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A large-scale European study on the role of sensory liking, emotional responses, and food neophobia in driving the acceptance of sustainable meals served in school canteens

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ABSTRACT

This study evaluated whether school meal recipes developed according to three key sustainability and nutritional principles (vegetarian composition, utilization of unrefined raw ingredients, and reduced salt content) could achieve sensory acceptance, elicit positive emotional responses among children, and consequently reduce food waste in school canteens. Additionally, children's food habits, food neophobia, and food waste behaviors were measured, investigating potential correlations between these factors and recipes acceptance and waste. Children (n = 2324, 54 % females, aged 9 to 15) from 16 geographical units across 12 European countries (Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Slovakia, Spain, and Sweden) completed a dedicated sensory test and a questionnaire. Results highlighted significant variability in recipe acceptance across geographical units, with pasta-based recipes and legume-based burgers generally receiving higher liking scores and resulting in lower waste compared to soups. Furthermore, a positive correlation emerged between sensory liking, positive emotional responses, and reduced food waste, emphasizing the critical role of sensory and emotional considerations in the design of school meals. Food neophobia negatively affected the recipes acceptance and was positively correlated with food-waste behaviors. Despite the observed differences among geographical units, the overall variability in food neophobia was relatively limited, suggesting that this trait is similar among children aged 9–15 in Europe. Overall, the results of this study underscore the importance of culturally tailored strategies to improve the sensory liking and emotional profile of sustainable school meals, promoting healthier dietary patterns while contributing to environmental sustainability by reducing food waste.

1. Introduction

Over the past century, globalization, rapid economic growth, and urbanization, alongside advancements in agricultural and food-processing technologies, have significantly transformed dietary patterns, raising critical concerns for both public health and environmental sustainability (Willett et al., 2019). Within this context, school canteens play a fundamental role in shaping children's eating behaviors, as they provide an opportunity to promote healthier and more sustainable diets (Eustachio Colombo et al., 2020; Graça et al., 2023). The significance of this transition and the pivotal role of schools are further reinforced by global strategies such as the UN Sustainable Development Goals (UN DESA, 2023) and the FAO's School Food and Nutrition Global Action Plan 2022–2026, which advocate for strengthened policies, investment in sustainable meals, and enhanced food education (FAO, 2022).

European studies indicated that children who regularly eat in school canteens tend to develop healthier eating habits and exhibit lower levels of sedentary behavior compared to their peers who do not, irrespective of socioeconomic and demographic factors (Dubuisson et al., 2012). Despite the potential of school meals to serve as catalysts for nutritional education and behavioral change, their effectiveness is often undermined by a range of factors including children's reluctance to consume novel, healthy, and sustainable foods (Tomic-Obrdalj et al., 2020). This reluctance is shaped not only by individual preferences or sensory characteristics of food but also by the broader social environment, including family habits and parental modeling, which strongly influence children's attitudes toward food and their willingness to accept school meals (Patrick & Nicklas, 2005; Scaglioni et al., 2018).

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A sustainable and nutritionally balanced diet should primarily consist of fresh, seasonal, plant-based foods, with a reduction in processed food consumption (Peker & Günal, 2023) and a reduction in salt content as recommended by the World Health Organization (WHO, 2023). However, promoting such diets among schoolchildren is challenging, as children generally exhibit low acceptance of vegetables (Cooke & Wardle, 2005; Donadini et al., 2022) and tend to avoid them when allowed to choose (Nicklaus et al., 2005). Numerous factors influencing the acceptance of school meals are well-documented in the literature (Santana et al., 2023). Among these, sensory characteristics, such as taste, texture, and visual appeal, and food neophobia (FN) play a crucial role in shaping children's food acceptance and willingness to consume school-provided meals, particularly concerning vegetables and plant-based proteins (Donadini et al., 2021; Donadini et al., 2022; Rodríguez-Tadeo et al., 2014; Santana et al., 2023). Additionally, cultural preferences, and school meal policies further influence food acceptance and waste reduction (Liz Martins et al., 2020; Santana et al., 2023). Consequently, while it is necessary to develop nutritionally balanced meals based on sustainability principles, it is equally crucial to identify useful strategies and techniques to improve the sensory acceptance of school menus. For example, modifying certain sensory properties of vegetables can be an effective strategy to enhance their acceptance among children (Donadini et al., 2012), thereby increasing their consumption. This can be achieved by optimizing the combination of colour, size, and shape to make vegetables more visually appealing as snacks. For example, children have been shown to prefer vegetables that are cut into familiar or playful shapes, such as stars, rather than served whole or in large chunks; sliced or stick-cut vegetables are also generally preferred over unprocessed forms (Olsen et al., 2012). Additionally, different cooking methods (e.g., boiling, frying), the use of flavorings, or the addition of seasonings can help mask undesirable flavors or enhance desirable ones (Donadini et al., 2012; Poelman et al., 2016; Zeinstra et al., 2010). These strategies are important to counteract the blandness and bitterness often associated with vegetables, sensory characteristics that commonly lead to rejection among children, while foods featuring sweet, salty, or umami notes are generally more readily accepted (Poelman et al., 2016). Furthermore, preferring crispy and juicy textures has been associated with greater acceptance of these products, stimulating a higher appetite for fresh and raw fruits and vegetables (Laureati et al., 2020). Thus, it is essential to take into consideration all these aspects when developing new healthy and sustainable dishes for pupils in order to increase the acceptance of school recipes and achieve their intended nutritional and environmental benefits.

To fully assess acceptance and better capture the eating experience, it is important to investigate the emotional responses elicited by food consumption (Gutjar et al., 2015; Spinelli et al., 2014). Recent review focusing on children's perspectives on meals highlights that children primarily judge food based on taste and positive emotions (Willemsen et al., 2023). Studies, for example, have found that positive emotions are associated with higher meal ratings (Piochi, Franceschini, et al., 2025; Tuorila et al., 2015) and contribute to a reduction in food waste within school canteens (Piochi, Franceschini, et al., 2025).

Despite extensive research on school meal acceptance and their impact, several limitations persist in the existing literature, primarily due to the use of diverse evaluation methods (Santana et al., 2023). Studies assessing emotional responses and food waste often rely on children's recollection of information rather than real-time consumption data, introducing potential biases in reported experiences (Piochi, Fino, & Torri, 2025; Piochi, Franceschini, et al., 2025). Additionally, food waste and acceptance assessments have often been based on indirect methods, such as analyzing leftovers on lunch trays (Boschini et al., 2020; Liz Martins et al., 2020) or using mathematical formulas and visual estimates by trained operators, which can be a source of bias (Santana et al., 2023). Furthermore, prior research has primarily focused on isolated national contexts, underscoring the need for large-scale, cross-cultural investigations into young children's eating behaviors across different cultural backgrounds (Eustachio Colombo et al., 2020; Willemsen et al., 2023). Our study aligns with this context by pursuing two key objectives: (1) To evaluate children's sensory liking, emotional responses, and food waste associated with school recipes designed according to nutritional and sustainability principles.; (2) To assess children's food habits, food neophobia, and general food waste behaviors, and to explore potential correlations between these factors and their liking for healthy and sustainable recipes.

To investigate these aspects, an exploratory study across 16 geographical units in 12 European countries (Austria, Belgium, Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Slovakia, Spain, and Sweden) was conducted. This large-scale approach provides valuable insights into how sustainable and nutritious recipes can be effectively integrated into school canteens, taking into account cultural and gastronomic contexts and ensuring they are well-received by children.

2. Materials and methods

2.1. Participants

The study involved children aged 9 to 15 years attending schools across 16 geographical units in 12 European countries. The implementation of the sensory test in each location was made possible through close collaboration with local institutional partners participating in the Horizon 2020 “SchoolFood4Change” project (DOI: https://doi.org/10.3030/101036763), who were responsible for selecting schools and administering the questionnaires. Teachers and school canteen staff also played a key role in supporting the practical organization of the test during lunchtime.

The term geographical unit is used throughout the study to describe either a single city or, in cases where data collection took place in multiple locations within the same country, the country itself as a whole. The 16 participating geographical units were: Vienna (Austria), Belgium, Copenhagen (Denmark), Czech Republic, Bratislava (Slovakia), Tallinn (Estonia), Viimsi (Estonia), Lyon (France), Essen (Germany), Nuremberg (Germany), Budapest (Hungary), Milan (Italy), Nuoro (Italy), Valencia (Spain), Malmö (Sweden), and Umeå (Sweden). In Belgium and the Czech Republic, although the geographical units are represented at the national level, data collection was carried out in specific cities: Ghent and Leuven in Belgium; Ludgeřovice, Hradec nad Moravicí, and Říčany in the Czech Republic. For consistency, these units are referred to as “Belgium” and “Czech Republic” throughout the manuscript. These geographic units were not homogeneous in terms of population size, urbanization level, or demographic composition. The whole study was approved by the Ethical Committee of the University of Gastronomic Sciences (Ethical Committee Proceeding No. 2024.04). Parental consent was obtained for all participants in accordance with GDPR regulations (EU Regulation No. 679/2016). Data were collected between September and December 2024 (4 months). A total of 2446 children initially answered the questionnaire, but 122 responses from them were removed due to the following general exclusion criteria: (1) failure to answer any of the questionnaire items and (2) selecting more than one option in single-choice questions. Finally, the responses of 2324 children were retained for data analysis. The number of valid responses from the single geographical units is presented in Table 1.

2.2. Recipe design

The recipe design process was a critical component of the study, aimed at ensuring the development of recipes that adhered to the principles of health, sustainability, and sensory acceptance. Given the diverse cultural, infrastructural and logistical contexts across the 16 geographical units participating in the study (e.g., different protocols for menu planning and validation, ingredient availability, and procurement systems), it was not feasible to require all schools to test the same recipe.

Table 1
Number and percentage of valid responses collected from 16 geographical units in 12 European countries (total number: 2324).

Geographical unit	N.	%
Vienna (Austria)	168	7
Belgium	156	7
Czech Republic	133	6
Copenhagen (Denmark)	111	5
Tallinn (Estonia)	156	7
Viimsi (Estonia)	196	8
Lyon (France)	154	7
Essen (Germany)	123	5
Nuremberg (Germany)	182	8
Budapest (Hungary)	139	6
Milan (Italy)	159	7
Nuoro (Italy)	139	6
Bratislava (Slovakia)	139	6
Valencia (Spain)	99	4
Malmö (Sweden)	117	5
Umeå (Sweden)	153	7

Such a requirement would have introduced several uncontrollable variables, including differences in cultural, gastronomic context, familiarity and potential variability in recipe execution due to local preparation methods, ingredient sourcing, and serving practices within school canteens. Instead, geographical units were tasked with developing from scratch or adapting an existing recipe based on their local context and culinary tradition while adhering to the following three guiding principles:

- Vegetarian composition: all recipes were required to exclude meat, emphasizing plant-based ingredients to support a protein transition toward more sustainable dietary patterns. This principle aimed to increase the intake of vegetables, fruits, legumes, and grains, while maintaining nutritional balance.
- Use of unrefined raw materials: recipes needed to prioritize unrefined and minimally processed ingredients, such as whole grains, natural sweeteners, and extra virgin oils. This requirement aimed to enhance the nutritional value of the recipes while reducing the reliance on refined and processed foods.
- Reduced salt content: to align with public health recommendations (WHO, 2023), partners were asked to reduce the amount of added salt. This principle was applied as a qualitative design guideline rather than a quantitatively controlled variable, since no standard reference version of each recipe with regular salt content was available for comparison. Compliance was supported by the researcher coordinating the recipe design phase, who encouraged local teams to enhance flavor through alternative methods, such as the use of products obtained through enzymatic processes, fermented products, spices, herbs, and cooking techniques like roasting and long cooking processes.

These principles are consistent with the concept of sustainable nutrition as outlined in the most recent scientific literature (Peker & Günal, 2023) and international dietary models as the planetary health diet introduced by the EAT-Lancet Commission in 2019 (EAT-Lancet Commission, 2019). However, we acknowledge that the environmental sustainability of plant-based foods and ingredients cannot be universally assumed and is highly dependent on context-specific factors such as agricultural practices, seasonality, transportation, and supply chain management (FAO & WHO, 2019). In this study, the adopted principles (vegetarian composition, use of unrefined raw materials, and reduced salt content) were selected not based on individual life cycle assessments of specific ingredients, but because they are broadly aligned with internationally recognized guidelines for sustainable and healthy diets (EAT-Lancet Commission, 2019; FAO & WHO, 2019).

Table 2
Selected recipe names and code tested in each geographical unit.

Geographical unit	Recipe name	Code
Vienna (Austria)	Bean burger	Burger_B
Belgium	Autumn ragout with rice and vegetables	Ragout_RV
Czech Republic	Carrot burger	Burger_C
Copenhagen (Denmark)	Shitake Adobada with 'Ingrid green Peas', flower sprouts & split pea flatbread.	Adobada_S
Tallinn (Estonia)	Cauliflower- chickpea soup	Soup_CC
Viimsi (Estonia)	Tomato-lentil soup	Soup_TL
Lyon (France)	Pasta with lentils, mushrooms and curry	Pasta_LMC
Essen (Germany) Nuremberg (Germany)	Potatoes, Curd, and Linseed Oil	Potatoes_CL
Budapest (Hungary)	Lentil lasagne	Lasagne_L
Milan (Italy)	Whole-wheat pasta with soy ragout	Pasta_SR
Nuoro (Italy)	Spelt and legume soup	Soup_SL
Bratislava (Slovakia)	Vegetable couscous with smoked tofu	Couscous_T
Valencia (Spain)	«Empedrao» rice with vegetables and Romesco sauce	Rice_VR
Malmö (Sweden) Umeå (Sweden)	Autumn Burger with coleslaw and potatoes	Burger_CP

To ensure the consistency of the recipe design process across all the geographical units, comprehensive guidelines were provided during preparatory meetings. Partners were asked to document their recipe ingredients and cooking process, highlighting how each principle was implemented. This documentation facilitated transparency and provided a framework for future replication (supplementary material 2). To support this process, one researcher within the central team was assigned the responsibility of coordinating the recipe development phase. This included collecting and reviewing the proposed recipes, verifying compliance with the shared nutritional and sustainability principles and offering technical feedback. The decentralized approach to recipe design allowed each geographical unit to create a recipe that reflected their local food culture while adhering to the project's design principles. The recipes tested across the geographical units were different, except for the two units in Germany (Essen and Nuremberg) and the two in Sweden (Umeå and Malmö), where the same recipe was evaluated within each country. This choice reflected internal coordination strategies and local implementation plans. In Italy, by contrast, the two units (Milan and Nuoro) tested different recipes, as they operated within distinct institutional contexts, each with its own school catering system and culinary framework. Table 2 shows the selected recipes tested in each geographical unit, including their names and the code used in the article to refer to the recipes.

2.3. Data collection

Data collection was performed using a questionnaire (supplementary material 1) consisting of two parts that were administered in two

separate sessions. The first part, which included questions about socio-demographic information (age and gender), frequency of eating in the school canteen, and about the evaluation of the selected recipe (liking test, emotional response, and self-reported estimation of food waste), was completed immediately after the children consumed the selected recipe in the school canteen. The second part, covering food habits and food neophobia, was filled out in the classroom either in the afternoon of the same day or, at the latest, the following day. This two-phase administration allowed for an approximate completion time of 10 min for the first part, accommodating the logistical constraints of several participating schools that needed to manage multiple lunch shifts, and aligning with existing evidence on the limited time typically allocated for mealtimes in school settings (Willemsen et al., 2023). The approximate completion time for the second part was 30 min.

To ensure linguistic accuracy and consistency across all regions, the translation of the questionnaire followed a meticulous process. The research team first produced a version using the back-translation method, a widely adopted approach for cross-cultural adaptation of instruments in international studies (Behr, 2017). Drafts were sent to the project coordinators of each geographical unit for an initial revision. The questionnaire was predominantly administered in paper format in most participating geographical units. However, for Viimsi (Estonia), Tallinn (Estonia), Malmö (Sweden), Umeå (Sweden), and Belgium, who decided to use tablets and smartphones for the administration, a digital version was prepared using the software Qualtrics (Qualtrics Provo, UT). A second review of the questionnaire was conducted once the official versions were prepared in both online and paper formats, to ensure that the final translations were accurate. To limit potential bias related to questionnaire format, both the paper and digital versions were identical in content, structure, and visual layout. By using a mixed administration method (paper and digital), the study was able to adapt to the specific logistical constraints of each participating geographical unit, ensuring the feasibility of implementation across diverse contexts. In both formats, teachers and local project coordinators played a crucial role in administering the questionnaire. Even if not experts in sensory and consumer science, the involvement of school staff has been recognized as essential in previous cross-national studies involving children, contributing to feasibility and data quality (Brug et al., 2012). To ensure methodological rigor and standardization in the administration process of the sensory test across all regions, the experts in sensory and consumer science of the University of Gastronomic Sciences coordinated and trained the local staff in charge of data collection. This coordination effort included, a specific in person training on sensory analysis that was held at the University of Gastronomic Sciences as part of a course within the "School Food for Change" project, one online plenary meeting with all SF4C project partners and a series of country partner-specific online meetings, where the protocol was discussed in detail, uncertainties were addressed, and procedural alignment was ensured. A follow-up report was produced for each meeting, and all questions that arose during the support process were collected in a guidelines document in the form of FAQs, which was later shared with all coordinating teachers and local project coordinators involved in the data collection. Moreover, a researcher from the central team was in charge of addressing questions and uncertainties, and providing continuous support throughout the entire process.

2.3.1. Recipe evaluation

During the evaluation of the recipe, children were asked to taste it and provide their overall liking on the visual hedonic nine-point scale developed by Torri and Salini (2016). Secondly, a Check-All-That-Apply (CATA) test with nine emoticons, each verbally described, was provided to answer the question, "How do you feel when you finished eating the selected recipe?". Emoticons and verbal descriptions were selected based on previous literature (Piochi, Franceschini et al., 2025) and included one emoticon for neutral emotional status, four emoticons for positive emotions and four emoticons for negative emotions. Positive and negative emotions were selected including four with lower arousal (positive: pleased, happy; negative: sad, annoyed) and two with higher arousal (enthusiastic, full of energy; angry, disgusted). Finally, to assess the amount of residual food left on the plate (recipe waste), children were asked to answer the question "How much food did you leave on your plate?" on the visual food waste scale used by Piochi et al. (2025b). The scale ranged from 1 to 6, with the following response options: 1 = Nothing, 2 = Very little, 3 = A little, 4 = Half, 5 = A lot, 6 = Everything.

2.3.2. Food habits and food neophobia

Investigation of children's food habits was conducted through the question "In general (at home and school), how often do you eat the products below?", focusing on eight different food items (pasta, rice, vegetables, potatoes, legumes (peas, beans, lentils…), fruits, meat, fish) and using an adapted version of the frequency consumption scale from Piochi et al. (2022), ranging from 1 (never) to 6 (multiple times a day).

To assess FN levels, the validated Italian Children's Food Neophobia Scale (ICFNS) (8 items) was adopted (Laureati et al., 2015), which has proven to be a reliable tool for evaluating FN in children from the age of eight. This scale was also chosen because it had already been translated and tested in Spain and Sweden (Proserpio et al., 2020), demonstrating satisfactory internal consistency (Cronbach's alpha >0.70). All language translations of the Food Neophobia Scale used in the study are available as supplementary material (Supplementary material 3). Ultimately, to assess the amount of residual food that children usually leave on their plates at the school canteen (general waste), children were asked to answer the question "Usually, how much food remains on your plate after lunch at school?" on the visual food waste scale used by Piochi et al. (2025b), ranging from 1 (nothing) to 6 (everything).

2.4. Data entry process

The data entry process for paper-based questionnaires was managed through a structured digitalization workflow. After collecting the completed questionnaires, the respective geographical units were responsible for scanning the documents and generating digital copies in PDF format. These scanned files were then submitted to the central research team for processing. To extract responses efficiently and minimize manual data entry errors, the digitalized questionnaires were processed using *Recogniform Reader* (Recogniform Technologies S.p.A., Rende, CS, Italy), an optical character recognition (OCR) software specifically designed for structured form scanning. This software enabled the automated extraction of responses from the scanned documents, ensuring consistency and accuracy in the dataset. Any uncertainties or anomalies in the extracted data were manually verified and reviewed to maintain data integrity.

2.5. Data analysis

All statistical analyses were performed using R software (version 4.4.2, R Core Team). To compare the composition of respondents across countries based on socio-demographic characteristics and canteen

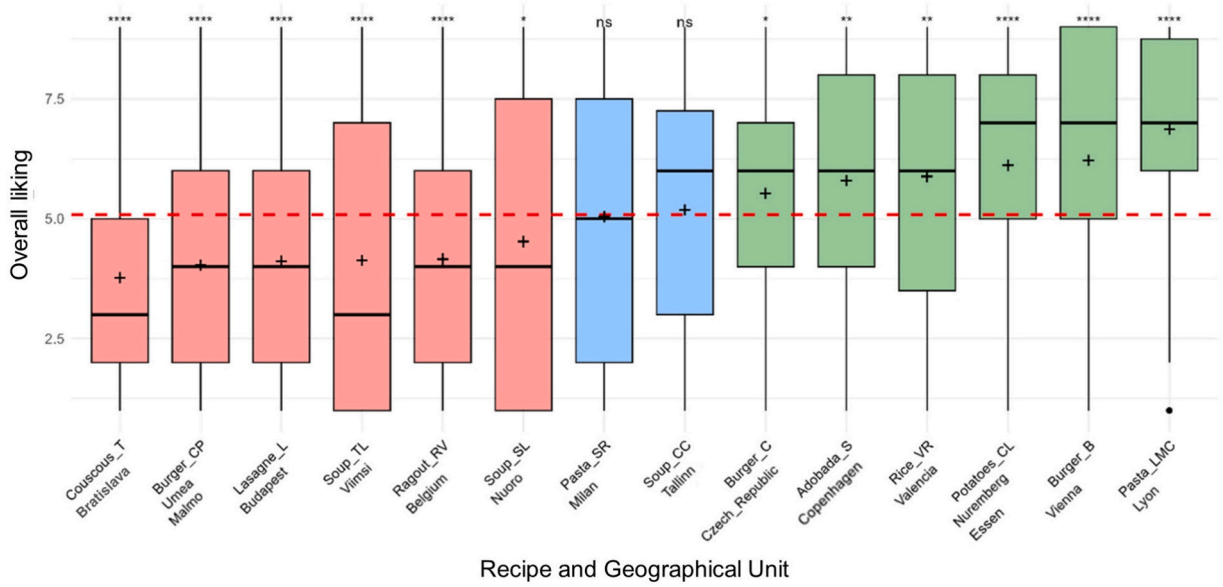

Fig. 1. ***Overall liking for the recipes.*** *The horizontal lines within the boxes represent the median liking scores, while the boxes themselves indicate the interquartile range, capturing the middle 50 % of the data. The whiskers display the range of the data excluding outliers. + within the bars indicate the mean liking scores. The red dotted line represents the general overall liking mean value, marking the* acceptance threshold for recipes. Recipes with a significantly lower mean liking than the acceptance threshold (5.0) are highlighted in red, while those not significantly different from the general mean are shown in blue. Recipes that received a significantly higher liking score, thus surpassing the acceptance threshold, are displayed in green. Asterisks above the bars denote significant differences from the general mean, whether in the positive or negative direction (* for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$, **** for $p < 0.0001$, ns for not significant). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

consumption frequency, Chi-squared tests were applied (John A. Bower, 2013, Ch. 6).

For liking data, a Kruskal-Wallis test was conducted to assess whether significant differences existed among the tested recipes. When significant effects were detected, post-hoc pairwise comparisons were performed using *t*-tests, comparing each recipe's mean liking score against the overall mean.

Regarding recipe waste and general waste, a mean waste score was computed for both variables. The Kruskal-Wallis test was then applied to assess overall differences among recipes, followed by t-tests comparing each recipe's waste score against the overall mean.

The emotional response analysis followed a two-step approach. First, for each recipe, a significance level (P_s) was calculated following Pineau et al. (2009) to determine whether a given emotion was reported at a frequency significantly higher than the chance level (P_o). P_s is derived from the confidence interval of a binomial proportion based on a normal approximation (1).

$$P_s = P_0 + 1.645\sqrt{\frac{P_0(1-P_0)}{n}} \quad (1)$$

P_0 is equal to 1/p, p being the number of attributes, while n indicates the number of subjects who evaluated the recipe. This allowed for identifying which emotions were significantly used by children to describe their post-consumption experience. Additionally, a correspondence analysis was conducted to explore the relationships between recipes and the emotions they elicited, allowing for a visual representation of patterns in emotional responses.

The same statistical approach used for liking was applied to the FN score. Additionally, the internal consistency of the ICFNS was assessed by calculating Cronbach's alpha (John A. Bower, 2013, Ch. 8) for each country and the total sample.

Regarding food habits, a mean consumption frequency score was calculated for each food category and geographical unit. To examine food habits across geographical areas, a correspondence analysis was conducted, allowing for a visual representation of how food habits varied across different geographical units and product categories.

To examine the relationships between FN score, liking, general waste, and recipe waste, Spearman's rank correlation was calculated separately for each country. The Spearman's correlation coefficient (ρ) and corresponding *p*-value were reported. This non-parametric method was chosen due to the ordinal nature of some variables and the potential for non-normal distributions (Zar, 2005).

To integrate CATA emotional data with liking and food habit data associated with general waste and recipe waste, a Multiple Factor Analysis (MFA) was conducted. The waste and liking scores were included as supplementary variables, while all other datasets were normalized using unit scaling before inclusion. Results from MFA were reported using loading and score plots, reporting also the average Food neophobia score for each geographic unit with gradient colour. The MFA analysis was performed using R (version 4.5.1; R Core Team, 2016) with package FactoMineR (Lê et al., 2008).

3. Results

3.1. Characteristics of participants

The socio-demographic characteristics and frequency of lunch consumption in the school canteen of the total respondents for each participating country are summarized in Table 3. A significant difference ($p < 0.001$) was observed among the geographical units for all the considered variables.

Table 3.

Sociodemographic information and canteen consumption frequency.

	Vienna (Austria)	Belgium	Czech Republic	Copenhagen (Denmark)	Tallinn (Estonia)	Viimsi (Estonia)	Lyon (France)	Essen (Germany)	Nuremberg (Germany)	Budapest (Hungary)	Milan (Italy)	Nuoro (Italy)	Bratislava (Slovakia)	Valencia (Spain)	Malmö (Sweden)	Umeå (Sweden)	TOT
Gender*																	
Female	57.1	51.9	57.1	55.0	52.6	52.6	67.5	61.0	38.5	61.2	40.7	50.4	50.4	50.5	57.3	49.7	53.6
Male	41.7	46.8	39.8	41.4	42.9	45.9	31.8	36.6	59.9	36.7	45.3	48.9	42.4	46.5	38.5	48.4	43.8
Other		0.0	0.8	2.7	1.3	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.7	0.0	4.3	2.0	0.7
Prefer not to declare	1.2	1.3	2.3	0.9	3.2	1.5	0.6	2.4	0.5	2.2	5.0	0.7	6.5	3.0	0.0	0.0	1.9
Age*																	
9	75.0	39.1	3.8	0.0	0.6	40.3	51.9	2.4	0.0	0.0	69.2	68.3	31.7	25.3	0.0	0.0	27.2
10	22.0	32.7	6.8	0.0	12.2	21.9	46.8	90.2	13.7	0.0	30.8	31.7	20.1	41.4	0.0	0.0	22.8
11	2.4	24.4	12.8	2.7	6.4	14.3	1.3	7.3	23.6	0.0	0.0	0.0	3.6	29.3	0.0	0.0	8.1
12	0.6	3.2	21.8	37.8	25.0	13.8	0.0	0.0	22.0	10.8	0.0	0.0	10.1	4.0	2.6	15.0	10.4
13		0.6	30.8	12.6	26.9	7.7	0.0	0.0	14.8	32.4	0.0	0.0	17.3	0.0	38.5	83.7	16.4
14	0.0	0.0	19.5	32.4	15.4	0.5	0.0	0.0	13.2	32.4	0.0	0.0	12.2	0.0	23.1	0.7	8.6
15	0.0	0.0	4.5	14.4	13.5	1.5	0.0	0.0	12.6	24.5	0.0	0.0	5.0	0.0	34.2	0.7	6.5
Canteen-Frequency*																	
0 (never)	7.1	1.9	2.3	6.3	10.3	5.6	0.0	36.6	0.5	0.7	0.6	0.0	0.0	0.0	4.3	0.7	4.6
1–2 times a week	6.5	16.7	15.0	7.2	23.7	13.8	5.8	46.3	20.3	0.7	11.3	0.7	0.0	0.0	11.1	7.8	11.9
3–4 times a week	36.3	38.5	21.1	19.8	26.3	30.6	10.4	13.8	41.8	29.5	13.8	18.0	5.8	4.0	24.8	30.7	24.0
Every day (always)	50.0	42.9	61.7	66.7	39.7	50.0	83.8	3.3	37.4	69.1	74.2	81.3	94.2	96.0	59.8	60.8	59.6

Data are presented as percentages of the total number of participants for each geographical unit. Chi-square analysis was used. *Significance indicated at $p < 0.001$

Table 4
Emotions felt after the recipe consumption in each geographical unit.

Emotions	Vienna (Austria) Burger_B	Belgium Ragout_RV	Czech Republic Burger_C	Copenhagen (Denmark) Adobada_S	Tallinn (Estonia) Soup_CC	Viimsi (Estonia) Soup_TL	Lyon (France) Pasta_LMC	Essen–Nuremberg (Germany) Potatoes_CL	Budapest (Hungary) Lasagne_L	Milan (Italy) Pasta_SR	Nuoro (Italy) Soup_SL	Bratislava (Slovakia) Couscous_T	Valencia (Spain) Rice_VR	Malmö - Umeå (Sweden) Burger_CP
Angry	3.0	3.8	6.8	0.0	3.8	1.5	0.6	3.3	7.2	8.8	12.9	11.5	3.0	10.4
Disgusted	**17.9**	**26.9**	**25.6**	4.5	**19.2**	**36.7**	9.7	12.1	**27.3**	**30.2**	**45.3**	**35.3**	**19.2**	**34.1**
Enthusiastic	**25.6**	3.2	8.3	8.1	10.3	12.8	**22.7**	11.5	2.2	11.3	13.7	0.7	13.1	4.1
Full of energy	**28.0**	9.6	8.3	1.8	9.0	13.3	**33.8**	13.8	3.6	14.5	**17.3**	2.9	**19.2**	7.0
Happy	**26.2**	**17.3**	7.5	**34.2**	**19.9**	**16.8**	**30.5**	**20.3**	5.0	**17.6**	**21.6**	6.5	**36.4**	13.7
Irritated	6.5	9.0	3.8	0.0	1.3	3.6	1.3	4.9	7.2	6.9	**17.3**	8.6	3.0	10.7
Neutral/ Indifferent	**25.6**	**32.1**	**39.8**	**45.9**	**43.6**	**26.0**	**37.7**	**28.9**	**56.8**	**35.2**	**16.5**	**50.4**	**44.4**	**44.4**
Pleased	**32.7**	9.6	**27.8**	**18.0**	**25.6**	**19.9**	**38.3**	**33.1**	11.5	**26.4**	**26.6**	**20.1**	**33.3**	11.9
Sad	1.2	3.2	12.8	7.2	5.1	4.1	1.9	2.3	7.9	5.7	10.1	12.2	4.0	11.1

Data presented in bold indicate cases where the percentage of participants selecting the emotion exceeds the 15 % significance threshold.

Out of the total sample, 53.6 % were female (ranging from 38.5 % in Nuremberg, Germany, to 67.5 % in Lyon, France), while 43.8 % were male (varying from 31.8 % in Lyon, France, to 59.9 % in Nuremberg, Germany). The proportion of respondents who selected "Other" and "Prefer not to declare" was 0.7 % and 1.9 %, respectively, with the highest percentage of non-binary responses in Malmö, Sweden (4.3 %).

Regarding age distribution, the majority of participants (68.5 %) belonged to the two younger age groups (9–12 year-olds), with the highest proportion of 9-year-old students recorded in Milano (69.2 %) and Nuoro (68.3 %), Italy. The older age groups (13–15 year-olds) were more represented in Budapest, Hungary (89.3 %), Malmö (95.8), and Umeå, Sweden (85.1 %).

Frequency of lunch consumption in the school canteen patterns also varied significantly across regions. The majority of respondents (59.6 %) reported eating at the school canteen every day, with the highest participation in Bratislava, Slovakia (94.2 %) and Valencia, Spain (96 %). Conversely, 4.6 % of students never consumed meals at the school canteen, with the highest rates of non-attendance in Essen, Germany (36.6 %). The proportion of students consuming their lunch at the school canteen 3–4 times per week was 24.0 %, with the highest frequency in Belgium (38.5 %). Additionally, 11.9 % of respondents consumed school meals only 1–2 times per week, with the highest percentage observed in Essen, Germany (46.3 %).

3.2. *Liking and acceptance of the recipes*

Each recipe was evaluated by a different subgroup of children depending on the school and geographical unit. As a result, comparisons among recipes were based on independent samples and do not involve direct comparison within the same group of children. Within this framework, the overall liking scores varied significantly across recipes, as indicated by the Kruskal-Wallis test ($p < 0.001$), confirming that the recipe type had a significant effect on liking (Fig. 1). The general mean of overall liking was 5.0, which is also considered the threshold of acceptance in a 9-point hedonic scale (Yan et al., 2008). Among the recipes, Couscous_T (3.8 ± 2.2), Burger_CP (4.0 ± 2.3), Lasagne_L (4.1 ± 2.1), Soup_TL (4.1 ± 2.9), and Ragout_RV (4.2 ± 2.4) showed the lowest overall acceptance, with scores significantly below the threshold. In contrast, Burger_C (5.5 ± 2.3), Adobada_S (5.8 ± 2.3), Rice_VR (5.9 ± 2.7), Potatoes_CL (6.1 ± 2.2), Burger_B (6.2 ± 2.65), and Pasta_LMC (6.87 ± 1.9) achieved the highest ratings, above both the mean and the acceptance threshold. Meanwhile, Soup_SL (4.5 ± 3.0), Pasta_SR (5.1 ± 2.8), and Soup_CC (5.2 ± 2.7) remained close to the general mean, aligning with the threshold.

3.3. *Emotional responses*

In Table 4, the percentage of participants who selected each emotion out of the total number of participants who evaluated each specific recipe is reported. An emotional response was considered significant only if it was chosen by more than the significance level of 15 % of participants, while emotions that did not reach this threshold were considered not relevant. The 15 % threshold corresponds to the approximate significance level (Ps) calculated for most geographical units (ranged between 14.3 % and 16.1 %).

A notable finding is that *Neutral/Indifferent* was the only emotion significantly used to describe the post-consumption emotional response for all recipes. This suggests that a substantial number of children in each geographical unit did not exhibit positive or negative reactions to the tested recipe.

Beyond neutrality, Burger_B, Adobada_S, Pasta_LMC, and Potatoes_CL were characterized by a significant presence of only positive emotions, including *Enthusiastic*, *Pleased*, *Happy*, and *Full of energy*. Conversely, Lasagne_L and Burger_CP showed a different trend, as they were the only recipes where, aside from neutrality, negative emotions were significantly present and specifically *Disgusted* and *Irritated*. An

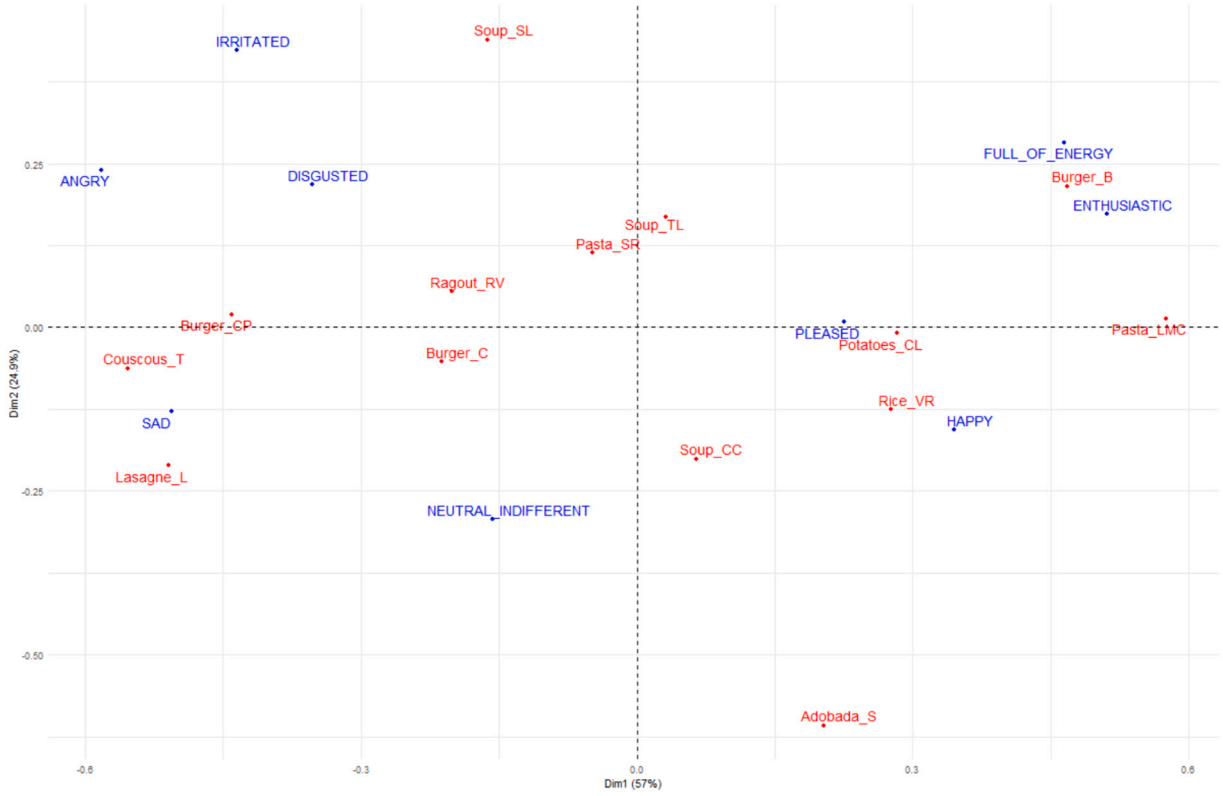

Fig. 2. *Correspondence analysis biplot illustrating the relationship between recipes (red) and emotions (blue).* (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

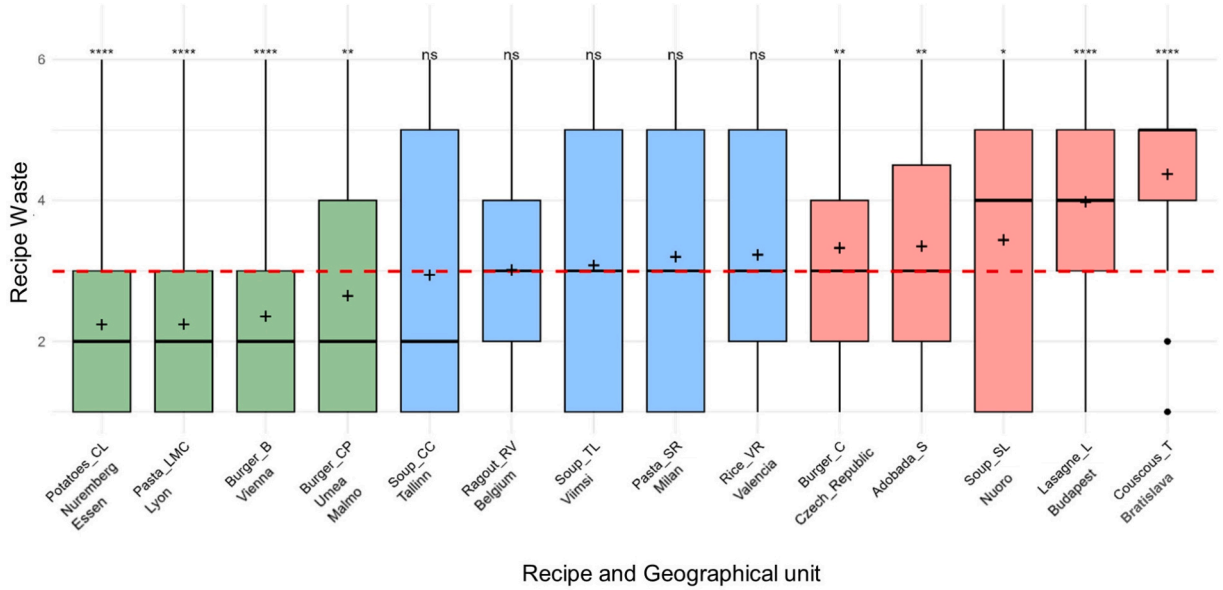

Fig. 3. ***Recipe waste of each recipe in the geographical units.*** The horizontal lines within the boxes represent the median recipe waste scores, while the boxes themselves indicate the interquartile range, capturing the middle 50 % of the data. The whiskers display the range of the data excluding outliers. + within the bars indicate the mean recipe waste scores. The red dotted line represents the mean recipe waste score across all tested recipes. Recipes with a significantly lower mean recipe waste score than the overall mean are highlighted in red, while those not significantly different from the overall mean are shown in blue. Recipes that received a significantly higher recipe waste score are colored in green. Asterisks above the bars denote significant differences from the general mean, whether in the positive or negative direction (* for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$, **** for $p < 0.0001$, ns for not significant). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

interesting observation is that two of the negative emotions, *Sad* and *Angry*, were not significantly used to describe the post-consumption response for any of the tested recipes.

To further explore the relationship between emotions and recipes, a correspondence analysis was performed, and the obtained biplot is presented in Fig. 2. The first dimension (Dim 1) accounts for 57.0 % of the variance, while the second dimension (Dim 2) explains 24.9 % of the variance. Together, these two dimensions capture 81.9 % of the total

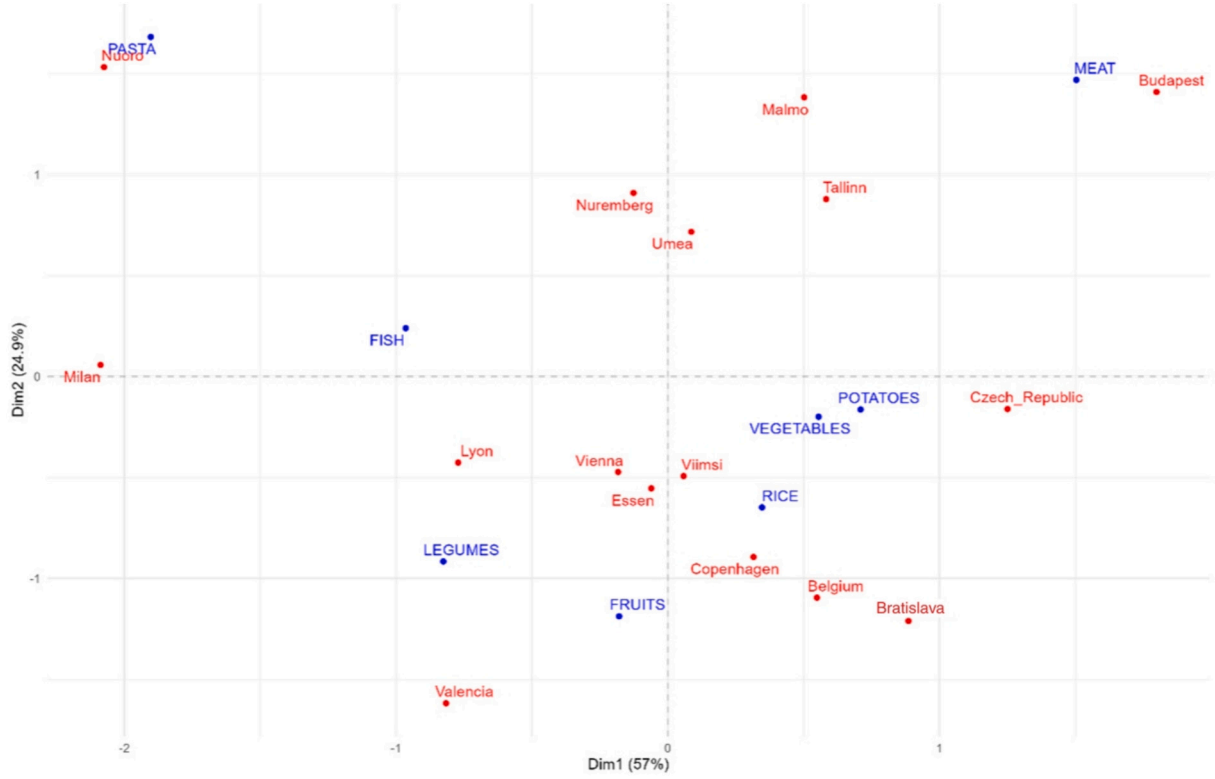

Fig. 4. ***Correspondence analysis between geographical units (red) and consumption habits for different food categories (in blue).*** (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

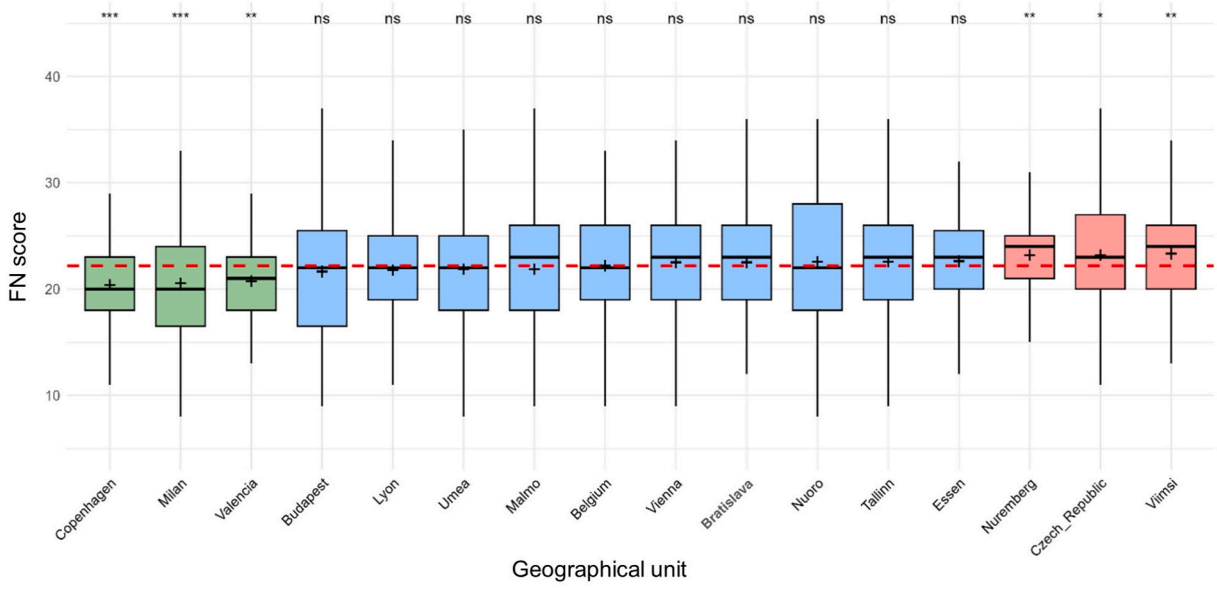

Fig. 5. ***Food Neophobia distribution in the geographical units.*** The horizontal lines within the boxes represent the median FN scores, while the boxes themselves indicate the interquartile range, capturing the middle 50 % of the data. The whiskers display the range of the data excluding outliers. + within the bars indicate the mean FN score. The red dotted line represents the mean FN score across all tested recipes. Geographical units with a significantly lower FN mean score than the overall mean are highlighted in green, while those not significantly different from the overall mean are shown in blue. Geographical units that received a significantly higher FN mean score are colored in red. Asterisks above the bars denote significant differences from the general mean, whether in the positive or negative direction (* for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$, **** for $p < 0.0001$, ns for not significant).

variance, providing a robust representation of the main trends in the data.

By examining the projection of emotions and recipes in the Dim1-Dim2 biplot, distinct positioning patterns emerge. Specifically, the four positive emotions (*Happy*, *Pleased*, *Full of Energy*, *Enthusiastic*) were positively correlated to Dim1, while the neutral emotion (*Neutral/Indifferent*) was positioned near the origin of the plot, reflecting its widespread use across all recipes. In contrast, negative emotions (*Sad*, *Angry*, *Disgusted*, *Irritated*) were negatively correlated to Dim1. Regarding individual recipes, Burger_CP, Lasagne_L, and Couscous_T

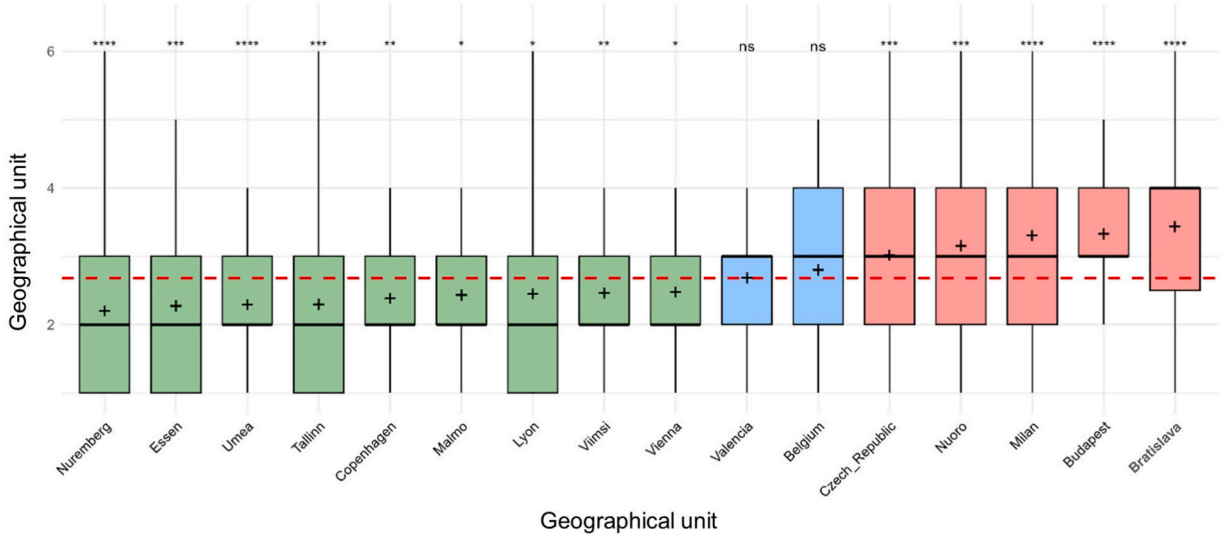

Fig. 6. ***Distribution of the general waste the geographical units.*** The horizontal lines within the boxes represent the median General Waste scores, while the boxes themselves indicate the interquartile range, capturing the middle 50 % of the data. The whiskers display the range of the data excluding outliers. + within the bars indicate the mean general waste scores. The red dotted line represents the mean general waste score across all the geographical units. Geographical units with a significantly lower waste mean value than the overall average are marked in green, while those that did not differ significantly from the mean are represented in blue. In contrast, geographical units associated with significantly higher waste levels are shown in red. Asterisks above the bars denote significant differences from the general mean, whether in the positive or negative direction (* for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$, **** for $p < 0.0001$, ns for not significant). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

were positively correlated to Dim1, aligning with negative emotions, indicating that these recipes were predominantly described using these terms. Conversely, Burger_B, Pasta_LMC, Rice_VR, and Potatoes_CL were positively correlated to Dim1, showing their strong association with positive emotions.

Some recipes, including Burger_C, Ragout_RV, Soup_CC, Soup_TL, and Pasta_SR, are closer to the origin of the plot, suggesting they were primarily described using the *Neutral/Indifferent* emotion rather than strong positive or negative reactions.

Notably, Soup_SL and Adobada_S are positioned at opposite extremes along Dim2. Soup_SL is strongly associated with *Irritated*, which was positively correlated to Dim2, while Adobada_S was negatively correlated to Dim2, aligning most closely with *Neutral/Indifferent*.

3.4. Recipes waste

Fig. 3 illustrates the distribution of recipe waste scores for each tested recipe. The recipe waste scores for the tested recipes varied significantly across the sample, as indicated by the Kruskal-Wallis test ($p < 0.001$), confirming that the recipe type had a significant effect on the waste left on the plate by the children. The mean waste recipe score across all recipes was 3.0 ± 1.7, representing the categorical option "A little".

Among the recipes, Potatoes_CL (2.2 ± 1.4), Pasta_LMC (2.3 ± 1.6), Burger_B (2.4 ± 1.3), and Burger_CP (2.7 ± 1.6) recorded significantly lower mean recipe waste scores compared to the overall mean, indicating that children who tasted these recipes left very little to nothing food on their plates. Other recipes, such as Soup_CC (2.9 ± 1.9), Ragout_RV (3.0 ± 1.4), Soup_TL (3.1 ± 1.8), Pasta_SR (3.2 ± 1.8), and Rice_VR (3.2 ± 1.7), showed mean recipe waste scores that did not significantly differ from the overall mean, suggesting little leftovers.

In contrast, the recipes with the highest mean recipe waste scores were Burger_C (3.3 ± 1.3), Adobada_S (3.6 ± 1.3), Soup_SL (3.4 ± 1.9), Lasagne_L (4.0 ± 1.5), and Couscous_T (4.4 ± 1.4), with around a half of the portion left uneaten.

3.5. Food habits

To explore the relationship between food habits and geographical units, a correspondence analysis was performed, considering the consumption frequency score for each food category and geographical unit. The resulting biplot is presented in Fig. 4. The first dimension (Dim1) accounted for 44.3 % of the variance, while the second dimension (Dim2) captured an additional 22.1 %, together explaining 66.4 % of the total variance.

By examining the projection of food categories and geographical units in the Dim1-Dim2 biplot, distinct patterns emerge. Pasta was negatively correlated to Dim1, strongly associated with Nuoro and Milan, indicating a higher reported consumption frequency of pasta in Italy. Similarly, meat was positively correlated to Dim1, aligning with Budapest (Hungary) and, to a lesser extent, with the Czech Republic and Bratislava (Slovakia), suggesting that children in these geographical units consume meat more frequently than in other areas.

In the third quadrant legumes and fruits were positioned, characterizing the food habits of children in Valencia. In the same quadrant, Lyon was strongly associated with legumes, while Vienna and Essen were characterized by a higher consumption of fruits. Considering the fourth quadrant (positive Dim1, negative Dim2), rice, vegetables, and potatoes appeared to define the food habits of Viimsi, Copenhagen, Belgium, Czech Republic and Bratislava, suggesting a greater consumption of these food categories by the children of these geographical units. Interestingly, Nuremberg, Umea, Tallinn, and Malmo were situated in the upper central part of the plot, mainly due to their positive correlation with Pasta and Meat.

3.6. Food neophobia

Considering the entire sample ($n = 2324$), the ICFNS demonstrates good internal consistency with Cronbach's alpha equal to 0.76. Considering the geographical units separately, variations in ICFNS reliability were observed. For Umea ($\alpha = 0.87$), Malmo ($\alpha = 0.86$), Budapest ($\alpha = 0.86$), Nuoro ($\alpha = 0.84$), Tallinn ($\alpha = 0.79$), Milan ($\alpha = 0.79$), Viimsi ($\alpha = 0.74$), Copenhagen ($\alpha = 0.72$), Belgium ($\alpha = 0.71$),

Table 5
Correlation analysis between liking (L), food neophobia (FN), recipe waste (RW) and general waste (GW).

		Vienna (Austria)	Belgium	Czech Republic	Copenhagen (Denmark)	Tallinn (Estonia)	Viimsi (Estonia)	Lyon (France)	Essen (Germany)	Nuremberg (Germany)	Budapest (Hungary)	Milan (Italy)	Nuoro (Italy)	Bratislava (Slovakia)	Valencia (Spain)	Malmö (Sweden)	Umeå (Sweden)
		Burger_B	Ragout_RV	Burger_C	Adobada_S	Soup_CC	Soup_TL	Pasta_LMC	Potatoes_CL		Lasagne_L	Pasta_SR	Soup_SL	Couscous_T	Rice_VR	Burger_CP	
X	Y	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ
FN	L	−0.16*	0.03	−0.09	−0.35***	−0.38****	−0.28****	−0.23**	−0.07	0.08	−0.30***	−0.45****	−0.32***	−0.18*	−0.28**	−0.28**	−0.31***
FN	RW	0.19*	0.14	0.14	0.33***	0.28***	0.23**	0.20*	0.25**	0.05	0.46****	0.50****	0.11	0.21*	0.39***	0.25**	0.34****
FN	GW	0.31****	0.32****	0.03	0.43****	0.12	0.08	0.29***	0.41****	0.12	0.32***	0.55****	0.46****	0.25**	0.26**	0.37****	0.41****
L	RW	−0.55****	−0.52****	−0.36****	−0.36****	−0.69****	−0.56****	−0.38****	−0.30***	−0.24***	−0.62****	−0.70****	−0.39****	−0.66****	−0.56****	−0.60****	−0.63****
L	GW	−0.25**	−0.36****	0.01	−0.29**	−0.30***	−0.18*	−0.17*	−0.09	−0.18*	−0.47****	−0.40****	−0.26**	−0.31***	−0.16	−0.29**	−0.38****
RW	GW	0.32****	0.57****	0.25**	0.42****	0.33****	0.22**	0.47****	0.17	0.42****	0.56****	0.56****	0.24**	0.36****	0.45****	0.41****	0.54****

Spearman's rank correlation coefficients (ρ) are reported. Statistically significant correlations are highlighted in bold with asterisks indicating significance level (* for $p < 0.05$, ** for $p < 0.01$, *** for $p < 0.001$, **** for $p < 0.0001$)

Essen (α = 0.71), Czech Republic (α = 0.71), and Bratislava (α = 0.70), values of Cronbach's Alpha suggest good internal consistency of the scale. Conversely, Lyon (α = 0.68), Vienna (α = 0.68), Nuremberg (α = 0.63), and Valencia (α = 0.55) showed lower internal consistency, with Cronbach's Alpha values below the recommended 0.70 (Nunnally & Bernstein, 1994). In cases where lower reliability values were observed, further investigation into the performance of the translated version of the ICFNS is warranted, particularly regarding potential issues related to cultural adaptation and translation accuracy.

The FN scores ranged from 8 to 40, with a mean across all geographical units of 22.2 ± 5.4. Fig. 5 illustrates the distribution of FN scores for each geographical unit. The Kruskal-Wallis test ($p < 0.001$) confirmed that the geographical unit had a significant effect on the FN level of children.

Among the geographical units, Copenhagen (20.4 ± 4.6), Milan (20.6 ± 5.7), and Valencia (20.8 ± 4.5) obtained significantly lower FN mean values compared to the overall mean, as indicated by the green coloring. Budapest (21.7 ± 6.0), Lyon (21.8 ± 5.1), Umea (21.9 ± 6.4), Malmo (21.9 ± 6.1), Belgium (22.2 ± 5.1), Vienna (22.5 ± 5.2), Bratislava (22.5 ± 4.7), Nuoro (22.6 ± 6.7), Tallinn (22.6 ± 5.4), Essen (22.6 ± 4.9), showed FN mean values that did not significantly differ from the overall mean, as represented in blue.

In contrast, the geographical units with the highest FN mean values were Nuremberg (23.2 ± 4.3), Czech Republic (23.2 ± 4.8), and Viimsi (23.3 ± 5.1), with values significantly above the overall mean, as indicated by the red coloring.

The FN mean values ranged from a minimum of 20.4 ± 4.6 in Copenhagen to a maximum of 23.3 ± 5.1 in Viimsi remaining close to the overall mean (22.2 ± 5.4) and indicating a relatively narrow variability in FN levels among the different geographical units. This suggests that, while significant differences were observed between some geographical units, overall, children's FN remains a relatively stable trait across all the participating countries.

3.7. *General waste*

Fig. 6 presents the distribution of general waste scores for each geographical unit. The amount of usual waste left on the plate varied significantly across the different geographical units, as confirmed by the Kruskal-Wallis test ($p < 0.001$), indicating that location played a significant role in the quantity of food usually discarded by children. The overall mean general waste score across all geographical units was 2.7 ± 1.2, aligning closely with the categorical option "A little".

Among the geographical units, Nuremberg (2.2 ± 1.2), Essen (2.3 ± 1.1), Umea (2.3 ± 1.1), Tallinn (2.3 ± 1.3), Copenhagen (2.4 ± 1.1), Malmo (2.4 ± 1.1), Lyon (2.5 ± 1.3), Viimsi (2.5 ± 1.1), and Vienna (2.5 ± 1.1) recorded significantly lower general waste mean values compared to the overall mean, indicating that children from these locations are used to leavevery little to nothing food on their plates. Valencia (2.7 ± 1.3) and Belgium (2.8 ± 1.1), instead presented mean values that did not significantly differ from the overall mean, suggesting little leftovers.

Conversely, geographical units that showed the highest general waste mean values were the Czech Republic (3.0 ± 1.0), Nuoro (3.1 ± 1.3), Milan (3.3 ± 1.4), Budapest (3.3 ± 1.0), and Bratislava (3.4 ± 1.2), suggesting that children from these units are used to leave around half of the portion as waste when they have lunch in school canteen.

3.8. *Correlation between liking, food neophobia and food waste*

In Table 5, Spearman's correlation coefficients (ρ) between FN, liking, recipe waste, and general waste across different geographical units are reported, highlighting both common trends and differences among the various contexts. A pretty consistent pattern emerges in the negative relationship between FN and liking of the evaluated recipes (range: 0.08 to −0.46). In Copenhagen, Tallinn, Viimsi, Budapest, Milan,

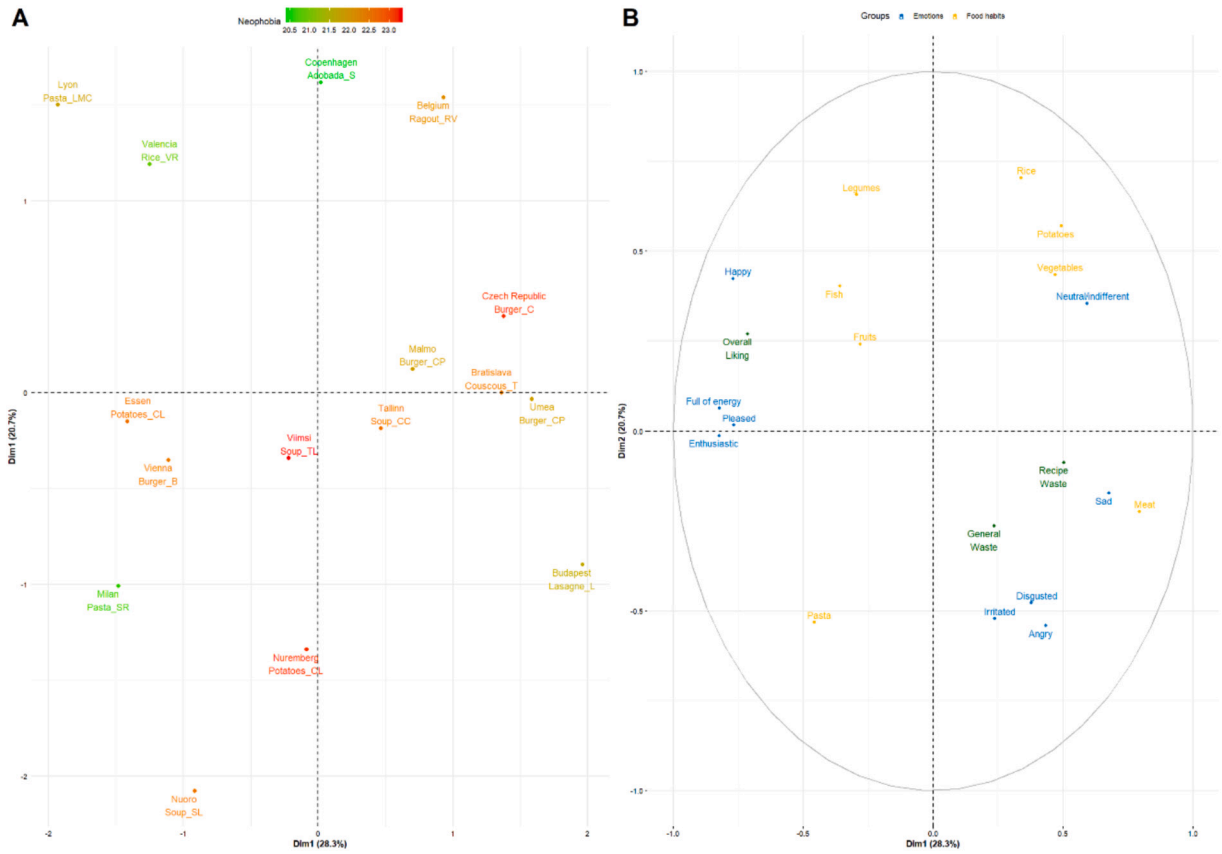

Fig. 7. ***Results of Multi Factor Analysis (MFA).*** In Figure A, a score plot is reported, containing the score values estimated for the first and second dimensions. Dots indicate the overall scores estimated for the average values for each geographic unit, colour indicates the average Food Neophobia scores estimated from the sample. Figure B reports the loading plot for the first and second dimensions. Each loading value is defined by dots and text; colour indicates the dataset of the variable. The waste and liking scores were included as supplementary variables, colored in dark green. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Nuoro, Malmö, and Umeå, this correlation was significant, suggesting that a higher level of FN in these locations is associated with lower liking scores for sustainable and nutritious recipes. However, this trend is not uniform across all units; in Belgium, the Czech Republic, and Germany (Essen and Nuremberg), no significant correlation between FN and liking was found.

FN were positively correlated with both recipe waste (range: 0.05 to 0.50) and general waste (range: 0.03 to 0.55). These relationships were significant ($p < 0.05$) in almost every geographical unit, except for Belgium, the Czech Republic, Nuremberg (Germany), and Nuoro (Italy) in the case of recipe waste, and the Czech Republic, Nuremberg, and Estonia (Viimsi and Tallinn) regarding general waste. Notably, the Czech Republic and Nuremberg (Germany) were the only locations where no significant correlation was observed between FN and food waste (both recipe and general), and also between FN and liking.

Liking and recipe waste showed a consistently significant strong negative association across all geographical units (range: −0.30 to −0.70), indicating that lower liking scores were linked to a higher amount of food left on the plate after consumption of the evaluated recipe.

Regarding the relationship between recipe waste and general waste, as expected, a significant positive correlation was found in all geographical units (range: 0.17 to 0.57), except for Essen (Germany). This suggests that food waste related to the evaluated recipes (recipe waste) mirrored children's habitual tendency to leave food on their plates during school lunches in the canteen (general waste).

3.9. MFA analysis results

The MFA results (Fig. 7) examined correlations between emotional responses, liking data, waste data (recipe and general waste), and food habits and key differences among geographic units.

The first dimension revealed a strong positive association between positive emotional responses (“Happy”, “Full of energy”, “Pleased”, and “Enthusiastic”) and liking. In contrast, negative and neutral emotions (“Angry” “Disgusted”, “Irritated”, “Sad”, and “Neutral/Indifferent”) were negatively associated with both positive emotions and liking. Recipe waste and general waste were also negatively associated with liking and positive emotions, and positively associated with negative emotions.

Interestingly, several geographical units positioned on the right side of the first dimension, such as Bratislava (Slovakia), Umeå (Sweden), Budapest (Hungary), and the Czech Republic, were associated with a higher reported frequency of meat consumption.

Considering the average food neophobia scores across geographical units, it is worth noting that this variable was not linearly associated with the first dimension, suggesting no direct aggregated relationship between neophobia and liking.

The second dimension was primarily influenced by food habit variables such as Pasta, Rice, and Legumes, which contributed to the differentiation between neutral and negative emotional responses. This dimension also reflected trends among the geographical units: high pasta consumption distinguished the Italian units (Milan and Nuoro), as well as Nuremberg. In contrast, geographical units such as Copenhagen, Belgium, Valencia, and Lyon were negatively associated with pasta consumption and positively associated with the consumption of rice and

legumes.

4. Discussion

4.1. Liking, emotional responses and waste analysis of the recipes

The results allowed us to observe different trends in acceptance across different recipe categories, suggesting that contextual and cultural factors may influence children's consumption behavior. In terms of liking scores, soups consistently positioned themselves around or below the acceptance threshold. For instance, Soup_CC in Tallinn (Estonia) hovered around the threshold, while Soup_TL in Viimsi (Estonia) and Soup_SL in Nuoro (Italy) fell below it, suggesting a generally limited appreciation for soups. This finding aligns with previous studies indicating that soups, especially when rich in vegetables or unfamiliar ingredients, may be less appealing to children, potentially due to their texture or the way flavors blend in a liquid base (Donadini et al., 2022; Liz Martins et al., 2020). However, the fact that some soups approached the acceptance threshold suggests that specific formulations, ingredient choices, or cultural influences may enhance their palatability. Plant-based burgers, on the other hand, received a more favorable response, with Burger_C in the Czech Republic and Burger_B in Vienna (Austria) achieving significantly higher liking scores, surpassing both the overall mean and the acceptance threshold. In contrast, Burger_CP in Sweden did not reach an acceptable level, highlighting the extent to which the success of plant-based recipes may depend on regional food cultures. The positive reception of some plant-based burgers supports the idea that children may be more willing to consume vegetables when presented in familiar and appealing formats, such as burgers. This aligns also with previous studies that suggest that hiding vegetables in meals by modifying their texture and presentation can significantly increase vegetable intake (Chow et al., 2022; Keller, 2014). However, the case of Burger_CP in Sweden suggests that such strategies are not universally effective and may require adjustments based on local dietary habits and expectations. Testing the acceptance of these recipes in different contexts is crucial to determine whether the intended strategy is achieving its goal of increasing vegetable consumption among children.

Similarly, pasta-based recipes exhibited variability in acceptance. Pasta_LMC in Lyon (France) received one of the highest liking mean values, reinforcing the widespread acceptance for pasta among children (Tuorila et al., 2015). Meanwhile, Pasta_SR in Milan (Italy) was positioned at the acceptance threshold, suggesting that factors such as sauce ingredients and pasta preparation may have influenced its evaluation (e.g., Caporale et al., 2009).

Beyond liking scores, the emotional responses elicited by the recipes provide additional insights into their acceptance. Neutral/Indifferent was the only emotion significantly reported for all recipes, indicating that a large proportion of children did not express strong positive or negative feelings toward the recipes. However, clear trends emerged in the association between specific recipes and emotional response. No recipe was significantly associated with the negative emotions “Sad” or “Angry.” This is consistent with previous findings showing that children tend to describe school meal experiences using predominantly positive emotions (Piochi, Franceschini, et al., 2025), which may partly explain the limited selection of certain negative terms in our study. Recipes that received high liking scores, such as Burger_B, Pasta_LMC, Potatoes_CL, Adobada_S, and Rice_VR, were also characterized by a predominant use of positive emotions, including enthusiasm, pleasure, happiness, and feeling full of energy. In contrast, Lasagne_L, Couscous_T, and Burger_CP, which were primarily associated with negative emotions, also received lower liking scores. This suggests that low liking scores often correspond with negative emotional response, reinforcing a general lack of acceptance for these recipes. Considering soups as a food category, it is interesting to note that the two soups with liking scores below the acceptance threshold (Soup_TL and Soup_SL) also had the highest percentages of participants selecting the emotion “Disgusted.” Meanwhile, the only soup that reached the acceptance threshold (Soup_CC) was associated with a more balanced distribution of positive and negative emotions. Moreover, when analyzing the three plant-based burgers (Burger_B, Burger_C, and Burger_CP), it was observed that the two burgers containing vegetables, Burger_C (carrots) and Burger_CP (coleslaw), were associated with fewer positive emotions compared to Burger_B, which was based on legumes such as beans. This finding aligns with a recent study by Pater et al. (2025), which investigated children's acceptance of plant-based meat alternatives, revealing that taste perception of these products varies depending on their ingredients and formulation. The study emphasized that children's acceptance of these products remains an understudied area in the current literature, highlighting the necessity of evaluating plant-based alternatives in real-life meal contexts (Pater et al., 2025).

Finally, to conclude the analysis of the evaluation of sustainable and nutritious recipes developed in this study, it was crucial to evaluate the food left on the plates by the children. The analysis of recipe waste revealed that the majority of recipes that had very little or no waste were also characterized by a positive emotional response and liking scores above the acceptance threshold. Conversely, most of the recipes that showed high levels of waste, approximately half of the portion, were also those with lower liking scores and a predominance of negative emotional responses. Specifically, a significant negative correlation between liking scores and the amount of food left on the plate was consistently observed across all the tested recipes, aligning with extensive previous literature demonstrating that higher liking corresponds to lower food waste. Similar results have been reported in Italy (Caporale et al., 2009; Piochi, Franceschini, et al., 2025), Spain (Bustamente et al., 2018), France (Giboreau et al., 2019), and Denmark (Thorsen et al., 2015), reinforcing the robustness of this relationship across different cultural and dietary contexts in Europe. Moreover, these results are consistent with previous literature indicating a strong relationship between food-related emotional response and perceived liking (Ng et al., 2013; Tan et al., 2024; Tuorila et al., 2015) and highlight the combined effect of these two aspects on the reduction of food waste within school canteens (Piochi, Franceschini, et al., 2025). Taken together, these findings emphasize the necessity of developing recipes that are not only nutritious but also appealing and emotionally engaging, ensuring both high consumption and minimal waste in school meal programs.

4.2. Food habits, food neophobia, and usual food waste between geographical units

Data collected on food habits across the various European geographical units showed that the Italian geographical units were strongly associated with high frequency of pasta consumption, aligning with existing literature and confirming the importance of pasta in traditional Italian gastronomy (Fernández-Alvira et al., 2013). This pattern was also reflected in the MFA results, where high pasta consumption contributed to distinguishing the Italian geographic units from the others. More broadly, the eating habits of children from the South European/Mediterranean geographical units: Nuoro (Italy), Milan (Italy), Valencia (Spain), and Lyon (France) resulted strongly associated with the consumption of pasta, fruit, legumes and fish. These findings are consistent with the principles of the Mediterranean diet, which emphasizes the daily consumption of grains, fruit, and legumes, alongside a regular intake of fish on a weekly basis (Sikalidis et al., 2021). In contrast, the geographical units located further east, such as Bratislava, the Czech Republic, and Budapest (Hungary), were associated with a higher consumption of meat and potatoes. These associations were also reflected in the MFA results, where these same geographical units appeared on the right side of the first dimension, in proximity to higher reported meat consumption frequencies. This trend aligns with dietary habits documented in Eastern European countries, where traditional meat-based dishes continue to play a central role in everyday food culture (Tomasevic et al., 2021).

Regarding FN, differences among the geographical units were observed, though they remained relatively minimal. The highest levels were recorded in Nuremberg (Germany), the Czech Republic, and Viimsi (Estonia). The presence of only slight differences in FN among countries aligns with findings from a 2020 cross-national study comparing food neophobic traits among children aged between 9 and 12 years from five European countries (Finland, Italy, Spain, Sweden, and the UK) (Proserpio et al., 2020). This relatively narrow range of FN scores in this study is likely related to the age group considered (9–15 years), a developmental phase during which FN is known to decline (Karaağaç & Bellikci-Koyu, 2022). As a result, detecting significant differences in FN across geographical units may be particularly challenging (Proserpio et al., 2020).

We have also investigated food waste, which is a pressing issue with significant environmental, social, and economic consequences. In the EU, nearly 59 million tonnes of food waste (131 kg/inhabitant) are generated each year, with 9 % arising in restaurants and food services, including school canteens (12 kg/person/year) (Eurostat, 2022). In our study, we found that across the considered geographical units, the habit of leaving food on the plate varied between “very little” and “a little”. Notably, the distribution of average waste values followed a pattern similar to that observed for mean waste recipe values, suggesting that individual food waste behaviors in school canteens are shaped not only by the acceptance of specific recipes but also by broader habitual waste patterns influenced by context, cultural and behavioral factors (Kaur et al., 2021). Although data collection was conducted anonymously and without adult supervision, it is still possible that children underreported the amount of food left on their plate due to social desirability bias. Recent findings suggest that even in low-pressure or non-observed settings, children's food-related behaviors and responses can be influenced by the desire to be perceived positively (Kelly et al., 2024).

4.3. Correlation between food neophobia, liking and food waste

In this study, a significant negative correlation was observed in most countries between FN and liking of the recipes. This findings allign with previous studies showing that higher levels of FN among children are associated with lower liking scores and reduced acceptance of school meals (Tuorila et al., 2015), unfamiliar foods (Laureati et al., 2015), and plant-based recipes (Kokkorou et al., 2023). In few geographic units no significant negative correlation was found. This may be due to a higher familiarity with the specific recipe tested, which can have attenuated the effect of neophobia on liking, as previously suggested by Donadini et al. (2021). This interpretation is consistent with the MFA results, where food neophobia scores were not directly associated with the liking of the recipes.

Consistently, FN was positively correlated with both recipe-specific waste and general waste in nearly all geographical units surveyed. These observations underline that neophobic children typically exhibit greater resistance toward tasting and accepting unfamiliar or novel foods, potentially restricting their dietary diversity and reducing their willingness to consume nutritionally balanced meals provided in school canteens. A similar pattern emerged for overall liking, which resulted to be inversely associated with both recipe and general food waste in the MFA, suggesting that recipes perceived more positively were also those with lower reported waste levels.

Although the relationships between food neophobia, liking, and food waste are well-established in the literature, this study provides additional insight by documenting these patterns across multiple European countries and diverse school contexts. While previous research has addressed these associations, many studies have been conducted within limited national contexts, with small or age-restricted samples, or adopted data collection settings that differ substantially from real-world conditions. For example, assessments of emotional responses and food waste have often relied on children's recollection of past experiences, introducing potential recall bias, or on indirect and observational methods such as photographic documentation, visual estimates, or the analysis of leftovers on trays (Boschini et al., 2020; Liz Martins et al., 2020; Piochi, Fino, et al., 2025; Piochi, Franceschini, et al., 2025). Although informative, these approaches are susceptible to measurement bias and may not capture the complexity of the eating experience from the child's perspective. In contrast, the present study implemented a real-time, child-centered assessment approach embedded within actual school canteen contexts, providing robust, ecologically valid evidence from 12 countries, involving over 2300 children. Thus, while the findings of the present research corroborate well-established associations, they also significantly extend current knowledge by demonstrating the consistency of these patterns across diverse cultural contexts and under authentic operational conditions. In this sense, the present work contributes not only confirmatory evidence but also practical insights for school food policy and public health strategies at the European level. Given the association between FN and lower acceptance of school meals, addressing this issue is crucial for improving children's dietary habits and reducing food waste in the school canteen. For example, it has been shown that school-based interventions that incorporate strategies such as reward systems, peer modeling, and repeated exposure have effectively mitigated neophobic responses and enhanced children's acceptance of new foods (Laureati et al., 2014).

4.4. Limitations, strengths and future outlook

The current study has three main limitations. First, the research employed a single-time-point design rather than a longitudinal approach. Conducting a longitudinal study evaluating existing school recipes alongside new recipes adhering to sustainability and nutritional principles would have provided more robust insights into the acceptance of these new recipes. Alternatively, assessing the same recipes repeatedly over time could offer deeper insights into how liking, emotional responses, and food waste evolve over time. In addition to this, previous research has demonstrated that repeated exposure significantly enhances children's acceptance of novel foods (Laureati et al., 2014), suggesting that future investigations should integrate repeated testing sessions to evaluate the effectiveness of progressive exposure strategies within school canteens.

Another relevant limitation relates to the variability among the analyzed recipes presents a limitation, as it complicates direct comparisons between different geographical units. Although recipes were deliberately adapted to reflect local contexts, this intentional variability introduces complexities in result interpretation. Future research could address this issue by employing standardized recipes tested concurrently across diverse geographical settings. Such an approach would allow for clearer differentiation between cultural influences and recipe-specific factors, facilitating more precise comparisons and interpretations.

In addition, the geographic units were not fully homogeneous in terms of size and sociodemographic characteristics, as often occur in cross-cultural studies (Markovina et al., 2015; Ribeiro et al., 2022; Torri et al., 2024).

Finally, although the research team applied standardized protocols and rigorous procedures, data collection was carried out by school staff who did not have specific expertise in sensory science. This circumstance might have introduced unintentional variability or bias, which cannot be entirely excluded. Similarly, despite adopting a meticulous translation procedure, the multilingual adaptation of the questionnaire remains a potential source of bias, as subtle inaccuracies in meaning may have occurred and influenced children's responses.

Despite the limitations, this study possesses a notable strength, that is its extensive scale of implementation across 16 geographical units in 12 European countries and considering cultural backgrounds within the experimental setup. To date, no studies in the literature have examined similar themes within such an extensive and diverse geographical context.

In terms of future perspectives, it would be interesting to explore the

efficacy of interventions aimed at mitigating food neophobia, such as sensory education programs, interactive cooking sessions, or repeated taste exposure activities in improving acceptance and reducing food waste across diverse European contexts.

5. Conclusions

This study underscores the importance of taking into account sensory and emotional aspects in school meal recipe design to achieve the dual goals of improving dietary patterns among children and reducing food waste. Notably, children's acceptance varied significantly according to the recipetype, with pasta-based recipesand legume-based burgers generally receiving higher sensory liking scores, while soups instead perform bad. The positive correlation between higher sensory acceptance, positive emotional responses, and reduced food waste highlights the critical need to prioritize sensory and emotional dimensions when developing sustainable and nutritionally balanced school meals. Furthermore, food neophobia was confirmed as a substantial barrier to children's acceptance of novel recipes, reinforcing the importance of strategies designed to mitigate neophobic behaviors through repeated exposure and familiarity enhancement. Future research should incorporate longitudinal and standardized assessments to clarify these cultural influences further and optimize strategies for introducing sustainable dietary practices in school contexts.

CRediT authorship contribution statement

Matteo Zanoni: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Matteo Bigi:** Writing – review & editing, Methodology. **Chiara Chirilli:** Writing – review & editing, Methodology. **Michele Ricci:** Writing – review & editing, Formal analysis. **Carol Povigna:** Writing – review & editing. **Nahuel Buracco:** Conceptualization. **Nadia Tecco:** Writing – review & editing, Project administration, Methodology. **Franco Fassio:** Writing – review & editing, Supervision, Project administration. **Luisa Torri:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2025.105732.

Data availability

Data will be made available on request.

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