



Research Paper

Can active and intelligent packaging support sustainability in food sector? Insights from a consumer's viewpoint



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ABSTRACT

Recent advances in the food packaging industry that improves product preservation and support sustainability make it increasingly important to understand how consumers perceive these changes. Building on Cue Utilization theory, the purpose of this study is to evaluate how consumers infer their perception of packaging sustainability in their purchase intention of Active and Intelligent packaging. On a sample of 1489 European consumers, the results of a quantitative methodology based on partial least squares structural equation model (PLS-SEM) show that the intention to purchase is positively related to the direct environmental impact (manufacture, materials, durability, and end-of-life management) and the indirect impact (food waste reduction) and the social sustainability of packaging. However, no significant relationship was found regarding packaging's economic function. Packaging attributes are an essential part of decision making. Industrial and waste managers can use our results to align packaging innovations with sustainability and waste management policies to facilitate their purchase intention. It is crucial to emphasize the environmental and social benefits while ensuring that perceived value outweighs any potential cost concerns.

1. Introduction

Increased concerns about the future of our planet have sparked significant interest in sustainable development. The debate is motivated by a growing awareness of the limitations on the capacity of the environment where the needs and aspirations of the present must be met without compromising those of the future (WCED, 1987). Food packaging is held responsible for one of the largest environmental impacts (Notarnicola et al., 2017), generating more than 84 million tonnes of waste in 2021 in the EU (Eurostat, 2023). In addition, consumers tend to consider packaging as superfluous and a serious resource waster, overestimating its negative environmental impact and underestimating its positive role in the safeguarding of products and in reducing food loss (Licciardello, 2017; Robertson, 2013).

Consumer preferences as well as the existence of initiatives such as the implementation of several policy frameworks in the EU context—such as the Packaging and Waste Packaging directive (94/62/EC), the REACH regulation (1907/2006), Waste Framework Directive (2008/98/EC) and the Ecodesign Directive (2009/125/EC) or the Extended

Producer Responsibility (EPR) that makes producers responsible for the waste management of their products and packages—have prompted a shift in the industry to assume its sustainability responsibilities related to packaging (Larrain et al., 2022).

In response, the packaging industry has been looking for rational and innovative solutions that integrate intrinsic and/or extrinsic attributes with the goal of making the environment more sustainable throughout the supply chain (Soro et al., 2021). The industry seeks packaging that is effective in containing and protecting products to reduce waste and improve the shelf life, that makes an efficient use of materials and energy throughout its life cycle, that is made of continuously cycled materials that do not pose a health risk, and that meets market criteria in terms of performance, cost, and consumer expectations (Granato et al., 2022; Santi et al., 2022). Large companies such as Tetra Pak invest significant resources in packaging research and development addressing the sustainability of their packages, resulting in new materials or plant-based caps, for instance (Tetra Pak, 2024). Nevertheless, do consumers perceive all the efforts of the packaging industry toward sustainable development?

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In recent years, a type of packaging called active and intelligent packaging (AIP) has emerged due to societal and consumer demands and lifestyle changes (Alves et al., 2023; Siracusa and Lotti, 2019). Active packaging is a preservative-releasing packaging system (antioxidants, ethylene scavengers, or other substances such as saffron extract) aimed at extending the shelf life of packaged foods while maintaining their quality and their organoleptic properties (Wyrwa and Barska, 2017). Intelligent packages are those that incorporate some system that allows monitoring and can communicate useful information about the properties and/or condition of the packaged food. They include non-invasive devices or sensors with various applications and ways to collect and display information about time and temperature, microbiological quality, and the level of dioxygen (O₂), carbon dioxide (CO₂), or other gases in the food atmosphere (De Jong et al., 2005).

AIP offers a variety of opportunities to apply sustainability development principles to food processing (Tichoniuk et al., 2021). These technologies are potentially applicable to seafood, meat, or dairy products, and are already being incorporated in certain packages. For instance, active packaging can incorporate moisture absorbers that are applied to fish or meat to extend shelf life and reduce spoilage, while intelligent packages including pH-sensitive dye indicator labels have also been used for fruits and vegetables (Ahmed et al., 2022; Cheng et al., 2022).

However, AIP commercialization is still limited due to technical and regulatory aspects or customer reluctance to buy food packaged in AIP (Siracusa and Lotti, 2019; Young et al., 2023). Difficulty of use and unfamiliarity with the innovations, lack of knowledge, and potential risks (economic, physical, functional, or social) or suspicions about the sustainability image of these packages are often cited as barriers to their acceptance and purchase (Young et al., 2020). It seems therefore necessary to provide further insights into the concept of packaging and sustainability, defined ecologically, socially, and economically (Sadeghi et al., 2022) and its relationship with the consumer.

Research has explored the relationship between the consumer and

packaging sustainability from different approaches, but it is limited. Most studies are theoretical (Lindh et al., 2016; Otto et al., 2021; Santi et al., 2022), and there are also empirical studies focused on food packaging in general (Granato et al., 2022; Herbes et al., 2020; Martinho et al., 2015; Steenis et al., 2017). However, this relationship has hardly been studied for the case of AIP (Aday and Yener, 2015; Tiekstra et al., 2020). Recognizing that consumers are increasingly concerned about sustainability and that they are the final judges of the success of AIP, this research aims to fill the following gaps. Social sustainability is incorporated into the study of sustainability at the theoretical level as it has hitherto been practically neglected. At the empirical level, we propose and test a model to explain the relationship between consumer perceptions of the environmental, social and economic sustainability of food packaging applications, and purchase intention of AIP.

For this purpose, after this introduction, we explain the potential contribution of packaging in general and AIP in particular to sustainability, and we then describe the study hypotheses, methodology and results. Finally, we present the discussion and conclusion sections, with the intention of stimulating an understanding of the importance of AIP in supporting efforts to improve sustainability practices.

2. The sustainability of packaging

For the proposes of this research, packaging sustainability implies integrating the main goals of sustainable development according to the triple bottom line model (Elkington, 1994; Nordin and Selke, 2010). This implies that environmental, social, and economic objectives should be part of the total life cycle of packaging from raw materials to final disposal and along the entire supply chain (Fig. 1).

For the consumer, sustainable packaging can be considered as a packaging design that evokes eco-friendliness implicitly or explicitly (Steenis et al., 2017). The abstract character of sustainability means that it cannot be directly assessed. According to Cue Utilization theory, individuals solve this problem by collecting information from cues that

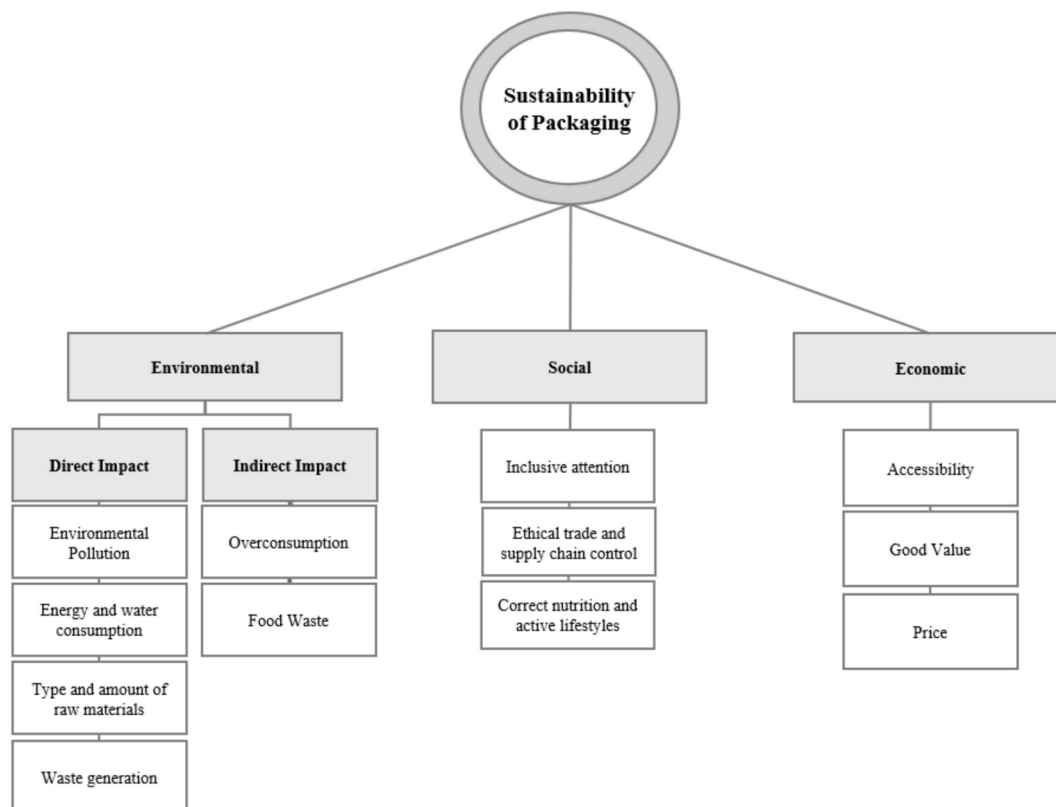


Fig. 1. Packaging triple bottom line Source: Authors' own creation.

indicate specific product attributes or utilities (Olson and Jacoby, 1972). These cues can be of different types: structural (e.g. appearance, size), informational (e.g. text, numbers, codes), visual (e.g. colour, shape, design), or sensory (e.g. texture, smell). They can also be intrinsic (e.g. material) or extrinsic (e.g. eco-label) to the product (Herbes et al., 2020). From the cues provided by the packaging, consumers can infer environmental, social, and economic sustainability (Steenis et al., 2017), and as Rees et al. (2019) point, “these sustainability cues, when recognized, are strong drivers of purchase intention towards food” (p. 842).

2.1. The dual environmental sustainability of packaging

Food packaging has a relative environmental impact. While it directly contributes to pollution, waste generation, resource depletion, and the release of harmful chemicals, it also protects products, reduces food waste, and enables efficient transportation (Licciardello, 2017).

2.1.1. Direct environmental impact

The direct environmental impact of packaging is related to its manufacture, the amount and type of material used, its durability, and end-of-life management (Beitzen-Heineke et al., 2017; Granato et al., 2022; Magnier and Schoormans, 2015; Meherishi et al., 2019; Otto et al., 2021; Sadeghi et al., 2022; Santi et al., 2022; Soro et al., 2021). The packaging manufacturing process generates gas emissions and requires the use of scarce natural resources such as water. In addition, due to the quantity and type of materials used, many of them become waste materials that are difficult to manage after use (Nordin and Selke, 2010; Petrescu et al., 2022). In response, the industry is replacing traditional packaging made of materials such as plastic, glass, or metal with renewable raw materials that do not compromise finite resource reserves and are reusable, biodegradable, and compostable, such as bio-based materials, paper, cardboard, plant-based fibers, and recycled polyethylene (Granato et al., 2022; Lindh et al., 2016; Magnier and Schoormans, 2015). Other contributions include optimizing designs that reduce the amount of material needed in the package (Lindh et al., 2016) or designs that can reduce food spoilage and waste (Granato et al., 2022).

In particular, AIP can reduce the materials used and replace fossil-based packaging materials (Soro et al., 2021) with bio-based ones that could decrease the percentage of non-recyclable solid wastes and reduce energy consumption or improve recycling, contributing to greater efficiency in resource utilization (Donkor et al., 2023; Tiekstra et al., 2021). For example, Realini and Marcos (2014) noted that active packaging is already incorporating natural active agents into more sustainable packaging materials. Similarly, Soro et al. (2021) and Ezati et al. (2023) pointed to the use of materials derived from natural sources in AIP, which, in addition to improving the shelf life of products such as meat and fish, could reduce the amount of waste and be biodegradable in the environment without any subsequent intervention, improving their safety and sustainability.

The direct environmental impact of packaging is a crucial concern for consumers, and is particularly pronounced in the food sector due to features such as high product demand and turnover. This has given rise to the “Zero Waste” movement, which advocates minimizing the amount of waste we generate in our daily lives by reducing the use of single-use packaging and opting for more sustainable alternatives such as bulk products. Some authors have analysed the prospects of zero-packaging foodstuffs (or non-packaged) to reduce plastics and other single-use materials that end up in landfills and the environment (Beitzen-Heineke et al., 2017). Nevertheless, in some sense, reducing food waste is contrary to reducing packaging (Young et al., 2023). Fresh fruits, vegetables, meat, and fish without packaging are often exposed to air and moisture, which can hasten deterioration. They tend to spoil quickly when not shielded by packaging, thereby limiting their shelf life. In addition, cereals, nuts, and grains can lose their freshness and quality if not stored properly. Air and light exposure can lead to rancidity in bulk

products, thereby affecting their taste and nutritional value. In addition, they are exposed to microbial contamination and undesirable physico-chemical and biological changes that will result in food loss (Ahmed et al., 2022; Ezati et al., 2023). This is an environmental problem because when food spoils, the natural resources used to produce it, such as water, land, and energy, are also wasted (Nordin and Selke, 2010).

2.1.2. Indirect environmental impact

Accepting all the above responsibilities within the industry, it is crucial to recognize food packaging as a support for sustainability efforts. Previous research pointed out that food packaging has a positive indirect (through the product) impact on the environment (Chirilli et al., 2022; Beitzen-Heineke et al., 2017; Granato et al., 2022; Lindh et al., 2016; Otto et al., 2021; Santi et al., 2022; Soro et al., 2021) as a driver of food waste behaviour (Vesela et al., 2023). Packaging reduces food waste to the extent that it fulfils its protective, containment, and informative function. In other words, packaging extends the shelf life of the product, or the period of time in which the food meets safety, nutritional, regulatory, and sensory standards under predefined storage conditions (Otto et al., 2021) It also contributes to efficient transport from the factory to the point of sale and to the home while providing information on the best form of conservation and its “Best before” or “Expiry” date (Ezati et al., 2023; Otto et al., 2021).

Especially, AIP has the potential to help address food loss and waste by extending the shelf life of food products, reducing the need for preservatives, and providing essential information to ensure consumer safety (Alves et al., 2023; Licciardello, 2017). Active packaging integrated with natural functional ingredients can interact with the contents and/or the surrounding environment to increase the shelf life of processed foods without affecting nutritional value while also boosting marketability (Ezati et al., 2023). They minimize the risk of food waste and edible food being discarded (Cammarelle et al., 2021). Meanwhile, intelligent packaging can monitor the condition and the environment of packaged food by providing information about different factors which can help control storage conditions from production to consumption (Janjarasskul and Suppakul, 2018; Pereira de Abreu et al., 2012).

Previous literature indicates that consumers place increasing importance on the environmental sustainability of packaging and that this has a positive effect on consumers’ purchase intention (D’Astous and Labrecque, 2021; Lindh et al., 2016).

According to Cue Utilization theory, consumers will utilize features of packaging to infer environmental sustainability. The type of packaging material, the size or the verbal information contained on the label, about its manufacturing process and recyclability but also about the condition of the product contained in the package are identified by consumers as signals of environmental friendliness (Herbes et al., 2020; Ischen et al., 2022). Given that AIP attributes potentially contribute directly and indirectly to environmental sustainability, we posit the following:

Hypothesis 1: Consumers’ perception of environmental sustainability of packaging is positively related to AIP purchase intention.

Hypothesis 1a: Consumers’ perception of direct environmental sustainability of packaging is positively related to AIP purchase intention.

Hypothesis 1b: Consumers’ perception of indirect environmental sustainability of packaging is positively related to AIP purchase intention.

2.2. The social sustainability of packaging

The social dimension of sustainability is key to achieving current and future human well-being (Toussaint et al., 2021). So far, the literature has not reached a consensus on its definition because social sustainability often depends on the context of analysis. However, in general terms, social impact is considered as the positive and negative long-term social change that an organization considers it is responsible for through its actions among its targeted stakeholders (Desiderio et al., 2022).

Several studies have examined the social impact of packaging from a

conceptual perspective. Nordin and Selke (2010) distinguish between two different senses of the social component of sustainable packaging: one is social equity, and the other is consumer interests and perceptions about environmental impact. For Azzi et al., (2012) the social dimension emerges from the ethical dimensions related to facilitating recycling, transmitting honest, truthful, sincere, understandable and complete information, considering the needs of the various potential consumers such as left-handed, elderly, people with disabilities or economically disadvantaged citizens, and ensuring safety. For their part, Beitzen-Heineke et al., (2017) refer to: food safety, nutrition, and ethical trade. Meanwhile, Santi et al. (2022) focus the social aspect mainly on usability characteristics. According to the above, in this work we understand that conventional packaging plays a significant role in meeting a social need by improving inclusivity through design (Waller et al., 2015) or including new technologies that facilitate the use and dispensing of the product to everyone and, in particular, to people with physical disabilities (Azzi et al., 2012; Goodman-Deane et al., 2016; Santi et al., 2022). Moreover, from a social point of view, packaging can guarantee ethical trade in the supply chain and the authenticity of the product (Dopico-Parada et al., 2021).

Precisely, the origin of AIP lies in a response to societal trends toward busier schedules and sustainable lifestyles (Young et al., 2020). On the one hand, active packaging can reduce food safety risks by contributing to a healthier lifestyle as it improves product safety. On the other hand, smart packaging in the food industry can provide more allergen information by using accessibility tools or inform on the content regarding cooking, storage, and ingredients and/or consumers' awareness of correct nutrition and active lifestyles. Moreover, along the lines of inclusive design, intelligent packaging integrates technologies such as a quick response code, AR or VR, or reading or listening devices, which enhance the user experience for all consumers, especially segments of the population that would otherwise be excluded due to cognitive or functional limitations (Lydekaityte and Tambo, 2018). Finally, intelligent packaging addresses social and market demand for ethical trade, transparency, and traceability in the supply chain. This is done by means of some specific devices, sensors, electronic labels, or tracking systems in the packaging that allow it to monitor and improve the quality and safety of the products while providing relevant information to the consumer to guarantee the authenticity of the product and transparency regarding suppliers (Beitzen-Heineke et al., 2017; Meherishi et al., 2019).

The literature points out that the development of sustainable packaging must start from the consideration of the social needs of consumers, which will influence their attitudes and behaviour (Nordin and Selke, 2010). However, these studies have been developed at the conceptual level but without empirical contrast linking the social benefit of packaging with purchase intention, much less the particular case of the AIP. Regarding Cue Utilization theory, aspects such as packaging design or packaging labels and claims about product content or country of origin allow consumers to consider visual cues related to social considerations (Goodman-Deane et al., 2016; Rees et al., 2019). Given that AIP attributes potentially contribute to social sustainability, we posit the following:

Hypothesis 2: Consumers' perception of the packaging's social sustainability is positively related to AIP purchase intention.

2.3. The economic sustainability of packaging

The economic sustainability of packaging focuses on the profit and loss aspects of the actors along the supply chain (Azzi et al., 2012; Meherishi et al., 2019). From the consumer's perspective, packaging must meet market criteria for performance and cost. Efforts must be made to develop sustainable packaging in the right balance with consumer demand for performance, convenience, and price sensitivity (Nordin and Selke, 2010).

Packaging cost could account for approximately 9 % of the costs of

any product, not only because of the packaging material itself, which accounts for approximately 10 % of the packaging cost, but also because of other factors related to design, environmental costs, and other hidden costs (Azzi et al., 2012). One of the barriers that has hindered the commercialization of AIP on a large scale is the high cost involved in these developments (Firouz et al., 2021; Siracusa and Lotti, 2019). As argued above, AIP can provide value in social and environmental terms, but their large-scale adoption must go hand in hand with strategies that prevent this innovation from making the product more expensive, especially in foods for daily use and frequent consumption (Tiekstra et al., 2021). Undoubtedly, it is important that most of the population have access to these new developments. If this is achieved, AIP will reach most households and can contribute to reducing spending.

Prior research suggests that price is a crucial factor affecting consumers' purchasing decisions (Ketelsen et al., 2020; Koutsimanis et al., 2012; Martinho et al., 2015). Based on Cue Utilization theory, consumers can discern the variation in prices due to packaging characteristics, such as design cues (Orth et al., 2010) or label information (Loose and Szolnoki, 2012) and they perceive and evaluate packaging alternatives when these entail a balance between sustainability and other decision criteria such as price, i.e. "the price of sustainability" (Granato et al., 2022). Therefore, given that sustainability of AIP should also be defined economically (Sadeghi et al., 2022), we posit the following:

Hypothesis 3: Consumers' perception of the packaging's economic sustainability is positively related to AIP purchase intention.

The potential impact on environmental, social, and economic sustainability of different food packaging applications (zero packaging, conventional packaging, and AIP) is shown in Annex 1.

Considering the above hypotheses, we suggest the subsequent model (Fig. 2):

3. Methodology and sample

To study how packaging sustainability perception relates to consumer decision-making regarding AIP, a structured online questionnaire was designed to collect information. Under a snowball sampling method, individuals involved in the COST Action FP1405 (ActInPack) were asked to collaborate in the dissemination. In order to mitigate potential biases due to the non-random selection of participants, the study established clear inclusion criteria for participants to obtain a diverse representation in the sample. After data cleaning, the final sample amounted to 1489 consumers from 16 European countries belonging to four sub-regions of Europe, in line with the EuroVoc classification. Most were women (62.32 per cent), and by age, 11.22 per cent were under 23, nearly 70 per cent were between 23 and 38 years, 15.31 per cent were between 39 and 54 years and the rest were over 55. Income amounts to 1500 or less in 51.13 per cent of the households.

Partial Least Squares (PLS) statistical package was used for data analysis (Ringle et al., 2015). PLS-SEM was chosen instead of CB-SEM due to appropriateness for the predictive objectives of the research, the reflective and formative nature of variables in the model, and the non-requirement of data normality and independence (Hair et al., 2011). All variables were measured by a 7-point Likert-type. The main steps taken for this research are illustrated in Fig. 3.

4. Results

4.1. Scale development

The procedure for item proposal and the test of the psychometric properties of the reflective and formative scales followed the indications proposed by Wright et al. (2017) and Hair et al. (2019b).

Item generation. The identification of items to measure each variable followed a thorough review of the literature. To the best of our knowledge, there is no previously developed scale in the literature to measure the three spheres of packaging sustainability, so we start from Dopico-

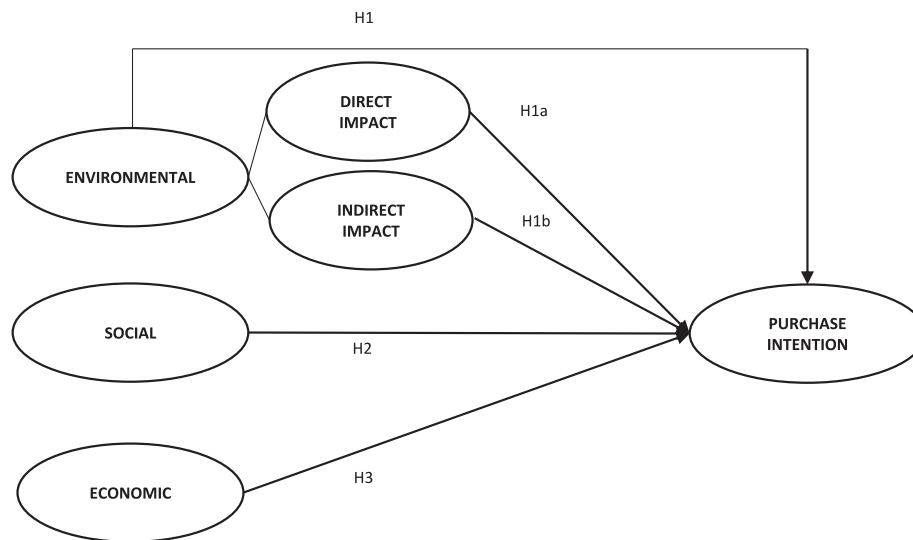


Fig. 2. Structural model. Source: Authors' own creation.

Parada et al.'s (2021) scales of packaging functions to construct a scale that captures the environmental, social, and economic sustainability aspects of packaging as defined in this research. For environmental sustainability, a total of 16 items were proposed, five items for the social sustainability variable and three items for the economic sustainability variable. Finally, the AIP purchase intention variable was measured with four items based on the research of Realini and Marcos (2014) (Annex 2).

4.2. Validation of reflective scales

Dimensionality. The scales' one-dimensional structure was verified initially through an Exploratory Factor Analysis (EFA) followed by a Confirmatory Factor Analysis (CFA). In addition, and as a preliminary step, we analyzed whether factor analysis is a suitable analytical tool to study the data.

First, the verification that the determinant of the correlation matrix for each scale is close to 0 and the KMO test result is close to 1 (Table 1) approves the factor analysis for the treatment of data (Lévy and Varela, 2003). An EFA is then performed, with Varimax rotation. To keep an indicator on a scale, it is verified that it does not present a high load on more than one variable. To determine the dimensions of each scale, it is verified that the communality of each item and that the variance extracted approach 0.5 and 60 %, respectively (Hair et al., 1999). As a result, four items were removed.

A CFA was then performed. To ensure the validity of the results, a bootstrap was performed with 5000 sub-samples (Hair et al., 2019b) (Table 2). The results confirm the one-dimensionality of the social and economic sustainability scales and the multidimensionality of the environmental scale, consisting of two dimensions: direct and indirect environmental sustainability.

Reliability. Cronbach's Alpha and composite reliability (CR) were used to assess scale reliability. The value of Cronbach's Alpha ranges between 0.781 and 0.915, thus exceeding the recommended threshold of 0.7 (Nunnally and Bernstein, 1994). The CR also exceeds the value of 0.7 (Hair et al., 1999), being located between 0.785 and 0.917 (Table 2). Thus, internal consistency and reliability of all the scales can be deduced.

Convergent validity. Convergent validity is checked by reviewing (Table 2): (1) the factor loadings and the degree of significance of these on the corresponding scales, as well as (2) the AVE value, which must be above 0.5 (Fornell and Larcker, 1981). The results show the convergent validity of all the scales.

Discriminant validity. Discriminant validity is guaranteed through two tests: (1) the Fornell and Larcker (1981) criterion, in which it is verified that the squared correlation between each pair of scales does not exceed the AVE of each of them and, (2) the Heterotrait-Monotrait ratio, which must be below 0.85 (Clark and Watson, 1995; Kline, 2011). According to the results (Table 3), it can be affirmed that there is discriminant validity between the variables.

4.3. Validation of the formative scale

The AIP purchase intention variable was proposed as formative. Its validation was based on two tests: (1) the analysis of the absence of multicollinearity, for which it is verified that the VIF is below the value of 5 (Hair et al., 2011) and (2) the analysis of the weight of the items proposed to measure the variable. In this second case, to guarantee the results, a bootstrap was performed again with 5,000 samples with a confidence level of 95 %. The results (Table 4) confirm the permanence of the items on the scale and the consequent validation of the scale.

4.4. Descriptive analysis

Descriptive analysis of the validated scales shows that direct and indirect environmental sustainability achieved the highest average scores (6.02 and 5.90) followed by economic sustainability and social sustainability (5.79 and 5.46). Purchase intention (5.04) had the lowest average.

4.5. Structural model

To test the proposed theoretical model, bootstrapping is performed (5,000 samples and a 95 % confidence interval). It is checked whether the Q^2 value of Stone-Geisser, proposed as a measure of the predictive value of the model, exceeds the value of 0 (Hair et al., 2019a). The results (Table 5) show a model with predictive relevance.

Consequently, the analysis of the factor loadings and their degree of significance allows us to contrast, with the expected sign, all the proposed hypotheses except H3, which is not supported. Thus, the variables environmental sustainability, direct environmental sustainability, indirect environmental sustainability, and social sustainability of packaging are positively and directly related with AIP purchase intention. On the other hand, it cannot be demonstrated that the economic sustainability variable influences the purchase intention of this type of package.

In addition, these results show the relative importance of these

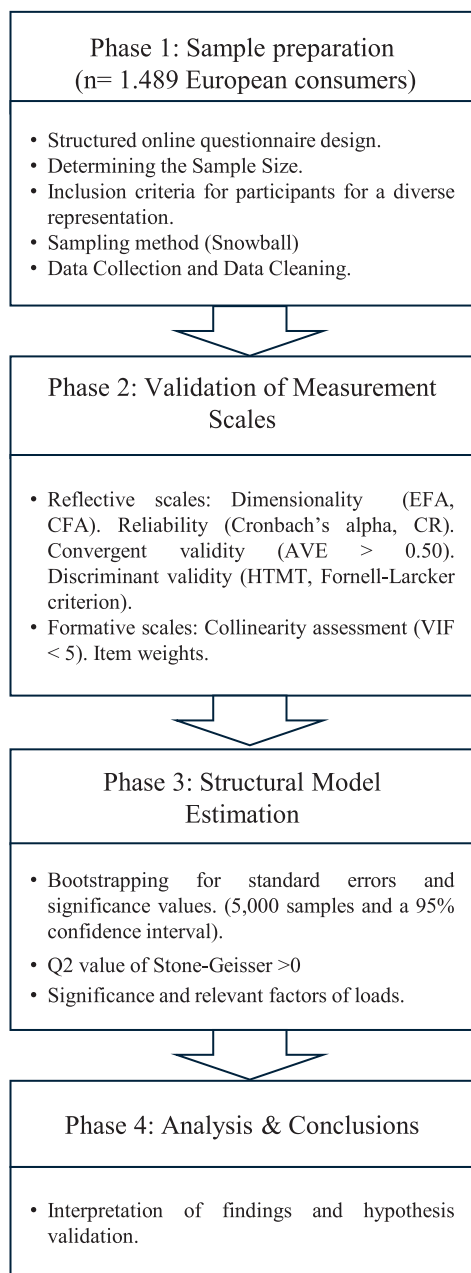


Fig. 3. Key steps in this research Source: Authors' own creation.

variables in generating the AIP purchase intention. Thus, packaging environmental sustainability is the most important in this prediction (0.235), followed by indirect environmental sustainability (0.211), direct environmental sustainability (0.195) and, finally, social sustainability (0.122).

Table 1
Adequacy of factor analysis for scales and dimensionality.

Variable	Items	Determinant	KMO	Rotated factor loadings	Explained variance	Communality
ES	12	0.000	0.915	0.697–0.874	69.23 %	0.498–0.800
SS	5	0.209	0.725		53.37 %	0.495–0.597
EcS	3	0.306	0.726		75.45 %	0.740–0.764

Note: ES: Environmental Sustainability; SS: Social Sustainability; EcS: Economic Sustainability.
Source: Authors' own creation

5. Discussion

In this paper we focus on the relationship between packaging sustainability and the purchase intention of AIP. As shown in this study, from a theoretical point of view, packaging, and in particular AIP, has great potential to reduce the direct environmental impact of packaging, in addition to fulfilling an indirect environmental, social, and economic function that, to the best of our knowledge, has not been analyzed in the literature.

From an empirical point of view, our outcomes help to understand which functions related to the sustainability of the packaging are related or not to the purchase intention of AIP.

Firstly, our results demonstrate that the environmental sustainability of the packaging is positively related to the AIP purchase intention. This is in line with previous research that analyzes and describes the environmental sustainability (direct and indirect) of food packaging in general (Beitzen-Heineke et al., 2017; Boubeta et al., 2018; Granato et al., 2022; Licciardello, 2017; Lindh et al., 2016) and its relationship with consumer variables such as consumers' awareness, behavior, and expectations (Chirilli et al., 2022; Magnier and Schoormans, 2015; Martinho et al., 2015; Rokka and Uusitalo, 2008).

Specifically, our results suggest that it is the indirect environmental sustainability of the packaging that has the greatest positive relationship with AIP purchase intention.

When packaging has a large direct environmental impact, aspects such as the efficient use of resources in manufacturing, the reduction of packaging or the substitution of materials is crucial (Herrmann et al., 2022; Licciardello, 2017; Realini and Marcos, 2014). But when the direct impact is not immediately visible or fully understood, the key will be to reduce food waste and loss, thus contributing to indirect environmental sustainability (Licciardello, 2017). In this aspect, AIP has shown its essential role, as suggested by previous conceptual (Alves et al., 2023; Ezati et al., 2023; Pereira de Abreu et al., 2012; Young et al., 2023) and empirical studies such as Cammarelle et al. (2021) who had already clarified the positive relationship between intention to reduce food waste and willingness to use AIP to achieve this goal on a sample of 206 Italian consumers.

Secondly, our results confirm the relationship between the social sustainability of the packaging and the consumer's AIP purchase intention, contributing to the theoretical (Meherishi et al., 2019; Nordin and Selke, 2010) and empirical literature (Beitzen-Heineke et al., 2017) on this topic that has usually been left aside and often overlooked (Azzi et al., 2012; Toussaint et al., 2021). The results are in line with previous studies such as those by Onurlubasa (2019), who showed that social impact has a moderately significant effect on the purchase behaviour of green products but did not specifically refer to the packaging.

Lastly, economic sustainability did not appear significantly related to the consumers' AIP purchase intention. This diverges from previous findings in the literature that suggest that economic consideration is important for customers when evaluating packaged food (Koutsimanis et al., 2012), sustainable packaging (Granato et al., 2022; Martinho et al., 2015; Petkowicz et al., 2024) and AIP (Soltani et al., 2021; Young et al., 2023). It could mean that consumers lack the knowledge and familiarity required (Cammarelle et al., 2021) to properly assess the price, accessibility and cost-benefits considerations of the AIP. If consumers do not understand or are unaware of benefits of AIP, such as extended shelf

Table 2
Dimensionality, reliability and convergent validity of the scales.

Variable/ <i>Dimensions</i>	Items	Bootstrap		CA	CR	AVE
		Factor loads	Confidence intervals			
ES	12	(0.831–0.897)**	(0.804–0.911)	0.915	0.917	0.520
<i>Direct ES</i>	5	(0.810–0.889)**	(0.781–0.903)	0.916	0.917	0.750
<i>Indirect ES</i>	7	(0.688–0.848)**	(0.625–0.871)	0.909	0.913	0.648
SS	5	(0.694–0.759)**	(0.638–0.802)	0.781	0.785	0.533
EcS	3	(0.838–0.906)**	(0.791–0.930)	0.837	0.909	0.748

Notes: ES: Environmental Sustainability; SS: Social Sustainability; EcS: Economic Sustainability; CA: Cronbach' Alpha; CR: Composite reliability; AVE: Average variance extracted.

*** p < 0.01; ** p < 0.05.

Source: Authors' own creation

Table 3
Discriminant validity of the scales.

	Direct ES	Indirect ES	SS	EcS
Direct ES	0.750	0.544	0.804	0.632
Indirect ES	0.249	0.648	0.761	0.587
SS	0.464	0.413	0.533	0.647
EcS	0.312	0.279	0.289	0.748

Notes: ES: Environmental Sustainability; SS: Social Sustainability; EcS: Economic Sustainability. Values on the diagonal: AVE; below the diagonal: square of the correlations between the factors; above the diagonal: Heterotrait-Monotrait (HTMT).

Source: Authors' own creation

Table 4
Validation of the formative scale (bootstrap results).

Scale/item	Bootstrap		VIF
	Weights	Confidence intervals	
AIP purchase intention			
<i>INTP1</i>	0.809 ***	(0.644–0.921)	1.336
<i>INTP2</i>	0.292 ***	(0.118–0.457)	1.472
<i>INTP3</i>	0.221 ***	(0.038–0.414)	1.337
<i>INTP4</i>	–0.231 ***	((–0.417)–(–0.027))	1.425

*** p < 0.01.

Source: Authors' own creation

Table 5
Hypotheses testing (bootstrap results).

Path	Bootstrap		Results
	Factor loads	Confidence intervals	
H1: ES > AIP purchase intention	0.235	(0.135–0.331)***	Supported
H1a: Direct ES > AIP purchase intention	0.195	(0.804–0.855)***	Supported
H1b: Indirect ES > AIP purchase intention	0.211	(0.883–0.911)***	Supported
H2: SS > AIP purchase intention	0.122	(0.038–0.215)***	Supported
H3: EcS > AIP Purchase intention	0.023	(–0.053)–(0.108) n.s.	Not supported

Note: ES: Environmental Sustainability; SS: Social Sustainability; EcS: Economic Sustainability; Q² (AIP purchase intention) = 0.115.

*** p < 0.01; ** p < 0.05; n.s.: not significant.

Source: Authors' own creation.

life, improved food safety, or reduced food waste, they may perceive it merely as an additional cost (Young et al., 2020). Indeed, consumers may associate these types of packages with exclusivity or luxury products, which may discourage them from including such items in their regular shopping basket.

Moreover, the relationship could be valid for certain active or intelligent packaging but not for both. Previous research, such as that of Tiekstra et al. (2021), indicated that the willingness to pay extra for AIP differed depending on the type of packaging, active or intelligent, placing IP in a better situation. This may provide additional support for the interpretation of our findings.

6. Conclusion and perspectives

The primary aim of this research is to enhance comprehension of how the importance that consumers attribute to sustainability in food packaging influences their intentions to purchase AIP. Through a quantitative methodology we identify that indirect environmental sustainability, related to reducing food waste, is particularly significant followed by direct impact related to packaging materials and recycling and by social sustainability. While economic sustainability has not proved to be significant.

AIP offers significant advantages in reducing food waste and optimizing the supply chain, aspects that are closely aligned with the objectives of EPR policies. This represents a strategic opportunity to achieve market success through innovation, reputation enhancement, competitive differentiation, and the creation of holistic value for consumers and society. However, for all of this to make sense, we need the consumers involvement. In this scenario, collaboration between public administration, industry and waste managers is crucial in raising awareness among families about the true environmental and economic cost of food waste, highlighting how innovative packaging can significantly help to reduce it. Through outreach campaigns, they can help households understand how much money they lose annually by wasting food, as well as the effect this has on the use of natural resources such as water and energy. They should explain how AIP will help them save time and money by facilitating more efficient pantry management. Moreover, the industry should take advantage of the potential of this packaging, especially intelligent packaging, when it comes to providing greater social sustainability in terms of ethics, inclusivity, traceability, and authenticity of the product, aspects that are playing an increasingly important role in purchasing decisions. There are limitations to this study that ideally will be addressed in future work. First, given the focus on the food industry, results should be taken with caution. Further research could test the model in other sectors such as pharmaceuticals or cosmetics. Second, given that both consumers and AIP are dynamic elements, longitudinal research should validate our results considering a real-world scenario and new AIP developments. Finally, our study is based on a sample of European consumers. Then, we proposed that future investigation includes specific analysis considering variables such as nationality, lifestyles or cultural values, to gain a broader and more comparative perspective on the phenomenon.

CRedit authorship contribution statement

María J. López-Miguens: Writing – review & editing, Writing –

original draft, Validation, Supervision, Software, Resources, Methodology, Investigation, Data curation. **Paula Álvarez-González:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Ana Dopico-Parada:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

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

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.wasman.2025.115018>.

Data availability

Data will be made available on request.

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