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A study of the behavioral and environmental factors influencing food waste in higher education

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ABSTRACT

Food waste is a growing global problem with serious social, environmental, and economic consequences. While the overall extent of food waste worldwide is well documented, research on specific population groups, such as university students, has only recently received attention. University students represent a unique demographic group. In 2024, a survey was conducted among students at the University of Debrecen, the second largest university in Hungary, to assess their knowledge and habits related to food waste. The survey was voluntary and included 133 questions in several groups of questions. After data cleaning, we prepared our study based on the responses of 618 students. The study used variable clustering and explanatory bifactor analysis to identify and create latent constructs related to food waste behavior. Differences in these constructs were examined using the Kruskal-Wallis and Mann-Whitney tests, while K-means clustering and factor analysis of mixed data were applied to analyze demographic influences. All analyses were performed in R. The results show significant differences in food waste behavior based on age, gender, and residential location. Older students (31–40 years) showed higher levels of environmental awareness and were less likely to waste food compared to younger students (under 20 years) who showed higher levels of impulse buying and carelessness, mainly influenced by promotions. Rural students showed more sustainable behaviors, likely influenced by traditional practices such as animal husbandry, while urban students showed greater susceptibility to promotions and discounts, leading to more food waste.

1. Introduction

Food waste, broadly defined as food and the associated inedible parts removed from the human food supply chain (UNEP, 2024), contributes to the loss or waste of approximately one-third of all food produced globally (FAO, 2011). 19 % of food that reaches the consumption stage is subsequently disposed of, representing 1.05 billion tonnes, and responsible for about 8–10 % of global greenhouse gas emissions (UNEP, 2024). Reducing food waste at both household and retail levels is an important aim to achieve the Sustainable Development Goal (SDG) 12.3, which aims to halve global per capita food waste by 2030. This problem is particularly pressing in Europe, where an estimated 88 million tons of food are wasted annually, resulting in an economic loss of approximately €143 billion (Stenmarck et al., 2016). In addition, its negative environmental impact further emphasizes the need for reduction (Scherhaufer et al., 2018). These findigs triggered joint efforts to identify efficient ways to reduce food waste, especially at the consumer level (Vittuari et al., 2023). In Hungary, as in most developed regions, food

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waste is a significant problem, with the National Food Chain Safety Office (NÉBIH) Project Wasteless (Maradék nélkül) estimating that the average household wastes about 65 kg of food per capita per year (Szabó-Bódi et al., 2018; Kasza et al., 2020).

University students, including those in Hungary, represent a unique demographic group due to their transient lifestyles, limited financial resources, and fluctuating schedules, as well as their higher educational attainment and, thus, more in-depth knowledge. In addition, today's students will be tomorrow's breadwinners, decision makers, and legislators, so a better understanding of their behavior will also give us insight into the future of food waste. The differences in food consumption and waste patterns need to be studied in a targeted manner. Understanding the reasons why students waste food is critical to developing effective interventions, especially as these individuals are in the transition period between adolescence and adulthood and are forming habits that may last a lifetime. In this study, we aim to assess the attitudes of students at the University of Debrecen towards food waste, what factors influence them and how much food they throw away. Previous research has largely treated university students as a homogeneous group, but this study aims to uncover subgroup differences based on age, education level, and place of residence. To address these research gaps, this study aims to identify key factors influencing food waste behavior among university students and to determine whether demographic variables such as age, education level, and place of residence significantly affect food waste attitudes and habits.

This paper is structured as follows: First, the theoretical background provides an overview of the factors influencing food waste behavior among university students. The subsequent section outlines our research hypotheses and methodological approach, detailing the survey structure and statistical techniques used. The results section presents key findings on demographic influences and behavioral clusters. Finally, the discussion interprets these results in the context of existing literature, highlighting policy implications and future research directions.

2. Theoretical background

2.1. Dietary habits and factors influencing food waste among university students

University students represent a unique population whose food consumption habits may have a significant impact on food waste generation (Ajina et al., 2024; Mi et al., 2024). Numerous studies have shown that a variety of factors, including lifestyle changes, the transition to independent living, and the availability of food alternatives both on and off campus, can directly influence changes in the behavior of university students (Li et al., 2021; Sánchez et al., 2021; Wang et al., 2022; Zhang and Jian, 2024). It is therefore essential to understand this relationship in order to develop effective interventions to minimize food waste among university students.

Lifestyle-related factors are critical to the generation of consumer food waste (Aschemann-Witzel et al., 2021; Myhrer et al., 2024). College students often exhibit irregular eating patterns due to their hectic schedules, academic pressure, and social activities (Pendergast et al., 2016). This inconsistency can lead to overspending and ineffective meal planning (Colatruglio and Slater, 2016; Murray et al., 2016; Stilling and Malene, 2012), both of which contribute to food waste. In addition, students are increasingly choosing ready-to-eat fast food meals to support their busy lifestyles (Bipasha and Goon, 2013). However, convenience foods often come in larger portions or multi-pack formats that are not always fully consumed, leading to increased food waste (Filho et al., 2021). In this context, university dining halls play a crucial role and offer a significant opportunity to reduce food waste by regulating the portion sizes of meals served in central locations (Filho et al., 2021). In addition, providing students with effective information on food waste about food waste is essential to empowering them to reduce waste (Filho et al., 2021). A number of programs have been successful in working with university students to reduce food waste. These include the provision of food banks or pantries for students who are food insecure and the implementation of meal swipe contributions to address food waste concerns in university settings (Musicus et al., 2022).

The institutional and environmental contexts in which students acquire and consume food also influence food waste (Filho et al., 2021). For example, university campuses with buffet-style dining halls tend to generate more food waste than those with à la carte dining alternatives (Filimonau et al., 2020; Martin-rios et al., 2018). Buffet-style dining halls, particularly those with an all-you-can-eat system, are particularly wasteful because consumers tend to choose larger amounts of food, resulting in higher levels of food waste (Filimonau et al., 2020; Juvan et al., 2017; Sakaguchi et al., 2018). This type of service results in more food being served than can be consumed, increasing the amount of food waste (Filho et al., 2021). Furthermore, buffet-style settings have been found to increase plate waste due to psychological factors, such as the large number of food choices available (Cozzio, 2021). The results of the study by Akhter et al. (2024) showed that several factors, such as attitudes, behavioural control, knowledge about food waste, moral standards, eating habits, and leftover reuse routines, have a significant impact on students' desire to avoid food waste. Knowledge about food waste was by far the most significant factor associated with the desire not to waste food.

2.2. Intervention and educational programs on food waste among university students

Given that students require effective knowledge of food waste in order to prevent the higher generation of food waste (Alarinta and Wirtanen, 2023), addressing food waste among university students requires a holistic approach that includes targeted interventions and educational programs that influence behavior and support sustainable behaviors. A number of interventions have been shown to be effective in overcoming student behavioral challenges related to waste minimization (Ahmed et al., 2018; Alattar and Morse, 2021; Bailey et al., 2020; Gonçalves, 2021; van Herpen et al., 2023; Knezevic, 2019). One of the most common strategies to address food waste in universities is the implementation of awareness campaigns. These campaigns aim to reduce food waste by increasing student awareness and knowledge of the issue (Falasconi et al., 2019; Mirosa et al., 2016; Wang et al., 2022). Awareness campaigns have the potential to encourage students to adopt more sustainable behaviors by highlighting the relevance of the issue and providing realistic perceptions of food waste (Burlea-Schiopoiu et al., 2021).

Mi et al. (2024) have shown that by leveraging the flexibility and influence of university students, campaigns emphasizing the necessity to prevent food waste, especially through social media, can have a positive impact on reducing food waste. Furthermore, environmental education programs have also been shown to be effective in reducing plate waste in university dining halls by increasing awareness of daily food waste (Wang et al., 2022).

Moreover, research has shown that awareness campaigns can be effective in influencing individuals' food waste behaviors (Soma et al., 2020). As observed by Mganga et al. (2021), the primary factors motivating students to avoid or reduce food waste were their understanding of the negative effects of food waste on the environment, society, and the economy, as well as their perception of their own behavioral control.

Furthermore, raising awareness and encouraging behavior change toward reducing food waste among university students may also be achieved through educational workshops and classes on the topic (Fraj-Andrés et al., 2023; Wang, 2024). As demonstrated by Ahmed et al. (2018), student involvement in the planning, implementation, and assessment of a multi-component food waste intervention that included portion control, educational messaging, and the use of smaller serving utensils was instrumental in modifying the attitudes and behaviors of the students toward food waste. In addition, the implementation of

student dining hall internship, which provides students with experience in food knowledge and awareness of food waste concerns, has been shown to have a beneficial influence on reducing food waste (Wang, 2024). Furthermore, workshop activities have been demonstrated to be an effective and engaging method for influencing students to reduce waste. This was evidenced by the success of cafeteria program activities, including the use of messaging, interactive activities, and visual examples of food waste, which have been shown to correlate with a reduction in food waste generation among students (Alattar and Morse, 2021).

Previous studies have considered university students as a single group. In the present study, we also seek to find out whether there are significant differences in the habits of students according to their level of education, gender, age, and the type of place of residence (village, city, county). This will help us to gain a deeper understanding of the habits of higher education students and to target measures for this group. Our study is incomplete in the sense that it does not treat university students as a homogeneous group, but tries to explore the differences within the group.

Based on the reviewed literature, it becomes evident that several factors, including demographic characteristics and purchasing behavior, influence students' food waste habits. To further explore these relationships, we formulate the following hypotheses:

Hypothesis 1.

There is a correlation between the age of the respondents and their food wasting habits, the older someone is, the less wasteful they are.

Hypothesis 2.

Food waste habits differ depending on whether the student comes from a rural or urban environment. Rural students are more conscious than urban students.

Hypothesis 3.

There is a positive correlation between education and food waste mitigiation. People with higher education waste less.

Hypothesis 4.

Students at the University of Debrecen waste less food than the national average.

3. Material and methods

To empirically test these hypotheses, we employed a structured survey methodology, incorporating statistical analyses to examine demographic and behavioral factors influencing food waste.

In 2024, a survey was conducted among students at the University of Debrecen, the second largest university in Hungary, to assess their knowledge and habits related to food waste. The survey was voluntary and included 133 questions in several groups of questions. After data cleaning, statistical analysis was conducted based on the responses of 618 students. Informed consent was provided to participants in the ethical considerations section, which detailed the purpose of the study, the anonymous nature of the respondent's participation, no specific requests for identity, data use, and voluntary participation. All responses were kept confidential and will only be used for research and scientific articles.

In the first phase, variable clustering (VARCLUS) was used to identify the structure of the items in the food waste behavior questionnaire, as well as the number of latent constructs to create. In the second phase, explanatory bifactor analysis was used to identify and create latent constructs using the Schmidt-Leiman transformation, and the so-called omega measure was calculated for internal reliability. McDonald's omega (McDonald, 1999) was used instead of Cronbach's alpha because the assumptions of Cronbach's alpha are often violated (Hayes and Coutts, 2020). The present study calculated omega using the square of the sum of the factor loadings from a bifactor model (McDonald, 1999). Variables with a loading less than 0.3 were excluded from the construct. After the explanatory analysis, a confirmatory bifactor analysis was performed. The Kruskal-Wallis test was used to look at differences in factor scores by age, and place of residence. In the case of gender and education level (lower vs. higher), the Mann-Whitney test was employed to compare the mean differences. In both non-parametric tests, the significance level was set at 5 % because the sample size was large enough. The K-means clustering algorithm was used to group respondents based on their perceived personal and national average food waste in kilograms. These food waste level groups were compared to the food waste behavior-related factors by using the Kruskal-Wallis test. The cluster characteristics and differences with respect to age, gender, place of residence, and education were examined using a chi-squared test with respect to gender, age, and place of residence. In order to visually represent the connection between food waste level clusters and food waste behavior factors together with the most influential demographic factors (age and place of residence), Factor Analysis of Mixed Data (FAMD) was used. All calculations were done in R Core Team (2023). To calculate VARCLUS, the Hmisc, Psych, and lavaan packages were used to perform hierarchical and confirmatory bifactor analyses and calculate the omega coefficient. FactoMineR package was employed to perform FAMD analysis. For cluster analysis, the packages EMCluster (for model-based clustering), stats (for k-means and HCA), cluster (for PAM), and ClusterCrit (for calculating Silhouette, Dunn, and C indices) were used. Fuzzy C-Means clustering was performed using the e1071 package. The NbClust package was used to determine the optimal number of clusters.

3.1. Cluster analysis

3.1.1. Variable clustering with VARCLUS

In large datasets, identifying irrelevant inputs is harder than it is for redundant ones. One approach is to first address redundancy and then tackle irrelevance in a lower-dimensional space. Variable clustering, related to principal component analysis, can eliminate redundant dimensions. The VARCLUS procedure can eliminate dimensions that aren't essential for the model. The procedure can also help reduce the number of variables used to build the segmentation model. The method tries to identify groups of variables that are as similar as possible while avoiding similarity with variables in other groups (Nelson, 1991). Vigneau and Qannari (2003) also suggested that clustering variables around latent components may be helpful for organizing multivariate data into meaningful structures. The goal is to identify clusters of variables around latent components. This process also detects the number of variable blocks in the dataset. The VARCLUS method was applied with hierarchical clustering and Ward's method. The Spearman's rank correlation coefficient was also used to measure the correlation between the latent components and the variables.

3.1.2. Cluster analysis of the respondents

To establish clusters on food waste level, perceived personal food waste, and the national average food waste were considered, and six clustering methods were tested, using Calinski-Harabasz (Caliński and Harabasz, 1974), Silhouette (Rousseeuw, 1987), Dunn (Dunn, 1974), and C-indices (Hubert and Levin, 1976) as internal measures of clustering goodness. A particular clustering solution can be considered superior to others if it has the highest value of the Calinski-Harabasz, Silhouette and Dunn indices and the lowest value of the C-index. The rationale behind testing so many clustering methods was to provide a well-established clustering. Therefore, the authors used the most commonly applied techniques, such as Hierarchical Cluster Analysis (HCA) with Ward's method (Ward, 1963), K-means clustering with MacQueen's (MacQueen, 1967), and Forgy methods, together with some advanced techniques, such as model-based clustering (McNicholas, 2016) Fuzzy C-means clustering (Dunn, 1974; Pal et al., 1996) and Partition Around Medoids (PAM) (Kaufman and Rousseeuw, 1990). Finally, K-means clustering /MacQueen/ with four clusters provided the most appropriate solution based on the selected cluster quality indices.

3.1.3. Explanatory and confirmatory bifactor analyses

An explanatory bifactor model was used to identify the most influential latent constructs and indicators. The following equations were used to estimate the factors score (Flora, 2020):

$$x_j = \lambda_{jg} g + \sum_{k=1}^{K} \lambda_{jk} f_k + e_j \quad (1)$$

$$X = \sum_{j=1}^{J} x_j \quad (2)$$

The symbol x_j represents the j-th item score, while X denotes the total score. λ_{jg} is the factor loading for item x_j on the general factor g, while λ_{jk} is the factor loading for item x_j on the k-th specific factor f_k. The omega total coefficient was calculated using the loadings from Eq. 1 and the sample variance of X (σ_X^2) (Flora, 2020):

$$\omega_{total} = \frac{\left(\sum_{j=1}^{J} \lambda_{jg}\right)^2 + \left(\sum_{j=1}^{J} \sum_{k=1}^{K} \lambda_{jk}\right)^2}{\sigma_x^2} \quad (3)$$

The omega coefficient was calculated separately for each specific and general factor, indicating the total reliable variance explained. The explanatory analysis was followed by a confirmatory analysis. For the confirmatory analysis, the authors used the same blocks, identified in the explanatory analysis (Fig. 1). The fit of the confirmatory bifactor model (Fig. 1 and Table 1) was evaluated using the chi-square test, Tucker-Lewis index (TLI) (Tucker & Lewis, 1973), comparative fit index (CFI) (Bentler, 1990), the root mean squared error of approximation (RMSEA) (Steiger, 1990), and the standardized root mean square residual (SRMR) (Byrne, 1994). The threshold for TLI and CFI was set at 0.9, with higher values indicating a good model fit. Conversely, a value below 0.08 for SRMR and RMSEA indicates a proper model fit (Byrne, 1994).

3.1.4. Factor analysis of mixed data

Finally, the factor analysis of mixed data (FAMD) technique (Pagés, 2014) was applied to create a map representing the respondents together with both continuous (components related to food waste behavior) and categorical data (age, place of residence, food waste level clusters). This map can highlight and summarize any relationships that exist in the data. The analysis includes a correlation circle that can help interpret the two dimensions of the map and three profiles that represent respondents with different colors in terms of age, location, and food waste level.

4. Results

The VARCLUS method was employed to identify the clusters of the most correlated variables in the Food Waste Behavior questionnaire. During the procedure, seven different blocks containing mostly four items were formed. Fig. 1 presents these blocks, where the first one separates items related to planning and awareness (14,17). The second block, which included questions 1, 2, 4, and 16, represented the avoidance of food waste. The third cluster is formed by questions 3, 15, 18, 22 and 26. The fourth block, which separated questions 11, 12, 21, 20, and 23, mainly indicated the wasted money and work. The fifth block clearly indicated the environment conscience, as evidenced by questions 24,25,27. The sixth block clearly indicated carelessness as the reason for food waste (questions 7,8,9,10). The final cluster consists of questions regarding price reductions and special offers (5,6,13,19).

The results of the VARCLUS clustering procedure applying Ward clustering and Spearman's correlation yielded seven variable blocks. Therefore, in the explanatory (hierarchical) bifactor analysis, seven components were used. Additionally, the total reliable variance for each specific vector was also reported (Table 1).

It should be mentioned that f2, f4, and f7 contained negatively worded questions. Therefore, the factor loadings were negative. In the analysis of food waste attitude, a general behavior factor was created and mainly defined by "environment protection," "less disposable stuff is better, "I don't throw out food," "It's worth dealing with in primary school," and "Selective waste collection is important." In addition, hierarchical bifactor analysis and VARCLUS analysis also isolated the following latent constructs: f1: Financial reasons; f2: Carelessness; f3: Environmentalists; f4: Discount seekers; f5: Planners. Omega coefficients were high (above 0.6), except for construct f6 and f7, which were omitted from further analysis. The highest omega can be observed for f1 and f3 special factors. The explanatory model's RMSEA value ranges between 2.6 and 3.8 percent, with an average of 3.2, indicating an appropriate model fit with a Chi-squared value of 331.27 ($p < 0.001$). In addition, the confirmatory model confirmed the structure as the fit was adequate (TLI and CFI >0.9; RMSEA and SRMR <0.08).

Table 2 shows that the sample contained mostly city residents (42.4 %) and students from county towns (40.6 %). Only one-sixth of the sample originated from villages. Age distribution indicated the 21–30 age group as the most frequent category (71.3 %), 12.2 % were from the 31–40 age group, and 8.8 % from the 41–50 group. The youngest and oldest age groups were represented by only 3.6 and 4.1 %, respectively. It should be noted that the sample includes not only full-time students but also part-time students, who typically study later in life while working for their existing job or to move on from it. This is due

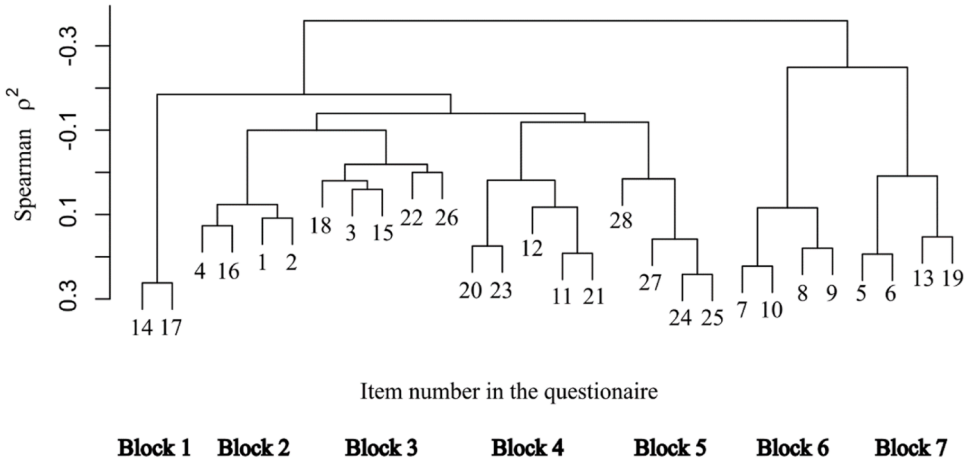

Fig. 1. Divisive Clustering and block structure of the variables in the Food Waste Attitude Scale.

Table 1
Explanatory bifactor analysis of the food waste behavior scale items.

Item	General factor	Specific factors						
	g	f1	f2	f3	f4	f5	f6	f7
I would feel embarrassed (1)	0.30	0.35						
Children should never throw out food (2)	0.36	0.40						
No time to deal with it (3)			−0.31					
Food has a value (4)	0.41	0.42						
I over plan my shopping (5)					−0.30			−0.46
I buy more groceries during sales (6)			−0.30		−0.50			
Food spoils in the fridge (7)			−0.63					
I cook more food (8)			−0.63					
A lot of food is thrown out after family events (9)			−0.59					
If I were more careful (10)			0.61					
It's worth dealing with in primary school (11)	0.51						0.41	
Think about what you need before buying (12)	0.40						0.54	
I buy larger quantities because of the discounted price (13)					−0.78			
I don't plan ahead (14)						0.50		
I know what's in the fridge (15)								
I don't throw out food (16)	0.51		−0.38					
I make a shopping list (17)	0.32					0.80		
More food on my plate (18)			−0.38					
Big packs are better value (19)					−0.46			
I am concerned about the money wasted (20)	0.36	0.36						
Hungary is also seriously affected (21)	0.40	0.34						
I cook by feel (22)								
I concern about the unnecessary work (23)	0.42	0.43						
Environment protection is important (24)	0.62			0.45				
Less disposable stuff is better (25)	0.53			0.42				
Quality matters over price (26)								
Selective waste collection is important (27)	0.44			0.50				
I like gardening (28)								0.30
Total reliable variance /Omega/	0.86	0.71	0.63	0.71	0.60	0.67	*0.57*	*0.14*

Note: Factor loadings lower than 0.3 were not depicted; the negative loadings indicate reverse questions. Only Items with loadings greater than 0.3 were used in the confirmatory model.
Explanatory model: RMSEA index was 3.2 % [90 % CI: 2.6 – 3.8]; Chi-squared = 331.27, $p < 0.001$
Confirmatory model: RMSEA: 0.069; CFI= 0.94; SRMR= 0.079; TLI= 0.927; Chi-squared = 885.91, $p < 0.001$
f1: financial reasons; f2: carelessness; f3: environmentalists; f4: discount seekers; f5: planners; f6: time consumed; f7: cook by feel

Table 2
Sample characteristics with respect to gender, age, and place of residence.

Gender	percentage (%)
Male	29.1 %
Female	70.9 %
Age	
18–20	3.6 %
21–30	71.3 %
31–40	12.2 %
41–50	8.8 %
51 <	4.1 %
Place of residence	
Village	17.0 %
City	42.4 %
County town	40.6 %

N = 618

to the higher age group in the sample.

59 % of the sample had only primary education, 25 % had college/university degrees from other sciences, 15 % had college/university degrees from natural sciences, and 1 % of the sample had only vocational schools. Another important factor is that students can study at four levels of education at the University of Debrecen, such as higher education vocational training, bachelor (BSc/BA), master (MSc/MA), and doctoral (PhD/MBA), and therefore there is a difference in the level of education they have already obtained and their age.

The Kruskal-Wallis analysis revealed that the financial reasons /f1/ (H=15.03; $p = 0.005$), environmentalists /f3/ (H=28.59; $p < 0.001$), discount seekers /f4/ (H=17.67; $p = 0.001$), and planners /f5/ (H=11.59; $p = 0.021$) exhibited significant differences in relation to age. Even the general food waste attitude varied between age groups (H=28.59; $p < 0.001$). Pairwise comparisons using the Mann-Whitney test revealed a significant difference between the under 20 and 41–50 age groups and the 31–40 and over 50 age groups for financial reasons. For environmental issues, the lowest scores of the 21–30 age group were the responsible for the significant differences compared to other age groups. The differences for the planning factor were driven by the lowest score of the youngest age group (<20).

The 31–40 age group showed the greatest level of awareness regarding food waste, as indicated by the general factor, with a score of 0.24. In contrast, the youngest cohort (under 20 years) demonstrated the lowest level of awareness, with a score of −0.23. Moreover, individuals over the age of 30 exhibited a greater degree of environmentally conscious behavior than those in the 21–30 age group. The oldest age group (over 51) placed greater importance on financial considerations, as indicated by a score of 0.13, in comparison to the youngest cohort (under 20), which obtained a negative score of −0.21. Additionally, food waste resulting from the purchase of additional items due to promotional offers and discounts was more prevalent among individuals in the under-40 age group. This was less of a concern for the over-40s. The practice of planning, or the preparation of a list, was less prevalent among younger (-0.42) and older individuals (-0.15) and more common among those in the age range of 31–50 (0.07 and 0.08), as Fig. 2. shows. This supports Hypothesis 1, which states that „There is a significant relationship between the age of respondents and their food wasting habits, the older someone is, the less wasteful they are."

The tornado chart (Fig. 3) showed the different factors by the place of residence. The Kruskal-Wallis test at a 5 % significance level showed a significant difference for the financial reasons (f1) and carelessness (f2) (H=6.28; $p = 0.043$ and 18.67; $p < 0.001$, respectively). According to the place of residence, it can be seen that there was less wastefulness for financial reasons in the villages (0.07) and in the county towns (0.06)

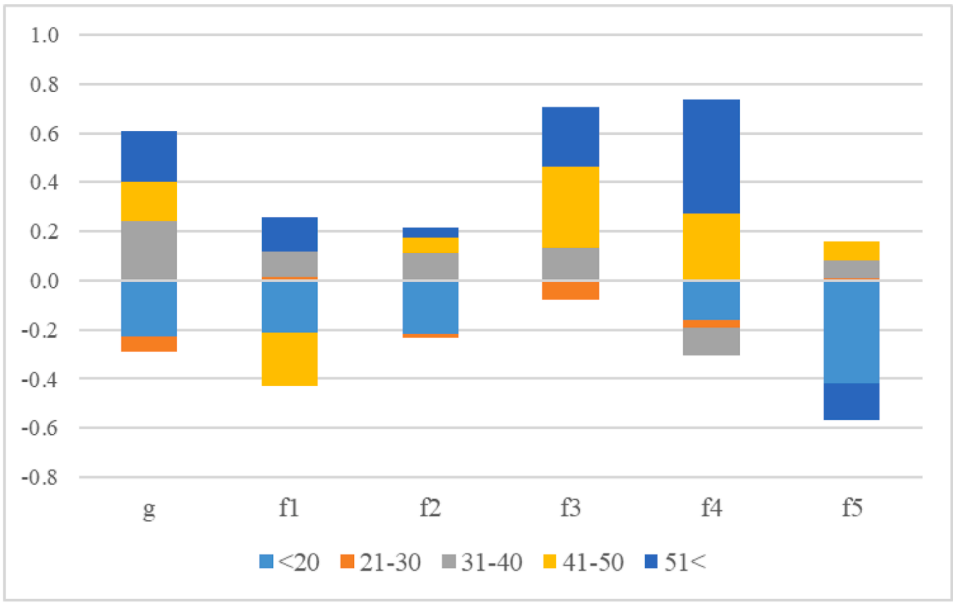

Fig. 2. Tornado chart of age differences in the food waste behavior-related components.

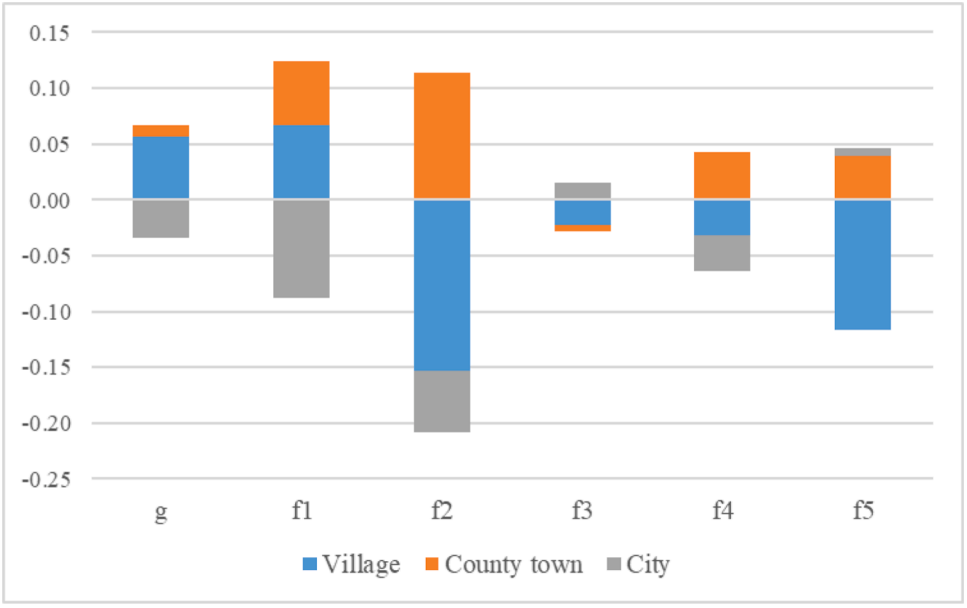

Fig. 3. The influence of the place of residence on food waste behavior.

compared to cities (-0.09). Respondents in cities showed less responsible behavior (-0.06), county towns were more careful not to waste (0.11), and villages were less careful (-0.15). This support our Hypothesis 2. Food wasting habits differ depending on whether the student comes from a rural or urban environment. Rural students are more conscious than urban students. The Mann-Whitney test showed significant pairwise differences between students in cities and county towns with respect to responsible food waste behaviour ($Z = -3.03$; $p = 0.002$) and financial attitude ($Z = -2.28$; $p = 0.023$).

By gender, only the general ($Z = -2.82$; $p = 0.005$) and the planning ($Z = -3.82$; $p < 0.001$) factor differed significantly using the Mann-Whitney test at 5 % significance level. Women (0.07) showed more responsible behavior than men (-0.16) on the general attitude scale. Women were significantly more planning and relatively more concerned about the financial side of food waste.

The tornado chart (Fig. 4) showed the development of different factors by educational level. The Mann-Whitney test at a 5 % significance level determined a significant difference in the general factor ($Z = -3.56$; $p < 0.001$) and the environmental issues ($Z = -4.27$; $p < 0.001$). According to the educational level (lower vs. higher), it can be seen that respondents with lower education were the least exposed to the influence of promotions, but they were highly affected by carelessness and were less concerned about the environmental issues of food waste. The group with higher level of education showed greater level of awareness regarding food waste, as indicated by the significantly different general factor. Accordingly, we accept Hypothesis 3, which states that there is a significant connection between education and food waste. People with higher education waste less.

The next step in the investigation was to create groups of food waste levels in terms of perceived food waste in kilograms (personal, and

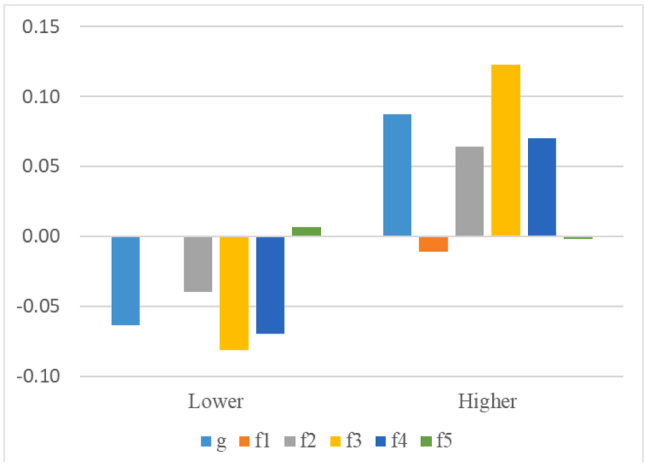

Fig. 4. The relationship between educational level and components of food waste behavior.

national average). Among the six clustering methods (Table 3), K-means clustering (MacQueen's method) with four groups was selected because it produced the best clustering based on the quality measures studied (Calinski-Harabasz, C-index, Dunn, Sihouette). The higher the index value, the better the cluster quality, except in the case of the C-index.

The four clusters were as follows: low, medium, high, and extreme. The low food waste group comprised the largest proportion (72.2 %) of the sample, followed by the medium and high groups with 13.4 % and 11.8 %, respectively. In addition, the size of the extreme food waste group was relatively small (2.1 %).

Respondents were also asked to estimate their own annual food waste and the average national food waste. In the low food waste group, respondents estimated their own personal food waste to be 12 kg. These estimates were 20 kg in the medium group and 53 kg in the high group. In the extreme food waste group, respondents reported 212 kg of personal food waste per year. Students in the low, medium and high categories estimated the national average annual food waste to be 44, 62 and 152 kg respectively, while the extreme group estimated 311 kg. The mean personal food waste for the total sample was 23.2 kg, with a standard deviation of 37.4 kg. The results are lower than the national average (65 kg) published by the NÉBIH (Kasza et al., 2020), supporting Hypothesis 4.

Among the five identified components, three were significantly different in the identified food waste levels, such as carelessness (f2, H=29.57; $p < 0.001$), environmentalists (f3, H=14.84; $p = 0.002$), and discount seekers (f4, H=10.04; $p = 0.018$). The pairwise Mann-Whitney comparisons revealed that the significant differences were due to lower scores in the middle and higher scores in the extreme clusters for promotion ($Z = -2.23$;$p = 0.026$). For carelessness (f2) and environmentalists (f3), there were significant differences between the low and medium levels (f2: $Z = -4.03$; $p < 0.001$ and f3: $Z = -3.03$; $p = 0.002$) and between the low and extreme levels (f2: $Z = -3.45$; $p = 0.001$ and f3: $Z = -2.36$; $p = 0.018$), respectively.

As can be seen in Fig. 5, the medium level was more exposed to the negative impact of promotions by overspending and buying more than necessary. Interestingly, the extreme-level respondents were the least exposed to the influence of promotions, but they were highly affected by carelessness and were less concerned about the environmental issues of food waste. There was a significant difference between the medium and the higher levels in terms of factors f1 and f4. Respondents in the medium level were relatively more concerned about food waste due to financial reasons, and students with higher levels of food waste were less exposed to promotions. The extreme cluster contains relatively high proportion (77 %) of students with a lower level of education (primary or vocational school) compared to the other clusters, where this proportion was around 60 %.

Fig. 6. presented the results from the FADM analysis. It presented the data from different points of view (age, place of residence, food waste level profile) and visually summarized the results discussed earlier. The correlation circle showed the relationship between the axes and variables. The x-axis was related to f2 and the general component. The y-axis was best described by f4, f3, and f1. From the food waste level profile, it can be seen that the x-axis separated the low level from the others in terms of carelessness (f2) and the general component (g). Respondents from the low food waste level group were located to the right (positive side) of the x-axis, indicating a higher level of responsibility and awareness of food waste. The y-axis separated the medium and the higher food waste level groups based on f4 and f1. Financial concerns and greater exposure to promotions may be associated with the medium level (downward). The age profile clearly showed that the 41–50 age group (pink) was more prevalent in the high food waste level, and the extreme level group consisted of relatively younger students (<20 years). There were relatively more 21–30-year-old respondents in the medium group, and the oldest respondents were more prevalent in the low food waste level group. It could be seen that there were more students from villages in the medium and especially in the extreme food waste group. County towns were more prevalent in the low and high food waste groups. The correlation circle also showed that environmentalists were negatively correlated with financial concerns. In general, those who had more financial concerns were less environmentally conscious (medium group). On the contrary, those who belonged to the high food waste group were less concerned with the financial side of food waste but were relatively more environmentally conscious.

The results highlight significant differences in food waste behaviors among students based on demographic variables. In the following section, we discuss these findings in the context of the existing literature and explore their implications for future interventions aimed at reducing food waste among university students.

Table 3
Cluster quality measures by method and number of clusters.

Method	Number of clusters	Calinski-Harabasz	C-index*	Dunn	Silhouette
K-means	3	248	0.053	0.014	0.187
(Forgy)	4	309	0.061	0.014	0.278
	5	292	0.099	0.018	0.254
K-means	3	296	0.043	0.028	0.274
(MacQueen)	**4**	**312**	**0.045**	**0.028**	**0.317**
	5	294	0.088	0.001	0.246
Hierarchical	3	179	0.118	0.012	0.180
Clustering	4	222	0.095	0.012	0.198
	5	273	0.069	0.031	0.307
Partition Around	3	234	0.095	0.010	0.172
Medoids	4	222	0.109	0.011	0.197
	5	213	0.128	0.010	0.239
Model-based	3	144	0.130	0.005	0.068
	4	156	0.156	0.005	0.085
	5	186	0.175	0.009	0.131
Fuzzy	3	267	0.077	0.010	0.212
(C-means)	4	285	0.073	0.021	0.250
	5	289	0.092	0.009	0.240

* : The lower value indicated the better quality

5. Discussion

This study provides valuable insights into the food-wasting behavior of university students in Hungary, specifically at the University of Debrecen. The results confirm all four hypotheses and provide a more nuanced understanding of how demographic factors such as age, place of residence and education level influence food-wasting behavior.

Based on the estimated amount of food waste, the students were classified into 4 clusters. Interestingly, in each cluster, they estimated their own waste to be lower than the national average, so even extreme consumers felt that they were producing less food waste than the

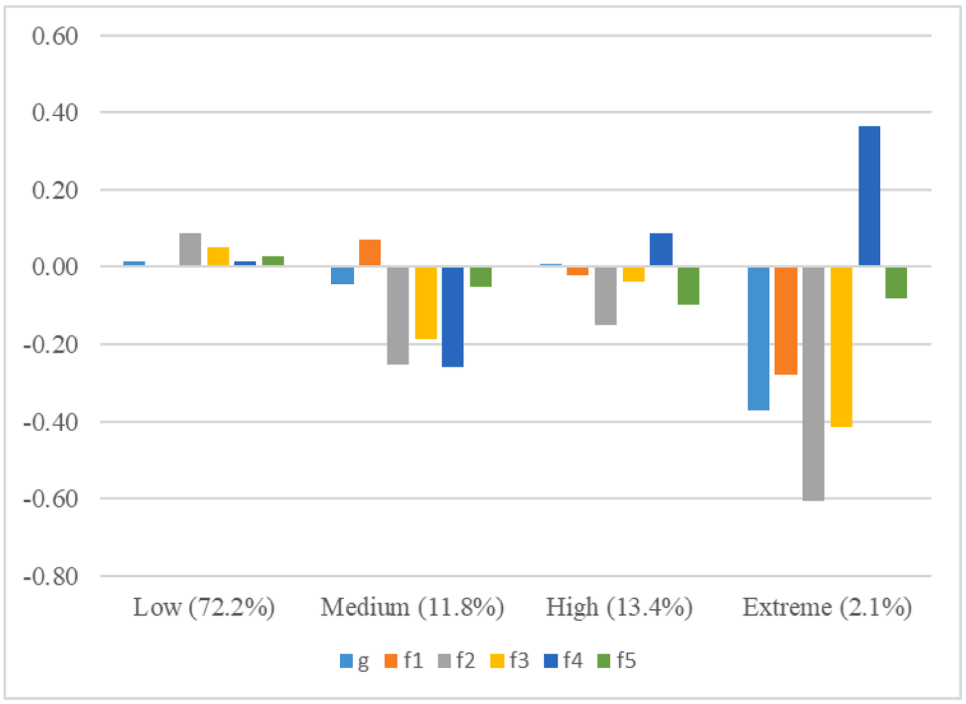

Fig. 5. The relationship between food waste level clusters and food waste behavior components.

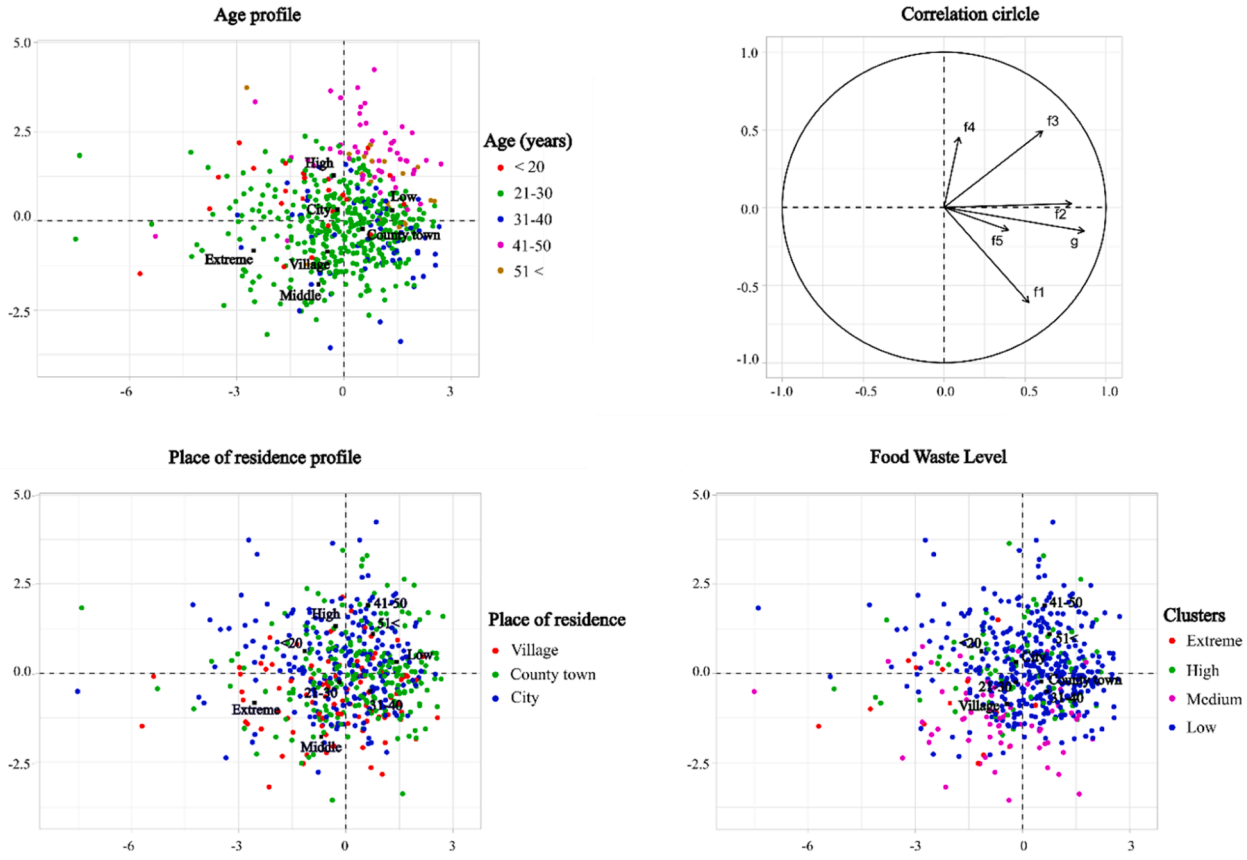

Fig. 6. Factor Analysis map of respondents by age, location, and level of food waste.

national average.

The results show that older students (31–40 years old) are more environmentally conscious, while younger students (under 20 years old) are more prone to waste food. Similar patterns were found in the study by Wang et al. (2022). This may be because, while older students are already self-sufficient and the family breadwinners (typically, these

students are studying part-time at university while working), they are more aware of the value of the money they earn and therefore organise their households more carefully. In contrast, young students manage their parents' money, which they are less careful about.

The results corroborate previous findings by Pendergast et al. (2016) and Sánchez et al. (2021), who identified lifestyle-related factors such as hectic schedules and inadequate meal planning as major contributors to food waste among students. Extreme food wasters show significantly higher levels of neglect (f2), highlighting the need for targeted interventions to address careless behavior. Low waste groups show higher levels of environmental awareness (f3), highlighting the importance of developing sustainable habits to reduce waste. Moderate wasters are most influenced by promotions (f4), suggesting that educational campaigns are needed to address impulse buying and promotion-driven behavior. Extreme food wasters are predominantly younger, urban students, while low food wasters are older, rural students, highlighting the role of demographics in shaping wasteful behavior.

However, the focus of this study on Hungarian university students highlights unique cultural and socio-economic factors. For example, the tendency of urban students to waste more food due to promotional offers underscores the need for targeted educational interventions tailored to their specific consumption patterns.

Excessive shopping and lack of proper planning are global problems among younger generations and are also observed among Hungarian students. It is noteworthy that urban students were more likely to waste food, especially under the influence of promotions and discounts, while rural students were less susceptible to this effect.

The results are consistent with international research, such as the studies by Sánchez et al. (2021) and Filho et al. (2021), which also found that students with higher levels of education and older students are more environmentally aware and more likely to participate in food waste reduction programs. Moreover, the observed correlation between higher levels of education and reduced food waste is consistent with global studies, such as those by Knezevic (2019) and Mi et al. (2024). These studies highlight the role of education in fostering critical thinking and sustainable habits. However, the present study found unique results for the specifics of the Hungarian university environment: for example, among Hungarian students, rural students are less wasteful than urban students, where promotional offers and impulsive shopping habits led to higher food waste.

Although backyard animal husbandry is becoming less and less common in Hungary, a significant proportion of rural university students still grow up in such an environment, which may influence their habits. In rural areas, where both livestock and crop production can be found in the gardens, zero waste and a circular economy could be practically achieved. These environmentally conscious habits will be retained by the children who grow up here as university students. In contrast, students growing up in the city do not encounter this and it is not built into their daily habits.

It should be noted that lifestyle and eating habits also play a significant role in food waste. Students often do not pay enough attention to meal planning due to lack of time and overcrowded schedules, which increases food waste. Although this study focused on food waste behaviors, further investigation into the proportion of students who rely on university dining halls, markets, or self-prepared meals is essential to contextualize the findings. Our studies also looked at where students obtain the food they eat. Contrary to the findings of international research, a higher proportion of our results identified self-shopping and cooking as a source of food, with relatively few respondents reporting that they bought their food from university dining halls, canteens, or restaurants. This part of the research and its detailed findings were not developed in this article. The findings are consistent with that described by Pendergast et al. (2016), who also found that students' hectic lifestyles contribute significantly to food waste. However, the present study sheds new light on the possibility that the impact of impulse buying and promotions may be more significant among Hungarian students, which calls for more targeted interventions.

These insights underline the importance of tailored interventions that address the specific needs and behaviors of different student groups. The next section summarizes key findings and outlines potential future research directions.

6. Conclusions

In this research, we have offered a framework for understanding food waste behaviour among the young generation which will help in comprehending food waste management and prevention of food waste. Several elements that influence food waste patterns have been identified.

This study makes a significant contribution to the literature by examining food waste behavior in the specific context of Hungarian university students. The results highlight the specific demographic and cultural factors that influence food waste and provide a basis for local interventions. For example, the prevalence of impulse buying among younger urban students suggests the need for awareness-raising campaigns that emphasize the financial and environmental impacts. In contrast, the sustainable practices of rural students can serve as a model for developing educational programs.

The study successfully identified patterns of food waste behavior among Hungarian university students, with crucial influencing factors being age, place of residence, and educational background as key influencing factors.

Given the results, all 4 hypotheses were accepted.

Hypothesis 1.

There is a correlation between the age of respondents and their food wasting habits, the older someone is, the less wasteful they are.

Hypothesis 2.

Food wasting habits differ depending on whether the student comes from a rural or urban environment. Rural students are more conscious than urban students.

Hypothesis 3.

There is a positive correlation between education and food waste mitigation. People with higher education waste less.

Hypothesis 4.

Students at the University of Debrecen waste less food than the national average.

In conclusion, the implementation of educational workshops and classes focused on food waste is of critical importance for the purpose of increasing awareness, shifting perspectives, and fostering sustainable practices among university students. To effectively reduce food waste, universities need interactive, experiential initiatives that are tailored to the specific needs and behavior of students.

The research delineated the two extremes of food waste: the group wasting the most food were young students under the age of 20 living in cities and currently in secondary education, while the group wasting the less food were older students with tertiary education living in rural areas.

The findings suggest a number of feasible strategies to reduce food waste among university students:

- Educational campaigns: Tailored programs that address the effects of promotions and impulse buying can reduce food waste among younger, urban students. Since research has shown that students with lower levels of education waste more food, it is recommended that education be implemented at a much lower level of education (even as part of the primary school curriculum).

- Institutional initiatives: Universities can implement portion control policies and support meal planning workshops to encourage sustainable habits.

- Community engagement: Leveraging the traditional habits of rural students can encourage peer-led initiatives and foster a culture of sustainability on campus.

Limitation

The limitation of the research is that the data collection is not based on exact measurement, but on self-reporting and estimation, as is the case with the national survey. More accurate data would be obtained through the direct measurement of food waste.

Future research goals

Extending the study to other Hungarian or foreign universities and comparing the results across regions could deepen the understanding of the national food waste crisis. The impact of changes in eating habits on impulse buying is also worth investigating. A number of other topics were covered in the survey, including food waste, knowledge and attitudes towards composting, and the results will be published after processing.

Ethical approval

This study did not involve any kind of clinical or medical experimentation or any identifiable human material and data. The data for analysis of research was collected from databases.

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CRediT authorship contribution statement

Bittner Beáta: Writing – original draft, Data curation, Conceptualization. **Kasza Gyula:** Writing – review & editing, Methodology, Conceptualization. **Kovács Sándor:** Writing – original draft, Visualization, Software, Methodology. **Vida Viktória:** Writing – review & editing, Data curation, Conceptualization. **Szakos Dávid:** Writing – review & editing, Methodology, Conceptualization. **Nagy Adrián:** Writing – review & editing, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used DeepL Write (deepl.com) in order to improve readability and language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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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Data Availability

Data will be made available on request.

References

Ahmed, S., Shanks, C.B., Lewis, M., Leitch, A., Spencer, C., Smith, E.M., Hess, D., Ahmed, S., Shanks, C.B., Lewis, M., Leitch, A., Spencer, C., Smith, E.M., Shanks, C.B., Lewis, M., Hess, D., 2018. Meeting the food waste challenge in higher education challenge. Int. J. Sustain. High. Educ. 19 (6), 1075–1094. https://doi.org/10.1108/IJSHE-08-2017-0127.

Ajina, A.S., Ali, S., Ali, M., Ali, B., 2024. Unleashing the potential of social media celebrities to promote food waste reduction in educational institutions: developing an extended model based on the value-belief-norm theory. Br. Food J. 126 (7), 2787–2808. https://doi.org/10.1108/BFJ-04-2023-0279.

Akhter, S., Rather, M.I., Zargar, U.R., 2024. Understanding the food waste behaviour in university students: An application of the theory of planned behaviour. ISSN 0959-6526 J. Clean. Prod. 437, 140632. https://doi.org/10.1016/j.jclepro.2024.140632.

Alarinta, J., Wirtanen, G., 2023. Needs to change behaviour in households producing lots of food waste. Int. J. Food Stud. 12 (April), 29–41.

Alattar, M.A., Morse, J.L., 2021. Poised for change: university students are positively disposed toward food waste diversion and decrease. Foods 10 (3), 510. https://doi.org/10.3390/foods10030510.

Aschemann-Witzel, J., de Hooge, I.E., Almli, V.L., 2021. My style, my food, my waste! Consumer food waste-related lifestyle segments. J. Retail. Consum. Serv. 59, 102353. https://doi.org/10.1016/j.jretconser.2020.102353.

Bailey, C.P., Simon, C., Economos, C.D., Hennessy, E., Hatfield, D.P., 2020. College campuses' influence on student weight and related behaviours: a review of observational and intervention research. Obes. Sci. Pract. 694–707. https://doi.org/10.1002/osp4.445.

Bentler, P.M., 1990. Comparative fit indexes in structural models. Psychol. Bull. 107, 238–246. https://doi.org/10.1037/0033-2909.107.2.238.

Bipasha, M.S., Goon, S., 2013. Fast food preferences and food habits among students of private universities in Bangladesh. South East Asia J. Public Health 3 (1), 61–64. https://doi.org/10.3329/seajph.v3i1.17713.

Burlea-Schiopoiu, A., Ogarca, R.F., Barbu, C.M., Craciun, L., Baloi, I.C., Mihai, L.S., 2021. The impact of COVID-19 pandemic on food waste behaviour of young people. J. Clean. Prod. 294, 126333. https://doi.org/10.1016/j.jclepro.2021.126333.

Byrne, B.M. (1994). Structural equation modeling with EQS and EQS/Windows. Thousand Oaks, CA: Sage Publications.

Caliński, T., Harabasz, J., 1974. A dendrite method for cluster analysis. Commun. Stat. 3 (1), 1–27. https://doi.org/10.1080/03610927408827101.

Colatruglio, S., Slater, J., 2016. Challenges to acquiring and using food literacy: Perspectives of young Canadian adults. Can. Food Stud. 3 (1), 96–118. https://doi.org/10.15353/cfs-rcea.v3i1.72.

Cozzio, C., 2021. Minimising plate waste at hotel breakfast buffets: an experimental approach through persuasive messages. Br. Food J. 123 (9), 3208–3227. https://doi.org/10.1108/BFJ-02-2021-0114.

Dunn, J.C., 1974. Well-separated clusters and optimal fuzzy partitions. J. Cybern. 4 (1), 95–104. https://doi.org/10.1080/01969727408546059.

Falasconi, L., Cicatiello, C., Franco, S., Segr, A., Setti, M., Vittuari, M., 2019. Such a Shame ! A study on self-perception of household food waste. Sustainability 11 (1), 270. https://doi.org/10.3390/su11010270.

FAO (2011). Global Food Losses and Food Waste – Extent, causes and prevention. ISBN 978-92-5-107205-9. Rome. ⟨http://www.fao.org/docrep/014/mb060e/mb060e00.pdf⟩.

Filho, W.L., Salvia, A.L., Davis, B., Will, M., Davis, B., 2021. Higher education and food waste: assessing current trends. Int. J. Sustain. Dev. World Ecol. 00 (00), 1–11. https://doi.org/10.1080/13504509.2020.1865474.

Filimonau, V., Todorova, E., Mzembe, A., Sauer, L., Yankholmes, A., 2020. A comparative study of food waste management in full service restaurants of the United Kingdom and the Netherlands. J. Clean. Prod. 258, 120775. https://doi.org/10.1016/j.jclepro.2020.120775.

Flora, D.B., 2020. Your coefficient alpha is probably wrong, but which coefficient omega is right? A tutorial on using R to obtain better reliability estimates. Adv. Methods Pract. Psychol. Sci. 3 (4), 484–501. https://doi.org/10.1177/2515245920951747.

Fraj-Andrés, E., Herrando, C., Lucia-Palacios, L., Pérez-López, R., 2023. Informative initiatives as a useful tool to raise awareness of food waste. Int. J. Sustain. Higher Educ. 24 (4), 840–858. https://doi.org/10.1108/IJSHE-03-2022-0103.

Gonçalves, C., 2021. University canteens — challenges and opportunities. Foods 10 (10), 2325. https://doi.org/10.3390/foods10102325.

Hayes, A.F., Coutts, J.J., 2020. Use omega rather than Cronbach's alpha for estimating reliability. But…. Commun. Methods Meas. 14 (1). https://doi.org/10.1080/19312458.2020.1718629.

van Herpen, E., Wijnen, T., Quested, T., Reynolds, C., Sharda, N., 2023. Convenient tools and social norms: measuring the effectiveness of an intervention to reduce household food waste. J. Clean. Prod. 429, 139604. https://doi.org/10.1016/j.jclepro.2023.139604.

Hubert, L.J., Levin, J.R., 1976. A general statistical framework for assessing categorical clustering in free recall. Psychol. Bull. 83 (6), 1072–1080. https://doi.org/10.1037/0033-2909.83.6.1072.

Juvan, E., Grün, B., Dolnicar, S., 2017. Biting off more than they can chew: food waste at hotel breakfast buffets. J. Travel Res. 1–11. https://doi.org/10.1177/0047287516688321.

Kasza, G., Dorkó, A., Kunszabó, A., Szakos, D., 2020. Quantification of household food waste in Hungary: a replication study using the FUSIONS methodology. Sustainability 12 (8), 3069. https://doi.org/10.3390/su12083069.

Kaufman, L., Rousseeuw, P.J., 1990. Partitioning around medoids (Program PAM). Wiley Series in Probability and Statistics. Hoboken, NJ, USA: John Wiley & Sons, Inc, pp. 68–125. https://doi.org/10.1002/9780470316801.ch2. ISBN 978-0-470-31680-1.

Knezevic, B. (2019). Typology of university students regarding attitudes towards food waste. https://doi.org/10.1108/BFJ-05-2018-0316.

Li, J., Li, W., Wang, L., Jin, B., 2021. Environmental and cost impacts of food waste in university. sustainability, 14 (18), 5907. https://doi.org/10.3390/en14185907.

MacQueen, J.B., 1967. Some methods for classification and analysis of multivariate observations. In: Le Cam, L.M., Neyman, J. (Eds.), Proceedings of the fifth Berkeley symposium on mathematical statistics and probability, 1. University of California Press, California, pp. 281–297.

Martin-rios, C., Demen-meier, C., Gössling, S., Cornuz, C., 2018. Food waste management innovations in the foodservice industry. Waste Manag. 79, 196–206. https://doi.org/10.1016/j.wasman.2018.07.033.

McDonald, R.P. (1999). Test Theory: A Unified Treatment. Mahwah, NJ: Lawrence Erlbaum.

McNicholas, P.D., 2016. Model-based clustering. J. Classif. 33 (3), 331–373. https://doi.org/10.1007/s00357-016-9211-9.

Mganga, P., Syafrudin, S., & Amirudin, A. (2021). A Survey of S tudents' Awareness on Food Waste Problems and Their Behaviour Towards Food Wastage: a Case Study of Diponegoro University (UNDIP), Indonesia. 01071, 1–9.

Mi, M., Amicarelli, V., Chrobak, G., Agnieszka, G., Bux, C., 2024. Do living arrangements and eating habits influence university students' food waste perception in Italy and Poland ? Sustainability 16 (5). https://doi.org/10.3390/su16052102.

Mirosa, M., Munro, H., Mangan-walker, E., Pearson, D., Mirosa, M., Munro, H., Mangan-walker, E., Pearson, D., 2016. Reducing waste of food left on plates analysis of customers in foodservice sector. Br. Food J. 118 (9), 2326–2343. https://doi.org/10.1108/BFJ-12-2015-0460.

Murray, D.W., Mahadevan, M., Gatto, K., O'Connor, K., Fissinger, A., Bailey, D., Cassara, E., 2016. Culinary efficacy: an exploratory study of skills, confidence, and healthy cooking competencies among university students Authors. Perspect. Public Health 136 (3), 143–151. https://doi.org/10.1177/1757913915600195.

Musicus, A.A., Challamel, G.C.A., Mckenzie, R., Rimm, E.B., Blondin, S.A., 2022. Food waste management practices and barriers to progress in U.S. University Foodservice. Int. J. Environ. Res. Public Health 19 (11), 6512. https://doi.org/10.3390/ijerph19116512.

Myhrer, K.S., Gaarder, M.Ø., Berget, I., Almli, V.L., 2024. Need to change, want to change, or hard to change? Targeting three dinner food waste profiles with regard to attitudes and personality traits. Food Qual. Prefer. 119, 105231. https://doi.org/10.1016/j.foodqual.2024.105231.

Nelson, B.D., 1991. Variable reduction for modeling using PROC VARCLUS. In Conference Proceedings SAS Users Group International. SAS Institute, pp. 1–3.

Pagés, J. (2014). Multiple Factor Analysis by Example Using R. New York, Chapman and Hall/CRC, pp. 67-78 https://doi.org/10.1201/b17700 ISBN 978 0-429-17108-6.

Pal, N.R., Bezdek, J.C., Hathaway, R.J., 1996. Sequential competitive learning and the fuzzy c-means clustering algorithms. Neural Netw. 9 (5), 787–796. https://doi.org/10.1016/0893-6080(95)00094-1.

Pendergast, F.J., Livingstone, K.M., Worsley, A., Mcnaughton, S.A., 2016. Correlates of meal skipping in young adults: a systematic review. Int. J. Behav. Nutr. Phys. Act. 13, 125. https://doi.org/10.1186/s12966-016-0451-1.

R Core Team (2023). R: A Language and environment for statistical computing. (Version 4.2.3) [Computer software]. Retrieved from ⟨https://cran.r-project.org⟩. (R packages retrieved from CRAN snapshot 2023-04-07).

Rousseeuw, P.J., 1987. Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. Comput. Appl. Math. 20, 53–65. https://doi.org/10.1016/0377-0427(87)90125-7.

Sakaguchi, L., Pak, N., Potts, M.D., 2018. Tackling the issue of food waste in restaurants: Options for measurement method, reduction and behavioral change. J. Clean. Prod. 180, 430–436. https://doi.org/10.1016/j.jclepro.2017.12.136.

Sánchez, L.A., Roa-díaz, Z.M., Gamba, M., Grisotto, G., Ballesteros, M., Kopp-heim, D., Minder, B., Suggs, L.S., 2021. What influences the sustainable food consumption behaviours of university students ? A systematic review. Int. J. Public Health 66 (September), 1–15. https://doi.org/10.3389/ijph.2021.1604149.

Scherhaufer, S., Moates, G., Hartikainen, H., Waldron, K., Obersteiner, G., 2018. Environmental impacts of food waste in Europe. Waste Manag. 77, 98–113. https://doi.org/10.1016/j.wasman.2018.04.038.

Soma, T., Li, B., Maclaren, V., 2020. Food waste reduction: a test of three consumer awareness interventions sustainability food waste reduction: a test of three consumer awareness interventions. Sustainability 19, 907. https://doi.org/10.3390/su12030907.

Steiger, J.H., 1990. Structural model evaluation and modification: an interval estimation approach. Multivar. Behav. Res. 25, 173–180.

Stenmarck, Å., Jensen, C., Quested, T., & Moates, G. (2016). Estimates of European food waste levels. FUSIONS EU Project DOI: 10.13140/RG.2.1.4658.4721.

Stilling, B., Malene, B., 2012. Lost in Transition ? Student food consumption. High. Educ. 65 (2013), 277–289. https://doi.org/10.1007/s10734-012-9543-2 (June).

Szabó-Bódi, B., Kasza, G., Szakos, D., 2018. Assessment of household food waste in Hungary. Br. Food J. 120 (3), 625–638. https://doi.org/10.1108/BFJ-04-2017-0255.

Tucker, L.R., Lewis, C., 1973. A reliability coefficient for maximum likelihood factor analysis. Psychometrika 38, 1–10.

United Nations Environment Programme (UNEP), 2024. Food Waste Index Report 2024. Nairobi.

Vigneau, E., Qannari, E.M., 2003. Clustering of variables around latent components. Commun. Stat. Part B: Simul. Comput. 32 (4), 1131–1150. https://doi.org/10.1081/SAC-120023882.

Vittuari, M., Herrero, L.G., Masotti, M., Iori, E., Caldeira, C., Qian, Z., Bruns, H., van Herpen, E., Obersteiner, G., Kaptan, G., Liu, G., Mikkelsen, B., Schwannel, R., Kasza, G., Nohlen, H., Sala, S., 2023. How to reduce consumer food waste at household level: a literature review on drivers and levers for behavioural change. Sustain. Prod. Consum. 38, 104–114. https://doi.org/10.1016/j.spc.2023.03.023.

Wang, D., 2024. Analysis of factors influencing college students' food waste behavior and evaluation of labor education intervention. Front. Public Health 12. https://doi.org/10.3389/fpubh.2024.1372430.

Wang, H., Ma, B., Cudjoe, D., Farrukh, M., 2022. What influences students' food waste behaviour in campus canteens. Br. Food J. 125 (71672008), 381–395. https://doi.org/10.1108/BFJ-10-2021-1103.

Ward, J.H., Jr, 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58, 236–244.

Zhang, W., Jian, J., 2024. Significance: a bibliometric analysis and review of global food waste of students research based on CiteSpace. Sustainability 16 (8), 3145. https://doi.org/10.3390/su16083145.