsustainable dietary patterns; meat overconsumption;	food waste reduction; plant-based diet; minimizing the environmental footprint; sustainable food consumption behaviours; systematic food environments monitoring; systematic interventions; multi-actor collaboration; long-term strategy; policy reform; awareness raising;	Manual
23.	Ali et al. [162]	Analysis of Circular Thinking in Consumer Purchase Intention	Journal article	Mixed-methods empirical (survey and interviews)	Hungary	waste-to-value food; circular economy; consumer intention;	food waste; consumer resistance; lack of awareness; unsustainable consumption; trust issues;	circular economy; behaviour change; awareness raising; waste-to-value (WTV) innovation; clear	Scopus database

	to Buy Sustainable-Waste-To-Value (WTV) Foods				sustainable consumption; nutritional value; consumer gender issues; consumer education issues	food safety concerns; consumers' perception of Waste-to-Value food	food labelling; education; transparent communication; product traceability; trust-building strategies	
24.	Ben Hassen et al. [163]	Food Behavior Changes during the COVID-19 Pandemic: Statistical Analysis of Consumer Survey Data from Bosnia and Herzegovina	Journal article	Empirical (quantitative survey)	Bosnia and Herzegovina	COVID-19; diet; food behaviour; food shopping; food waste; Bosnia and Herzegovina; Balkans	shopping behaviours; fragmented food systems; fragmented health system; food insecurity risk; food safety concerns; unsustainable food sourcing habits; low food safety awareness; vulnerability during crises	awareness raising; healthy diet promotion; local food consumption; behaviour change; sustainable food choices;	Scopus database
25.	Buczacki et al. [100]	HoReCa Food Waste and Sustainable Development Goals—A Systemic View	Journal article	Systematic literature review	Global	food waste; food services; HoReCa; Sustainable Development Goal; regional policy	food waste; fragmented responsibility; insufficient stakeholder collaboration; lack of systemic integration; high operational and environmental costs; lack of micro–macro synergy	stakeholder collaboration; systems engineering approach; food waste monitoring; food waste management; organizational improvements in food services; food waste reduction	Scopus database
26.	Hamam et al. [172]	Circular Economy Models in Agro-Food Systems: A Review	Journal article	Systematic literature review	Global	circular economy; business model; sustainability; agro-food; sustainable; food waste; supply chain	unsustainable consumption models; food waste; lack of policy support	circular economy strategies; stakeholder engagement; awareness raising; political support; change in consumption patterns; behaviour change; consumer acceptance	Scopus database
27.	Hoehn et al. [132]	A Novel Composite Index for the Development of Decentralized Food Production, Food Loss, and Waste Management Policies: A Water-	Journal article	Empirical (case study and model development)	Spain	sustainable development goals; food waste; composite index; water-climate-food nexus	food loss and waste; unsustainable dietary patterns; lack of SDGs compliance in food systems; low policy integration	water-climate-food nexus approach; vegan diet; vegetarian diet; pescatarian diet; plant-based diet; food consumption impact assessment	Scopus database

	Climate-Food Nexus Approach							
28.	Introducing a Degrowth Approach to the Circular Economy Policies of Food Production, and Food Loss and Waste Management: Towards a Circular Bioeconomy [Hoehn et al. [85]]	Journal article	Empirical (case study)	Spain	degrowth; food supply chain; food loss and waste; Global North; Paris Agreement; spiral bioeconomy; circular bioeconomy	resource-intensive food consumption; food over-consumption	sustainable degrowth; circular bioeconomy; food waste management; plant-based diet; food waste reduction; localized policies; food-climate nexus awareness raising	Scopus database
29.	Policy Options for Sustainable Food Consumption—Review and Recommendations for Sweden [Röös et al. [131]]	Report	Systematic mapping and Expert workshop	Sweden	N/A	food waste; meat over-consumption; affordability and availability of plant based options;	public procurement reform; municipal initiatives; environmental and nutrition-based meal planning; diet shift guidelines; food environment interventions; multi-level governance;	Manual
30.	The Attitude-Behavior Gap–Drivers and Barriers of Sustainable Consumption [Wintschnig, [146]]	Journal article	Literature review	Global	Sustainable consumption; attitude-behaviour gap; sustainable choices; sustainable consumer behaviour	attitude–behaviour gap; habitual behaviour; emotional resistance; poor sustainability knowledge; stereotypes about sustainable products; structural barriers; infrastructure gaps; high costs of sustainable food options; insufficient institutional support; information overload;	value-based motivation; education and awareness; accessible infrastructure; behavioural nudges; improved sustainability communication; holistic strategies;	Manual
31.	Communicating Food Sustainability to Consumers: Towards more effective labelling [Bishop et al. [133]]	Report	Comparative case review/best practices analysis	Global	N/A	food loss; food waste; health inequalities; over-consumption; unclear labelling; inadequate data and measurement;	government coordination; cross-sectoral initiatives; behaviour change campaigns; education; technological innovations; measurement and	Manual

No.	Author	Title	Type	Method	Region	Keywords	Challenges	Solutions	Source
							affordability challenges; weak food governance;	monitoring tools; effective communication; clear food labelling; stakeholder collaboration;	
32.	Borghesi & Morone, [164]	A review of the effects of COVID-19 on food waste	Journal article	Systematic literature review	Global	Food waste; COVID-19; Food system; Sustainability	food waste; intention-action gap; supply–demand shocks; food purchasing practices; food storage practices; crisis	policy support; behaviour change; home cooking; awareness raising; education; sustainable food practices	Scopus database
33.	Feodorov et al. [166]	Toward a Circular Bioeconomy within Food Waste Valorization: A Case Study of an On-Site Composting System of Restaurant Organic Waste	Journal article	Empirical (case study)	Romania	circular bioeconomy; food security; composting; food waste; in-vessel composter; fertilizers; soil improver	food waste; food security challenges; disposal practices	circular bioeconomy; composting; food waste management; on-site composting system	Scopus database
34.	Fry et al. [9]	A Tale of Two Urgent Food System Challenges: Comparative Analysis of Approaches to Reduce High-Meat Diets and Wasted Food as Covered in U.S. Newspapers	Journal article	Qualitative content analysis	Global	climate change; food system; food waste; news media; sustainable	meat overconsumption; food waste; resistance from stakeholders; fragmented governance; accessibility and affordability; short-term strategies;	whole-system food strategies; governments partnerships; inclusive governance; food policy councils; long-term planning; capacity-building for municipalities; awareness raising; education; food waste reduction; plant-based diet;	Manual
35.	Gallo et al. [74]	Food Recommendations for Reducing Water Footprint	Journal article	Model development (based on secondary dataset analysis)	Global	sustainable food consumption; food recommendation system; water footprint; food waste; good practice	resource-intensive dietary patterns; water-intensive food choices	Mediterranean diet; food recommendation system; behaviour change	Scopus database
36.	Gravelines et al. [144]	The Role of Green Self-Identity and Self-Congruity in	Journal article	Empirical (survey-based)	Lithuania	sustainability; sustainable food consumption; green	uncertainty about sustainable food; low behavioural control; low	green self-identity; self-congruity; symbolic	Manual

	Sustainable Food Consumption Behaviour				self-identity; self-congruity with green food products	awareness; limited sustainable consumption routines; low green self-identity; low self-congruity;	marketing; educational campaigns;	
37.	Lehtokunnas et al. [126]	Towards a circular economy in food consumption: Food waste reduction practices as ethical work	Journal article	Empirical (participant observation and diaries)	Finland	Sustainability; consumption; food waste; ethical subjectivity; Foucault; circular economy; moral economy; practice theory	food waste; time constraints; lack of motivation to cook with leftovers; limited consumer skills in managing food; behaviour–system misalignment;	circular economy; stakeholder collaboration; multi-level interventions; consumer empowerment; awareness campaigns; emotional engagement with food;	Manual
38.	Lourenco et al. [156]	Psychological Barriers to Sustainable Dietary Patterns: Findings from Meat Intake Behaviour	Journal article	Empirical (survey-based)	Brazil	sustainable diets; dietary behaviour; meat intake; construal level theory; transtheoretical model; psychological barriers	meat overconsumption; behaviour-action gap; cultural attachment to meat; lack of knowledge; lack of skills; social resistance; structural constraints; limited availability and accessibility of plant-based options; limited plant-based meal options;	sustainable dietary patterns; awareness raising; sensory appeal; accessibility of plant-based options; stakeholder collaboration;	Manual
39.	Macura et al. [36]	What evidence exists on the effects of public policy interventions for achieving environmentally sustainable food consumption? A systematic map protocol	Journal article	The systematic map	Global	Biodiversity loss; Climate change; Environmental impacts; Greenhouse gas emissions; Public policy; Sustainable consumption; Sustainable diets	unsustainable consumption; food waste; greenhouse gas emissions; lack of regulation; limited policies;	policy tools; taxes; subsidies; labelling; information campaigns; procurement standards; marketing regulation; nudging; capacity building; voluntary agreements; education; marketing regulation;	Manual
40.	Malefors et al. [129]	Food waste reduction and economic savings in times of crisis: The potential of machine learning methods to plan	Journal article	Empirical (case study)	Sweden	Food waste school kitchens forecasting random-forest system optimization	food waste in public catering; changing consumption patterns; overproduction	food waste reduction; meal planning; attendance forecasting models; technological innovation	Scopus database

	guest attendance in Swedish public catering during the COVID-19 pandemic							
41.	Stanley et al. [158]	Overcoming barriers to sustainable, healthy diets	Journal article	Literature review	Global	N/A	meat overconsumption; Sensory dislike; food neophobia; cultural norms; traditions; health and nutrient concerns; preparation complexity; perceived artificiality of substitutes; lack of plant-based options;	education; awareness raising; media campaigns; labelling; sustainability indicators; recipe access; shopping guides; improved sensory design; availability and affordability of plant-based products; alternative protein sources; behavioural interventions; stakeholders collaboration;	Manual
42.	Strambu-Dima, [159]	Food-Related Consumer Behavior Endorsing European Food Chain Sustainability—A Marketing Study on the Romanian Consumer	Journal article	Empirical (survey based)	Romania	sustainability; food-related consumer habits; food chain; retailers; groceries; customer profiling; pro-sustainability interventions	food waste; food purchasing habits; food-related choices; meat overconsumption;	purchased food reduction; waste valorization; sustainable food options; eating at home; waste management; consumer involvement; stakeholder collaboration; policy support; education	Scopus database
43.	Vargas-Lopez et al. [165]	Consumer expenditure, elasticity and value of food waste: A Quadratic Almost Ideal Demand System for evaluating changes in Mexico during COVID-19	Journal article	Empirical (survey based)	Mexico	Household food waste; COVID-19 lockdown; Expenditure elasticity; Consumer responsiveness; QUAIDS	food waste; consumer habits; consumer behaviour; cooking skills	food waste reduction; grocery lists; more time for food planning and preparation; behaviour change; using leftovers on other meals; public policy support for household practices	Scopus database
44.	Wang et al. [103]	Understanding Consumers' Food Waste Reduction Behavior—A Study Based	Journal article	Empirical (survey-based)	China	food waste reduction; norm activation model; self-efficacy	food waste; low awareness; lack of perceived responsibility; behaviour-action gap;	food waste reduction; personal norms; ascription of responsibility; self-efficacy; behaviour intentions;	Manual

	on Extended Norm Activation Theory							
45.	Barker et al. [142]	Towards Sustainable Food Systems: Exploring Household Food Waste by Photographic Diary in Relation to Unprocessed, Processed and Ultra-Processed Food	Journal article	Empirical (photo diary and interview-based case study)	United Kingdom	food waste; food security; processed food; ultra-processed food; diet quality; nutrition; household; consumer; photographic diary	food waste; food affordability; rising living costs; food security	food waste reduction; targeted interventions; focus on avoidable waste; food literacy; preparation skills	Scopus database
46.	Biresselioglu et al. [125]	How to Exploit Sustainable Food Consumption Habits of Individuals: Evidence from a Household Survey in Izmir, Türkiye	Journal article	Empirical (survey-based)	Turkey	sustainability; food consumption; food shopping; dietary habits; food waste	food waste; low awareness; lack of knowledge; high costs of sustainable options; weak behavioural control	awareness raising; education; affordability and availability of organic products; targeted interventions;	Manual
47.	Casonato et al. [37]	What a waste! Evidence of consumer food waste prevention and its effectiveness	Journal article	Systematic literature review	Global	Food waste; Waste prevention interventions; Consumer behaviour; SDG12.3; Sustainable consumption	food waste; complex consumer behaviour; limited food waste data; standalone interventions; unclear food labelling; poor monitoring; short-term focus; policy incoherence; rebound effects; access to effective tools; lack of technologies;	food waste reduction; nudges; education; digital tools; citizen science; skill training; co-creation; social norms; gamification; feedback systems; targeted messaging; food sharing; systemic approach; nutrition education; supportive policies; behaviour change;	Manual
48.	Dekšne et al. [86]	Circular economy strategies for reducing food waste in schools: A systematic literature review	Journal article	Systematic literature review	Global	circular economy, R strategies, food waste, sustainability	food waste; menu inflexibility; disliked meals; weak food literacy; low reuse practices; no leftover recovery; poor waste tracking; limited composting; low technology use; weak circular	circular economy; menu adaptation; reuse in recipes; food donation; composting; food-to-feed use; circular education; by-product valorization; bioenergy from waste; behaviour change;	Manual

						economy integration; knowledge gap;		
49.	European Commission, [35]	Towards sustainable food consumption: promoting healthy, affordable and sustainable food consumption choices	Report	Evidence-based policy review	EU	N/A	meat overconsumption; food waste; low awareness; availability and affordability to sustainable options; unclear labelling; trust issues; cultural habits; fragmented policies; short-term effects; taxes;	food education; awareness raising; clear labelling; green procurement; social marketing; trusted info sources; digital nudges; stakeholder collaboration; circular economy; long-term vision; EU Farm to Fork strategy; policy support; plant-based diet; subsidies;	Manual
50.	Mansor et al. [127]	Antecedents and barriers to sustainable food waste practices among lower-middle income households in Malaysia	Journal article	Empirical (case study)	Malaysia	Antecedents; barriers; food waste; households; lower-middle income	food waste; over-preparing; over-buying; dietary transition; improper storage; price barriers; low availability; cultural norms; low awareness; lack of motivation; information gaps; lack of time; perceived inconvenience; trust issues; lack of education; low awareness; policy gaps; lack of facilities;	environmental concern; health motivation; ethical values; social norms; perceived behavioural control; knowledge and education; food labels; reliable information; affordability; availability; policy incentives; policy support; community engagement; accessible infrastructure; time-saving solutions; accessible tools;	Manual
51.	Pais et al. [111]	How to Promote Healthier and More Sustainable Food Choices: The Case of Portugal	Journal article	Empirical (survey-based)	Portugal	food economics; food choices; sustainable development; food education; primary data; logistic regressions	meat overconsumption; animal-based products; low awareness; price barriers; unclear labelling; routine behaviour; lack of motivation; limited sustainability knowledge; weak info channels;	food waste reduction; education and awareness; policy support; plant-based diet; food accessibility and affordability; dietary guidelines; behavioural interventions; cultural adaptation; environmental concern; informed choices; local and	Manual

No.	Author	Title	Type	Methodology	Region	Keywords			Source
								organic preference; food waste reduction;	
52.	Paparella et al. [135]	Measuring consumer effort in circular economy initiatives in the food domain: An exploratory analysis	Journal article	Qualitative, Multiple-Case Study	Global	Circular economy; Consumer effort dimensions; Consumer parameters of effort; Consumer effort index	consumer resistance; perceived effort; time demands; financial cost; uncertainty; limited product choice; inconvenient access; lack of complete product info; psychological discomfort; unfamiliar routines;	local food networks; food sharing; food waste reduction; reuse of by-products; circular behaviour; community-based models; technological tools; policy incentives; transparency; consumer involvement; sustainability values;	Manual
53.	Principato et al. [138]	Introducing digital tools for sustainable food supply management. Tackling food loss and waste in industrial canteens	Journal article	Mixed-methods empirical (case study)	Italy	artificial intelligence; canteen waste; effective food service management; industrial ecology; LCA; Random Forest	food waste in workplace canteens; plate waste; low awareness	digital tools; education initiatives; sustainable food service management	Scopus database
54.	Trollman et al. [167]	Crowdsourcing food security: introducing food choice derivatives for sustainability	Journal article	Conceptual and case study	Ukraine/Global	Crowdsource; Derivatives market; Food security; Food waste; Sustainability	food waste; overconsumption; food choices; consumer behaviour; unpreparedness for shocks	food waste reduction; consumption reduction; place-based solutions; behaviour change; food choice derivatives; data-driven consumer tools	Scopus database
55.	Vittuari et al. [96]	How to reduce consumer food waste at household level: A literature review on drivers and levers for behavioural change	Journal article	Systematic literature review	Global	Food waste prevention; Consumer behaviour; Food systems sustainability; Consumption patterns; Food waste reduction	food waste; behavioural complexity; low motivation; poor food literacy; limited access to tools; lack of infrastructure; unclear labelling; fragmented responsibility; insufficient policy integration;	behavioural change; policy support; food donation incentives; labelling clarity; multi-level interventions; awareness campaigns; infrastructure access; collaborative governance; food literacy;	Manual
56.	von Braun et al. [134]	Reduction of Food Loss and Waste: The	Book section	Policy- and Strategy-Oriented Review	Global	N/A	food waste; hunger; affordability and access to healthy food; inequity;	subsidies; education; behavioural incentives; circular economy; multi-	Manual

#	Author	Title	Type	Methodology	Country	Keywords	Drivers/Barriers	Actions/Solutions	Source
		Challenges and Conclusions for Actions					nutrition gaps; weak food environments	actor cooperation; investments;	
57.	Yamabe-Ledoux et al. [153]	Exploring the Opportunities and Challenges of ICT-Mediated Food Sharing in Japan	Journal article	Empirical (case study and survey-based)	Japan	food loss and waste; surplus food redistribution; food sharing; food supply chain	food loss and waste; overconsumption; food choices; consumer behaviour; unpreparedness for shocks; consumer distrust; safety concerns; financial viability	food sharing platforms; education; government support; community-based models; food redistribution policies	Scopus database
58.	Genova & Allegretti, [145]	Sustainable Food Consumption: Social Representations of Definitions, Drivers, and Obstacles	Journal article	Qualitative, Exploratory Study	Italy	sustainable food; definitions; representations; drivers; obstacles	availability and affordability of sustainable options; costs; limited skills; culinary traditions; unclear definitions; trust issues; knowledge gap;	health and environment concern; ethical values; taste and culture; food literacy; clear labelling; local market support; subsidies; social norms; community engagement;	Manual
59.	Kechagias et al. [101]	A Holistic Framework for Evaluating Food Loss and Waste Due to Marketing Standards across the Entire Food Supply Chain	Journal article	Conceptual (framework development)	Global	food waste; food loss; marketing standards; supply chain management; food systems; sustainable food chain	food loss and waste; marketing standards; consumer preferences; aesthetic considerations; consumer behaviour; knowledge gaps	targeted interventions; education; sector-specific actions; regional adaptation	Scopus database
60.	Mundo-Rosas et al. [170]	Characterization and Analysis of Public Policies to Prevent and Manage Food Waste in Mexico	Journal article	Policy document review	Mexico	food waste; food waste policy; food waste prevention; food waste hierarchy pyramid; Mexico	food waste; lack of food waste management strategies; underfunded infrastructure; policy focus; lack of structural changes; limited funding	targeted interventions; public policy improvement; food waste prevention	Scopus database
61.	Schulze et al. [109]	How to move the transition to sustainable food consumption towards a societal tipping point	Journal article	Empirical (case study)	Denmark	Societal tipping point; Sustainability transition; Food consumption; behaviour change	meat consumption; processed food consumption; unsustainable dietary habits; environmental impact; economic constraints; cultural norms; low awareness; habits; complex behaviour;	societal tipping interventions; coordinated public campaigns; supportive policy; stakeholder collaboration; food access and affordability; multi-actor engagement; collective behavioural shift;	Manual

						complexity of systemic change;		
62.	Phan, [97]	Understanding the acquisition, usage, and disposal behaviours in sustainable food consumption: A framework for future studies	Journal article	Systematic literature review	Global	Sustainable food consumption; Sustainable food consumption indicators; Food waste; Sustainable home cooking; Food purchase planning; Sustainable eating patterns	high price; bad taste perception; habitual eating; low awareness; disbelief in food impact; low motivation; distrust in label; poor cooking skills; time constraints; convenience prioritization; food neophobia; product availability; limited sustainable choices; unclear information; information overload; fragmented policy;	organic food choices; local products; seasonal products; plant-based diet; purchase planning; meal planning; shopping list use; flexible planning; awareness raising; critical thinking; food waste reduction;	Manual
63.	Ribeiro et al. [154]	Citizens' deliberation on solutions to fight urban household food waste and nexus with growing urban gardens: The case of Porto metropolitan area in Portugal	Journal article	Empirical (case study)	Portugal	Food waste; Household food waste (HFW); Urban gardens; Deliberative methods; Deliberative focus groups (DFG); Sustainable food systems	food waste; consumer behaviour	holistic actions; urban gardens; behaviour change; preventive practices; economic incentives; education; technological solutions; awareness raising; public policy adaption	Scopus database
64.	Acosta Mereles et al. [152]	Good Practices of Food Banks in Spain: Contribution to Sustainable Development from the CFS-RAI Principles	Journal article	Mixed-methods empirical (case study)	Spain	food bank; sustainable development goals (SDGs); principles for responsible agricultural investment (CFS-RAI); food waste; good practices; food security; sustainable development	food waste; low awareness; consumer behaviour; food insecurity	food banks; cross-sector collaboration; policy support	Scopus database
65.	Liu et al. [168]	Enhancing Student Behavior with the	Journal article	Empirical (case study)	Taiwan	hospitality education; learner-centred	food waste; low sustainability competence; low	food waste reduction; food safety and health;	Manual

	Learner-Centered Approach in Sustainable Hospitality Education				approach; responsible consumption; responsible production; societal transformation	awareness; theory–practice gap; outdated teaching methods; lack of sustainability education; high environmental impact; education–industry mismatch; weak food system empathy	low-carbon operations; energy saving; green purchasing; use of local ingredients; responsible consumption; experiential learning; learner-centred approach; sustainability education; entrepreneurship simulation; farm-to-table model; behaviour change; stakeholder engagement; green restaurant practices;	
66.	Ungureanu et al. [148]	Analysis of Food Purchasing Behavior and Sustainable Consumption in the North-East Region of Romania: A PLS-SEM Approach	Journal article	Empirical (survey-based)	Romania	consumer behaviour; food sustainability; purchase decision; PLS-SEM	purchasing behaviour; lack of sustainability awareness; limited waste recycling behaviour; knowledge–practice gap; insufficient sustainability education; university involvement; inadequate waste infrastructure; lack of motivation; low policy enforcement; waste sorting habits; waste management;	university-level policies; awareness campaigns; student engagement initiatives; education; sustainability integration in curricula; environmental responsibility; recycling systems; campus sustainability policies; behaviour change; stakeholder engagement; stakeholder collaboration;	Manual
67.	Nichifor et al. [95]	Drivers, Barriers, and Innovations in Sustainable Food Consumption: A Systematic Literature Review	Journal article	Systematic literature review	Global	sustainable food consumption; consumer behaviour; barriers and motivations; technological innovations; corporate sustainability initiatives	low awareness; knowledge–behaviour gap; high price of sustainable products; habitual consumption; limited availability; trust in labelling; weak policy support; unclear information; time constraints; behavioural resistance;	environmental awareness; education and information; health consciousness; cultural sustainability values; policy incentives; product availability; trust in eco-labels; social norms; corporate responsibility; sustainability education;	Manual

68.	Kong et al. [157]	Dynamic changes and sustainability assessment of food consumption footprint in megacities: A comparative analysis from four Chinese municipalities	Journal article	Empirical (quantitative, secondary data-based)	China	Food consumption footprint; Food consumption sustainability; Dietary structure; Assessment framework; Obstacle degree model; Megacities	ecological footprint; unsustainable dietary patterns; urbanization pressure; economic consumption bias; regional disparities; policy fragmentation; low resource efficiency; limited green infrastructure; weak subsystem synergy;	policy reform; footprint monitoring; integrated urban planning; green technology; public awareness; food system optimization; subsystem coordination; spatial analysis tools; resource efficiency improvement; plant-based diet;	Manual
69.	Yılmaz et al. [147]	The Environmental and Economic Dynamics of Food Waste and Greenhouse Gas Emissions: A Causal Time Series Analysis from 2000 to 2022	Journal article	Quantitative (longitudinal and causality explanatory time series study based on secondary data analysis)	Global	sustainable food systems; greenhouse gas emissions; food loss and waste	food loss and waste; food security; food insecurity	food waste reduction; education; targeted interventions; sustainable food policies	Scopus database

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