

Doctoral (PhD) dissertation abstract

A SUSTAINABILITY ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF PACKAGING MATERIALS FOR THE MAIN FOOD CATEGORIES

Aliz Vuk

Supervisor:

Andrea Bauerné Dr. habil Gáthy

Associate Professor



UNIVERSITY OF DEBRECEN

Doctoral School of Management and Business

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1. BACKGROUND TO THE RESEARCH, ITS OBJECTIVES AND A PRESENTATION OF THE RESEARCH HYPOTHESES

Population growth poses a global challenge, requiring an expanding supply and leading to increased use of food packaging. Today, the volume of food packaging material generated by the overconsumption characteristic of consumer society is causing irreversible damage to the natural environment (SCHENKER et al., 2021). The environmental impact of packaging has traditionally been a neglected area, but this appears to be changing thanks to economic, environmental and consumer trends. A number of factors have contributed to the growing focus on reducing the environmental impact of packaging today. Most importantly, globalisation and the resulting economic changes, together with a shift in attitudes towards environmental issues, have led to the emergence of environmentally friendly packaging (DÖRNYEI, 2019). Due to the scale of its production of new products, the food industry has created entirely new demands in the packaging market (WYRWA–BARSKA, 2017). Currently, the latest trend towards reducing packaging and minimising environmental impact involves the use of natural and more environmentally friendly packaging materials. All this underscores the importance of analysing and assessing the extent to which the carbon and energy footprints can be reduced by replacing traditional fossil-based materials with bio-based alternatives, which would contribute to achieving the UN Sustainable Development Goals (SDG), the Paris Agreement and national energy and carbon strategies. Globally, packaging accounts for 1–4 per cent of GDP and is growing in both value and volume. For the packaging industry, the European market is the most significant geographical region (30 per cent), followed by North America (28 per cent) and Asia (27 per cent). In terms of raw materials, paper (36 per cent) and plastic (34 per cent) are the most widely used. In terms of sectors, the food industry is the most significant player (38%), followed by beverage packaging (18%). In Hungary, the packaging industry is growing at the same rate as GDP; as early as 2014, it had already reached a turnover of 482 billion forints (DÖRNYEI, 2019). Household waste, which accounts for 5 per cent of total waste, consists of 30 per cent packaging waste. One of the main reasons for this is the over-packaging of food (BECZNER et al., 1997). The introduction of the circular economy paradigm has changed the European Commission's (EC) approach and encouraged the development of strategic measures aimed at reducing packaging waste. With the adoption

of the ‘Directive on single-use plastics’ in 2019 and the application of circular economy principles, the EC introduced a systematic sectoral approach to packaging for the first time. The new Circular Economy Action Plan, adopted in 2020, aims to reduce (excessive) packaging and packaging waste by promoting new, reusable and recyclable designs; reducing the complexity of packaging materials; introducing labelling to aid sorting; and reviewing waste collection regulations (SAZDOVSKI et al., 2022).

The main objectives of the research

This research project examines ways of reducing the environmental impact caused by food packaging materials, with particular regard to food industry products. The primary objective is to identify the types of food packaging materials currently in use; to explore ways of reducing their relative quantities, in line with the European Union’s objectives; and to assess the potential for the wider adoption of alternative, environmentally friendly food packaging materials.

My objectives are as follows:

1. To investigate the environmental impact of fossil-based and alternative food packaging materials in order to compare them.
2. To assess the extent to which consumers are mindful of packaging materials when buying food; whether they are willing – and, if so, to what extent – to pay more for alternative food packaging materials.
3. To discover why food manufacturers prefer fossil-based packaging materials and what difficulties they may encounter when switching to alternative food packaging materials.

In line with my objectives, I aim to provide scientifically sound answers to the following research questions:

- **Q1:** What is the scale and nature of the difference in the environmental impact between fossil-based and alternative food packaging?
- **Q2:** What impact does the use of recycled materials have on the production of food packaging?
- **Q3:** What do university students know about alternative food packaging materials, to what extent are they willing to accept them?

- **Q4:** Are university students willing to pay more for alternative food packaging materials?
- **Q5:** What role do sustainability considerations play in university students' food purchasing decisions?
- **Q6:** Does environmental awareness affect the food-purchasing decisions of university students?
- **Q7:** What factors and reasons have led to domestic food industry companies still using packaging made mainly from fossil-based materials even today?
- **Q8:** What challenges do food industry companies face in their manufacturing, distribution and communication with consumers?

According to Schenker et al. (2021), the total environmental impact of plastics is 3–5 kg CO₂-eq/kg, whilst that of cellulose-fibre-based materials is less than 1.5 kg CO₂-eq/kg. However, not all fibre-based packaging performs better, as the amount of material required to provide a given level of protection may vary. Peantham and Varabuntoonvi (2024) demonstrated that PLA packaging outperforms PP in 13 out of 18 impact categories. This is similar to the findings of Arfarelli et al. (2024) regarding paper packaging.

Based on the above, my **H1** hypothesis is as follows:

There is a distinct difference in the environmental impact of fossil-based and alternative food packaging materials when comparing materials of the same weight; and in 13 out of 18 midpoint categories, the alternatives perform better.

In their study, Stefanini et al. (2021) examined PET packaging made from recycled raw materials (rPET). Their results showed that rPET bottles had the lowest environmental impact across all the LCA categories they selected. They concluded that this was due to savings in virgin material, low weight, and lower energy consumption during the manufacturing phase and transport. In their study, Christos et al. (2025) concluded that the recycling of EPS waste has a positive impact in terms of its effects on the environment and human health. This is because recycled material replaces virgin polystyrene.

Based on the above, my **H2** hypothesis is as follows:

Increasing the use of recycled materials reduces the environmental impact of food packaging.

Consumers have a positive attitude towards sustainable packaging and are willing to choose more sustainable packaging options, which reflects a certain level of knowledge and understanding (LIN et al., 2025). However, the literature frequently cites a lack of information as a barrier to purchasing alternative packaging, which is linked to a lack of knowledge about these packaging materials (CARVALHO et al., 2022; KOCHANska et al., 2022; NIFATOVA et al., 2025). Numerous surveys in the literature have demonstrated that consumers worldwide are in favour of replacing conventional plastic food packaging made from fossil fuels with alternative (bio-based) packaging materials (LI et al., 2020; HERRMANN et al., 2022; KOCHANska et al., 2022). This positive willingness to accept such alternatives was observed in the case of bioplastics, active packaging and unpackaged fruit and vegetables.

Based on the above, my **H3** hypothesis is as follows:

University students have a good knowledge of alternative food packaging materials and have a positive attitude towards their use.

Research into consumers' willingness to pay for alternative food packaging has shown that a 10 per cent price premium is the most acceptable (YOUNG et al., 2020; CARVALHO et al., 2022; KOCHANska et al., 2022; ATTA-DELGADO et al., 2024). Several studies have shown that younger consumers were more inclined to pay more for food in environmentally friendly packaging (WALKER et al., 2021; HERRMANN et al., 2022). Young consumers are becoming increasingly aware of sustainable consumption and are changing their habits accordingly; 30 per cent of them strive to make sustainable choices, which represents a significant market segment (KOVACS – KERESZTES, 2022). The preference for sustainable packaging is likely to grow, as the younger generation is more concerned about issues relating to global climate change (NIFATOVA et al., 2025). Although some studies have demonstrated a positive correlation between age and environmental awareness, other studies suggest that younger consumers are more conscious of and committed to sustainability issues (CHIRILLI et al., 2022). Generation Z is the most influential group of consumer trend-setters, and their consumption behaviour generally leans towards environmentally friendly products (HORSKÁ et al., 2021; OLIVER et al., 2023).

Based on the above, my **H4** hypothesis is as follows:

University students are willing to pay a higher price for food products packaged in sustainable alternatives.

In a survey by Nifatova et al. (2025), the sustainability of packaging proved to be important. In a study by Carvalho et al. (2022), 44.2 per cent of respondents would purchase recyclable packaging for the sake of environmental protection. The importance of eco-packaging is growing, as consumers are increasingly prioritising sustainability. Environmentally friendly packaging reinforces a brand's commitment to sustainability and increases trust and loyalty amongst environmentally conscious consumers (SIUDA-GREBOSZ-KRAWCZYK, 2025).

Based on the above, my **H5** hypothesis is as follows:

University students take the sustainability characteristics of packaging materials into account when making food purchasing decisions, particularly their environmental impact and recyclability.

Food purchasing decisions are influenced by price (KOVACS – KERESZTES, 2022; FENNELL et al., 2023; LIN et al., 2025); the recyclability of food packaging (HORSKÁ et al., 2021), its protective function (KONSTANTOGLU et al., 2020) and the shape of the product (BOZ et al., 2020). Although product characteristics dominated in the survey by Carvalho et al. (2022), the environmental impact of packaging was less prominent. In the case of eco-friendly packaging, price is often cited as a barrier (BOZ et al., 2020; KOVACS – KERESZTES, 2022; ATTA-DELGADO et al., 2024), and it influences purchase intention. At the same time, environmental concerns correlate positively with the intention to purchase eco-friendly packaging (NGUYEN et al., 2020).

Based on the above, my **H6** hypothesis is as follows:

Among university students, there is a distinct cluster of environmentally conscious consumers who attach particular importance to the sustainability characteristics of packaging materials when making food purchasing decisions.

Many companies are reluctant to switch to environmentally friendly materials and adopt circular economy approaches that go beyond recycling, particularly if this requires additional resources (NIELSEN – HAKALA, 2023). The maturity of established plastic food packaging technologies and business processes also hinders the shift towards more sustainable alternatives (KERÄNEN et al., 2021). However, production strategies are also

influenced by consumer preferences and demand for sustainable products (CHAPMAN et al., 2024).

Based on the above, my **H7** hypothesis is as follows:

In line with current regulations, domestic companies are increasingly opting for fossil-based materials that are cheap, readily available and widely applicable.

In their study, Kapronczai et al. (2009) examined small and medium-sized enterprises in the domestic food industry and highlighted the strict and complex licensing system, high taxes and increasingly expensive sources of finance as factors hindering production. They mention that it is difficult to find a workforce with the necessary professional skills. In terms of sales, the enterprises they surveyed engaged in limited marketing activities, and the distribution of their products was also concentrated within a small geographical area.

Based on the above, my **H8** hypothesis is as follows:

The low level of vocational training among the workforce, limited marketing activity and a complex licensing system represent bottlenecks in the food packaging decisions of domestic food industry companies.

2. DESCRIPTION OF THE DATABASE AND THE METHODS USED

In the course of my research, I carried out both secondary and primary research. My review of the literature was based on various international and domestic statistical databases, publications in academic journals, doctoral dissertations, sector-specific professional papers, specialist articles and relevant legislation.

2.1. Life-cycle assessment of food packaging materials

I assessed the environmental impacts of food packaging materials using the Life-cycle assessment (LCA) method, in accordance with the ISO 14040:2006+Amd 1:2020 and 14044:2006+Amd 1:2017+Amd 2:2020 standards. According to the European Commission (COM(2003) 302), LCA is the most suitable method for assessing the environmental impacts of products. The main objective of the LCA is to assess the environmental impacts associated with the life cycle of the food packaging materials under investigation and to identify the most environmentally favourable solution. The research covers (i) the life-cycle assessment of 16 food packaging materials, and (ii) an examination of the environmental impacts of EPS packaging whilst increasing the proportion of recycled raw materials. In this research, I assume that the primary function of the packaging materials under investigation is the packaging of food products (storage, protection, shelf life). The food packaging materials and systems examined in the research are illustrated in the table below (*Table 1*). The results are presented uniformly on the basis of 1 kg of packaging material.

Table 1. Food packaging materials included in the study

An overview of the packaging materials examined				
glass base	paper base	PE base	polimer base	recycled material contained
glass, brown glass, green glass, white	Tetra Pak	LDPE packaging	PLA granulate	10% recycled EPS
	Carboard box	LDPE granulate	PET granulate	45% recycled EPS
	Corrugated cardboard	LLDPE granulate	PP granulate	100% recycled EPS
	Kraft paper	HDPE granulate	EPS manufacturing	
			PVC granulate	

Source: own editing

The results are expected to be of use to policy-makers and corporate decision-makers, as they quantify the environmental impacts associated with the production of individual food

packaging materials, thereby providing a basis for industry stakeholders' decisions on the choice of raw materials. The life cycle data were provided by the cut-off version of the Ecoinvent 3.7.1 database, which follows the principles of attribution-based LCA during life cycle analysis and primarily applies the revenue-based method to resolve multi-criteria problems. The model employs a 'cut-off' approach, whereby waste, as a secondary raw material, enters the system 'burden-free' – that is, the environmental burdens from previous life cycles are not attributed to it – whilst the impacts of further processing and waste management are attributed to the system under investigation. For the 16 food packaging materials, I examined the environmental impact of the production processes on a cradle-to-gate basis. Consequently, my results do not include any potential impacts associated with the use of the packaging materials or their end-of-life management. The time scope of the case study covers both short-term (0–100 years) and long-term (100–60,000 years) time horizons. The results for each scenario show the sum of time-integrated (i.e. cumulative) emissions, resource use and associated environmental impacts for the modelled periods mentioned. The geographical scope of the study covers Europe, and where possible, I have applied region-specific characteristics (e.g. soil, climate, farming practices) and inventory data.

I carried out the life-cycle impact assessment (LCIA) using the ReCiPe 2016 methodology (HUIJBREGTS et al., 2017), which I selected due to its comprehensive environmental coverage, recent developments and reliable documentation. ReCiPe 2016 quantifies impacts across 18 midpoint categories, which can be grouped into three aggregated endpoint categories: adverse effects on human health (measured in disability-adjusted life years, measured in DALYs), adverse impacts on ecosystem quality (measured in the number of species lost over time, species.yr) and adverse impacts on resource availability (measured in excess extraction costs, in USD 2013). The calculations were carried out using the OpenLCA software (version 2.1.1), applying the ReCiPe method with a hierarchical approach, which provided the life-cycle inventory (LCI) data required to assess the environmental impacts associated with activities relating to raw materials, infrastructure, substitute products and transport.

2.2. Methodology of the questionnaire-based survey

I employed a quantitative method to examine the consumer perspective. During my review of the literature, the youth demographic emerged as a key focus. For this reason, the target population for my survey was university students, specifically those enrolled on accredited economics programmes at the Faculty of Economics, University of Debrecen. This is an age group that is already active as consumers, and whose attitudes are influenced by environmental concerns. The quantitative method I chose was a questionnaire-based survey using non-probability sampling. In the case of non-probability sampling, it can be said that: ‘In certain research situations, a list of the target population to be studied does not exist, or we are unable to compile one, because it would not be representative and therefore cannot be generalised. However, the validity of the results obtained in this way is high’ (BELLA, 2017; BABBIE, 2021). In my case, it does not ensure representativeness in the statistical sense for the entire population, but whilst this is not the case for DE-GTK students as a whole, it is the case by degree programme and year group. The data on the population were provided to me by the DE-GTK Academic Affairs Department. Within non-probability sampling, I employed quota sampling. In quota sampling, ‘we aim for a representative sample, but unfortunately we do not have a list of the population. However, we do know the structure of the population. Our starting point is a table (matrix) describing the population according to variables relevant to the research. If we know the proportions of individuals in each cell of the matrix, we select our sample so that each cell contains a number of respondents corresponding to the proportions in the population, whilst ensuring that the inclusion of respondents in the sample is random. Thus, our sample reflects the proportions characteristic of the entire population’ (BELLA, 2017; BABBIE, 2021). The large sample size contributes to the reliability of the analyses and enhances internal validity. I conducted the survey at the Faculty of Economics between 9 September 2024 and 3 October 2024. I carried out the survey at all levels of accredited economics programmes (Higher Vocational Education, Bachelor’s and Master’s programmes). The survey took the form of a self-administered questionnaire, which students accessed via a QR code and completed using Google Forms. I carried out the survey during in-person class visits, with the Dean’s permission and the cooperation of the teaching staff. When designing the questionnaire, I took care to use a variety of question types so that completing it would not become

monotonous for the students; furthermore, when formulating the questions, I endeavoured to avoid conforming to social expectations. The questionnaire included multiple-choice, open-ended, rating-scale and true/false questions. It comprised a total of 35 questions, with six questions relating to demographic background variables placed at the end of the questionnaire. It took an average of 10–15 minutes to complete. The survey was preceded by a pilot test, which was completed by one group at each level of education. Based on the feedback received from them, the questionnaire was further refined and then finalised. The number of completed questionnaires received during the survey was $n=1,313$, of which I excluded 7 (due to invalid responses to demographic and segmenting questions), resulting in a final sample size of $n=1,306$. The distribution of the sample by gender, subject and year group is representative of the distribution of the underlying population. Limitations of the survey include the fact that the results are based on self-reporting; the findings relate specifically to the students participating in the study; and the cross-sectional design does not reflect changes over time.

I summarise the methods and software used in the analysis of the responses in the following *Table 2*, in parallel with the research questions. Before selecting the tests used in the statistical analyses, I checked that the necessary conditions were met. I tested the normality of the distribution of the variables using the Kolmogorov–Smirnov and Shapiro–Wilk tests, whilst I checked the homogeneity of variances across the groups using the Levene test. Where the conditions for parametric tests were not met, I carried out the non-parametric Kruskal–Wallis test.

Table 2. The methods used, broken down by research question

Research question	Method used	Statistic programme
Q3	Contingency table, Chi-square test, Descriptive statistics, frequency table, independent samples t-test, Mann-Whitney U test, descriptive statistics by group	JASP 0.19.1.0, Microsoft Excel
Q4	Contingency table, Chi-square test, Creating indices and formulas, Descriptive statistics, Frequency table	JASP 0.19.1.0, Microsoft Excel
Q5	Spearman's correlation	JASP 0.19.1.0
Q6	Independent samples t-test, Mann-Whitney U-test, Descriptive statistics, ANOVA, Post hoc test, Descriptive statistics, Factor analysis, Kaiser-Meyer-Olkin and Bartlett's tests, Hierarchical cluster analysis, K-means cluster analysis, frequency table, contingency table, chi-square test, Kruskal-Wallis test	JASP 0.19.1.0, SPSS 27.01.0

Source: own editing

2.3. Methodology for expert interviews

In addition to the literature reviewed, I supplemented the analysis of the corporate sector with semi-structured expert interviews. The aim of this was to identify the reasons underlying the packaging material selection decisions of domestic food packaging material manufacturers and food manufacturers that package their own products.

To achieve the research objective, I first developed a two-loop model of packaging material selection decisions by domestic food industry stakeholders using the Berkana two-loop model (BERRY, 2022) – an alternative qualitative research method. The Berkana two-loop model identifies the roadmap for change, from the initial challenge to a potential solution. The aim is to create a sustainable packaging system that fully integrates policies and systems, technology, the environment, mindsets and behaviour, initiatives and exceptional values (BERRY, 2022). The two-loops model is a map of how change operates within living systems. It charts the movement and relationship between existing systems and emerging systems, and serves as a useful tool to help decision-makers assess where their organisation stands within the current system and what kind of leadership is most effective. In living systems, change does not occur in a linear or predictable manner. New forms emerge from within old forms and develop amidst the ‘inherited system’. At the heart of the map lies the relationship between the ‘inherited system’ and the ‘emerging system’. For leaders, the double-loop model helps to initiate the process of understanding that change is not a linear process, and assists in assessing where their strengths lie and what relationships and capabilities they need to develop in order to work with emergence (CORRIGAN, 2024). I developed the two-loop model based on the interviewees’ responses and the dimensions they identified. The main focus of the interview questions was on packaging materials and methods used for foodstuffs, issues relating to the use of alternative packaging materials, as well as the companies’ future plans and current challenges. Data collection was carried out using semi-structured interviews. The interviews were conducted in person and online between August 2024 and April 2026, and lasted between 40 and 90 minutes. I interviewed a total of 10 corporate decision-makers from Alföld tej Kft., Euroadvance Kft., Felföldi Édességgyártó Kft., Globus Konzervipari Zrt., Hajnal Tejmalom, Kecskeméti Konzerv Kft., Nestlé Hungária Kft., Nyír-Aranytojás Kft., the Özse Group, and the Unifood Food Industry Innovation Centre. I identified the interviewees using the so-called ‘snowball method’

(MAHBUB et al., 2019), taking care to ensure that representatives were drawn from as broad a spectrum of the industry as possible. All interviews were confidential, and the interviewees were assigned unique codes for the purposes of presenting the results. It is important to note that the sample does not represent the entire Hungarian food industry. A key consideration during the selection process was to interview decision-makers from both SMEs and large companies. This ensured that the findings were not limited to just one segment of the industry. The interviewees included decision-makers from companies producing confectionery, tinned goods, dairy products and meat products, as well as a company specialising in vegetable packaging and another dealing with egg packaging (*Table 3*).

Table 3. Classification of the companies surveyed

Food category	SME	large companies
Meat products	INT II.	INT IX.
Dairy product	INT II.	INT X.
Sweets	INT III.	INT VI.
Tinned food	INT IV.	INT V.
Pasta	INT VII.	INT IX.
Egg		INT VIII.
Packaging	INT I.	

Source: own editing

The number of interviews was sufficient to achieve theoretical saturation. Theoretical saturation is reached when no further significant new information emerges (RÁCZ, 2006). The recurrence of the main themes was clearly observable throughout the research. I carried out a reliability test on the coding, which achieved an 85 per cent agreement in the structure of the sub-categories and categories established on the basis of the interviews (MILES – HUBERMAN, 1994). As regards the transition to sustainable packaging materials in the food industry, the use of this model has not yet been reported in the literature, either in Hungary or abroad. I present the current challenges faced by Hungarian food industry companies, grouped according to the problems arising during production, distribution and communication with consumers.

3. MAIN FINDINGS OF THE THESIS

During the life-cycle assessment of food packaging materials, I found that, on a weight-for-weight basis, glass packaging performs better than paper and plastic packaging in 11 out of 18 impact categories. PLA performs worse than glass, paper and plastic packaging in 14 out of 18 impact categories. In the case of plastic packaging, various types of PE and PP granules performed better than other fossil-based plastics. Combined packaging, such as Tetra Pak, also results in a very high environmental impact in most categories. These results were also confirmed by an analysis of the end-point impact categories. In the ‘Human Health’ category, PVC granules showed an impact that was an order of magnitude greater than that of other packaging materials. In the ‘Environmental Damage’ category, Tetra Pak had the greatest impact. In terms of ‘Depletion of Mineral Resources’, the impact of all fossil-based plastic packaging was very high.

On this basis, I **reject** my **H1** hypothesis (*There is a marked difference in the environmental impact of fossil-based and alternative food packaging materials when comparing materials of the same mass; and the alternatives perform better in 13 out of 18 midpoint categories*).

I used life-cycle analysis to examine the impact of increasing the recycled content in the production of EPS packaging. My results show that EPS packaging made from 100 per cent recycled material achieved better results in 15 out of 18 midpoint impact categories. This finding was also confirmed by the results of the analysis of the end-point impact categories. For all three aggregated end-point categories, I found that harmful emissions affecting the environment decreased in proportion to the increase in the proportion of recycled raw material. I concluded that increasing the use of recycled raw materials leads to improvements in all three environmental protection areas, thereby substantiating the benefits of the circular economy model.

On this basis, I **accept** my **H2** hypothesis (*Increasing the proportion of recycled raw materials reduces the environmental impact of food packaging*).

I examined the knowledge of students at the Faculty of Economics, University of Debrecen, regarding alternative food packaging materials and found that the students taking part in the survey were familiar with cellulose fibre, biopolyethylene, as well as active and smart food packaging. I identified a significant correlation in relation to these packaging materials and

techniques; specifically, in four out of the five options provided, there was a significant correlation between the students' self-reported (subjective) and objective responses regarding their knowledge of alternative food packaging materials. I also analysed the students' willingness to accept (WTA) alternative food packaging materials. My findings show that students are most willing to accept alternative packaging for snacks; vegetables and fruit; sweets; and bottled soft drinks (with an average score above 3.9). However, for two food categories (dairy products and processed meat products), the level of willingness to accept is low. In the case of processed meat products in particular (where the standard deviation was 1.173), students' opinions were divided. When compared with what they absolutely could not imagine without plastic packaging, there was some overlap. Students were least receptive to replacing meat products with alternative packaging materials; this is confirmed by the fact that most of them could not imagine these products being packaged in anything other than plastic. Bottled mineral water was mentioned more times among the products that absolutely must be packaged in plastic than dairy products, which is in contrast with the level of willingness to accept alternatives found in other cases.

On this basis, I **reject** my **H3** hypothesis (*University students have a good knowledge of alternative food packaging materials and have a positive attitude towards their use.*).

I investigated how much more students would be willing to pay (WTP) for alternative food packaging. The students who took part in the survey were mostly willing to pay a 5 per cent premium. Students who spend over 100,000 Ft a month on food would not be willing to pay 10 per cent of the price. There were also differences in this regard based on gender: a higher proportion of female respondents would be willing to pay a 5 per cent surcharge, whilst a higher proportion of male respondents would not be willing to pay a premium for this purpose. As part of my research, I created a Willingness-to-Pay Index, which I compared with the amount students spent on food each month, and determined the monthly willingness to pay among those in the sample. On average, they would be willing to pay 1,000 Ft per person per month for environmentally friendly food packaging. I also put this into perspective against the national average wage (525,900 Ft as of November 2025), meaning that students would be willing to pay 0.19 per cent of the average monthly wage as a surcharge for environmentally friendly food packaging. 76.3% of the students surveyed stated that they were willing to pay more for an environmentally friendly product, and these

students also found every possible percentage surcharge acceptable for alternative food packaging options.

On this basis, I **accept** my **H4** hypothesis (*University students are willing to pay a higher price for food products packaged in sustainable alternatives.*).

I found a positive and significant correlation between the responses given by the students surveyed regarding recyclable, environmentally friendly and recycled packaging. Those who gave a higher score for one question also gave higher scores for the other two questions. Among those who had already taken the Environmental Economics module during their studies, a stronger correlation was observed between two questions: regarding products in recyclable packaging and those in environmentally friendly packaging.

On this basis, I **accept** my **H5** hypothesis (*University students take the sustainability characteristics of packaging materials into account when making food purchasing decisions, particularly their environmental impact and recyclability.*).

I carried out a factor analysis on the factors influencing students' food purchases, and then formed clusters from the surveyed students based on the resulting factors. I analysed the resulting clusters according to demographic questions and, to gain a deeper understanding, also based on their responses to individual questions in the questionnaire. I identified the following clusters:

Price-sensitive, economically-minded students are very strongly influenced by price and promotions. In terms of gender distribution, this cluster mirrors the proportions of the overall population; in terms of year group, third-year students are represented in the highest proportion here. Students studying Finance and Economics are over-represented. Overall, they show little interest in recyclable, eco-friendly and recycled packaging. For 97.29 per cent, the price of food is important; of these, 49.3 per cent are greatly influenced (5) by the price of the product. Their willingness to pay for environmentally friendly products is the lowest (62.9% said 'yes') among the clusters. 49.8% would be willing to pay a 5% surcharge for environmentally friendly packaging. Their average monthly willingness to pay amounted to 747.7 Ft.

The Neutral group of students showed low influence across all factors, particularly in relation to Price and Promotions. Proportionally, men and first-year students were over-

represented in this cluster. This cluster also contains the highest proportion of FOSZ and BSc students. The group is mainly comprised of those studying Business Management. They show low to moderate interest in aspects such as recyclable, environmentally friendly and recycled packaging. For 81.74 per cent of them, product price is an important consideration, but they are less strongly influenced by price than the previous cluster. In almost every food category, they differ significantly from the other clusters in terms of willingness to accept such packaging, and in every case they gave the lowest average values. 51.7 per cent of them would be willing to pay a 5 per cent surcharge for environmentally friendly packaging. Their average monthly willingness to pay stood at 1,146 Ft.

Practicality-oriented students are strongly influenced by packaging-related considerations. Their gender distribution mirrors that of the general population, and the 26–30 age group is represented in the highest proportion within this group. Those studying finance are over-represented, and the proportion of those living in county towns is also particularly high in this group. They pay the least attention to aspects such as recyclable, environmentally friendly and recycled packaging. This group also proved to be highly price-sensitive (96.01% consider the product's price important, of which 56.75% rated it as a '5'), which contrasts with the fact that the 'Price and promotions' factor was less significant for them. 43.9% of them would be willing to pay a 5% surcharge for environmentally friendly packaging. However, in their case, the 'no+not at all' combination is present in the highest proportion (66%) in terms of the distribution of respondents. Their average monthly willingness to pay amounted to 769.1 Ft.

Environmentally conscious students are very strongly influenced by the criterion of eco-friendly packaging (sustainability). This is a group with a strong female majority, and it has the highest proportion of MSc students. It is mainly characterised by those studying finance, but the proportion of students on other master's programmes is highest here. This group has the lowest proportion of students living in large cities. These students pay the most attention to aspects such as recyclable, eco-friendly and recycled packaging. This group also proved to be extremely price-sensitive (95.79% consider the product's price important, of which 46.59% rated it a 5 and 37.56% a 4). Although sustainability is of paramount importance to them, price is also a significant factor in their decisions. In terms of willingness to accept, they differ significantly for most food categories, as they gave higher average scores than

members of the other clusters. 55.1% would be willing to pay a 5% surcharge for environmentally friendly packaging, whilst 19.2% would pay a 15% surcharge and 21% a 10% surcharge. Their average monthly willingness to pay stood at 1,173 Ft, which is the highest among the clusters.

On this basis, I **accept** my **H6** hypothesis (*Among university students, there is a distinct cluster of environmentally conscious consumers who attach particular importance to the sustainability characteristics of packaging materials when making food purchasing decisions.*).

Based on expert interviews with decision-makers at domestic food industry companies, I have developed a two-factor model of packaging material use in the food industry. I have grouped the reasons for using the current system into three sub-categories. The interviewees identified technical barriers mainly as a lack of the equipment and technology required to use alternative packaging materials; furthermore, a lack of knowledge about these alternatives, or indeed the very absence of such alternatives, is what keeps them using fossil-based packaging. It is also of particular significance that there is no relevant legislation in Hungary; consequently, anyone switching to these alternatives would be at a competitive disadvantage. Costs also emerged as a deterrent. As both the transition and the raw materials involve higher costs, this deters companies. Furthermore, food-related criteria cannot be ignored either. As the types of packaging materials that may be used for specific products are regulated by law, companies' options are limited. In addition, consumer expectations as perceived by retailers and companies – such as a long shelf life – often tie the hands of decision-makers.

On this basis, I **accept** my **H7** hypothesis (*Domestic companies are even more likely to opt for cheap, readily available and widely usable fossil-based materials, in line with current regulations*).

I have summarised the challenges faced by the companies surveyed, categorising them into production, distribution and communication with consumers.

1. Problems arising during production include a shortage of skilled workers and labour in general; high raw material and energy prices; and economies of scale, i.e. the need

to adapt to changes made by packaging manufacturers (such as changes in packaging volume or thickness).

2. Problems arising during distribution include a lack of marketing activities; retailers' expectations (extending shelf life, other packaging-related requirements); and the increase in transport distances resulting from globalisation.
3. Problems arising in communication with consumers include a lack of consumer education, or indeed an excess of it; a complete lack of communication and feedback; and consumer expectations, particularly in the event of oversupply.

On this basis, I **reject** my **H8** hypothesis (*The low level of vocational training amongst the workforce, limited marketing activity and the complex licensing system represent bottlenecks in the food packaging decisions of domestic food industry companies.*).

4. NEW OR ORIGINAL FINDINGS OF THE THESIS

By achieving the objectives of this thesis, I have identified the following new and original scientific findings:

1. I quantified the environmental impacts of food packaging materials – including both fossil-based and alternative types – across 16 different material categories, thereby establishing a uniform, mass-based framework for comparing environmental impacts.
2. I have demonstrated that increasing the proportion of recycled raw materials reduces the environmental impact of the production of food packaging materials, thereby supporting the viability of the circular economy model.
3. I developed the Willingness-to-Pay Index (WTPI), which made it possible to quantify the monthly amount that young consumers (DE-GTK students) were willing to pay for alternative food packaging; the average value of this was 1,000 Ft per month.
4. Using cluster analysis, I identified a distinct, environmentally conscious group amongst young consumers, in which environmentally conscious behaviour regarding food packaging materials is demonstrably reflected in their willingness to accept alternative packaging solutions for snacks, vegetables and fruit, sweets, bottled soft drinks, bottled mineral water and baked goods. Among members of the environmentally conscious cluster, this is also reflected in their willingness to pay, the average value of which is 1,173 Ft per month.
5. I have created a two-loop model of packaging material use in the food industry, based on expert interviews with decision-makers in the sector, which explores the cause-and-effect relationships underlying the packaging material choices made by domestic companies.
6. With the involvement of domestic food packaging companies and industry stakeholders, I identified, based on factual evidence, the challenges relating to food packaging materials that arise during production, distribution and consumer communication, and then organised them into a structured framework.

5. THE PRACTICAL APPLICABILITY OF THE RESULTS

Based on a review of the literature and the findings of my own research, I put forward the following recommendations.

At government level, I recommend the introduction of comprehensive, industry-wide regulations to facilitate the transition to a circular economy model and to ensure that the statutory recycling targets are met. This includes financial support (replacement of production lines, development of sites); improving transparency (corporate operations, inter-company cooperation); and encouraging the use of alternative raw materials (the use of fossil-based raw materials should be subject to higher taxation). A review of current regulations is necessary to clarify any potentially conflicting standards. The aim of this is to simplify the production and food packaging phases. It would be worthwhile to publish a guide providing detailed guidance on packaging options for individual food categories, taking into account food safety, shelf life and environmental impacts. Such a guide would assist companies in making decisions regarding the choice of food packaging materials. Furthermore, I urge the implementation of selective waste collection at premises, the strengthening of policies that encourage innovation, and the establishment of a support scheme. The current quotas for packaging materials must be reviewed to ensure that companies do not face a competitive disadvantage when introducing alternatives. At a national level, it is essential to improve waste management and develop the recycling infrastructure for separately collected waste. I propose extending the existing DRS scheme to cover further packaging materials and types of packaging. However, this requires the development of the necessary infrastructure.

At sector level, I recommend that, whilst using the best food packaging materials currently available, companies should strive to adopt alternatives, including reducing the amount of plastic used and applying eco-design principles. Whilst the development of alternative food packaging materials is ongoing, companies can use these alternatives to optimise their costs while also reducing their harmful environmental impact. In addition to keeping a close eye on research and development, remain open to innovations that drive the shift towards a circular economy, whether they come from consumers, suppliers or food packaging manufacturers. When optimising production processes, bear in mind the social and

environmental aspects of sustainability. Avoid unnecessary over-packaging and focus on production activities that are free from waste and involve fewer changeovers. Pay greater attention to the end-of-life management of their product packaging by participating in consumer education and using standardised labelling on food packaging. In their marketing activities, they should strive for transparent communication on sustainability and a shift towards a minimalist design for packaging. This will help reduce the negative impact on the environment and also promote more conscious consumer behaviour.

At a consumer level, I suggest that we consciously influence the direction of trends in the food industry through our actions. After all, our demand determines what ends up on the shop shelves. When buying food, let's strive to choose the best option, taking packaging into account. Let's take reusable shopping bags and mesh bags for fruit and vegetables with us, thereby reducing the use of unnecessary plastic packaging. As well as a willingness to pay and accept these measures, specific environmentally conscious actions are also necessary. These must be reflected in our actual behaviour in the marketplace; if we are willing to pay a higher price, then we should actually choose these options. I recommend introducing education on selective waste collection at an institutional level, starting as early as primary schools. The literature has also shown that countries where pupils are taught how to sort waste from an early age perform better in this regard. There is certainly a case for raising widespread awareness among consumers about alternative packaging, as younger generations are keen to learn about and purchase such products. However, we must not focus solely on the raw materials, as there is little point in food being packaged in environmentally friendly materials if consumers do not dispose of the packaging correctly.

6. PUBLICATIONS RELATED TO THE SUBJECT OF THE THESIS



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List of publications related to the dissertation

Articles, studies (8)

1. **Vuk, A.**, Bauerné Gáthy, A.: Environmental impacts of food packaging materials: Systematic review of life cycle assessments from 2018 to 2025.
Cleaner Waste Systems. 14, 1-11, 2026. ISSN: 2772-9125.
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DOI: <http://dx.doi.org/10.14232/jtgf.2025.1.101-115>
3. **Vuk, A.**, Bauerné Gáthy, A.: Assessing international Deposit-Refund Systems: lessons and transferable practices for Hungary.
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4. Czine, P., Gorton, M., Bauerné Gáthy, A., **Vuk, A.**, Balogh, P., Chou, Y. c., Török, Á.: Bottling it? Consumer responses to less environmentally friendly products: A choice experiment for water in plastic packaging in the UK.
Journal Of Environmental Management. 373, 1-16, 2025. ISSN: 0301-4797.
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Address: 1 Egyetem tér, Debrecen 4032, Hungary Postal address: Pf. 39. Debrecen 4010, Hungary
Tel.: +36 52 410 443 Fax: +36 52 512 900/63847 E-mail: publikaciok@lib.unideb.hu, Web: www.lib.unideb.hu



6. **Vuk, A.**, Szűcs, I., Bauerné Gáthy, A.: Waste management and plastic waste recycling in Japan, China, Singapore and South Korea - What trends can be observed under different regulations.
International Review of Applied Sciences and Engineering. 16 (1), 118-131, 2025. ISSN: 2062-0810.
DOI: <http://dx.doi.org/10.1556/1848.2024.00841>
7. **Vuk, A.**, Bauerné Gáthy, A.: Hulladékgazdálkodási esettanulmányok feldolgozása.
Jelenkori Társadalmi és Gazdasági Folyamatok. 19 (1-2), 153-166, 2024. ISSN: 1788-7593.
DOI: <http://dx.doi.org/10.14232/jtgf.2024.1-2.153-166>
8. **Vuk, A.**, Szűcs, I., Bauerné Gáthy, A.: Packaging waste and recycle in EU.
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DOI: <http://dx.doi.org/10.1556/1848.2023.00615>

List of other publications

Articles, studies (1)

9. **Vuk, A.**, Juhász, L.: A keltike fajok (Corydalis) térképezése a nagycserei kőrises arborétumban.
Calandrella. 21-22, 48-53, 2020. ISSN: 0865-6665.

Conference presentations (1)

10. **Vuk, A.**: A keltike fajok (Corydalis) térképezése a Nagycserei Kőrises Arborétumban.
In: XXI. Eötvös Konferencia : Absztraktfüzet, Eötvös Collegium, Budapest, 21-21, 2020.

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