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Research article

Shaping "green" choices: the role of information, product appearance and environmental attitudes in consumers' willingness to pay for sustainable food packaging

Roberta Selvaggi, Matilde Reitano *, Stefania Lombardo, Gioacchino Pappalardo

Department of Agriculture, Food and Environment (Di3A), Agricultural Economics and Valuation Section, University of Catania, Via Santa Sofia n. 98-100, 95123, Catania, Italy

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ABSTRACT

Increasing environmental pressure and the transition to a circular economy are redefining the priorities of the agri-food sector, particularly in the development of sustainable food packaging solutions. This study estimates consumers' willingness to pay for an innovative biodegradable material, made from citrus pectin and glycerol, tested on a real product (a 30g pack of shelled almonds). By means of a non-hypothetical Random Nth-Price auction conducted on 100 participants, the effects of environmental information, visual/tactile sensory exposure and individual characteristics on economic evaluation are analyzed. The experimental design, consisting of two treatments and nine auction rounds, varied the sequence of exposure and communication. The results show a "sustainability penalty": unfamiliar aesthetic features reduce willingness to pay, even in the presence of detailed environmental information. The order of exposure proves decisive, with first impressions prevailing over cognitive reformulations. Multivariate analysis shows that attributes such as naturalness and practicality positively moderate willingness to pay, while generic environmental attitudes are not significant. The study highlights the importance of integrating sensory design, technological innovation and narrative communication to foster the adoption of high-potential sustainable pre-commercial materials.

1. Introduction

Growing environmental concerns and the global shift toward a circular economy are profoundly transforming the agri-food sector, especially in relation to food packaging. Food packaging, originally designed to ensure product preservation, protection, and communication, is now required to meet increasingly stringent environmental criteria. In particular, the widespread use of conventional plastic materials, derived from fossil resources and non-biodegradable, raises growing ecological concerns and contributes to long-term environmental pollution, micro plastic accumulation, and increased carbon emissions, prompting companies and researchers to develop sustainable and renewable alternatives (Jahangiri et al., 2024). In this context, there is rising interest in biodegradable and compostable packaging materials derived from agro-industrial by-products. Specifically, citrus pomace, a solid residue from the industrial processing of oranges, lemons, and other citrus fruits, composed of peels, pulp, and seeds, represents a resource with high biochemical potential. Rich in pectin, polyphenols, and essential oils, this waste can be utilized to produce active and intelligent sustainable food packaging, contributing to the valorization of organic waste and the closure of production cycles (Fiorentini et al., 2022; Bertolo et al., 2025).

Recent scientific literature supports this trajectory. Bertolo et al. (2025) demonstrated that incorporating natural components derived from citrus waste, particularly pectin and antioxidant compounds, enables the fabrication of active materials that enhance the film's barrier properties and extend food shelf-life. Zhang et al. (2024), using an ultrasound-assisted thermal treatment, produced biodegradable films from citrus peels exhibiting mechanical performance suitable for preserving horticultural products. Building on these findings, Bocker and Silva (2024) further demonstrated that incorporating phenolic compounds into pectin-based emulsions enhances oil phase distribution,

* Corresponding author. Department of Agricultural, Food and Environment (Di3A), Agricultural Economics and Valuation Section, University of Catania, Via Santa Sofia n. 98-100, 95123, Catania, Italy.

E-mail addresses: roberta.selvaggi@unict.it (R. Selvaggi), matilde.reitano@phd.unict.it (M. Reitano), stefania.lombardo@unict.it (S. Lombardo), gioacchino.pappalardo@unict.it (G. Pappalardo).

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stability, and crystalline structure, improving the films' functional properties.

From an industrial perspective, Fiorentini et al. (2022) emphasize the scalability of the process, understood as the feasibility of transferring laboratory technologies to large-scale production, an essential factor for future commercial application. Furthermore, Midolo et al. (2024), through a life cycle assessment (LCA), highlighted the superior environmental sustainability of pectin and limonene extraction processes from citrus pomace compared to traditional methods, reinforcing interest in integrating these practices into existing agro-industrial supply chains.

While technical and environmental advancements in citrus waste-derived bio packaging are well-documented, consumer acceptance, particularly regarding willingness to pay (WTP), remains underexplored. Understanding this dimension is essential for commercial scalability and market adoption. Recent studies suggest that sensory factors such as matte color or natural texture and informational cues, such as the presence or absence of environmental labeling, significantly influence packaging value perception and, consequently, expressed WTP (Cazón et al., 2025; Nahar et al., 2025). In addition to functionality and sustainability, consumers increasingly expect packaging to be visually attractive and pleasant to the touch, aligning with their aesthetic and emotional expectations. If a material, although sustainable, is perceived as unaesthetic or unfamiliar, it may negatively affect purchasing decisions. Within this framework, the effectiveness of communication, specifically the sequence in which environmental information is presented, emerges as a strategic factor warranting investigation (Jahangiri et al., 2024).

In light of these considerations, the present study aims to estimate consumers' WTP for a food product packaged with an experimental biodegradable material made from citrus pectin and glycerol, a by-product of the biodiesel supply chain. The experimental design combines sensory exposure (visual and tactile) with a sequential presentation of technical and environmental information. In contrast to previous studies, which were mainly based on hypothetical scenarios or commercial prototypes, our research adopts a non-hypothetical experimental auction, using a physically realized, but not yet commercialized packaging.

The experimental design was developed to investigate how information and visual and tactile exposure sequences influence consumers' WTP for experimental sustainable biodegradable food packaging. Drawing from literature on information framing, product appearance and sustainable consumer behavior, the research questions (RQs) were formulated and aligned with the experimental design and data analysis plan. In particular, this study aims to answer the following RQs: RQ1: "Does technical and environmental information increase consumers' WTP for sustainable food packaging compared to conventional plastic packaging?" RQ2: "Does visual and tactile exposure to sustainable food packaging influence WTP differently than information alone?" RQ3: "Does the order of exposure (first information vs. first sensory experience) have an impact on consumers' WTP?" RQ4: "Can environmental information, if provided after the sensory experience, mitigate the negative effect on WTP expression?" RQ5: "Which individual factors (e.g. environmental attitudes, food values) significantly influence the variation in WTP?".

Although the experimental auction comprised a total of nine rounds, these were structured into three distinct phases: three rounds referred to the baseline condition with conventional plastic packaging; three rounds focused on exposure to technical and environmental information about the sustainable food packaging; and three rounds involved participants' visual and tactile exposure to the sustainable packaging.

This study offers three key contributions. First, it tests a novel sustainable food packaging material that has been physically produced but not yet commercialized, representing a concrete pre-industrial innovation. Second, the experimental design uniquely combines sensory exposure (visual and tactile) with sequential technical and environmental information. Third, it investigates how individual environmental attitudes interact with sensory perceptions and information framing to shape consumers' valuation of sustainable food packaging.

The next section describes the experimental design, product characteristics, and methodological framework adopted for the study.

1.1. Theoretical framework

The most recent scientific literature on the sustainable agri-food product packaging has shown that the following aspects influence consumers' choices: "information framing", "product appearance and sensory exposure", and "sustainable consumer behavior".

In particular, research on "information framing" demonstrates that the way in which information is structured can systematically alter individuals' evaluations and choices. In consumer studies, framing effects have been shown to influence WTP, particularly when health or environmental benefits are highlighted. For example, Lazaroiu et al. (2019) show that consumers' purchase intentions for environmentally sustainable products are strongly conditioned by the trust they place in information sources and eco-labeling, underlining the critical role of communication strategies in activating pro-environmental choices. Such evidence suggests that manipulating technical versus environmental frames can stimulate distinct motivational pathways (efficiency-oriented vs. pro-social) with consequences for WTP.

As regard "product appearance and sensory exposure", previous studies highlight that visual and tactile cues are decisive in shaping consumer perception, perceived quality, and loyalty. In the context of sustainable packaging, Socaciu et al. (2022) demonstrate that biopolymer films are assessed not only on their technical and functional characteristics but also on their sensory and aesthetic appeal, which enhances consumer preference and acceptance. Dabija et al. (2024) expand this line of research by introducing an experiential consumption perspective, showing that consumers value biopolymer active films through the interplay of functional benefits (e.g., spoilage prevention, nutritional preservation) and hedonic dimensions (e.g., aesthetics, materiality). These findings converge in indicating that product appearance and material properties are central drivers of consumer valuation, not merely peripheral attributes.

The third aspect is "sustainable consumer behavior", which examines the psychological and social factors that support environmentally responsible consumption. Previous studies show that attitudes, values, and perceived trust in sustainability claims directly affect consumers' readiness to pay price premiums for eco-friendly products (Lazaroiu et al., 2019). Socaciu et al. (2022) confirm that consumers are willing to accept higher costs for biopolymer packaging when environmental and functional benefits are clearly communicated. Complementarily, Dabija et al. (2024) demonstrate that transparency, health-related claims, and the overall experiential dimension of packaging reinforce consumer loyalty and repeated preference.

2. Materials and methods

2.1. Data collection

The experimental study was conducted out in Sicily (Italy), between May and June 2024, with the objective of eliciting consumers' WTP for a food product packaged in innovative, sustainable and sustainable food packaging. A total of 100 participants were recruited to take part in a Random Nth-Price experimental auction designed to assess how different types and sequences of product-related information and aspect influence consumer valuation. Given the early-stage development of the packaging material still under laboratory experimentation and not yet available for large-scale production, the sample size was intentionally limited to 100 participants. The auctioned product was not a commercial prototype but was based on the outputs of laboratory testing conducted within the framework of the CIRCLE research project (Citrus

waste ReCycLing for addEd value products). Although this constraint limited the sample size, it enabled the controlled investigation of how sustainability information and sensory exposure affect consumer preferences for a tangible, pre-commercial product.

Participants were individually scheduled to attend experimental sessions at the laboratory of the local university on prearranged dates and times, ensuring controlled conditions and minimizing external influences on bidding behavior. Recruitment was carried out through advertisements posted on university campuses and through email distribution lists targeting students, faculty, and administrative staff at a local university. This strategy was chosen to mitigate the risk of self-selection bias and facilitated an efficient recruitment in a controlled setting. However, it is important to recognize the potential for self-selection bias, as individuals who responded to the call may have had a pre-existing interest in environmental issues or in the research itself. Prior to participation, all individuals provided written informed consent. The study was conducted in full compliance with the General Data Protection Regulation (GDPR) 2016/679.

2.2. Description of the innovative sustainable food packaging material

The innovative packaging material investigated in this study was experimentally produced using only two ingredients: pectin, extracted from citrus pulps (an agro-industrial by-product) and glycerol, a by-product of biodiesel production. The resulting material is classified as home compostable, as it undergoes spontaneous degradation in household organic waste conditions without the need for industrial composting. Complete degradation occurs within three to six months, depending on environmental variables such as temperature and humidity. This material was specifically developed as a sustainable alternative to conventional plastic packaging, addressing the increasing demand for environmentally friendly solutions.

For the purposes of this study, the sustainable food packaging was used to contain a 30-g portion of sliced almonds. Despite the novel material, the product's shelf life remained consistent with conventional plastic packaging, lasting up to one year. However, during the sealing process, a primary limitation was observed: the Maillard reaction between residual sugars and amino acids led to a browned, non-transparent appearance of the material. Furthermore, the surface exhibited slight stickiness to the touch.

Fig. 1 shows the product as presented to participants.

2.3. Auction mechanism

A non-hypothetical Random Nth-Price Auction was employed to elicit participants' WTP for a 30g package of sliced almonds. In this mechanism, each participant submits a private bid, and the winner is determined randomly based on the Nth highest bid, paying the corresponding Nth price. This mechanism was selected for its strong incentive compatibility properties, encouraging participants to reveal their true valuations and thereby providing a reliable measure of WTP (Shogren et al., 2001; List, 2003). Unlike other mechanisms, such as the Vickrey auction, the Random Nth-Price auction reduces the risk of bias associated with extreme bids and has become a robust and accepted approach in the experimental economics literature for eliciting non-hypothetical valuations (Lewis et al., 2016).

Fig. 1. 30g pack of sliced almonds in sustainable food packaging.

The random Nth-price auction format has been extensively used in consumer preference studies for evaluating food products and sustainable food packaging due to its ability to elicit truthful bidding behavior in an experimental context (Bo and Yang, 2022; Yan et al., 2024).

The experimental design included two treatments, each consisting of nine rounds, to evaluate how both the provision of technical and environmental information and direct visual and tactile exposure to the sustainable food packaging influenced participants' WTP. These nine rounds were systematically organized into three distinct phases: the first three rounds concerned the baseline condition, in which participants bid for the ordinary conventional plastic packaging; other three rounds introduced detailed technical and environmental information about the sustainable food packaging; and three rounds involved direct visual and tactile exposure to the sustainable food packaging.

Participants were randomly assigned to one of the two treatments, differing in the order in which product-related information and visual and tactile exposure were introduced.

In Table 1 the experimental design is outlined.

In both Treatment 1 and Treatment 2, rounds 1 to 3 involved bidding for a 30g package of sliced almonds in conventional plastic packaging, similar to products commonly found in supermarkets. All branding, pricing, and logos were removed from the packaging to control for brand-related biases and focus participants' attention solely on the packaging material. Furthermore, participants were informed that the shelf life of the product was one year. This product served as a baseline reference, and no additional information was provided between rounds 1 and 3. Participants were asked to submit three bids across these three initial rounds, all referring to the conventional product, thereby allowing for the calculation of a stable baseline WTP.

From round 4 to round 6, the focus shifted to the 30g a packet of sliced almonds packaged with the innovative sustainable food packaging. In treatment 1 involved a "blind" presentation of the innovative product, i.e. without the possibility of seeing it, however, prior to round 4, detailed information was provided regarding the technical and environmental characteristics of it, specifically the following information was provided:

> "*The experimentally produced packaging is composed of only 2 ingredients, pectin (extracted from citrus pulps obtained as processing waste by-products) and glycerol (waste of biodiesel production).*
>
> The packaging is definable as « biodegradable», more properly « home compostable » i.e., it degrades spontaneously in the wet without the need for industrial composting conditions.

Table 1
Experimental design.

Round	Treatment 1	Treatment 2
R1	Conventional plastic packaging	Conventional plastic packaging
R2		
R3		
R4	Blind condition + detailed information	Visual and tactile exposure
R5	on sustainable food packaging	only (no detailed info)
R6		
R7	Visual and tactile exposure of	Detailed information on
R8	sustainable food packaging	sustainable food packaging
R9		

Complete degradation of the product occurs in 3-6 months, depending on external conditions.

The shelf life of the pack of almonds packaged with this packaging is 1 year".

After this informational intervention, participants were asked to submit three bids (rounds 4 to 6) for the same 30g a packet of sliced almonds packaged with the innovative sustainable food packaging described.

From round 7 to round 9, participants in Treatment 1 were then given direct access to the physical sustainable food packaging, which they could freely observe and touch. This round aimed to simulate real-world sensory exposure. Following this tactile and visual exposure, participants again formulated three bids (rounds 7 to 9).

In treatment 2, the sequence was reversed: participants first experienced the tactile and visual exposure (rounds 4 to 6) without receiving any accompanying technical or environmental information, except for the mention that the packaging was composed of pectin and glycerol. This allowed the assessment of sensory-based valuation independent of informational framing. The objective was to detect the WTP associated with only the visual and tactile of the change in packaging, without the influence of informational elements. Only after this initial tactile and visual exposure were the same participants presented with the informational content before submitting the final three bids (rounds 7 to 9), now integrating both tactile and visual exposure and information knowledge. This structure resulted in a total of nine auction rounds per participant. For analytical purposes, the mean WTP across each block of three rounds (i.e., rounds 1–3, 4–6, and 7–9) was computed to reduce intra-participant variance and stabilize valuation estimates.

This experimental design enabled not only to evaluate consumers' WTP for sustainable food packaging, but also to investigate how the provision of information and the visual and tactile exposure of the product affect purchasing decisions, as well as whether the sequence in which consumers receive information or physically observe the product influences their choices.

At the conclusion of the auction, participants completed a questionnaire collecting: (i) socio-demographic information; (ii) personal food value priorities; (iii) attitudes toward ethical-environmental issues; (iv) sustainable behaviors and awareness; (v) anxiety and concern about climate change.

2.4. Experimental auction procedure

Upon arrival at the experimental laboratory participants were randomly and anonymously assigned an identification code, in full compliance with data protection regulations. Each auction session involved between 5 and 16 participants. To facilitate management, participants were organized into subgroups of approximately 5 to 6 individuals, depending on the session size. In total, 100 participants took part in the experimental auction, distributed across nine separate sessions.

To ensure participants fully understood the auction mechanism, each session began with two training rounds using a test product, a 500g package of pasta. This preliminary phase familiarized participants with the bidding process in a non-binding environment, reducing the risk of procedural errors during the actual auction.

Following the training, the real random N-th price experimental auction was conducted using the target product, a 30g packet of sliced almonds. Bidding occurred over 9 rounds, structured to capture changes in WTP across informational and visual and tactile exposure conditions.

At the end of each round, participants submitted a bid representing the amount they were willing to pay for the product. After completing all nine rounds, one round was randomly selected to be binding. This approach, standard in experimental economics, mitigates strategic behavior by ensuring that participants treat each round as potentially consequential. Within the selected binding round, a random integer N (e.g., 2nd, 3rd, or 4th highest bid, depending on the number of participants) was drawn to determine the transaction price, following the Random Nth-Price Auction protocol. Participants who submitted bids strictly higher than the randomly selected Nth-highest bid won the auction and were allowed to purchase the product at the Nth-highest price, rather than at their own stated bid. This mechanism preserves incentive compatibility by encouraging truthful bidding. "Participants whose bids were equal to or below the Nth price did not purchase the product and incurred no financial cost.

No maximum bid constraints were imposed. However, participants were told that bids had to be non-negative. Despite the absence of a maximum limit, the Random Nth-Price auction mitigates the risk of bias from extreme bids, as an excessively high bid does not guarantee victory and does not directly affect the winner's purchase price, which is determined by the Nth highest bid (Canavari et al., 2019; Shogren et al., 2001).

Finally, each participant received a gadget box valued at €15 as a token of appreciation for their time and contribution to the study.

2.5. Measurement of consumer values and environmental attitudes

To complement the auction-based data, participants were asked to complete a series of 5-point Likert scale items designed to assess their food-related values and environmental attitudes. These items were adapted from validated scales in the literature and administered at the end of each experimental session. The choice of a 5-point scale is supported by the literature, as it provides a balance between sensitivity and cognitive simplicity, reducing respondent fatigue while allowing meaningful differentiation among responses (Dawes, 2008; Joshi et al., 2015). Moreover, a neutral midpoint was included, allowing participants to express indecision or ambivalence, which is important when evaluating subjective attitudes (Kankaraš and Capecchi, 2024).

Furthermore, Likert scales were preferred due to their widespread use in consumer behavior and attitudinal research, and because they facilitate comparison across constructs and statistical analyses (Joshi et al., 2015).

Participants evaluated nine distinct food values to assess the relative importance they attribute to different product characteristics. Each value was assessed on a 5-point Likert scale, ranging from "Not at all important" to "Extremely important". Appendix A reports the list of values along with their definitions, which were inspired by previous works, including Lusk and Briggeman (2009), Lusk (2011), Pappalardo and Lusk (2016), Cerroni et al. (2021) and Reitano et al. (2024).

In addition to food values, the questionnaire assessed participants' environmental attitudes, sustainable behaviors, and climate change concerns. These constructs were measured using a 5-point Likert scale and were drawn from previously validated instruments in the literature (see Appendix B).

2.6. Data processing

Data analysis was performed using Stata SE® version 17.0 (Stata Corp LLC, College Station, TX, USA). For each participant, the three auction rounds within each phase were averaged to compute a single representative WTP value per condition: Rounds 1–3, Rounds 4–6, and Rounds 7–9. This aggregation reduced the nine auction rounds into three analytically meaningful stages, enabling consistent comparisons across treatments. A Chi-square test was conducted to verify the homogeneity of sociodemographic characteristics between the two treatment groups. The statistical evaluation focused on identifying differences in WTP within rounds and between treatment conditions. Within each treatment, paired t-tests were used to compare WTP values across rounds, assessing the impact of informational and sensory exposure to sustainable food packaging.

For evaluations based on Likert-scale questions, the mean score of each attribute was used in the analysis. The internal consistency of the

Likert scales was assessed using Cronbach's alpha. Values between 0.70 and 0.95 are typically considered acceptable (Tavakol and Dennick, 2011). However, values as low as 0.64 may still be adequate depending on the construct complexity and number of items (Izah et al., 2023). Accordingly, alpha values obtained in this study were interpreted in light of these classifications. Finally, an Ordinary Least Squares (OLS) regression analysis was performed to identify the factors influencing changes in WTP. The dependent variable was the variation in WTP across conditions, while independent variables included the treatment condition and the four validated Likert-scale constructs. No aggregation was performed for food values; each was included as an individual predictor. The others validated scale were used as the mean of the variable scores-

To facilitate the interpretation of the analyses, Appendix C outlines the coding schemes and descriptions of the main variables employed in the study. In addition to the socio-demographic characteristics, participants were asked to rate a series of constructs measured through Likert-scale items, treated as categorical variables.

Within-treatment analysis was designed to assess whether consumers' WTP changes when exposed to information and visual and tactile exposure to sustainable food packaging compared to conventional plastic packaging. The first Research Question (RQ1) focuses on Treatment 1, in which participants first evaluate the product with conventional packaging (Rounds 1-3) and then the same product with innovative sustainable food packaging, accompanied by comprehensive technical and environmental information (Rounds 4-6). It is hypothesized that the provision of detailed information regarding the environmental benefits of the sustainable food packaging will lead to a significant increase in WTP (H1: $MeanWTP\_T1_{R4-6} > MeanWTP\_T1_{R1-3}$). This expectation is supported by previous research showing that environmental information enhances consumer valuation of sustainable products (Lee et al., 2019). Research Question 2 (RQ2) addresses whether this initial increase in WTP persists when consumers are exposed to the product's physical appearance. In Rounds 7-9, participants can observe and handle the sustainable food packaging. Given its potentially less appealing visual aspect compared to conventional packaging, it is hypothesized that WTP may decrease relative to Rounds 4-6 (H2: $MeanWTP\_T1_{R4-6} > MeanWTP\_T1_{R7-9}$). Prior literature has highlighted that visual aesthetics play a critical role in consumer preferences, especially when sustainable alternatives diverge from conventional expectations (Jahangiri et al., 2024).

In Treatment 2, the information sequence is reversed, leading to different hypotheses. Research Question 3 (RQ3) explores whether consumers' WTP is affected when they are first exposed to the sustainable food packaging without receiving any information (Rounds 4-6). Coming immediately after the conventional packaging (Rounds 1-3), it is hypothesized that WTP may decrease, as the sustainable option is perceived as less visually attractive and lacks context to justify its value (H3: $MeanWTP\_T1_{R4-6} > MeanWTP\_T1_{R1-3}$). This aligns with findings that a lack of information can result in undervaluation of sustainable innovations (Jahangiri et al., 2024). Research Question 4 (RQ4) investigates whether the subsequent provision of technical and environmental information (Rounds 7-9) can mitigate the negative effect of the unattractive appearance of the packaging. The hypothesis is that WTP will increase in these final rounds as information helps reframe the product in terms of its sustainability benefits, possibly overcoming the initial visual disadvantage (H4: $MeanWTP\_T2_{R7-9} > MeanWTP\_T2_{R4-6}$). Prior work has shown that cognitive understanding of environmental attributes can compensate for suboptimal product aesthetics in shaping consumer preferences (Mookerjee et al., 2021; Wang et al., 2023).

Finally, the fifth research question (RQ5) explores the factors that influence consumers' WTP for sustainably packaged food products. To this end, we examined the role of both validated scales measuring pro-environmental attitudes and behaviors and food values expressed by participants. The corresponding hypothesis (H5) suggests that higher WTP is associated with consumers who display stronger pro-environmental attitudes and behaviors, as well as, though less so, a greater importance attributed to specific food values choices, such as naturalness, safety, and packaging.

3. Results

3.1. Sample characteristics

Summary statistics of the participants in the two treatments (T1 and T2) are reported in Table 2. The two groups were found to be homogeneous across all observed variables, as confirmed by Chi-square tests (all $p > 0.05$). The final sample comprised 100 individuals. Gender distribution showed a prevalence of male participants. Most respondents were between 18 and 31 years old, with an overall mean age of 27.24 years. Regarding income, majority of participants reported an annual net income below €20,000, while the next most represented income range fell within the €20,000–29,999. In terms of educational attainment, there is a majority of graduate participants, especially in treatment 1. The majority of respondents were students, most households were composed of more than three members, and lastly, most of participants reported not having underage family members.

3.2. Analysis of consumers preferences and behavior

To assess the internal consistency and reliability of the Likert scales used in the survey, Cronbach's alpha coefficient was calculated for three distinct constructs: (i) Attitudes toward environmental issues, (ii) Sustainable behaviors and awareness, and (iii) Anxiety and concern about climate change. Each construct was measured using multiple Likert-scale items. The reliability analysis assessed whether these items consistently captured the intended underlying dimensions.

Cronbach's alpha values ranged from 0.64 to 0.93, indicating adequate to excellent internal consistency in line with established literature (Tavakol and Dennick, 2011; Izah et al., 2023).

Analysis of the averages for the importance attached to various food values, reported in Table 3, shows that consumers attach particular

Table 2
Characteristics of the sample.

Variable	n.		p
	T1 (54 units)	T2 (46 units)	
Gender			0.96
Male	32	26	
Female	21	19	
I prefer not to answer	1	1	
Age			0.99
18-24 y.o.	27	23	
25-31 y.o.	17	15	
>31 y.o.	10	8	
Net annual household income			0.24
Less than €20,000	20	22	
Between €20,000 and €29,999	12	11	
Between €30,000 and €39,999	9	5	
Between €40,000 and € 49,999	4	6	
More than €50,000	9	2	
Level of education			0.51
Undergraduates	20	20	
Graduates	34	26	
Job level			0.50
Student	32	30	
Self-employed worker	2	2	
Employee	12	8	
Unemployed	5	6	
Other	3	0	
Family member			0.11
1 member	5	0	
2-3 members	19	17	
>3 members	30	29	
Underage familiar			0.52
yes	9	10	
no	45	36	

importance to product safety (which was awarded the highest minimum value, indicating a common agreement on its relevance) and quality. Healthiness, traceability and price also scored highly, indicating a strong focus on health-related aspects, product origin, and affordability. Price, naturalness, healthiness and quality were the attributes with a minimum score of 2 instead of 1, suggesting a baseline importance consistently attributed to them. In contrast, convenience and packaging received relatively lower scores, suggesting that consumers are less inclined to prioritize these features when making food choices. This highlights a broader pattern: consumers appear to prioritize health and safety over ease of use or packaging-related concerns, which may have implications for how sustainable food packaging innovations are perceived and valued.

The results shown in Table 4 indicate participants' environmental attitudes, sustainable behaviors, and climate change concerns.

The results for the first construct "Attitudes toward environmental issues" indicate widespread agreement with statements that emphasize the importance of environmental protection and sustainability. In particular, strong agreement emerges for the belief that schools should promote ethical environmental thinking, followed by the view that environmental protection is related to quality of life. Participants also strongly agreed on the need to promote sustainable policies and on the prevalence of environmental protection versus industrial development. Conversely, there was less adherence to the other statements, suggesting a selective endorsement of sustainability-related values. It is worth noting that, for all items, the full range of the Likert scale was used by participants, with scores ranging from 1 ("Never true") to 5 ("Always true").

As shown in "Sustainable behaviors and awareness", participants reported high awareness and engagement in sustainability-related behaviors. The highest scores were associated with awareness about pollution and destruction of nature (the only one along with Personal contribution to sustainability with a minimum value greater than 1), attention to health, importance attributed to recycled products, and attention to labels. These findings suggest a relatively high level of individual awareness and commitment to sustainable consumption. The other statements are moderately less supported. Once again, participants employed the full Likert range, indicating variation in behavioral engagement.

Finally, data for "Anxiety and concern about climate change" reveal that participants expressed a moderate to high level of concern about climate change. The highest mean values were recorded for the influence of climate change on weather patterns, concern about how the world will be in the future, and interest in how climate change will affect one's own life and the lives of others. These results suggest a high level of cognitive and emotional engagement with the issue. While these results suggest widespread awareness and emotional engagement, more intense psychological manifestations such as nightmares, crying, and emotional paralysis showed relatively low mean values, indicating that while concern is present, it rarely escalates to severe emotional distress. As with previous sections, it is worth noting that the full range of the Likert scale was used by participants, reinforcing the heterogeneity of emotional responses to climate change.

Table 3
Average attribute scores related to importance of food values.

Variable	Mean	Std. dev.	Min	Max
Price	4.14	0.75	2	5
Convenience	3.63	1.00	1	5
Naturalness	4.02	0.82	2	5
Healthiness	4.41	0.73	2	5
Safety	4.78	0.46	3	5
Traceability	4.20	0.92	1	5
Packaging	3.73	0.92	1	5
Sustainability	4.11	0.90	1	5
Quality	4.53	0.66	2	5

Table 4
Average attribute scores related to attitudes toward ethical-environmental statements.

Construct	Variable	Mean	Std. dev.	Min	Max
Attitudes toward environmental issues	Environmental disasters	3.32	1.14	1	5
	Environmental protection is related to quality of life	4.54	0.64	1	5
	Biodiversity versus agricultural industrial development	3.60	1.18	1	5
	Urban development versus environmental protection	3.36	1.29	1	5
	Environmental protection versus industrial development	4.06	0.94	1	5
	Need to promote sustainable policies	4.28	0.86	1	5
	Economic policies based on natural resource exploitation	2.95	1.43	1	5
	Poverty reduction versus economic well-being in industrialized countries	4.09	0.97	1	5
	Schools should promote ethical environmental thinking	4.63	0.64	1	5
Sustainable behaviors and awareness	Personal contribution to sustainability	4.02	0.78	2	5
	Help to small community	3.43	1.04	1	5
	Superior quality of organic products	3.73	1.06	1	5
	Attention to recyclable packaging	3.62	0.98	1	5
	Avoidance of animal-tested products	3.08	1.29	1	5
	Online search to change the way I consume	3.47	1.12	1	5
	Environmental documentaries	3.90	1.10	1	5
	Awareness of environmental certifications	4.00	0.82	1	5
	Pollution and destruction of nature	4.56	0.71	2	5
	Values reflected on labels	3.94	0.88	1	5
	Attention to labels	4.11	0.84	1	5
	Attention to health	4.28	0.82	1	5
	Importance of recycled products	4.23	0.87	1	5
	Perceived superiority of organic products	3.87	1.07	1	5
	Effort to buy recycled packaging	3.74	0.99	1	5
Anxiety and concern about climate change	Difficulty concentrating	2.70	1.29	1	5
	Difficulty sleeping	2.60	1.29	1	5
	Nightmares	2.39	1.31	1	5
	Crying	2.08	1.19	1	5
	Sense of guilt	3.37	1.24	1	5
	Solitude	2.60	1.33	1	5
	Emotional paralysis	2.40	1.26	1	5
	Readiness to face climate challenges	3.01	1.35	1	5
	Obsessive thoughts about climate change	2.71	1.33	1	5
	How climate change will affect one's own life and the lives of others	3.77	1.20	1	5
	Preoccupation more for others	3.06	1.34	1	5
	How the world will be in the future	3.83	1.23	1	5
	Climate worry	3.52	1.18	1	5
	Escape from environmental problems	3.74	1.12	1	5
	Influence of climate change on weather	4.10	1.03	1	5

3.3. Willingness to pay

Table 5 reports the mean values for WTP across the two treatments. The experimental auction consisted of nine rounds, grouped into three phases: Rounds 1-3 (R1-3), Rounds 4-6 (R4-6), and Rounds 7-9 (R7-9). The first phase involved bids on the conventional plastic packaging, while the second and third phases introduced the sustainable food packaging.

Participants' WTP decreased progressively over the first three rounds in both treatments. This decline is particularly evident between R1-3 and R4-6, coinciding with the change in packaging from the conventional plastic format (R1-3) to the sustainable biodegradable alternative (R4-6 and R7-9).

In Treatment 1, participants received detailed information about the sustainable food packaging during R4-6 (in a blind condition), followed by visual/tactile exposure in R7-9. The steady decline in WTP across phases could reflect initial skepticism or a perceived loss in product quality or convenience, often referred to as a "sustainability penalty", which was not offset by the subsequent physical exposure.

In Treatment 2, the initial exposure to sustainable food packaging was purely visual/tactile in R4-6 (without information), while detailed information was introduced only in R7-9. Here, the sharp initial decline from R1-3 to R4-6 might suggest a negative reaction to unfamiliar packaging in the absence of contextual information. However, the fact that WTP remained stable between R4-6 and R7-9 could indicate a learning effect, adaptation to the new packaging, or a positive influence of the sustainability label provided later. These patterns suggest that both the type and timing of information, as well as sensory exposure, can meaningfully influence consumers' valuation of sustainable food packaging solutions.

To evaluate the impact of treatments on participants' WTP across the two treatments and for different rounds, a *t*-test was conducted, as reported in Table 6.

The decrease in WTP from R1-3 to R4-6 is statistically significant for both treatments, indicating a robust drop in bids after the first round of exposure to the conventional product. However, the decrease from R4-6 to R7-9 is statistically significant only in Treatment 1, while in Treatment 2, no significant difference is observed between these rounds.

To further investigate the determinants of participants' variation in WTP the OLS regression model was estimated as illustrated in Table 7. The dependent variable was defined as the change in WTP between rounds, defined as the difference between the average WTP. The explanatory variables were the treatment group, the average score of variables of Likert scales and the socio-demographic characteristics. The overall model was statistically significant ($p < 0.001$), explaining approximately 55% of the variance in WTP ($R^2 = 0.55$; adjusted $R^2 = 0.44$).

Results from the regression model show that the treatment variable has a negative and statistically significant effect on the change in WTP ($\beta = -0.270$; $p < 0.001$), indicating that individuals in Treatment 2 had a significantly lower change in WTP compared to those in Treatment 1. Among the perceived importance of food values, "Practicality" ($\beta = 0.060$, $p < 0.05$) and "Naturalness" ($\beta = 0.082$, $p < 0.05$) were positively associated with variation in WTP, suggesting that consumers who consider these attributes important are more likely to increase their WTP. In contrast, "Packaging" ($\beta = -0.098$, $p < 0.05$) and "Quality" ($\beta = -0.146$, $p < 0.01$) had negative and significant effects on variation in WTP.

Among the socio-demographic variables, age had a statistically significant negative effect on variation in WTP ($\beta = -0.014$, $p < 0.01$), suggesting that older participants were less likely to change their WTP. The number of family members was also negatively associated with variation in WTP ($\beta = -0.113$, $p < 0.05$). Income was marginally significant at the 10% level ($\beta = -0.039$, $p = 0.064$).

None of the broader psychological constructs, that is attitudes toward environmental issues, sustainable behaviors, and climate anxiety were significantly associated with changes in WTP.

Table 5
Mean bid values across rounds, by treatments.

	T1 (54 units)		T2 (46 units)	
	Mean WTP [€]	Standard deviation	Mean WTP [€]	Standard deviation
R1-3	0.90	0.43	0.91	0.52
R4-6	0.67	0.42	0.51	0.33
R7-9	0.54	0.36	0.50	0.29

Table 6
t-test for equality of mean WTP within groups.

	T1 (54 units)		T2 (46 units)	
	Mean WTP difference	p-value	Mean WTP difference	p-value
R1-3 vs R4-6	0.23	0.0000***	0.39	0.0000***
R4-6 vs R7-9	0.13	0.0003***	0.01	0.7219

Note: The null hypothesis is mean difference = 0 and probability is ($|T| > |t|$). *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.

Table 7
Regression analysis of factor influencing WTP.

Variable	Coefficient (β)	p-value
Treatment	−0.270	0.000***
Price	−0.046	0.200
Convenience	0.060	0.036**
Naturalness	0.082	0.030**
Healthiness	0.033	0.486
Safety	−0.077	0.274
Traceability	0.054	0.151
Packaging	−0.098	0.013**
Sustainability	0.057	0.158
Quality	−0.146	0.010***
Attitudes toward environmental issues	0.061	0.303
Sustainable behaviors and awareness	0.070	0.227
Anxiety and concern about climate change	0.021	0.548
Gender	0.057	0.265
Age	−0.014	0.001***
Education Level	−0.032	0.488
Job Level	0.045	0.110
Family Members	−0.113	0.031**
Underage Family Member	−0.028	0.706
Income	−0.039	0.064*

*, **, and *** denote significance at 10%, 5%, and 1% levels, respectively.
Model statistics: R-squared: 0.55; Adjusted R-squared: 0.44; p-value 0.000.

4. Discussion

This study sheds light on the complex relationship between consumers' valuation of biodegradable packaging and the interplay of information, sensory perception, and individual attitudes. By focusing on an innovative biodegradable packaging material made from citrus pectin and glycerol, our findings contribute to the broader discourse on how sustainable materials are perceived and economically evaluated by consumers, especially in early-stage commercialization contexts.

- RQ1: Does technical and environmental information increase consumers' WTP for sustainable food packaging compared to conventional plastic packaging?

Contrary to expectations and prior literature (e.g., Lee et al., 2019; Socaciu et al., 2022; Jahangiri et al., 2024), our results show that information alone did not enhance WTP. On the contrary, a significant decrease was observed following the presentation of sustainability-related information, even before participants physically interacted with the packaging. This suggests that aspects related to "information framing" and "sustainable consumer behavior" when detached from sensory congruence ("product appearance and sensory exposure"), may lack persuasive power. Consumers may remain skeptical or indifferent if the benefits communicated at a cognitive level are not supported by an intuitive or emotional match, particularly in a product domain like food where packaging is not only functional but symbolic of safety, freshness, and quality.

- RQ2: Does visual and tactile exposure to sustainable food packaging influence WTP differently than information alone?

This limitation of informational framing becomes even more evident when considering RQ2. As expected, contact with the sustainable material further reduced consumers' valuation. This finding aligns with prior evidence highlighted by literature (Dabija et al., 2024; Cazón et al., 2025; Nahar et al., 2025) that consumers heavily rely on sensory cues when evaluating packaging. In our case, the brownish, opaque appearance of the new material and its slightly sticky texture elicited unfavorable reactions that were not offset by its environmental credentials. This "sustainability penalty" reflects a fundamental dilemma in sustainable design: materials that excel in terms of ecological performance may struggle to gain acceptance if their appearance and texture deviate too much from established aesthetic norms. This highlights the need to integrate technological development with sensory design from the earliest stages of innovation.

- RQ3: Does the order of exposure (first information vs. first sensory experience) have an impact on consumers' WTP?

The sequence in which information and sensory stimuli are presented to consumers, addressed in RQ3, plays a critical role in shaping their responses. Participants exposed to information before interacting with the product (Treatment 1) reported a slightly more moderated decline in WTP, while those who encountered the packaging first (Treatment 2) and received information only afterward, displayed a sharper and more persistent drop in valuation. This confirms that first impressions especially negative ones are difficult to reverse, even when subsequent information provides a rational framework. This phenomenon echoes findings from cognitive psychology and behavioral economics, which emphasize the durability of initial sensory judgments and the limitations of corrective information (Mookerjee et al., 2021).

- RQ4: Can environmental information, if provided after the sensory experience, mitigate the negative effect on WTP expression?

In line with this, RQ4 asked whether post-sensory environmental information could mitigate the negative impact of a first unimpressive sensory experience. The results show that it did not as WTP remained low even after the provision of detailed information. This suggests that once consumers formed an unfavorable judgment based on visual and tactile cues, subsequent messages even informative or well-intentioned, were largely ineffective. The lack of a "cognitive reframing" effect indicates that the persuasiveness of sustainability concept is contingent not only on message content, but also on its timing relative to consumer experience.

- RQ5: Which individual factors (e.g. environmental attitudes, food values) significantly influence the variation in WTP?

Interestingly, general pro-environmental attitudes, sustainable behavior, and even climate-related concern were not significant predictors of WTP variation. This contrasts with some strands of literature that emphasize the strength of ethical and environmental motivations in driving sustainable choices (Biasutti and Frate, 2016; De Carvalho et al., 2015; Innocenti et al., 2021). Instead, our findings suggest that when a product has clear aesthetic or sensory shortcomings, ethical motivations alone are insufficient to justify a premium. On the other hand, more concrete food values such as naturalness and convenience emerged as positive moderators of WTP, indicating that consumers who prioritize these dimensions may be more receptive to novel materials even if visually unfamiliar. Conversely, the importance attributed to quality and packaging was negatively associated with WTP variation, reinforcing the idea that deeply ingrained expectations regarding packaging performance can hinder the market adoption of sustainable alternatives that deviate from standard aesthetics.

Overall, our findings highlight the complexity of consumer resistance to sustainable innovations. Beyond technological functionality and ecological performance, successful adoption requires alignment of sensory experience, communication timing, and value alignment. The study illustrates how even well-informed and environmentally conscious individuals can resist change when the materiality of innovation conflicts with sensory expectations. To overcome this obstacle, sustainable packaging must not only "be" environmentally friendly, but also "appear" and "feel" right.

5. Conclusion

This study contributes to the growing literature on sustainable packaging by providing experimental evidence on how consumers evaluate a biodegradable material derived from citrus waste, under varying conditions of sensory exposure and informational framing. By adopting a non-hypothetical auction with a real pre-commercial prototype, the research reveals that consumer acceptance of sustainable packaging is shaped not only by environmental concern, but also and often more decisively by aesthetic compatibility and the order in which sensory and cognitive stimuli are experienced.

The findings carry important implications for different stakeholders. For researchers, our findings highlight the need to move beyond attitude-based models and incorporate perceptual and contextual variables into the study of green consumer behavior. For practitioners and innovators, the study underscores that ecological performance alone is not sufficient. In fact, successful market adoption will require packaging solutions that also meet consumers' sensory expectations. Design thinking and early-stage consumer testing should therefore be integral to sustainable packaging development.

From a policy perspective, the results suggest that informational campaigns promoting eco-packaging must be strategically timed and emotionally engaging to be effective. Policymakers should also consider supporting certification schemes and communication tools that help consumers recognize the value of novel materials, especially when their appearance departs from familiar norms. In addition, public investment in design-driven innovation and industry-academia collaboration can help accelerate the market readiness of sustainable materials that are both functional and consumer-acceptable.

However, this study has some limitations that should be addressed in future research. The experiment was conducted in a controlled environment, so the findings may not be directly generalizable to real-world retail contexts, where multiple external factors influence consumer behavior. Moreover, upcoming surveys should include a variety of product categories and culturally and geographically diverse samples to assess generalizability. Additionally, exploring the role of information, communication strategies, and marketing campaigns could help bridge the perception gap between traditional and innovative packaging, emphasizing transparency and environmental value.

In sum, fostering the transition to sustainable packaging requires more than technological innovation. It demands a nuanced

understanding of how consumers perceive, feel, and make meaning around "green" materials bridging environmental performance with sensory appeal, communication strategy, and behavioral insight.

CRediT authorship contribution statement

Roberta Selvaggi: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation. **Matilde Reitano:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation. **Stefania Lombardo:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Gioacchino Pappalardo:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition.

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

Table A.1
Food values.

Values	Description
Price	The cost of the product and its affordability.
Convenience	Ease and convenience in transporting and/or consuming a product.
Naturalness	Sense of naturalness when buying that product.
Healthiness	The food you are buying must be good for your health.
Safety	When consuming a product does not pose a risk to your health.
Traceability	Information about the origin of the product you are buying.
Packaging	Packaging that wraps the product you are buying.
Sustainability	Environmental issues involved during the production process.
Quality	The product you are buying must be of good quality in terms of the various nutraceutical and organoleptic indices.

Appendix B

Table B.1
Constructs on environmental and sustainable attitudes.

Constructs	Description	Scale	Source
Attitudes toward environmental issues	General beliefs and concerns regarding environmental protection and pollution.	From 1- "Not at all agree" to 5-"Very agree"	Biasutti and Frate (2016)
Sustainable behaviors and awareness	Personal values and commitment toward sustainable consumption and lifestyle.	From 1- "Never true" to 5-"Always true"	De Carvalho et al. (2015)
Anxiety and concern about climate change	Level of worry, perceived severity, and urgency regarding climate change.	From 1- "Never true" to 5-"Always true"	Innocenti et al. (2021)

Appendix C

Table C.1
Coding and description of key variables.

Variable description	Possible values	Type
Willingness to pay	Bid in euros for 1 package of sliced almonds (30g)	Continued
Gender	0 = Male 1 = Female 2 = I prefer not to answer	Categorial
Age	Number of years	Continued
Education level	0 = Undergraduates 1 = Graduates	Dummy
Net annual household income	1 = less than €20,000 2 = between €20,000 to €29,999 3 = between €30,000 to €39,999 4 = between €40,000 to €49,999 5 = more than €50,000	Categorial

(*continued on next page*)

Table C.1 (*continued*)

Variable description	Possible values	Type
Job level	1 = Student 2 = Self-employed worker 3 = Employee 4 = Unemployed 5 = Other	Categorial
Family member	1 = 1 member 2 = 2-3 members 3= > 3 members	Categorial
Underage familiar	0 = no 1 = yes	Dummy

Data availability

Data will be made available on request.

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