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Juta Dekšne

TOWARDS ZERO-WASTE FOOD CONSUMPTION: ORGANISATION OF THE CATERING PROCESS IN LATVIAN SCHOOLS WITHIN THE FRAMEWORK OF A SUSTAINABLE CIRCULAR ECONOMY

Summary of the Doctoral Thesis

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RTU RĒZEKNE ACADEMY, VENTSPILS UNIVERSITY OF APPLIED SCIENCES, VIDZEME UNIVERSITY OF APPLIED SCIENCES

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To be granted the scientific degree of Doctor of Science (PhD), the present Doctoral Thesis has been submitted for defence at the open meeting of the Promotion Council of the joint doctoral study programme "Economics and Business" of RTU RA, VeA, and ViA on 18 December 2025, at 12:00 p.m. at RTU Rēzekne Academy of Riga Technical University, Atbrīvošanas aleja 115, Rēzekne, Room 112.

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for review to the Promotion Council of the joint doctoral study programme "Economics and Business" of RTU RA, VeA, and ViA for promotion to the scientific degree of Doctor of Science (PhD) is my own. I confirm that this Doctoral Thesis has not been submitted to any other university for promotion to a scientific degree.

Juta Dekšne ……..(signature)

Date: ……

The Doctoral Thesis has been written in Latvian. It consists of an Introduction, 3 chapters, Conclusions, 17 figures, 2 tables, and 8 appendices; the total number of pages is 322, including appendices. The Bibliography contains 168 titles.

CONTENTS

ABBREVIATIONS 5
FREQUENTLY USED TERMS 6
Information on publications and research work 7
INTRODUCTION 10
1. THEORETICAL FRAMEWORK 17
1.1. The issue of food waste and its significance in the context of sustainable development 17
1.2. The concept of the circular economy and its role in food waste reduction 19
1.3. The significance of the consumption stage in transforming the food system 21
1.3.1. The role of school meal programmes in the food system 21
1.3.2. Factors influencing food system transformation at the consumption stage 23
2. EVALUATION OF THE CATERING PROCESS ORGANISATION IN REZEKNE CITY SCHOOLS WITHIN THE FRAMEWORK OF A SUSTAINABLE CIRCULAR ECONOMY 25
2.1. Food waste in the school catering process: The first pilot study in Rezekne city schools 25
2.2. Evaluation of the effectiveness of plate waste reduction interventions: The second pilot study in Rezekne city schools 27
2.3. Sustainable food consumption in the school catering process: Students' awareness and assessment 31
3. SOLUTIONS FOR THE ORGANISATION OF SCHOOL CATERING PROCESSES AND THE TRANSFORMATION OF FOOD SYSTEMS 36
3.1. Technological solutions for food waste prevention 36
3.2. A conceptual action plan for promoting zero-waste food consumption in the school catering process 37
3.3. Conceptual framework for consumption-based food system transformation 38
MAIN CONCLUSIONS 40
MAIN PROBLEMS AND SOLUTIONS 42
REFERENCES 45

ABBREVIATIONS

AI – Artificial Intelligence

ANOVA – analysis of variance

CDD – Capability-Driven Development

CE – Circular Economy

E-mentor – project "E-mentor as a Transformation Tool for Ensuring Zero-Waste Food Consumption in Educational Institutions"

EU – European Union

FAO – Food and Agriculture Organisation

FLW – Food Loss and Waste

FSC – Food Supply Chain

FW – Food Waste

HLPE – High Level Panel of Experts

LLM – Large Language Model

MOA – Motivation–Opportunity–Ability (framework)

NAM – Norm Activation Model

PW – Plate Waste

SDGs – Sustainable Development Goals

SNW – The method for analysis of Strengths, Neutrals and Weaknesses

UNEP – United Nations Environment Programme

UNGA – United Nations General Assembly

WRAP – Waste and Resources Action Programme

FREQUENTLY USED TERMS

Circular economy. An economic model which, by applying the "R" strategies, is primarily aimed at slowing down resource use and reducing waste by extending the life cycle of materials and products.

Food system. A complex and dynamic system and network of interactions that encompasses the food supply chain, the food environment (food availability and food information), consumer behaviour, and the full spectrum of food-related activities from production to consumption and waste management.

Free school meals. Lunch meals for students funded by the state and/or municipalities, provided to them free of charge.

Meal serving model. The way in which meals are organised and served. For example, in Rezekne city schools, the meal serving model is based on fully or partially pre-portioned meals individually served in advance.

Organisation of the school catering process. A set of activities related to menu planning, meal preparation, serving, consumption, and monitoring of the catering process in schools.

Principles of a sustainable food system. Derived from the definition of a sustainable food system – ensuring food security and nutrition for the present generation, preserving resources, promoting responsible consumption, shifting dietary habits, preventing food waste, and ensuring socially just governance of the food system, while safeguarding the environmental, social, and economic foundations for future generations.

School meal programmes. State and/or municipal initiatives that provide students with regular, nutrient-rich meals in schools, with the aim of improving children's health, promoting social equity, and enhancing educational achievement.

Sustainable circular economy. An extended circular economy model primarily aimed at preventing and reducing waste by changing consumption behaviour and incorporating the social dimension, thereby ensuring a balance between economic, social, and environmental aspects.

Zero-waste food consumption. The organisation of the school catering process in such a way as to primarily ensure the prevention and reduction of plate waste.

Information on publications and research work

This Doctoral Thesis was developed as a thematically unified set of publications, based on eight articles published in peer-reviewed scientific periodicals that are internationally accessible in scientific information repositories and cited in internationally available databases. Seven publications are indexed in Scopus and six in the Web of Science databases; and in the Doctoral Thesis they are denoted by Roman numerals.

Article 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))*

Article 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*. https://doi.org/10.22616/rrd.28.2022.022 *(Open Access, ind. Scopus, Web of Science™, etc.)*

Article 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)*

Article 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)*

Article 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))*

Article 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))*

Article 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))*

Article 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))*

In accordance with Paragraph 9 of the Cabinet of Ministers Regulation No. 1001 of 27 December 2005 (with amendments of 30.04.2020) "Procedure and Criteria for Awarding the Scientific Doctoral Degree (Promotion)" (Ministru kabinets, 2005), the Doctoral Thesis includes the written consents of the co-authors of the publications incorporated in the Thesis for the use of these publications in the promotion process.

Other publications not included in the Doctoral Thesis

- **Deksne, J.**, Lonska, J., Litavniece, L., Kotane I., Zvaigzne, A., & Silicka, I. (2025). Age effect on plate waste in Latvian schools. Submitted to the journal *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

Participation in Conferences

- 5th International Conference "RETASTE: Rethink Food Resources, Losses, and Waste 2025", Harokopio University and Hellenic Mediterranean University, Athens, Greece (24–27 September 2025).

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

- 65th International Scientific Conference "Scientific Conference on Economics and Entrepreneurship (SCEE'2024)", Riga Technical University, Riga, Latvia (11 October 2024).

Presentation: *Towards sustainable food systems: An analysis of barriers and drivers in the food consumption stage* (based on the article *Shaping Sustainability Through Food Consumption: A Conceptual Perspective*).

- 4th International Conference "RETASTE: Rethink Food Resources, Losses, and Waste 2024", Hellenic Mediterranean University and Harokopio University, Heraklion, Greece (25–27 September 2024).

Presentation: *Assessing Schoolchildren's Awareness and Perceptions of Food Waste and School Catering: A Study of Rezekne City Schools, Latvia* (based on the article *Insights into Awareness and Perceptions of Food Waste and School Catering Practices: A Student-Centred Study in Rezekne City, Latvia*).

- The 15th International Scientific Practical Conference "Environment. Technology. Resources.", organised by the Faculty of Engineering, Rezekne Academy of Technologies, held at "Vasil Levski" National Military University, Bulgaria (27–28 June 2024).

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

- Annual 29th international scientific conference "Research for Rural Development 2023", Latvia University of Life Sciences and Technologies, Jelgava, Latvia (17-18 May 2023).

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

- Annual 28th international scientific conference "Research for Rural Development 2022", Latvia University of Life Sciences and Technologies, Jelgava, Latvia (18-19 May 2022).

Article: *Analysis of factors affecting zero-waste food consumption in schools.*

Participation in research projects

The author is currently involved in two projects within the framework of which the Doctoral Thesis has been prepared, and it has been defined as an expected outcome of the project:

1) Latvian Council of Science, project "Testing Interventions and Developing a Knowledge-based Recommendation System to Reduce Plate Waste in School Catering in Latvia", project No. lzp-2022/1-0492;

2) European Union (EU) Recovery and Resilience Facility within the Project No. 5.2.1.1.i.0/2/24/I/CFLA/003 “Implementation of consolidation and management changes at Riga Technical University, Liepaja University, Rezekne Academy of Technology, Latvian Maritime Academy and Liepaja Maritime College for the progress towards excellence in higher education, science and innovation” academic career doctoral grant (ID: 1055).

3) In addition to these two projects, the empirical data of the research were obtained within the framework of the Latvian Council of Science project “E-mentor as a Transformation Tool for Ensuring Zero-Waste Food Consumption in Educational Institutions”, project No. lzp-2020/2-0115 (hereinafter – E-mentor).

INTRODUCTION

The Doctoral Thesis has been prepared as a thematically unified set of scientific publications on the organisation of the catering process in Latvian schools within the framework of a sustainable circular economy (CE). The main focus of the Thesis is on targeted actions to reduce food waste (FW) and to promote responsible food consumption in schools. The concept of a sustainable CE was used as a strategic framework for zero-waste food consumption, as it is based not only on the waste hierarchy, where the main priority is the prevention and reduction of food waste, but also incorporates the social dimension and changes in consumption behaviour, thereby ensuring a balance between economic, social, and environmental aspects. Following this approach, in schools in the city of Rezekne a plate waste (PW) analysis was carried out, targeted interventions to reduce FW were practically implemented and evaluated, students' attitudes and knowledge about FW issues and their views on school lunch organisation were assessed, a knowledge-based prototype of a recommendation system was developed, and the organisation of the catering process was evaluated. Additionally, the role of the food consumption stage in the broader context of food system sustainability was analysed.

As a result of the Doctoral Thesis, a conceptual action plan for the transformation of the existing school catering model, based on the principles of the sustainable CE and a sustainable food system, as well as a conceptual framework for the transformation of the food system through the prism of consumption, has been developed. Both are grounded in the Motivation–Opportunity–Ability (MOA) consumer behaviour change theory, which provides a structured understanding of the role of behaviour change in the transition towards sustainable food consumption.

By combining the sustainable CE approach with consumer behaviour theories and behavioural economics, the study is oriented towards resource efficiency, process management and policy solutions, thereby ensuring its alignment with the Economics and Business sub-field.

The results of the Doctoral Thesis provide a scientifically substantiated and practically tested basis for the development and implementation of targeted FW reduction strategies in Latvian schools, as well as offer a conceptual solution for the sustainable transformation of both the school catering model, characterised by fully or partially pre-portioned, individually served meals, and food systems.

The choice and relevance of the topic are determined by:

1) The global significance of FW. It is a complex and multidimensional problem within the food system that significantly affects all aspects of sustainability (de los Mozos et al., 2020; Massari et al., 2021) and the overall resilience of the planet (Caesar et al., 2024). Every year, one third of food intended for human consumption is lost or wasted in the food supply chain (FSC) (UNEP, 2024; WFP, 2024), exacerbating social inequality, as the amount of discarded food could provide meals for approximately 2 billion people; undermining economic resilience, as the economic losses of FW amount to around USD 1 trillion annually (WFP, 2024); and harming environmental sustainability, as it generates nearly five times more greenhouse gas emissions than the aviation sector – 8–10 % annually (WRAP, 2024).

2) The high proportion of FW at the consumption stage. FW in middle- and high-income countries is the main problem at the consumption stage of the FSC (Derqui et al., 2018; FAO, 2011; García-Herrero et al., 2019; Ishangulyyev et al., 2019; Kasavan et al., 2021; Wunderlich & Martinez, 2018), where approximately 35 % of total global food loss and waste (FLW) is generated (FAO, 2011; Yahia & Mourad, 2019). The situation in the EU is even more complex, as households and the food service sector together account for 65.4 % of the total volume of FW. In 2022, households and the food service sector in Latvia generated 68.6 % of the country's total FW, exceeding the EU average (Eurostat, 2024). It has been found that the consumption stage of the FSC, with the consumer at its centre, plays a key role in the transition towards a sustainable food system, as consumer decisions and actions directly affect all other stages of the FSC and, consequently, all processes within the food system as a whole (Deksne,

Lonska, Litavniece, et al., 2025). This clearly indicates the need to implement FW reduction measures precisely at this stage.

3) FW reduction is one of the priority issues to be addressed at the global, EU, and national levels. The United Nations Sustainable Development Goals (SDGs) for 2030, Goal 12, aim to promote responsible production and consumption and to halve per capita FW at the consumer level by 2030 (UNGA, 2015). In the EU's core initiative and comprehensive strategy, the *European Green Deal* (European Commission, 2019b; European Council, Council of the EU, 2025a), and in this context, the European Commission's "*New Circular Economy Action Plan: For a Cleaner and More Competitive Europe*" (European Commission, 2020b) and the "Farm to Fork" strategy (European Commission, 2020a; European Council, Council of the EU, 2025b) clear guidelines have been set for Member States regarding the measurement and management of FW. These documents emphasise the need to change consumption habits and behaviour and to integrate the principles of the CE into all stages of the FSC, with a primary focus on waste prevention and optimal resource use (European Commission, 2020b). In Latvia, at the national level, FW reduction is also being addressed, and this task has been integrated into several policy planning documents, such as the "*Sustainable Development Strategy of Latvia until 2030*" (LR Saeima, 2010b; Pārresoru koordinācijas centrs, 2016), the "*National Development Plan of Latvia for 2021–2027*" (Pārresoru koordinācijas centrs, 2020), the "*Action Plan for the Transition to a Circular Economy 2020–2027*" (VARAM, 2020b), among others.

It should be noted that the majority of policy planning documents are approaching the end of their implementation period (2027–2030), which makes it essential and timely to evaluate the measures implemented so far and to compile data in order to assess whether the set objectives are being achieved, as well as to provide a basis for planning new strategies and developing policy documents for the next period.

4) The role of the CE in the food sector. Food is one of the main value chains of the CE and, in this context, is positioned as a strong conceptual and policy instrument in shaping a sustainable food system (Deksne, 2024; European Commission, 2020b; Skawińska & Zalewski, 2018; The Ellen Macarthur Foundation, 2025). CE strategies are based on the principles of the waste hierarchy, where the highest priority is given to the prevention and reduction of FW (European Parliament & Council, 2008; Khaw-ngern et al., 2021). According to the concept of the CE, its aim is to create a zero-waste food system (The Ellen Macarthur Foundation, 2025).

5) The development potential of school meal programmes in the context of sustainability. The public catering sector can significantly influence the transition towards a sustainable food system (Kretschmer & Dehm, 2021). In this context, the transformation of the school catering environment provides an opportunity to offer children healthy and sustainable food, as well as to introduce and implement various initiatives for FW reduction (Lonska et al., 2022, 2025), and for promoting responsible food consumption and attitudes among future generations of consumers (Newsome et al., 2023). School catering also provides quantitative data on the volumes of FW, which makes it possible to identify this problem at the national and EU levels (Lonska et al., 2022, 2025). Moreover, in the process of transforming school catering, students act as agents of change not only at the local level but also in the broader context of food system governance (Fudla et al., 2022; World Health Organisation, 2017).

In Latvia, compared to other EU countries, the potential of school meal programmes has not been fully recognised. Deksne, Lonska, Kodors, et al. (2025) found that several initiatives for FW reduction have been implemented in school catering in Latvia; however, the empirical studies carried out within the framework of this Doctoral Thesis are among the first and most extensive in this field in Latvia. At present, the issue has also been highlighted at the national level, with the Ministry of Agriculture developing an action plan for the improvement of the school catering programme in Latvia. In 2024, a report entitled "On the Improvement of the School Catering System in Latvia" was submitted to the Cabinet of Ministers, with the aim of increasing the share of local and organic food in school catering, developing short supply chains and involving local producers, as well as enhancing awareness of healthy nutrition, food culture,

and sustainable lifestyles among all parties involved in school catering (Zemkopības ministrija, 2024). In the report, the issue of FW is mentioned as one of the aspects of promoting sustainability that should be viewed as part of the organisation of the catering process. This confirms that the need to change the existing organisation of the catering process in schools has been recognised at the policy level and indicates a targeted development of the school catering process in the coming years.

In this Doctoral Thesis, the organisation of the catering process in schools is examined as an essential part of the consumption stage of the FSC in the context of the CE, the transformation of which can promote sustainable food consumption and serve as a starting point for driving change in the wider food system and for achieving the SDGs.

Object of the research: Organisation of the catering process in schools within the framework of a sustainable CE.

Subject of the research: Food consumption and PW in Rezekne city schools.

Aim of the research: To examine the organisation of the catering process in Rezekne city schools within the framework of a sustainable CE and, based on the results of this case study, to develop solutions for promoting zero-waste food consumption in schools with a similar catering model, in line with the principles of a sustainable food system.

Tasks:

1. Carry out a comprehensive theoretical study of the FW problem.
2. Perform a PW analysis in Rezekne city schools to identify the volumes of FW generated and the factors influencing them.
3. Analyse the concept of the CE and assess its role in promoting zero-waste food consumption and reducing FW.
4. Examine and compile FW prevention and reduction measures at the consumption stage, identifying interventions aimed at changing student behaviour that could be implemented in schools, and assess the impact of the selected interventions on PW volumes in three schools, using a fourth school as a control group.
5. Investigate and assess students' awareness and knowledge of FW issues, their attitudes towards school meals and the organisation of catering, and identify the subjective causes of PW.
6. Develop an AI- and expert knowledge-based prototype of a recommendation system to evaluate the school ecosystem and provide personalised recommendations for improving the organisation of the catering process in schools in order to reduce PW, and assess its applicability in the management of school catering processes.
7. Conduct an evaluation of the catering process in Rezekne schools and develop a theoretically grounded conceptual action plan for promoting zero-waste food consumption in Latvian school catering with a similar catering model, based on the principles of the sustainable CE and a sustainable food system.
8. Assess the role of the food consumption stage in the transformation of the food system towards a sustainable model, and develop a conceptual framework for food system transformation through the prism of responsible consumption.

Research 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 on the school catering process.

Research period: September 2021 to August 2025.

Limitations. In this Doctoral Thesis, it is essential to distinguish two types of results: empirical (case-study data) and theoretical–conceptual (developed solutions). The empirical studies of this Doctoral Thesis were conducted in schools in the city of Rezekne, Latvia, where the meal serving model consists of fully or partially pre-portioned meals individually served in

advance and standardised menus without the possibility for students to choose the type and quantity of food. Therefore, the results obtained may limit the generalisability of the conclusions to other schools in Latvia or abroad with a different organisation of the catering process. This limitation does not apply to the developed solutions, as they are grounded in the identification of systemic drivers of food waste at the consumption stage, the MOA behavioural theory, and the principles of a sustainable CE and food system. Therefore, these solutions are generalisable and applicable in schools with a similar catering model, also beyond Rezekne.

The empirical studies are based on PW, i.e., only the FW left on students' plates after eating. Other types of FW, such as those generated during food preparation, were not analysed. Furthermore, in grades 1–7 (students aged 6/7 to 13/14 years) included in the study, state- and municipality-funded free school meals were provided, which may have influenced students' attitudes towards school meals and FW.

The research focuses on the examination of PW volumes, causes, and related factors, as well as on the reduction and prevention of PW. In addition, the study identified substantial financial losses associated with PW in schools. This information was included in the Doctoral Thesis to highlight the hidden costs that are not accounted for in state and municipal financing systems and, therefore, indicate significant losses of financial resources at the consumption stage. A detailed cost–benefit analysis was not conducted in this Thesis, as it would require extensive financial and institutional data and long-term performance indicators that fall beyond the empirical scope of this research.

Ethical Considerations. 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).

Regarding the involvement of students in the pilot study and survey. The school administrations agreed to participate in the project and gave permission for the implementation of the project activities. The heads of the schools involved in the project informed the parents of the students about the project and about their children's anonymous and voluntary participation in the experiment and survey via the online school management system "E-klase". Written parental consent for children's participation was not required, as no sensitive data from the students were collected during the project. Parents who did not wish their children to participate in the survey could provide a written response to the message sent via the "E-klase". However, in this pilot study, all parents agreed to their children's anonymous participation in the survey. During the study, students were not exposed to any physical or emotional risk.

The theoretical and methodological basis of the research consists of international and national policy planning documents, Latvian and EU regulatory acts, and scientific articles on zero-waste catering process organisation and the implementation of CE principles in schools abroad and in Latvia.

The most notable authors who have conducted extensive research on FW and PW in school catering, including its quantification, underlying causes, and reduction possibilities, are Belén Derqui, Mattias Eriksson, Luca Falasconi, Laura García-Herrero, Christopher Malefors, and Saraswathy Kasavan. Clara Cicatiello has contributed to the broader study of FW and has also conducted several important studies on PW in school canteens. Claudia Giordano has contributed by advancing methodologies for measuring FW and by exploring the role of policies and governance in shaping sustainable food systems. In the exploration and development of the CE concept, particularly significant contributions have been made by Walter R. Stahel, Julian Kirchherr, José Potting, and Daniel Holzer. Furthermore, Folke Ölander and John Thøgersen introduced the MOA framework for explaining consumer behaviour, while Matteo Vittuari expanded it by analysing consumer behaviour from a multi-level perspective.

Research design and methods

The Doctoral Thesis comprises 72 pages, excluding the list of references and appendices. It includes 17 figures and 2 tables. The list of references contains 168 sources.

In line with the specifics of the Doctoral Thesis and taking into account theoretical approaches, a mixed-methods research design was chosen as the basis for the study structure, combining quantitative and qualitative methods, including experimental research. The structure of the research was developed in accordance with the defined aim and the objectives set to achieve it. The study consists of several sequential stages, which are reflected in the scientific publications. Each stage employed specific methods that ensured the achievement of the defined aim and objectives (Fig. 0.1).

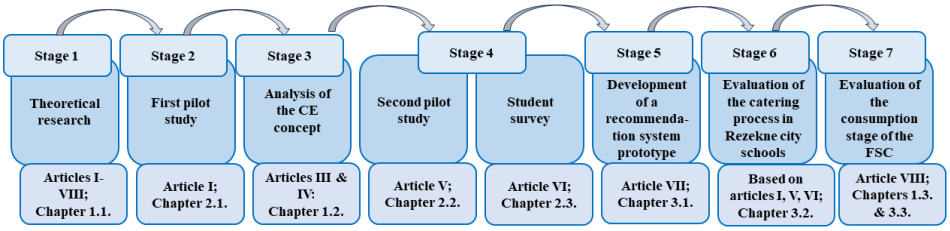

Fig. 0.1. Schematic representation of the research structure (author's own elaboration).

In **Stage 1**, using such methods as literature reviews (including systematic, integrative, and narrative), literature synthesis and analysis, the monographic (descriptive) method, and the method of logical construction, the problem of FW at the global and EU levels, FLW in the FSC, as well as the relevant political and strategic framework, were analysed (Articles I and II; Chapter 1.1 of the Thesis).

In **Stage 2**, the first pilot study was carried out – a five-day field study in seven schools in Rezekne city – to identify the volumes of FW generated and the factors influencing them (Article I; Chapter 2.1 of the Thesis). The pilot study employed the following methods: field research, secondary data analysis, quantification of PW, PW cost calculation, strengths, neutrals and weaknesses (SNW) analysis, observation, semi-structured interviews, descriptive statistics, and one-way analysis of variance (ANOVA).

In **Stage 3**, using narrative and systematic literature reviews, literature synthesis and analysis, the monographic (descriptive) method, and the method of logical construction, the concept of the CE and its application possibilities for promoting zero-waste food consumption in school catering were analysed (Articles III and IV; Chapter 1.2 of the Thesis).

In **Stage 4**, two studies were conducted aiming to evaluate the organisation of the catering process in Rezekne city schools within the framework of a sustainable CE:

- **The second pilot study** (a quasi-experiment) – three five-day field studies in four schools in Rezekne, carried out to practically test and evaluate the impact of selected interventions on PW volumes in three schools, using the fourth school as a control group (Article V; Chapter 2.2 of the Thesis). The pilot study employed the following methods: three field studies, intervention testing (quasi-experiment), secondary data analysis, quantification of PW, observation, descriptive statistics, and the Wilcoxon rank-sum test.
- **A student survey** in Rezekne city schools (Article VI; Chapter 2.3 of the Thesis). The study employed the following methods: student survey, pilot interviews with students to validate the survey, descriptive statistics, Kruskal–Wallis H test, Mann–Whitney U test (with Bonferroni correction), and Spearman's rank correlation.

In **Stage 5**, an AI- and expert knowledge-based prototype of a recommendation system was developed for optimising the organisation of the catering process (Article VII; Chapter 3.1 of the Thesis). The study employed the following methods: secondary data analysis, audit and development of recommendations, expert evaluation using the pairwise comparison method,

the capability-driven development (CDD) approach, and testing of a large language model (LLM) to verify classifier functionality.

In **Stage 6**, based on the results of the empirical research (Articles I, V, and VI), the catering process in Rezekne city schools was evaluated, and a theoretically grounded conceptual action plan was developed to promote zero-waste food consumption in the organisation of school catering in Latvia, based on the principles of a sustainable CE and sustainable food system (Chapter 3.2 of the Thesis).

In **Stage 7**, using bibliometric analysis and integrative literature review methods, the food consumption stage was analysed in the broader context of food system transformation, and a conceptual framework for guiding change was developed (Article VIII; Chapters 1.3 and 3.3 of the Thesis).

In the Conclusions of the Doctoral Thesis, the main findings are presented, the key problems are defined, and proposals for their solution are put forward.

Such a structure provides a comprehensive assessment of the school catering process within the framework of a sustainable CE and is applicable to schools with a similar organisation of the catering process. By adapting the methods to the specific parameters of the school ecosystem, the research structure can also be applied to other catering models.

Research novelty and scientific contribution

For the first time in Latvia, a comprehensive mixed-methods study on FW reduction in school catering within the framework of a sustainable CE has been conducted, which can be used as a tool for evaluating the organisation of school catering processes by combining qualitative, quantitative, and experimental methods. Unlike previous studies that have examined separate aspects, this Thesis offers a holistic approach and sequential research stages that make it possible not only to assess the current situation but also to practically apply the developed action plan for implementation in the school catering process and the conceptual framework for the transformation of the food system.

The activities carried out within the framework of this Doctoral Thesis:

1. For the first time in Latvian schools, with a unified menu, PW was measured by food category simultaneously in several schools.
2. The factors affecting the generation of PW and zero-waste food consumption in the school catering process were identified and summarised.
3. A comprehensive analysis of interventions aimed at reducing FW was carried out, identifying and classifying interventions focused on changing student behaviour that could be implemented in schools.
4. For the first time in Latvia, a study (quasi-experiment) was conducted to test the effectiveness of FW reduction interventions developed within the framework of international best practice in the conditions of the Latvian school catering model.
5. For the first time in Latvia, a large-scale student survey was conducted to assess students' awareness and knowledge of the FW problem, as well as their attitudes towards the food served in school canteens and the organisation of the catering process.
6. By integrating expert knowledge, the first AI-based prototype of a recommendation system in Latvia was developed for personalised FW reduction in the school catering process.
7. The CE concept was analysed in depth and adapted for FW prevention and reduction, and the promotion of sustainable food consumption in the school catering process, offering a sustainable CE concept that integrates environmental, economic, and social aspects and addresses the limitations of the traditional CE.
8. The school catering process in the city of Rezekne was evaluated, and a scientifically and practically grounded conceptual action plan for the transformation of the organisation of the catering process was developed, based on the principles of a sustainable CE and food system.

9. An in-depth analysis of the consumption stage of the FSC was carried out, revealing the main problems and their solutions, and a conceptual framework for the transformation of the food system through the prism of consumption was developed. This framework is based on the MOA model at the micro, meso, and macro levels and positions consumer behaviour at the core of sustainable transformation.

Socio-economic significance of the research

The results obtained within the framework of this Doctoral Thesis are of practical use for the Ministry of Education and Science, the Ministry of Agriculture, the Ministry of Smart Administration and Regional Development, and the Ministry of Health, both in improving the organisation of the school catering process and in FW reduction policy. The developed proposals and recommendations can be used by municipalities, school administrations, caterers, and other stakeholders to enhance the organisation and management of the catering process, thereby improving the quality of school catering, reducing costs in the state budget, and promoting students' awareness of FW and sustainable consumption.

The developed conceptual action plan for the transformation of the organisation of the catering process provides a basis for the development and implementation of school catering policies and strategies, both at the national policy planning level and at the level of local municipalities and schools.

The developed conceptual framework for the transformation of the food system through the prism of consumption can serve as a guide for policymakers in designing and implementing targeted interventions and strategies to address the problems of the consumption stage and to promote the transition towards a sustainable food system.

Moreover, by promoting sustainable and responsible food consumption from an early age, during the stage of education, a society is formed in the long term that is aware of and understands the environmental impact of FW, as well as its economic and social consequences. This represents an important contribution to the sustainable development of the country.

Theses for defence:

1. FW constitutes a challenging and multidimensional problem within the food system, particularly at the consumption stage of the FSC.

2. A considerable amount of PW is generated in school catering, accounting for approximately 20 % of the total volume of food served.

3. The concept of a sustainable CE provides the theoretical and strategic basis for promoting zero-waste food consumption in schools, primarily emphasising FW prevention and a structured approach to its reduction, at the same time integrating behavioural change in consumption and the social dimension, thereby ensuring a balance between economic, social, and environmental aspects.

4. No single intervention implemented in isolation is sufficient as a long-term solution for reducing FW in schools.

5. Students in Rezekne city schools have limited knowledge of the FW problem, low awareness of its negative impacts, a rather negative attitude towards school meals, and an insufficient sense of personal responsibility and motivation to reduce FW.

6. The implementation of an AI- and expert knowledge-based recommendation system can provide each school with a set of personalised, practically applicable solutions for reducing PW in school catering.

7. The meal serving model with fully or partially pre-portioned meals individually served in advance in Rezekne city schools is not sustainable.

8. The consumption stage of the FSC, with the consumer as its central element, is strategically important for the transformation towards a sustainable food system.

1. THEORETICAL FRAMEWORK

In the first chapter, the problem of FW is analysed at the global and EU levels, together with food losses and waste in the FSC, as well as the relevant political and strategic framework. The CE concept and its role in FW reduction are examined. The role of the consumption stage of the FSC in the broader context of food system sustainability is also analysed, including the role of school meal programmes in the food system and the factors influencing food system transformation. The theoretical chapter provides the conceptual basis for the subsequent empirical research. The first chapter comprises 19 pages and includes six figures.

1.1. The issue of food waste and its significance in the context of sustainable development

FW is one of the most pressing global problems, with far-reaching impacts on environmental sustainability, economic resilience, and social equity (de los Mozos et al., 2020; UNEP, 2022).

Food losses and waste occur throughout the entire FSC – from production to consumption. The framework of FLW definitions according to the FSC stages is presented in Fig. 1.1.

Fig. 1.1. Schematic representation of the food supply chain stages and the distribution of food loss and waste (Deksne, Lonska, Litavniece, et al., 2025).

In the scientific literature, the concepts of "food loss" and "food waste" are distinguished (Ishangulyyev et al., 2019; Kaur et al., 2021; Lonska et al., 2022; Zvaigzne et al., 2021) and classified according to the stage of the FSC in which they occur. Food loss arises in the early stages of the FSC – production, post-harvest handling and storage, and processing. In contrast, FW occurs in the later stages – distribution and marketing, as well as consumption, where food intended for human consumption is discarded regardless of whether it is still edible or has already spoiled (Aschemann-Witzel et al., 2017; Ishangulyyev et al., 2019; Kaur et al., 2021; Prescott et al., 2019).

FW generated at the final stage of the FSC – consumption – is categorised according to the moment at which the wastage occurs (Lonska et al., 2022) (Article I) (Fig. 1.2).

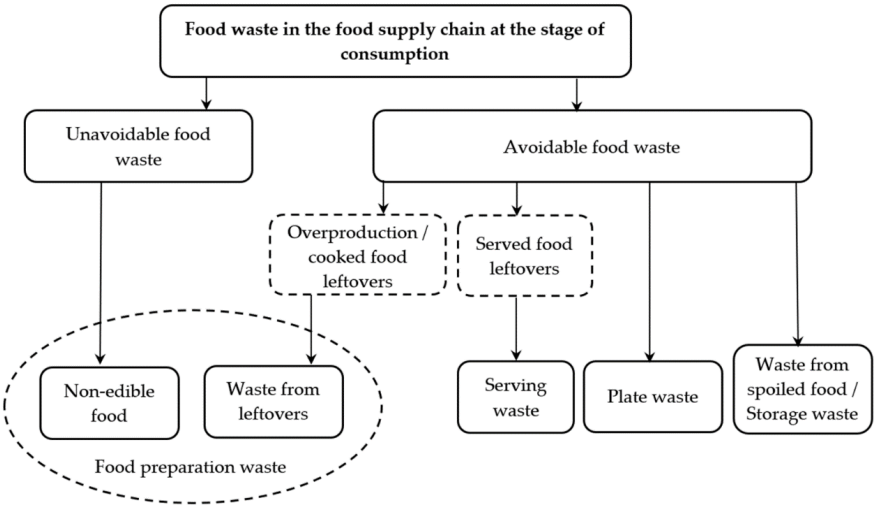

Fig. 1.2. Kinds of FW at the consumption stage of the food supply chain (Lonska et al., 2022).

FW generated at the consumption stage of the FSC is divided into two main categories: unavoidable and avoidable FW (Lonska et al., 2022; Zvaigzne et al., 2021). Unavoidable FW refers to food parts that are generally not consumed by humans, such as bones, peels, shells, etc. Avoidable FW is divided into four main groups:

1) cooked food leftovers (Dietary Guidelines Advisory Committee, 2015; García-Herrero et al., 2019; Kasavan et al., 2021);
2) serving waste (García-Herrero et al., 2019; Kasavan et al., 2021);
3) PW (Dietary Guidelines Advisory Committee, 2015; García-Herrero et al., 2019; Kasavan et al., 2021);
4) spoilage FW or storage waste (Kasavan et al., 2021; Persson Osowski et al., 2022).

Within the framework of this Doctoral Thesis, the concept of PW is used, referring to the amount of food served to the student that remains uneaten on the plate and is subsequently discarded (Kasavan et al., 2021).

Although FW is a widespread problem across all stages of the FSC, the greatest losses from discarded food occur at the consumption stage. This stage involves the use of significant natural resources, financial means, energy, labour, and other inputs, thereby creating a substantial burden on the environment, causing economic losses, and generating social consequences (FAO, 2011; Ishangulyyev et al., 2019; UNEP, 2021). This highlights the need to direct waste reduction efforts specifically towards the consumption stage.

Since 2015, when the United Nations General Assembly (UNGA) approved the 17 SDGs (UNGA, 2015), increased attention has been paid to sustainable development, including the creation of sustainable food systems. A sustainable food system is defined as one that ensures food security and nutrition for the present generation, while at the same time maintaining the environmental, social, and economic foundations necessary to secure these benefits for future generations as well (HLPE, 2014; Nguyen, 2018; United Nations, 2025). This definition emphasises the importance of intergenerational equity and the capacity of the food system to maintain or enhance its functions in the long term to ensure societal well-being (Chandra et al., 2019; Prosperi et al., 2014; UNEP, 2023; Valette et al., 2019). Research shows that the functioning of the global food system is closely linked to all 17 SDGs; therefore, the transition to a sustainable food system can significantly contribute to the achievement of these goals (Chaudhary et al., 2018; Kretschmer & Kahl, 2021; Schmitt & Khouri, 2023). To ensure the sustainability of the food system, it is necessary to improve existing economic practices and address shortcomings throughout the entire system, primarily by introducing more sustainable

production and consumption models (European Commission, 2019a). In this context, preventing FW is essential. However, it is a complex task, as it requires coordinated and targeted actions at all levels of governance – micro, meso, and macro (Kodors et al., 2024).

At the EU level, the commitment to ensuring sustainable development is reflected in several key policy initiatives. The Member States of the EU have committed to achieving climate neutrality by 2050 through the implementation of the *European Green Deal*, the central objective of which is the transition to a CE (European Commission, 2019b; European Council, Council of the EU, 2025a; United Nations Climate Change, 2016). In this context, in 2020 the European Commission developed *A new Circular Economy Action Plan: For a cleaner and more competitive Europe* (European Commission, 2020b), as well as amended legislation related to waste management, establishing the obligation to reduce FW by 30 % at the retail and consumption levels by 2030 (European Commission, 2019c), and to ensure FW measurement at each stage of the FSC (European Commission, 2019c; European Council, Council of the EU, 2025a) in order to obtain comparable and reliable data for future policy-making. In parallel, in 2020 the European Commission developed the "Farm to Fork" strategy (European Commission, 2020a; European Council, Council of the EU, 2025b) which, by adopting CE principles, aims to ensure sustainable primary production, stimulate sustainable practices in food processing, retail and catering services, promote sustainable food consumption, and reduce FW throughout the FSC, thereby advancing the transition towards a fair and sustainable food system (European Commission, 2020a; European Council, Council of the EU, 2025b; Zou et al., 2023).

In Latvia, as an EU Member State, several national-level measures have also been implemented to support global and EU-wide initiatives to reduce FW and promote sustainable consumption (European Commission, 2024; VARAM, 2021). Sustainability initiatives have been integrated into several long-term and medium-term strategies and policy planning documents and plans, such as the *Sustainable Development Strategy of Latvia until 2030* (LR Saeima, 2010b), the *National Development Plan of Latvia for 2021–2027* (Pārresoru koordinācijas centrs, 2020) and the *Action Plan for the Transition to a Circular Economy 2020–2027* (VARAM, 2020b), where the priorities are sustainable lifestyles, responsible consumption, climate neutrality, and CE principles (LR Saeima, 2010b; Pārresoru koordinācijas centrs, 2020; VARAM, 2020b). Strategies such as the *Strategy of Latvia for the Achievement of Climate Neutrality by 2050* (VARAM, 2020a) and *Latvia's National Energy and Climate Plan 2021–2030* (Klimata un enerģētikas ministrija, 2024) further emphasise the need to reduce FLW through targeted actions, such as raising public awareness, rational use of resources, and educational initiatives (European Commission, 2024; VARAM, 2021). Amendments have also been made to the Waste Management Law (LR Saeima, 2010a) stipulating that, as of 1 January 2024, the separation of biological waste is mandatory.

1.2. The concept of the circular economy and its role in food waste reduction

Building on the policy framework and strategic objectives for addressing the problem of FW, the CE has been recognised as a powerful conceptual and policy instrument in advancing sustainability (Deksne, 2024; European Commission, 2020b; Skawińska & Zalewski, 2018; The Ellen Macarthur Foundation, 2025), particularly in the food sector, where FW remains a persistent challenge (Ishangulyyev et al., 2019; Khatami et al., 2024; Rabbi & Amin, 2024).

The concept of the CE has emerged as a transformative alternative to the traditional linear model of production and consumption, based on the "take-make-dispose" approach (Khawngern et al., 2021; Kirchherr et al., 2023), which is no longer suitable in the context of today's world (Sulich & Rutkovska, 2021). Unlike the linear model, the CE is inherently regenerative, aiming to gradually decouple growth from the consumption of non-renewable resources (The Ellen MacArthur Foundation, 2019b) (Fig. 1.3).

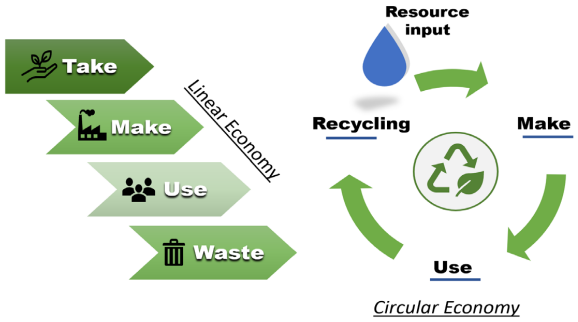

Fig. 1.3. Linear economy model vs circular economy model (Deksne, 2024).

The growing sustainability challenges prompted the search for a new development model based on resource circulation, leading to the creation of the CE concept. This concept is grounded in the closed-loop "produce-use-recycle" approach and is defined in the scientific literature as a framework of "3R" strategies (Dekšne et al., 2023; Ghisellini et al., 2016; L. Liu et al., 2017).

In the EU, the core principles of the CE are closely linked to the waste management hierarchy established in the Waste Framework Directive 2008/98/EC (European Parliament & Council, 2008), where the primary aim is to prevent waste generation or to reuse it as a resource in a manner that does not endanger human health or the environment (European Parliament & Council, 2008; Khaw-ngern et al., 2021). In the EU Circular Economy Action Plan, FW prevention is also highlighted as one of the priority areas (European Commission, 2020b). Building on the waste hierarchy, the CE concept was expanded into the "4R" strategy framework with the additional principle of "Recover" (European Parliament & Council, 2008), which in some cases is also defined as "Regenerate" (Kirchherr et al., 2017), emphasising the importance of recovering the value of energy and resources, as well as restoring natural systems.

Dekšne et al. (2023) (Article IV) have shown that, given the overall need to adopt circular principles and practices, the approach to implementing the CE has gradually become more nuanced and structured. As a result, the CE model has evolved into a framework of 10 strategies, defined in the scientific literature as "9R" or "10R" (Holzer et al., 2023; Kirchherr et al., 2017; Potting et al., 2017) (Fig. 1.4).

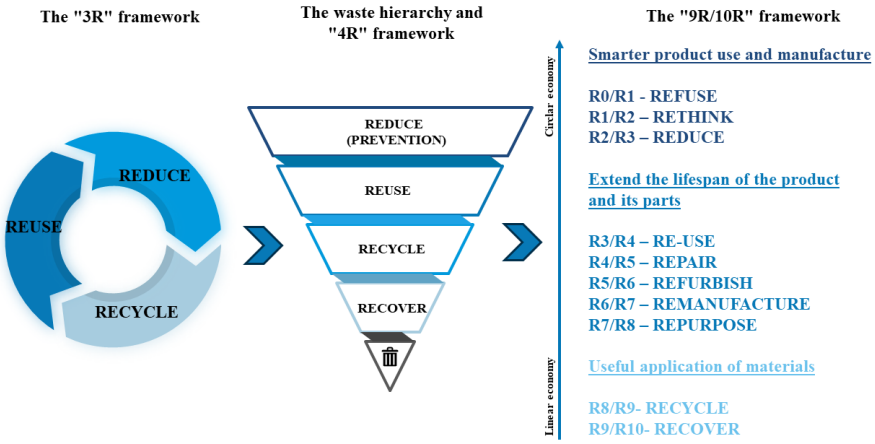

Fig. 1.4. Evolution of CE strategies (Deksne, 2024).

The evolution of CE strategies aims at systemic change to prevent waste throughout the entire FSC and to promote the achievement of the SDGs by extending product life cycles, ensuring the maximum retention of resource value in circulation, and transforming consumption habits (Holzer et al., 2023; Kirchherr et al., 2017; Potting et al., 2017).

Although the CE has gained wide attention as an instrument for achieving sustainability, its definition remains incomplete, and the concept and definition of the CE are expected to continue evolving (Deksne, 2024). The existing definitions of the CE do not fully encompass all aspects of sustainable development and largely reflect the current understanding of researchers and policymakers (Deksne, 2024; Kirchherr et al., 2017, 2023). Moreover, their primary aim is to slow down resource use and waste generation rather than to completely transform the economic system (Suárez-Eiroa et al., 2019). Thus, the current concept of the CE does not encompass essential social and ecological aspects that form an integral part of the sustainable development paradigm. To fully realise its transformative potential, the CE concept should be holistically integrated into all dimensions of sustainable development and considered within the broader sustainable development system. In this context, the comprehensive concept of "Sustainable CE" has emerged as an overarching framework that combines the rational use of resources and closed-loop systems with key elements of social responsibility and environmental protection. It reflects a paradigm shift towards a holistic and continuous approach to sustainability, where economic activity is closely interlinked with the preservation of social well-being and environmental protection (Deksne, 2024).

The circular approach is particularly important at the stage of food consumption, where consumer choices and habits directly affect the entire FSC – food demand, production practices, resource use, the amount of FW, and the overall environmental impact (Biresselioglu et al., 2023; Pais et al., 2023; Spiller et al., 2020; Wintschnig, 2021). Consequently, changing consumer behaviour is a crucial prerequisite for the transition to a sustainable food system (Deksne, Lonska, Kodors, et al., 2025; Deksne, Lonska, Litavniece, et al., 2025; HLPE, 2017; Lonska et al., 2025), where FW is addressed as a deeply embedded systemic problem in current consumption patterns (Diekmann & Germelmann, 2023; García-Herrero et al., 2019).

In the context of school meal programmes, the CE can serve as a strategically appropriate instrument for addressing the systemic problems mentioned above, particularly those related to PW, which has become a significant sustainability challenge in out-of-home catering (Dhir et al., 2020). As noted earlier, CE strategies are grounded in the waste hierarchy, integrated from the EU Waste Framework Directive. At the top of this hierarchy are waste prevention and reduction (European Parliament & Council, 2008; Khaw-ngern et al., 2021), which provide the theoretical and practical foundation for organising zero-waste catering in schools. This is feasible only if the multi-level structure of the food system is taken into account and active engagement is promoted at the micro, meso, and macro levels (Diekmann & Germelmann, 2023; Vittuari et al., 2023). All stakeholders must work together to build a responsible and sustainable culture of food consumption that goes beyond technical solutions and is rooted in participation, collaboration, and shared responsibility for the future.

Thus, in this study, the sustainable CE concept is employed as the theoretical basis for practical solutions aimed at preventing and reducing FW in schools.

1.3. The significance of the consumption stage in transforming the food system

1.3.1. The role of school meal programmes in the food system

School canteens form part of the final stage of the FSC – the consumption stage (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). Apart from households, schools have been recognised as a significant source of FW (Derqui et al., 2018; Qian & Xiong, 2022; Zhang et al., 2024).

In many parts of the world, schools provide free and nutritious meals; however, not all children consume them responsibly (Deksne, Lonska, Kodors, et al., 2025; Mauer et al., 2022). Several studies confirm that schools generate large amounts of FW, most of which is PW (Derqui et al., 2018; Eriksson et al., 2017; Lonska et al., 2022, 2025; Malefors, 2022; Vizzoto et al., 2021). In many countries, including Latvia, 20–30 % of the food served ends up as waste (Eriksson et al., 2017; García-Herrero et al., 2019; Lonska et al., 2022, 2025; Malefors, 2022), revealing that FW is a widespread and persistent problem in school catering and pointing to significant resource wastage and shortcomings in the organisation of catering processes.

Based on an extensive literature review, the factors influencing PW were identified (Article I, Table 1), and the authors have divided the factors into exogenous (objective) and endogenous (subjective) (Lonska et al., 2022; Zvaigzne et al., 2021). In addition, drawing on a systematic literature analysis, eight groups of factors affecting zero-waste food consumption in schools were identified: demographic, political, school food policy, environmental, socio-economic, personal, physical, and geographical factors (Deksne et al., 2022) (Article II). Overall, it was concluded that the generation of PW in schools is influenced by a broad and diverse range of factors, which calls for a well-considered and complex approach to addressing this problem.

School meal programmes are among the most widespread solutions worldwide in the fight against inequality, poverty, food insecurity, and malnutrition (Howard, 2018; WFP, 2022, 2023). According to the World Food Programme (WFP, 2022), in 2022, approximately 418 million children in 176 countries received school meals, which is 30 million more than in 2020, reflecting the recovery and expansion of school meal programmes following the COVID-19 pandemic. Unfortunately, 153 million children in 79 countries still face acute food insecurity and hunger. In this context, school meal programmes play a crucial role in ensuring at least one daily meal, thereby not only reducing hunger and inequality but also improving children's health, nutrition, and educational outcomes (WFP, 2022).

Globally, the organisation of school catering practices varies significantly depending on each country's policies, economic situation, and cultural traditions (Global Child Nutrition Foundation, 2022; Storcksdieck et al., 2014). In many countries, such as Finland and Sweden, school lunches are fully or partly funded by the state (Guio, 2023), as nationwide free lunch programmes have been introduced (Mauer et al., 2022). In others, such as Germany, support is provided only to children from low-income families (Nationale Qualitätszentrum für Ernährung in Kita und Schule (NQZ), 2023; WBAE – Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim BMEL, 2020).

School catering models also differ considerably. Studies have revealed two dominant approaches: the self-service or buffet-style system, which is widespread in the United States and in several European countries such as Sweden and Finland, allowing children to choose both the type of food and the portion size themselves (Bucher et al., 2016; Malefors et al., 2022; Waling et al., 2016); and the pre-portioned and pre-served meal system, which, similar to Latvia, is also applied in countries such as France, Italy, and Brazil (Boschini et al., 2020; Favuzzi et al., 2020; Sehnem et al., 2023; Vieux et al., 2013). This approach limits students' opportunities to choose the type and quantity of food but ensures that school lunches comply with nutritional standards (Deksne, Lonska, Kodors, et al., 2025; Lonska et al., 2022, 2025; Zvaigzne et al., 2021). Although the buffet-style catering model has certain drawbacks, it is currently recognised as the most appropriate solution, as it increases students' satisfaction with school meals, promotes responsible food consumption, and reduces FW (Y. Liu et al., 2016; Lonska et al., 2022, 2025; Zvaigzne et al., 2021).

EU education initiatives play a priority role in reducing FW (Giordano et al., 2020; Piras et al., 2023), and responsible consumption practices form the basis for promoting sustainable development (United Nations Department of Economic and Social Affairs, 2023). In this respect, the school environment serves as a fundamental platform for teaching and instilling healthy eating habits and responsible food consumption from an early age, shaping educated

and responsible future consumers capable of making conscious and environmentally friendly choices (Newsome et al., 2023). Moreover, students act as agents of change both within their families and in the wider society, promoting more sustainable food consumption (Fudla et al., 2022; World Health Organisation, 2017), which further highlights the school environment as a crucial turning point in transforming the food system and fostering sustainability.

School canteens are a unique setting where education and practical action can directly influence consumer attitudes and behaviour from childhood, provide a controlled environment for quantifying FW volumes, and allow the testing of interventions aimed at reducing FW. This makes them an ideal platform for implementing and monitoring food system transformation initiatives, as well as for developing evidence-based policies.

1.3.2. Factors influencing food system transformation at the consumption stage

At the consumption stage, daily decisions are made that directly affect all processes within the FSC, from production to waste management. In this context, the consumption stage becomes a critical point of interaction, where the consumer plays a central role. It is their decisions and actions that influence the direction of the food system towards sustainability (Deksne, Lonska, Litavniece, et al., 2025).

The stages of the FSC are interconnected and influenced by various structural factors (Abideen et al., 2021; Aday & Aday, 2020; Govindan, 2018), with consumer behaviour being one of the most dynamically changing aspects of this system. Figure 1.5 presents the structure of the food system, clearly illustrating how consumer behaviour is shaped through the interaction between the food environment and personal choices. Thus, the consumption stage serves as a key leverage point in transforming the food system, where coordinated action at all levels, from individual decisions to systemic change, can promote the transition to a sustainable zero-waste food system.

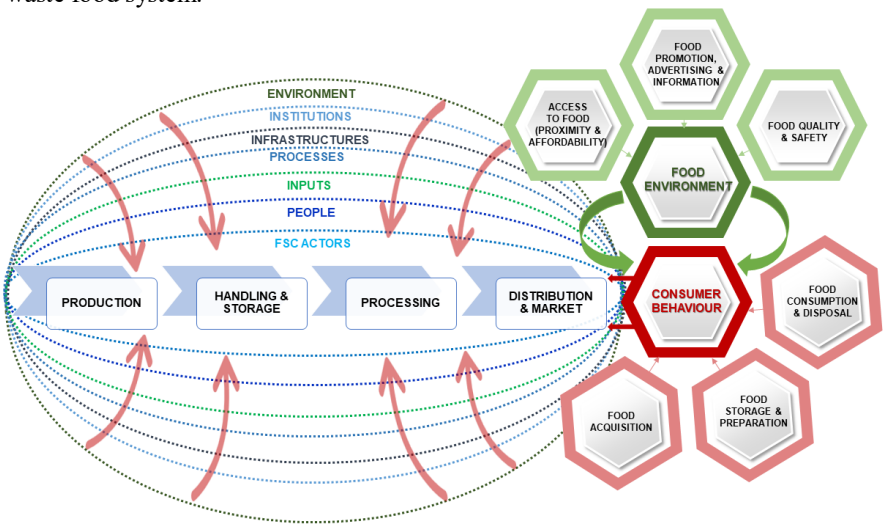

Fig. 1.5. The food consumption stage within the food system framework (Deksne, Lonska, Litavniece, et al., 2025).

Based on an integrative literature review and a bibliometric analysis approach (Article VIII), the key aspects at the consumption stage influencing the transformation of the food system towards a sustainable model were identified (Deksne, Lonska, Litavniece, et al., 2025): FW and its reduction, sustainable dietary shifts, consumer awareness and behaviour, and policy and systemic transformations. At the same time, it was concluded that the main driver

of change is consumer behaviour transformation, which entails a deeper shift in perceptions and attitudes towards the conscious adoption of sustainable consumption. Therefore, a targeted and comprehensive approach is needed, incorporating behavioural change mechanisms and supportive policies to create an environment in which sustainable consumption becomes an integral part of everyday life (Deksne, Lonska, Litavniece, et al., 2025).

To understand how to foster changes in consumer behaviour, it is essential to identify the factors and reasons that influence their decisions, choices, and actions (Pais et al., 2023). In the scientific literature, consumer behaviour is analysed through various behavioural theories and models that explain decision-making processes and behavioural motivation, such as the *Theory of Planned Behaviour* (TPB) (Ajzen, 1985, 1991); the *Norm Activation Model* (NAM) (Schwartz, 1977); the MOA framework (Ölander & Thøgersen, 1995), which has been expanded by (Vittuari et al., 2023) in analysing consumer behaviour from a multi-level perspective – micro (individual), meso (household, school), and macro (policy and market context); *Nudge Theory* (Thaler & Sunstein, 2008); and behavioural economics (Cartwright, 2011, 2014; Ogaki & Tanaka, 2017).

Within the framework of this Doctoral Thesis, students' school food consumption behaviour was analysed using the MOA approach, which emphasises that behaviour is influenced not only by internal motivation (attitudes, norms, intentions) but also by external conditions (e.g., resource availability, physical environment) and individual abilities (knowledge, skills). The advantage of the MOA framework lies in its ability to simultaneously account for cognitive, practical, and social factors that determine behaviour (Ölander & Thøgersen, 1995). Students' motivation, opportunities, and abilities to reduce FW in out-of-home catering were assessed, specifically in the context of Rezekne city schools (Articles V and VI). This approach made it possible to understand behaviour in a multidimensional way and to link it with structural and environmental factors.

Reducing FW at the consumption stage requires a comprehensive approach tailored to the specific operational context. Therefore, in recent years, various activities or interventions aimed at preventing and reducing FW at the consumer level, including in schools, have been developed and analysed both in the EU and worldwide (Lonska et al., 2025). Based on an extensive literature review (Article V, Tables 2–5), practical solutions aimed at changing consumer behaviour to reduce FW were identified, compiled, and analysed. Particular attention was paid to changes in students' consumption behaviour and the prevention of FW in school catering. It was concluded that such targeted initiatives can have a significant impact; however, their outcomes largely depend on the conditions of implementation, their duration, and the type of interventions chosen (Lonska et al., 2025).

Based on the theoretical analysis (Article VIII), it was revealed that the consumption stage of the FSC plays a strategically important role in transforming the food system, as it provides an opportunity to directly influence consumer behaviour and promote sustainable, zero-waste food consumption (Deksne, Lonska, Litavniece, et al., 2025). The school catering process is positioned as a unique setting for implementing these changes, where, in a controlled environment, it is possible to combine the educational process with practical action to carry out initiatives that foster food system transformation and to monitor their progress. In this Doctoral Thesis, the CE concept is employed as the theoretical basis for practical solutions aimed at zero-waste food consumption in the school catering process. The theoretical framework provides the foundation for the subsequent empirical research, which evaluates the catering process in Rezekne city schools within the CE context.

2. EVALUATION OF THE CATERING PROCESS ORGANISATION IN REZEKNE CITY SCHOOLS WITHIN THE FRAMEWORK OF A SUSTAINABLE CIRCULAR ECONOMY

Chapter 2 summarises the results of empirical studies aimed at evaluating the organisation of the catering process in Rezekne city schools within the framework of a sustainable CE. The first pilot study involved an analysis of PW, identifying the volumes and trends of FW. The second pilot study implemented and evaluated targeted interventions for FW reduction in practice. The third study assessed students' attitudes and knowledge regarding FW issues and their views on the organisation of school lunches. Chapter 2 comprises 15 pages and includes eight figures and two tables.

2.1. Food waste in the school catering process: The first pilot study in Rezekne city schools

This study was the first stage of the overall research process. The field study was carried out in the autumn of 2021 in seven Rezekne city schools, covering grades 1 to 7, where state- and municipality-funded free school meals were provided (Lonska et al., 2022) (Article I). The study was conducted over one school week, i.e., five working days, ensuring simultaneous data collection in all participating schools.

A methodological advantage of the study was the use of a unified menu across all seven participating schools. It was developed based on the results of a semi-structured interview with school representatives and their assessment of meals using SNW. A total of 11 individuals participated in the interviews – seven school canteen managers, three canteen staff members, and one nurse involved in menu development. All respondents provided experience-based, partly subjective information on students' food preferences – dishes that children liked, disliked, or towards which they had a neutral attitude. As a result, five dishes usually consumed by more than 90 % of students were identified, along with five dishes that students ate reluctantly (less than 20 %) and five dishes to which they showed a neutral attitude (around 65 %). This approach ensured data comparability across schools, grade groups, and food categories.

Data collection in schools was carried out by project researchers who followed a unified protocol and worked in close cooperation with the catering staff. The study combined quantitative and qualitative methods. Direct weighing of PW by food product categories was performed, yielding data from a total of 7,064 lunch plates. In addition, during the study, the researchers documented the organisation of the catering process, including photographic records (without personal identification). Observations were made on the design of the dining hall, the arrangement of food on plates, the serving method, students' behaviour during meals, and the duration of eating. Preparatory work necessary for the quantitative measurement of PW was also undertaken (dish labelling, portion accounting, etc.).

Quantitative PW data were analysed using descriptive statistics and one-way ANOVA.

The results revealed that a considerable amount of PW was generated in schools. PW accounted for 28.75 % of the total weight of food served, including beverages, meaning that almost one-third of the food served was discarded (Table 2.1).

Table 2.1

Shares of plate waste (%) in the total weight of food served at the Rezekne city school canteens (by school) (Lonska et al., 2022)

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 Article I, 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.
Source: Lonska et al. (2022) calculations based on the results of the field study.

The highest recorded amount of PW was 44.08 % (grades 1–4) and 42.55 % (grades 5–7). The average weight of PW per student was 178 grams, including beverages. Younger students (grades 1–4) generated slightly more waste (182 g) compared to older students (grades 5–7) (172 g) (Table 2.2). However, the one-way ANOVA test did not reveal statistically significant differences in PW volumes between the age groups ($p = 0.678644$).

Table 2.2

Weights of plate waste identified by the field study at the Rezekne city school canteens (by school and by grade group) (Lonska et al., 2022)

School	Grade group	Total weight of plate waste, g/week	Actual number of lunch participants (number of samples)	Average plate waste per schoolchild, g
S1	Grade 7	52,578	234	225
S2	Grades 1–4	99,397	677	147
	Grades 5–7	64,353	450	143
S3	Grades 1–4	109,544	603	182
	Grades 5–7	88,130	421	209
S4	Grades 1–4	180,518	663	272
	Grades 5–7	117,085	447	262
S5	Grades 1–4	15,416	94	164
	Grades 5–7	55,715	399	140
S6	Grades 1–4	190,644	1,239	154
	Grades 5–7	66,289	574	115

Table 2.2 (continued)

School	Grade group	Total weight of plate waste, g/week	Actual number of lunch participants (number of samples)	Average plate waste per schoolchild, g
S7	Grades 1–4	152,566	829	184
	Grades 5–7	64,064	434	148
Total for Grades 1–4		748,085	4,105	182
Total for Grades 5–7		508,214	2,959	172

Analysing PW by food product categories showed that the most wasted category was beverages, accounting for 42.24 % of total PW, followed by staple foods (potatoes, pasta, rice) (28.38 %) and meat (11.77 %). The lowest proportions of PW were recorded for vegetables, fruit, bread, and curd-based products, such as curd snacks. Unlike other international studies, where vegetable waste is dominant, in this study, it was relatively low, which may be explained by the limited inclusion of fresh vegetables in school menus. This, in turn, results from insufficient state and municipal funding for school lunches, which restricts schools' ability to diversify menus with a wider range of fresh products.

In addition, a monetary value analysis of PW was conducted, which revealed that the average cost of PW (excluding beverages) per student was €0.236, representing 16.6 % of the state and municipal funding of €1.42 per meal portion at that time. Calculated over a 5-day period, the losses amounted to €1,666.88, or approximately €333 per day, which would total around €7,000 over a school month (21 working days). Given the differences in price levels across countries, it was not possible to determine the absolute value of this amount, yet in the local context, the losses were significant. It was estimated that, based on the cost of free school meals at €1.42 per portion, these losses could have covered meals for almost 5,000 students per month.

An additional issue identified in this study was the served meals that remained untouched. Since PW weighing took place during the COVID-19 pandemic, it was difficult to predict the number of students attending lunch, as children could suddenly fall ill. Kitchen staff often lacked precise information to adjust meal quantities, thereby increasing the risk of ordering and preparing food that remained completely uneaten.

Overall, the study revealed that the existing organisation of the catering process in Rezekne city schools is not sustainable, as almost one-third of the meals served are not consumed, resulting in significant resource and financial losses, including inefficient use of state budget funds. The main causes of PW in the catering process of Rezekne city schools were identified as the mismatch between menus and students' tastes, limited choice, insufficient student involvement, and shortcomings in the organisation of the catering process. Based on the results obtained, recommendations were developed to improve the organisation of catering, increase students' awareness, and optimise resource use. It was concluded that future research should develop individual recommendations for school management and test their practical application in school canteens.

2.2. Evaluation of the effectiveness of plate waste reduction interventions: The second pilot study in Rezekne city schools

In the next stage of the research, during the 2023/2024 study year, experiments and field studies were conducted in four Rezekne city schools (S1, S2, S3, S4), covering grades 1–7, where state- and municipality-funded free school meals were provided (Lonska et al., 2025) (Article V). To evaluate the impact of interventions aimed at reducing PW, various solutions were implemented and experimentally tested in three Rezekne city schools, while the fourth

school (S4) served as a control group, where no interventions were introduced, but PW measurements were carried out.

At S1, a PW tracker (Matomatic AB, Uppsala, Sweden) was installed (LOWINFOOD, 2022). This was a digital tool – a kitchen scale connected to a tablet computer equipped with dedicated software. Students recorded the reasons for PW (e.g., portion too large, did not like the taste, etc.) and simultaneously received visual feedback on the amount of food discarded and its impact.

At S2, an awareness and educational campaign was implemented. Informative posters with slogans encouraging the reduction of FW were displayed in the school canteen, alongside table talkers featuring interesting facts about various food products to stimulate students' interest in eating them. In addition, lessons were delivered on FW issues. Furthermore, a creative poster competition was organised, involving students from grades 1 to 9, thereby promoting their participation and fostering behavioural change through peer influence.

At S3, a set of organisational changes was introduced, including the use of larger-diameter lunch plates, the extension of the lunch break to 30 minutes, and the presence of a supervising teacher for each class during the lunch period.

To evaluate the impact of the interventions, PW was measured at three points in time: in September, prior to the start of the interventions to establish a baseline; in December, to assess short-term effects; and in April, to evaluate long-term impact. At each stage of the study, PW was measured over one school week, i.e., five consecutive working days, ensuring simultaneous data collection across all participating schools. During the measurement weeks, a unified menu was provided in all four schools to minimise the influence of external factors on the experiment and to ensure the comparability of PW data between schools. In total, PW data were collected from 17,144 plates across the three measurement rounds: 5,772 in September 2023, 5,751 in December 2023, and 5,621 in April 2024.

First, the total amount of PW was calculated, including all served food – both individually served main courses and items provided in common containers, such as soup, salad, and bread. Beverages were not included in the PW analysis on this occasion (Fig. 2.1).

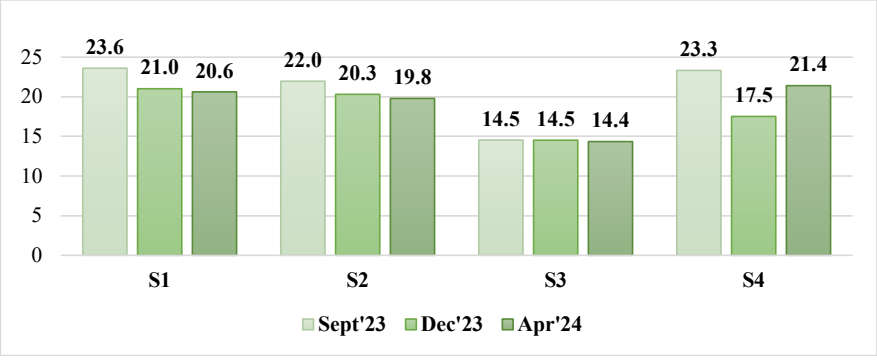

Fig. 2.1. Total PW as a % of the food served (Lonska et al., 2025).

Figure 2.1 shows that the amount of plate waste ranged from 14.4 % to 23.6 % of the total food served.

As the serving practices for certain food items, such as soup, salad, and bread, differed in S4 compared to the other schools, the data were filtered to ensure comparability. The statistical analysis, therefore, included only PW from individually served main courses, fruit, confectionery products, and curd snacks. PW data were analysed using two models – by class (Model 1) and by day (Model 2) – both in the short and long term, with the Wilcoxon signed-rank test applied to statistically assess the significance of the observed changes.

The results of the study revealed that none of the interventions implemented achieved a significant and lasting reduction in PW. Although some positive trends were observed in the short term, in the long term, the volume of PW increased again.

In the short term (September–December 2023), based on Model 1 (by class) data (Fig. 2.2), a significant reduction in PW was observed only in S1, where the digital PW tracker was installed. In this case, the observed reduction in PW, with a Wilcoxon signed-rank test *p*-value = 0.000 < 0.001, was statistically significant, indicating a positive change in students' behaviour, possibly due to increased engagement. By contrast, in S3, where organisational changes in the catering process were implemented, PW significantly increased in the short term ($p = 0.011 < 0.05$). A possible explanation was the extended lunch break, during which students had sufficient time to purchase competing food items in the school canteen for an additional cost. In S2, where an awareness and educational campaign was implemented, as well as in the control school (S4), short-term changes in PW volumes were not statistically significant (S2: $p = 0.159$; S4: $p = 0.095$).

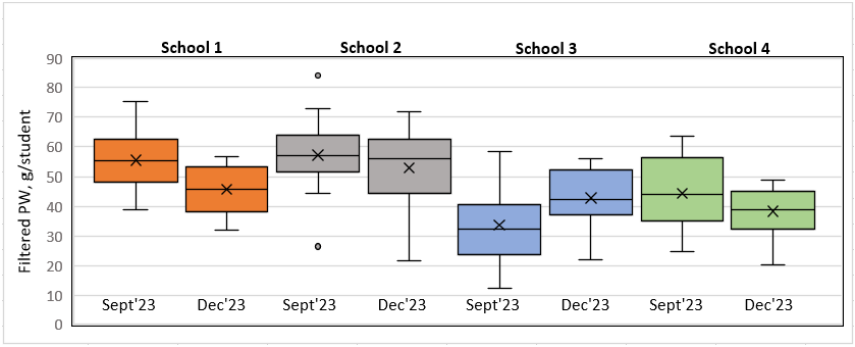

Fig. 2.2. Analysis of filtered PW data in the short run, g/student, Sept'23–Dec'23 (by class) (Lonska et al., 2025).

In the long run (September 2023–April 2024), Model 1 data (Fig. 2.3), based on the results of the Wilcoxon signed-rank test, showed that no statistically significant changes in PW volumes were observed in any of the schools except S3: S1 ($p = 0.107 > 0.05$), S2 ($p = 0.890 > 0.05$), and S4 ($p = 0.639 > 0.05$). By contrast, at S3, the volume of PW continued to increase in the long term, and the difference was statistically significant ($p = 0.004 < 0.01$), confirming a negative trend in line with the short-term results already observed.

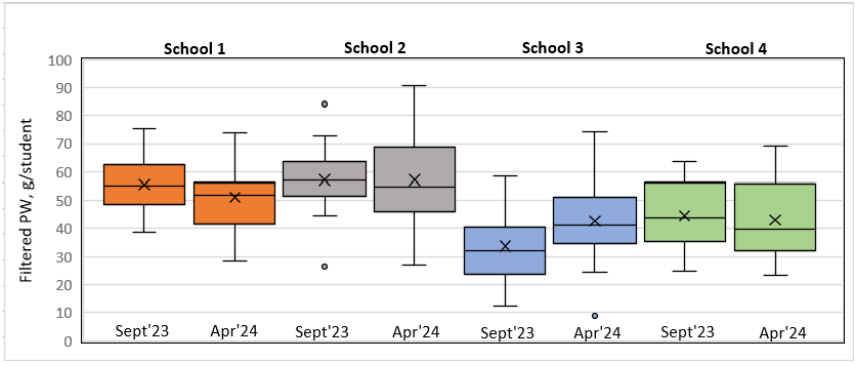

Fig. 2.3. Analysis of filtered PW data in the long run, g/student, Sept'23–Apr'23 (by class) (Lonska et al., 2025).

Based on Model 2 (day-level) data (Figs. 2.4 and 2.5), no statistically significant differences in PW volumes were observed in any of the schools, either in the short run or in the long run. The results of the Wilcoxon signed-rank test confirmed in all cases that the observed changes were not statistically significant. This indicates that none of the interventions implemented at the day level produced substantial changes in students' food consumption behaviour or PW volumes. However, it should be noted that in the case of S3, in the long run, the *p*-value = 0.063 was close to the statistical significance threshold of 0.05, suggesting a possible trend of increasing PW in the long run, although further in-depth analysis would be required for confirmation.

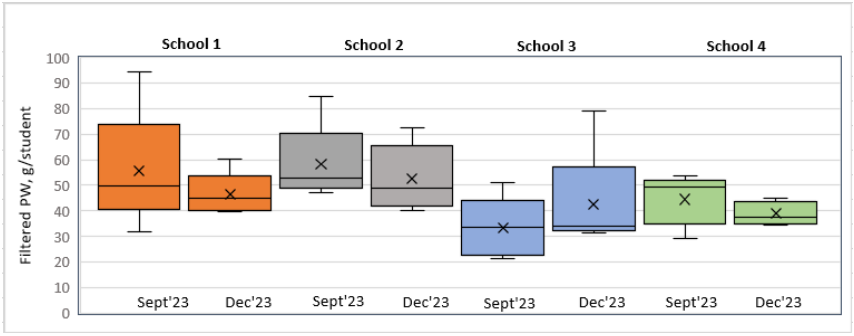

Fig. 2.4. Analysis of filtered PW data in the short run, g/student, Sept'23–Dec'23 (day-level) (Lonska et al., 2025).

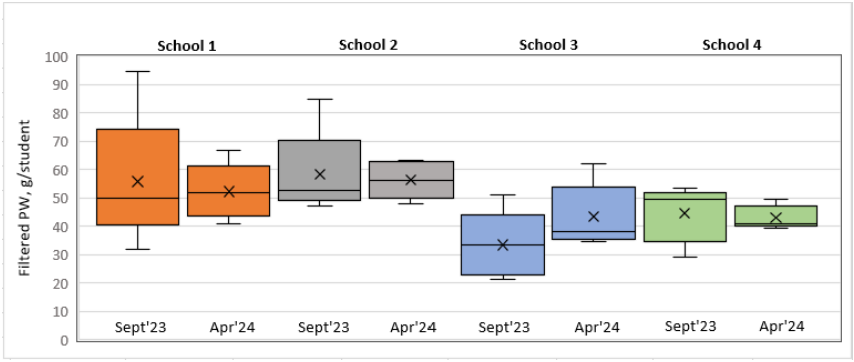

Fig. 2.5. Analysis of filtered PW data in the long run, g/student, Sept'23–Apr'23 (day-level) (Lonska et al., 2025).

This pilot study also revealed that meals served in schools often remained untouched. This situation was mainly related to inaccurate planning of student numbers, as information about children's absence did not always reach kitchen staff in time. In particular, at S2 and S4, the number of meals served exceeded the actual number of students attending lunch. Most of these meals were partially eaten by classmates (usually the meat was consumed while the side dishes were left on the plate) or sold to older students; however, a large proportion ended up being discarded. Such meals contributed to the overall increase in PW and influenced fluctuations in results between schools.

When analysing students' food consumption behaviour within the MOA framework, particular attention should be paid to the structural barriers in the Latvian school catering model, where meals are predominantly fully or partially pre-portioned and individually served, leaving students without the opportunity to choose either the type of food or the portion size. According to the MOA behavioural model, under such conditions, students' opportunities to act

responsibly and reduce FW are restricted, as sustainable consumption practices are only possible when all three components – motivation, opportunities, and abilities – are ensured.

The results of the interventions by the school confirm that reducing PW in school catering is a multidimensional challenge, and there is no single universal approach to solving it. Achieving sustainable results requires a comprehensive and combined strategy that integrates changes in the catering model with portion and meal choice, PW monitoring and meal planning, educational activities, and teacher involvement. Moreover, the solutions implemented must be tailored to the specific operational context and regularly refined based on evaluation and feedback.

2.3. Sustainable food consumption in the school catering process: Students' awareness and assessment

To assess students' awareness and knowledge of FW issues, their attitudes towards school meals and the organisation of lunches, as well as to identify subjective causes of PW, a student survey was conducted in four Rezekne city schools (Deksne, Lonska, Kodors, et al., 2025) (Article VI).

The survey was organised in two rounds: before the intervention period in September 2023 and after the intervention period in April 2024, simultaneously in four Rezekne city schools, covering students from grades 1 to 7 who received state- and municipality-funded free school meals. Prior to conducting the survey, the questionnaire was validated in May 2023 through face-to-face interviews with 28 students (one student from each grade in each of the four schools). This procedure made it possible to assess the clarity of the questions and their suitability for the students' age and level of understanding. However, during the pre-intervention survey, it was found that first-grade students' reading and writing skills were not sufficient to participate fully, as they required too much time to understand each question. Therefore, it was decided to exclude first-grade students from the survey process. It should be noted that, for several reasons, the analysis of the study results was based on the post-intervention survey conducted in April 2024, while the pre-intervention survey data were included in the Spearman correlation analysis to meet the sample size requirement.

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 organisational dimension – students' opinions on the sensory quality of food (taste, smell, appearance, temperature) and their assessment of the organisation and management of the school canteen.

The questionnaire included both open-ended questions and structured closed-ended questions with multiple-choice answers. The survey questionnaire was available in both paper and digital formats: students in grades 2–4 mainly completed paper questionnaires, while students in grades 5–7 filled in digital ones. Access to the e-questionnaire was provided through the project website by entering a password. This approach was chosen, taking into account the digital skills of younger students as well as the availability of computer classrooms in schools.

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.

In total, 944 students participated in the post-intervention survey, representing 82 % of the population. The distribution of respondents across all categories and groups was balanced

(Article VI, Table 1), thus ensuring that the sample was representative and that the survey results were not disproportionately influenced by the dominance of any single group.

For the analysis of the survey results, statistical methods were applied, including descriptive statistics, the Kruskal–Wallis H test, the Mann–Whitney U post hoc test, and Spearman's correlation analysis.

The results of Dimension II of the survey revealed that students' awareness and knowledge of FW were incomplete. The majority associated FW with spoiled food (66.4 %) and peels or bones (59.3 %); only 45.4 % recognised that uneaten food left on the plate should also be considered FW, while one-third associated it with food packaging. A small proportion of students (14.6 %) believed that school meals were not healthy, and 24.1 % did not know how to answer this question. Regarding environmental aspects, 21.7 % of respondents disagreed with the statement that FW has a negative impact on the environment, while one-third were unable to answer this question. The economic aspects were also not fully understood: 18.7 % of students (responses "No" and "Rather no") did not agree that wasting food also means wasting money, while 17.4 % could not answer this question. Limited awareness and knowledge of FW management were also revealed. Most respondents (43.9 %) believed that PW ends up in the bin, almost as many thought that it is fed to pets, and one-third indicated that they did not know what happens to PW.

Overall, the results revealed that students in Rezekne city schools had incomplete awareness and limited knowledge of FW issues.

An analysis of Dimension III of the survey, concerning students' attitudes towards FW and school meals, revealed that the majority of students (65.4 %) in Rezekne city schools were not concerned about FW, although one-third admitted that this issue did concern them. Responses to the questions on how much of the food served at lunch was usually eaten showed substantial differences in the consumption of different food items (Fig. 2.6).

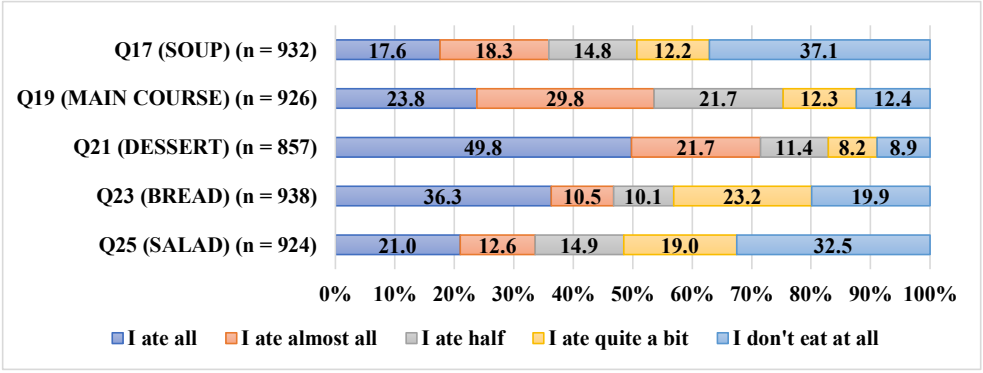

Fig. 2.6. Distribution of the respondents' answers to questions about how much of the food served at lunch was usually eaten, % (Deksne, Lonska, Kodors, et al., 2025).

The data analysis revealed that dessert (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 most consumed food item, with 71.5 % of respondents indicating that they ate all or almost all of it. This was followed by the main course, with 53.6 % reporting that they ate all or almost all, and bread, which was eaten in full or almost in full by about half of the respondents (46.8 %). By contrast, the least consumed items were vegetable salads, which 32.5 % of respondents indicated they did not eat at all, and soup, which was not eaten at all by 37.1 % of students.

It was concluded that such a disproportion in food choices does not ensure adequate nutrient intake and may negatively affect the quality of students' daily diet.

With regard to the reasons why the food served at lunch was not eaten, the survey results revealed the main causes of PW from the students' perspective (Fig. 2.7).

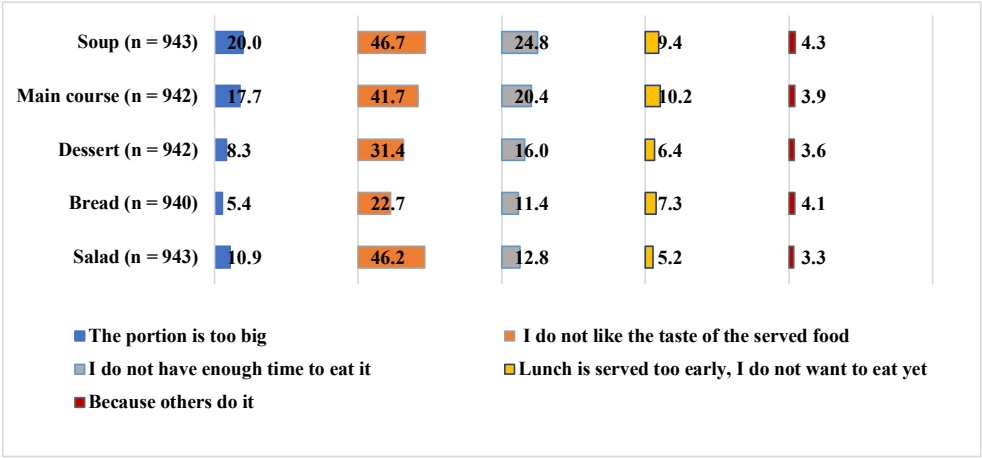

Fig. 2.7. Distribution of the respondents' answers to the questions about the main reasons, why they did not eat the food served, % (Deksne, Lonska, Kodors, et al., 2025).

One of the main reasons reported by nearly half of the respondents for not eating soup (46.7 %), salad (46.2 %), and the main course (41.7 %) was that they did not like the taste of the food served. The second most frequently mentioned reason was insufficient time for eating – 24.8 % of respondents indicated this in relation to soup and 20.4 % in relation to the main course. In addition, 20 % of respondents identified overly large portions as a reason for PW in relation to soup and 17.7 % in relation to the main course.

Nearly one-third of students said they gave uneaten food to classmates, while 14.2 % took items such as fruit, bread, or dessert to eat later. Most (58.7 %), however, left food on the plate. This reflects the limited options in Rezekne city schools, where students have no alternatives for dealing with leftovers. Organisational changes are therefore needed to offer choice in food type and portion size, which could improve eating habits and reduce PW.

An analysis of Dimension IV of the survey, concerning students' satisfaction with the sensory qualities of school meals – taste, smell, appearance, and temperature – revealed that students' evaluations in these categories varied considerably between schools, classes, and genders. However, the overall data indicated that satisfaction with the sensory qualities of food in Rezekne city schools was relatively low, with particularly low ratings given for food temperature and smell (Fig. 2.8).

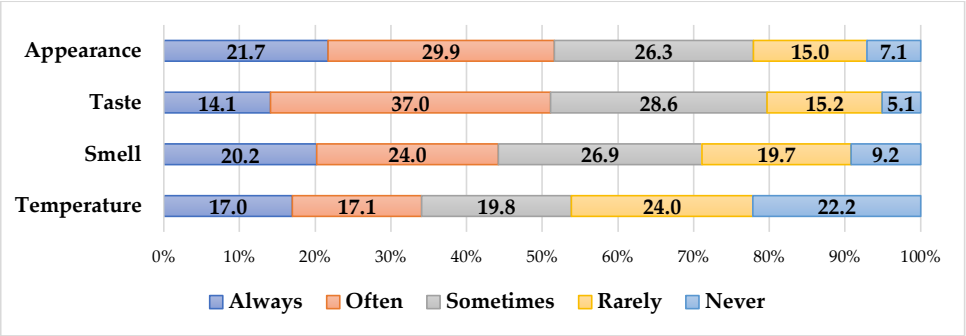

Fig. 2.8. Distribution of the respondents' answers to questions about satisfaction with sensory characteristics of the food served at school, % (n = 944) (Deksne, Lonska, Kodors, et al., 2025).

Only a small proportion of students indicated that they were always satisfied with the sensory qualities of the food. When combining the responses "always" and "often," the highest ratings were given for food appearance (51.6 %) and taste (51.1 %), while the lowest were for food temperature (46.2 %) and smell (28.9 %).

Overall, it was concluded that the food served at schools largely does not meet students' perception of a quality meal. Age- and gender-related differences were also observed: younger students generally gave more positive ratings, while older students expressed greater dissatisfaction. Similarly, boys assessed the food more positively, whereas girls were more critical. These findings highlight shortcomings of the Rezekne city schools' catering model, where pre-portioned meals are often cold by the time they are eaten, reducing taste and appeal.

The results of the Spearman correlation test revealed no statistically significant relationship between students' satisfaction with the sensory qualities of school meals and PW ($p > 0.05$), indicating the influence of other factors, including the opportunity to choose the type of food and portion size.

The survey results revealed that more than half of the students were satisfied with the key aspects of the catering organisation. A total of 55.2 % expressed satisfaction with the lunch serving time, 56.8 % with the duration of the lunch break, and 60 % stated that they liked the fact that the food was already served at the tables. However, about one-third of students would prefer lunches to be served earlier, a longer lunch break, and the opportunity to choose both the type of food and portion size themselves. It was concluded that improvements in catering organisation are needed, involving not only adjustments to lunch timing and duration but also a more flexible approach to portion and meal choice, which could enhance student satisfaction while at the same time reducing PW.

The majority of students rated the attitude and involvement of both canteen personnel and teachers during lunchtime positively. A total of 74.7 % of respondents indicated that canteen personnel were always or often kind and helpful, 77.6 % stated that teachers always or often assisted during lunch, and 58.4 % noted that teachers often or always ate together with them at the same table. In Rezekne city schools, teacher involvement in the catering process varied considerably between schools and grade groups. Teachers most frequently assisted only younger students (grades 1–4), as in Latvia, teacher involvement during lunchtime is voluntary, and their motivation to participate in this process depends on personal initiative and attitude.

The analysis of the survey results within the MOA framework clearly revealed that the current restrictive school meal serving model in Rezekne City – in which meals are pre-portioned and individually served – does not provide students with the opportunity to choose either the type or the quantity of food themselves. Such a choice is an important aspect of out-of-home food services, and its absence limits students' opportunity to engage in responsible food consumption behaviours, thereby contributing to PW. The findings highlight the need to revise the organisational principles of school catering by introducing greater flexibility, choice,

and student involvement. Only in this way will it be possible to establish a sustainable, student-oriented catering model that fosters responsible food consumption and contributes to the long-term reduction of FW.

3. SOLUTIONS FOR THE ORGANISATION OF SCHOOL CATERING PROCESSES AND THE TRANSFORMATION OF FOOD SYSTEMS

Chapter 3 presents solutions for changing the organisation of the catering process and transforming the food system within the framework of a sustainable CE and in line with the principles of a sustainable food system. A knowledge-based prototype of a recommendation system and a theoretically grounded action plan for promoting zero-waste food consumption in schools were developed. The importance of the consumption stage of the FSC in food system transformation was assessed, and a conceptual framework for food system transformation through the consumption stage was proposed, emphasising consumer behaviour as a catalyst for broader changes at this stage. The length of the third chapter is seven pages, and it includes two figures.

3.1. Technological solutions for food waste prevention

To address the identified problems and promote sustainable management of the school catering process, a prototype of a knowledge-based recommendation system was developed. Operating on an artificial intelligence (AI) basis, it is designed as a practical decision-support tool for school management and staff (Kodors et al., 2024) (Article VII). Its aim is to support decision-making in shaping the school ecosystem in a way that reduces PW while simultaneously promoting responsible food consumption and improving the organisation of the catering process in schools.

The prototype of the knowledge-based recommendation system was developed based on the CDD approach, which makes it possible to link recommendations with measurable parameters of the school ecosystem in order to meet the requirements of a data-driven approach. It was grounded in expert knowledge gained from the E-mentor project. The experts identified 26 key recommendations for reducing FW, which were linked to specific evaluation criteria, and a total of 53 self-assessment questions were developed. These covered the most essential aspects of school catering organisation, thereby enabling the identification of each school's current problems and the provision of the most appropriate recommendations.

The recommendation system consists of three components:

- an audit module;
- a knowledge base;
- PW forecasting module.

In addition, within these components the functionality of an LLM classifier was experimentally tested, aimed at providing users with the ability to filter questions and recommendations using free-text queries. The LLM was trained on customised data and tested in various scenarios; however, this functionality has not yet been fully integrated into the prototype available to users. To ensure the digitalisation of recommendations in line with the CDD approach, experts were involved in restructuring the recommendations, linking them to measurable indicators and specific audit criteria that characterise the organisation of the catering process in schools. Furthermore, a structured pairwise comparison method was applied to assess the significance of the recommendations. The consolidated results made it possible to determine their relative weight and classify them into three priority levels – from the most essential to the least significant. Based on the experts' voting, the highest-rated recommendations were: offering students a choice between two meals, introducing a buffet-style catering model, and ensuring coordinated and timely information exchange between the school and catering staff, enabling accurate planning of student numbers and, accordingly, the required amount of food to be prepared.

With the developed recommendation system prototype, it is possible to:

- carry out a structured self-assessment of the school catering process, covering 10 key contextual areas (e.g., organisation of the dining environment, lunch schedule, serving method, etc.);
- provide each school with tailored recommendations for reducing FW, based on the identified audit results and risk factors;
- use the forecasting tool, which, drawing on school parameters and student survey data, allows the estimation of the expected amount of PW;
- experimentally apply the LLM classifier, enabling relevant recommendations and audit questions to be filtered through free-text queries.

The development of a knowledge-based recommendation system is an important step towards data- and evidence-driven FW reduction in school catering processes. Such a tool can serve as practical support for the self-assessment of school catering, helping to identify the most pressing problems and receive individually tailored solutions, thereby enabling targeted progress towards more efficient resource management, more responsible food consumption, and improved quality of the catering process in Latvian schools.

3.2. A conceptual action plan for promoting zero-waste food consumption in the school catering process

The empirical research conducted within the framework of the Doctoral Thesis revealed several critical aspects that hinder the transition towards zero-waste food consumption in the school catering process in Rezekne. These are primarily related to the existing meal serving model, which restricts changes in students' consumption behaviour.

To facilitate changes in the organisation of the school catering process, it is necessary to develop a system that simultaneously strengthens students' knowledge and skills, fosters their motivation, and provides real opportunities for responsible action.

To address the limitations of the existing meal serving model and to ensure the transition towards sustainable, zero-waste food consumption in schools, a conceptual action plan was developed, based on the principles of a sustainable CE and food system (Fig. 3.1).

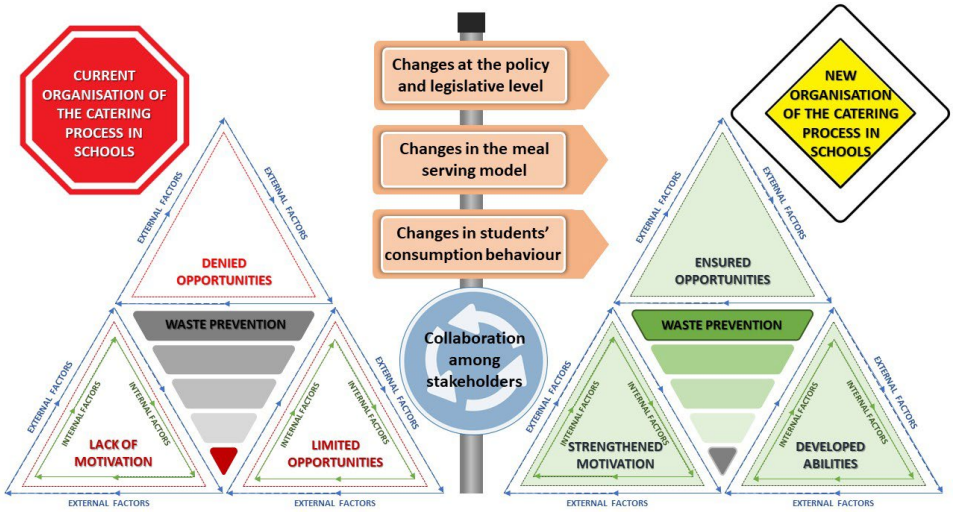

Fig. 3.1. Conceptual action plan for promoting zero-waste food consumption in the organisation of school catering in Latvia, based on the principles of a sustainable circular economy and a sustainable food system (developed by the author).

The conceptual action plan presented in Fig. 3.1 illustrates the transition process from the current restrictive organisation of the school catering process to a sustainable, zero-waste food consumption model. It is developed on the basis of the MOA behavioural theory and demonstrates how specific courses of action can enable the transformation of the organisation of the catering process.

The action plan outlines three main directions for change.

Changes at the policy and legislative level. Based on the current rigid regulatory framework, schools are often compelled to mechanically comply with legal requirements without considering the actual situation, as well as students' needs and preferences. Therefore, amendments to the existing regulations are required in order to provide schools with greater flexibility and the opportunity to implement solutions tailored to the specific context and operational environment. Such solutions may include, for instance, differentiating portions according to students' age and appetite, adapting menus to students' demand, or ensuring the beneficial use of uneaten food. It is also essential to allow the possibility of testing alternative solutions aimed at improving the organisation of the catering process without the risk of violating regulations.

Changes in the meal serving model. Substantial modifications are needed in the daily school catering process, ensuring that students are given the opportunity to choose the quantity and type of food in line with their preferences and needs. It should also be possible to take away uneaten food, and the planning of served portions must be improved to reduce overproduction. These changes would help decrease the volume of PW while improving the quality of the catering process and students' satisfaction.

Changes in students' consumption behaviour. This involves strengthening students' awareness and knowledge of FW issues and school meals, fostering a sense of personal responsibility, creating a motivating environment, and providing opportunities for responsible and sustainable action. This can be achieved through integrated strategies adapted to the specific context and operational environment, combining educational activities, students' practical involvement, and organisational changes in the meal serving model.

At the core of the action plan lies a collaboration-based approach, the implementation of which is possible only if all stakeholders – namely policymakers, school administrations, caterers, teachers, parents, and students – act in a coordinated manner, recognising their role and responsibility in the change process. Only such an approach can ensure a successful transition towards the organisation of the school catering process that promotes sustainable, zero-waste food consumption.

3.3. Conceptual framework for consumption-based food system transformation

In the final stage of the Doctoral Thesis, the consumption stage of the FSC was analysed as a strategically significant turning point in the transformation of the food system towards a sustainable model (Deksne, Lonska, Litavniece, et al., 2025) (Article VIII).

Based on the bibliometric analysis and the integrative literature review, four overarching thematic directions were identified as central to the food consumption stage: FW and its reduction, sustainable dietary shifts, consumer awareness and behaviour, and policy and systemic transformations (Deksne, Lonska, Litavniece, et al., 2025). These aspects formed the basis for the development of the conceptual framework (Fig. 3.2), in which identified problems are systematically linked to targeted solutions. These solutions can be implemented through various tools that act as drivers in promoting a paradigm shift, thereby transforming the food system.

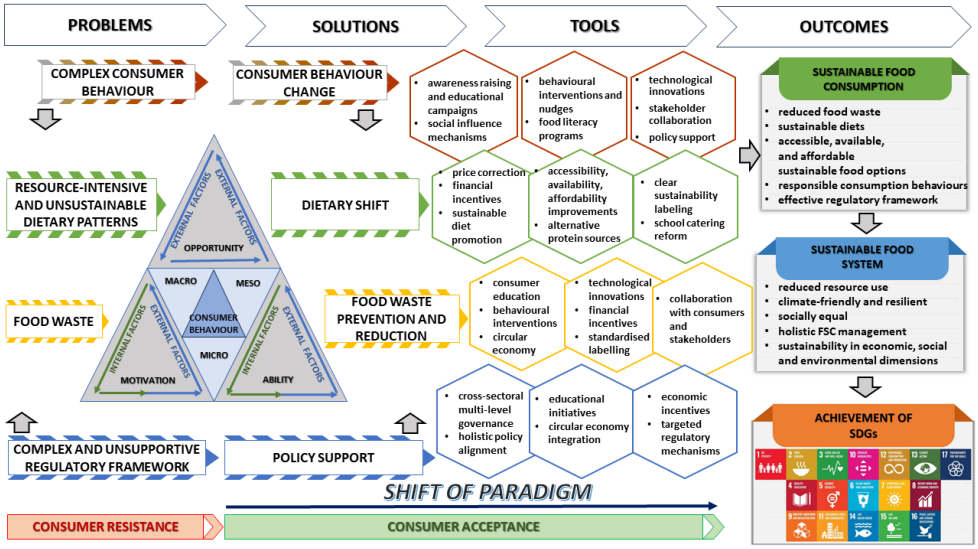

Fig. 3.2. A framework for transforming the food system into a sustainable food system through the food consumption stage (Deksne, Lonska, Litavniece, et al., 2025).

At the centre of the conceptual framework is the consumer, whose decisions and behaviour significantly influence all processes within the FSC. Consumer behaviour is determined by factors operating at the micro, meso, and macro levels, as well as by motivation, ability, and opportunity, in line with the MOA consumer behaviour theory (Deksne, Lonska, Litavniece, et al., 2025).

The framework emphasises that consumer behaviour change can be achieved through policy support, for example, educational activities, behavioural interventions, technological innovations, financial incentives, and other instruments. Changes in consumer behaviour may serve as a catalyst for broader transformations within the food consumption stage. However, for a paradigm shift to occur, a transition from consumer resistance to the acceptance of sustainable consumption is required. Only when sustainable food consumption is adopted as an everyday choice and lifestyle, will a lasting transformation of the food system be possible. Achieving such change requires a complex, context-specific, and consumer-oriented approach that combines targeted activities and policy support to ensure the transition towards sustainable food consumption, which in turn fosters the development of a sustainable food system and contributes to the achievement of the United Nations SDGs (Deksne, Lonska, Litavniece, et al., 2025).

Although the framework was developed on the basis of literature analysis, the empirical research carried out within the Doctoral Thesis revealed similar problems, highlighting the framework's relevance and practical applicability in planning and implementing change. It can be used as a practical tool in food policy planning and implementation, in education, and in the organisation of catering, particularly in schools, where there is a unique opportunity to foster a culture of consumption grounded in awareness, responsibility, and sustainability. In this context, the developed framework is not only a theoretical construct but also a guide for driving change in practice, especially in schools, where future consumer habits and behaviours can be shaped from an early age and where the greatest potential for a paradigm shift exists.

MAIN CONCLUSIONS

The aim of the study has been achieved, and the objectives have been fulfilled.

1. The results obtained in the Doctoral Thesis confirm that FW is a global, multidimensional, and persistent problem with far-reaching consequences, particularly at the consumption stage of the FSC.
2. The exploration of the CE concept revealed that the broader framework of a "sustainable CE" is a theoretically and practically appropriate basis for implementing zero-waste food consumption, as it is primarily oriented towards waste prevention, resource circulation, and changes in consumer consumption patterns. It reflects a paradigm shift towards a holistic and continuous approach to sustainability, in which economic activity is closely linked to the preservation of social well-being and environmental protection.
3. The results of the empirical research revealed that the catering process, based on fully or partially pre-portioned meals individually served in Rezekne city schools, is not sustainable, as approximately 20 % of the prepared food remains uneaten, resulting in considerable resource losses, including the inefficient use of state budget funds.
4. The empirical research identified the main causes of PW in the catering process of Rezekne city schools – the mismatch between the menu offers and students' preferences, limited possibilities to choose meal types and portion sizes, insufficient student involvement, and shortcomings in the organisation of the catering process.
5. The second pilot study confirmed that no single intervention can serve as a long-term solution to reduce PW. The digital tracker in School S1 (by class) showed a short-term significant reduction, but the effect did not last, while organisational changes in School S3 increased PW in both the short and long term. This indicates that changes not grounded in an analysis of the specific context and operational environment may produce the opposite effect. The findings show that reducing PW in school catering is a multidimensional challenge requiring a combined approach. Sustainable results depend on integrating serving model changes with portion and menu adaptation, monitoring and planning, educational activities, and teacher involvement. Solutions must also be tailored to the specific context and continuously refined through student feedback.
6. According to the MOA behavioural theory, the school meal serving model, in which food is predominantly fully or partially pre-portioned and individually served to each student without the possibility of choosing the type of food or portion size, significantly restricts students' "opportunities". This, in turn, hinders behavioural change, even when students possess the abilities (knowledge, skills) and motivation (awareness, attitudes) to consume food responsibly and sustainably.
7. The survey results confirmed that students in Rezekne city schools have an incomplete understanding and limited knowledge of the issue of FW. They lack awareness of the concept of FW, its impact on the environment and the economy, as well as of waste management options. Therefore, a key prerequisite for effectively reducing FW in schools is the development of students' understanding and the strengthening of their knowledge of sustainable food consumption.
8. The results of Spearman's correlation revealed no statistically significant relationship between students' satisfaction with the sensory properties of school meals and PW ($p > 0.05$), indicating the influence of other factors, including the opportunities to choose portion size and type of food.
9. The development of a knowledge-based recommendation system is an essential step towards data- and evidence-driven reduction of FW in the organisation of school catering. Such a tool can provide practical support for schools in auditing the catering ecosystem, helping to identify the most critical problems and receive individually tailored solutions, thereby enabling targeted progress towards more efficient resource management, more responsible food consumption, and improved quality of the catering process in schools.

10. School catering, as part of the food consumption stage, plays a strategically important role in the transformation of the food system, as it provides a unique opportunity to shape students' understanding, attitudes, and behaviour towards responsible and sustainable food consumption from an early age. By creating a school catering environment that simultaneously develops knowledge, fosters motivation, and provides real opportunities for sustainable action, it is possible to promote responsible and sustainable food consumption and reduce the volume of PW.
11. The results of the Doctoral Thesis confirm that the creation of a sustainable food system is not possible without a structured, multi-level, and holistic approach that involves stakeholders at the micro, meso, and macro levels throughout the entire food value chain. Such an integrated approach is essential to simultaneously address environmental, economic, and social challenges and to strengthen both public health and well-being, as well as the sustainability of the planet.
12. The hypotheses put forward in the Doctoral Thesis were confirmed.
    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.
13. Several pilot studies were carried out within the framework of the Doctoral Thesis, representing the first research of this kind in Latvia. Therefore, further studies should be conducted on a larger scale – in other regions and at the national level. Future research should assess the long-term impact of complex interventions and test digital solutions in practice to evaluate their durability and effectiveness in different contexts. It would also be useful to compare various school catering models.

MAIN PROBLEMS AND SOLUTIONS

Problem 1

A considerable amount of PW is generated in the school catering process. Research conducted in Rezekne city schools confirms that approximately 20 %, or one-fifth, of the served food is discarded.

Proposals for solving the problem

1. Proposals based on the recommendations developed within the framework of the E-mentor project (Lonska et al., 2022):

1) For the Ministry of Education and Science and municipalities – to design and implement educational and communication strategies in schools aimed at sustainable and responsible food consumption, integrating the topics of FW and healthy nutrition into the curriculum and school life.
2) For the management of municipal education departments –, to ensure more active involvement of school administrations and teachers in promoting sustainable food consumption, serving as role models for students and their parents.
3) For school administrations and caterers – to plan menus not only in line with nutritional guidelines but also according to students' preferences and demands, reviewing and diversifying the menu regularly based on students' wishes.
4) For school and catering process managers – to optimise catering organisation by introducing digital solutions for recording and planning student attendance and for timely information exchange with caterers, in order to forecast the required amount of food more accurately.
5) For school and catering process managers – to plan lunch breaks thoughtfully and adapt the dining environment by applying different approaches, such as allowing students to taste food before it is served (tasting spoons), implementing elements of the Smarter Lunchrooms Movement – simple and cost-effective solutions (posters, attractive food names, etc.) that stimulate students' interest in food, encourage responsible food consumption, and reduce FW.
6) For school administrations and caterers – to improve the serving method by allowing students to choose portion sizes and food types, as well as by improving the sensory properties of food and ensuring its easier consumption. For example, offering peeled and sliced fruits and vegetables in small, easy-to-eat pieces for primary school students.
7) For the Ministry of Education and Science, the Ministry of Agriculture, and municipalities – to provide financial support for the modernisation of school canteen kitchens through the acquisition of modern equipment and technologies, as well as for the recruitment of professional kitchen staff.

2. The Government of Latvia should integrate digital management of the school catering process into national sustainability strategies in the upcoming periods (after 2027). The Ministry of Agriculture should ensure the development of guidelines and cooperation with municipalities to promote the introduction of innovative technological solutions in the management of school catering processes, for example, a knowledge-based recommendation system that enables schools to conduct ecosystem audits and self-assessments, identify problems, and receive personalised recommendations for reducing PW. It would be advisable to make it a mandatory requirement for schools to carry out at least once a year a self-assessment with the help of the system, as well as an FW audit. Based on the results and the personalised recommendations provided, an action plan should be developed for the following school year to reduce the volume of PW and improve the quality of the catering process.

Problem 2

The meal serving model in schools, based on fully or partially pre-portioned meals individually served in advance, does not promote zero-waste food consumption. This is due to

a rigid regulatory framework and significant shortcomings in the organisation of the catering process, which hinder changes in students' consumption behaviour.

Proposals for solving the problem

1. The responsible ministries should review and revise the existing regulatory framework for school catering, granting school catering management greater flexibility, as defined in the organisational guidelines for the catering process:
   - menu planning should be based on students' preferences and demand;
   - safe opportunities should be provided to use unserved food on the following day in the preparation of other dishes;
   - the meal serving model should allow students to choose the quantity and type of food themselves;
   - solutions aimed at improving the school catering process should be implemented, such as testing new recipes, introducing buffet-style catering, and others.
2. Municipalities and caterers, in cooperation with school administrations, should establish a School Food Council in each school (as in Sweden, Finland, and other countries) to bring together parents, teachers, and kitchen staff in addressing sustainable catering issues. The aim is to promote dialogue among stakeholders on catering matters, to conduct quantitative and qualitative FW audits and assess their causes, to encourage the implementation of practical solutions (e.g., thematic food days, student involvement in menu planning, etc.), and to monitor improvements in the catering process, taking into account students' needs, demand, and feedback.
3. The Ministry of Education and Science should develop a unified curriculum and methodological materials that incorporate educational activities, information campaigns, student participation, behavioural influence mechanisms, and digital solutions to reduce PW in the school catering process. The aim is to develop and strengthen students' abilities (knowledge and skills), their sense of personal responsibility, and their motivation for sustainable food consumption. The implemented measures should be regularly refined based on students' evaluation and feedback.

Problem 3

School meal programmes are a strategically important part of the consumption stage of the FSC; however, their potential for planning and implementing targeted changes in a broader context has not been fully recognised or acknowledged.

Proposal for solving the problem

In policy planning and strategy development aimed at addressing issues such as FW, unsustainable dietary habits, and consumption behaviour, the responsible ministries and municipalities should use the school catering process as a fundamental platform for change. Schools provide a unique environment where education can be combined with practical action, making it possible not only to implement food system transformation initiatives but also to achieve, assess, and monitor their progress. The shaping of sustainable food consumption behaviour from an early age can serve as the foundation for a broader paradigm shift in society, fostering the long-term transition towards a sustainable food system.

Problem 4

The reduction of FW and the transition to a sustainable food system are hindered by insufficient cooperation and involvement of stakeholders in addressing problems at the macro, meso, and micro levels.

Proposal for solving the problem

It is necessary to implement coordinated and targeted measures at all levels of governance.

- **For the responsible ministries and municipalities** – to ensure the participation of schools and society in the implementation of sustainable catering organisation in schools, to

provide financial support for the execution of sustainability initiatives, and to foster cross-sectoral cooperation with the aim of reducing FW, improving nutritional quality, and strengthening public health.

- **For caterers, school administrations, and kitchen managers** – to promote mutual cooperation in two directions: on the one hand, with students, parents, and teachers, ensuring their active involvement in decision-making, menu development, FW reduction, and educational activities; on the other hand, with education authorities and food suppliers, ensuring the quality of the catering process.
- **For students and their families** – to act as active and responsible participants in promoting sustainable consumption. They should engage in improving the school catering process by expressing their opinions and suggestions, and by collaborating with school administrators and caterers; they should also develop a sense of personal responsibility and sustainable consumption habits not only at school but also within their households. Equally important is voicing their position by actively participating in public consultations or civic initiatives, thereby influencing broader political decisions at the national level and fostering changes in the food system.

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