From creepy to crispy: species-specific acceptance of insect flours in crackers through a discrete choice experiment on young consumer preferences

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Abstract: This study aims to investigate Italian consumers' interest and their willingness to pay (WTP) for crackers containing *Tenebrio* and cricket flour. Through a discrete choice experiment this study estimated consumers' utility and WTP of a stratified sample of young consumers for different combinations of extrinsic attributes—such as flour type, extrinsic characteristics, and packaging—while incorporating psychometric scales to capture trade-offs across product alternatives. Results indicate that insect flours generate lower utility compared to wheat flour. However, when socio-demographic and psychological interactions are considered, substantial variability in WTP emerges. This heterogeneity is largely driven by gender, age, and food neophobia. For cricket flour, female respondents and late Millennials exhibit lower WTP, whereas mealworm flour acceptance is more strongly influenced by psychometric traits, with older and more neophobic consumers showing greater resistance. Overall, acceptance declines with age and varies within generational cohorts, highlighting the importance of intra-generational differences in shaping consumer responses.

Keywords: insect-based food; neophobia; packaging; colour; discrete choice experiment; intra-generational heterogeneity; late millennials; early millennials

1. Introduction

The growing pressure on global food systems, linked to population growth, food waste and climate change, makes it urgent to identify alternative protein sources capable of ensuring sustainability and food security (Lanfranchi et al., 2016; van Huis, 2022; Di Vita et al., 2024a). Edible insects represent one of the most promising solutions thanks to their high protein content, efficient feed conversion, and reduced environmental impact compared to traditional livestock farming (van Huis and Oonincx, 2017; Berggren et al., 2019; Hamam et al., 2024).

Despite these potential advantages, acceptance of insect-based products remains limited in Italy and other Western countries. Numerous studies have shown that psychological and cultural barriers, such as disgust and food neophobia, significantly hinder willingness to consume them (Verbeke, 2015; Hartmann and Siegrist, 2016). At the same time, factors such as environmental awareness, the search for healthy foods, and exposure to positive information can foster more open attitudes toward these products (Hartmann et al., 2015; Mancini et al., 2019; Spina et al., 2026).

European consumer acceptance remains heterogeneous and highly segmented: early adopters are typically young, more open to new foods, and sensitive to environmental issues (Hamam et al., 2025; Schäufele et al., 2019). In Italy, where gastronomic tradition and product origin strongly influence purchasing decisions, the adoption of innovative ingredients such as insect flour is particularly complex (Iannuzzi et al., 2019).

Several studies have shown that both the degree of processing of insects and consumers' familiarity with the product strongly influence acceptance. Processed foods that "hide" the insect ingredients are generally more acceptable than those in which insects are visible (Tan et al., 2016). In this sense, baked snacks represent a strategic channel, as they combine widespread consumption with the ability to integrate novel ingredients in a form that is not perceived as foreign (Caparros Megido et al., 2014).

Yet, despite growing interest in edible insects, the literature still presents notable limitations. Most studies have focused on general attitudes or sensory evaluations (Hartmann and Siegrist, 2016;

Mancini et al., 2019), while relatively few have examined how extrinsic attributes jointly shape consumer preferences (Bonaiuto et al., 2021).

The rising demand for sustainable protein sources has spurred growing interest in different edible insect species as alternatives to conventional animal products. Among these, *Acheta domesticus* (cricket) and *Tenebrio molitor* (mealworm) are two of the most widely studied species due to their favorable nutritional profiles, relatively low environmental footprint, and increasing market availability (Orkusz et al., 2023; Farkas et al., 2025; Moruzzo et al., 2021).

Incorporating insect flour into familiar products such as crackers offers a promising strategy to reduce consumer neophobia and facilitate market acceptance (Djouadi et al., 2022; Akullo et al., 2018).

However, consumer willingness to pay (WTP) and the trade-offs they are willing to make between sensory, functional, and sustainability attributes remain underexplored, particularly in bakery products where insect flours can be seamlessly integrated (Arodin et al., 2020; Arama et al., 2023). While some studies have used discrete choice experiments (DCEs) to assess preferences for insect-based foods (Alemu and Olsen, 2019; Michel and Begho, 2023; Puteri et al., 2024), direct comparisons of WTP across different insect species are still scarce. Understanding these trade-offs is crucial not only for guiding product development but also for marketing strategies and policies aimed at normalizing insect consumption.

Recent research applying DCEs has identified consumer segments more likely to adopt insect-based foods and explored interactions with sociodemographic and psychological variables (Nazzaro et al., 2024; Puteri et al., 2024). In the Italian context, research is even more fragmented, largely confined to attitudinal surveys or small-scale prototype tests, with limited application of robust choice-based methodologies (Sogari et al., 2019). Indeed, in Italy, studies remain limited, descriptive in nature, and rarely integrate multiple product attributes with individual-level factors in an analytical framework (Mancini et al., 2019; Sogari et al., 2019).

This study helps fill these gaps by applying a DCE to simultaneously analyze six product attributes within a realistic consumption scenario. The analysis focuses on young Italian consumers, a

population particularly relevant for the future market of edible insects, and incorporates psychological variables such as food neophobia and environmental awareness to better capture drivers and barriers to acceptance. Specifically, the study examines preferences for single-serving crackers in which wheat flour is partially replaced with cricket (*Acheta domesticus*) or mealworm (*Tenebrio molitor*) flour. It evaluates the relative importance of key extrinsic attributes—flour type, packaging type and color, geographical origin, surface salt, and price—while estimating consumer WTP for each. Moreover, it investigates the influence of sociodemographic and psychological variables on these preferences.

By directly comparing WTP and attribute trade-offs between cricket- and mealworm-based crackers, the study provides species-specific insights into consumer acceptance and highlights the market potential of insect-enriched bakery products.

2. Study background and research hypotheses

The existing literature on edible insects has examined psychological, social, and extrinsic factors that influence food choices. Previous studies consistently indicate that consumers perceive insect-based products less favorably than conventional alternatives due to neophobia and cultural barriers (Hartmann and Siegrist, 2016; Tan et al., 2016). Moreover, familiarity and market exposure differ across insect species, with cricket-based products being more established in Europe than mealworm, potentially affecting consumer trust and acceptance (Caparros Megido et al., 2014; Mancini et al., 2019). In light of these findings, the following hypotheses are proposed:

H1. Crackers formulated with insect flour are expected to yield lower consumer utility compared to conventional wheat-based crackers.

H2. The type of insect species incorporated into crackers (cricket vs. mealworm) exerts a differential effect on consumer utility and willingness to pay.

Extrinsic product attributes strongly influence food choices, shaping perceptions of quality and purchase intentions. Factors such as packaging, color, geographical origin, and price act as key decision drivers (Marshall et al., 2006; Bonaiuto et al., 2021; Mitterer-Daltoé et al., 2024), while sustainability cues are increasingly important in guiding consumer responsiveness (Kuff et al., 2023). Consequently, the following hypothesis is proposed:

H3. Extrinsic product attributes, packaging color, country of origin, and sustainability influence consumer preferences and willingness to pay.

Consumer acceptance of novel and sustainable foods is shaped by heterogeneity in psychological and attitudinal traits. Food neophobia represents a major barrier, lowering willingness to try ingredients perceived as unfamiliar or culturally distant (Pliner and Hobden, 1992; Laureati et al., 2016; Sogari et al., 2023). Conversely, pro-environmental orientation, health consciousness, and sustainability concerns can foster more positive attitudes, mitigating resistance and encouraging adoption (Bae and Choi, 2021; Ghali-Zinoubi, 2022).

H4. Individual differences in food neophobia and environmentally conscious consumer behavior significantly moderate consumer preferences and willingness to pay for insect-based crackers.

Previous studies highlight that gender and age significantly shape the adoption of food innovations and willingness to pay (WTP), with women and older consumers often exhibiting greater reluctance toward insect-based products (House, 2016; Laureati et al., 2016). In light of this, the following hypothesis is proposed:

H5. Sociodemographic characteristics exert heterogeneous effects on willingness to pay, depending on the type of flour used.

3. Materials and methods

3.1 Choice experiment

In recent years, research has made extensive use of discrete choice models to study individual decision-making processes (Cerroni et al., 2019; Kim et al., 2020). Numerous studies in the literature employ this methodology to analyze the influence that different product attributes can have on consumer preferences and purchasing decisions (Güney and Giraldo, 2020; Califano and Spence, 2024). This approach is particularly useful when evaluating product characteristics not yet available on the market, such as insect meal-based products (Puteri et al., 2024). This method is based on the assumption that each product can be described as a set of attributes, and that consumers make choices between alternatives during the various stages of the decision-making process (Lancaster, 1966).

The aim of the study was to analyze the impact of the presence of insect flour—specifically cricket flour (15%) and *Tenebrio* flour (10%)—in a 25g single-serving pack of crackers on consumers' propensity to choose and consume the product. To this end, six attributes deemed essential for the investigation were selected (Table 1).

Table 1. Attributes and levels considered for a 25g single-serving cracker.

Attributes	Levels
Flour	Wheat flour (100%)
	Cricket flour (15%)
	Tenebrio flour (10%)
Packaging	Not biodegradable
	Biodegradable
Packaging color	Red
	Green
	Yellow

Origin	Foreign
	Italy
Presence of salt on the surface	No
	Yes
Price	€0.50
	€1.20
	€1.90

The first attribute concerns the type of flour used: wheat flour (100%), cricket flour (15%), and *Tenebrio* flour (10%). This variable was chosen because, while wheat flour is well-known and commonly accepted by consumers, the presence—even partial—of insect flour can arouse feelings of repulsion or uncertainty (Gmuer et al., 2016). The percentages of flour present in insect-based crackers were determined based on a market survey on baked goods containing insects. The second attribute refers to the type of packaging, distinguishing between biodegradable and non-biodegradable packaging. This choice is based on the hypothesis that more environmentally conscious consumers are more inclined to prefer sustainable packaging (Mitterer-Daltoé et al., 2024).

The third attribute is the color of the packaging, divided into three variants: red, green, and yellow. The choice of color can influence the perception and attractiveness of the product (Marshall et al., 2006). The fourth attribute concerns the product's origin, with two levels: Italian and foreign. Generally, consumers tend to attribute greater trust and quality to products of domestic origin (Bonaiuto et al., 2021). The fifth attribute refers to the presence or absence of salt on the surface, a characteristic that can influence taste perception and product satisfaction (Hurst et al., 2022).

Finally, the sixth attribute is price, divided into three levels: a low price (€0.50 for a 25g single-serving), a medium price (€1.20), and a high price (€1.90). The definition of these levels was based on an analysis of the average prices of similar products available in various supermarkets and

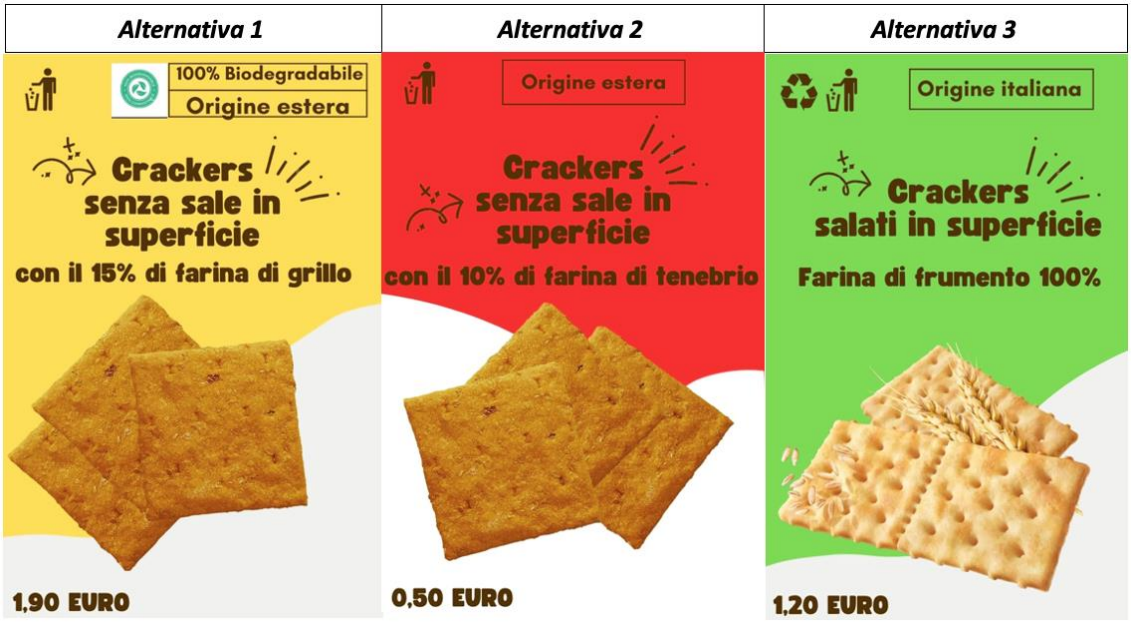
hypermarkets (Michel and Begho, 2023). Table 1 summarizes the six attributes considered and their levels employed in the choice set.

The experimental design is particularly important in multi-attribute valuation approaches for increasing the reliability of responses and improving the accuracy of estimates (Zanchini et al., 2025). The D-optimal experimental design used in this study included a total of 12 experimental combinations. The design was generated using the modified Fedorov algorithm, which optimizes the design's D-efficiency based on the covariance matrix associated with the conditional logit model (Carlsson and Martinsson, 2003; Di Vita et al., 2024b).

The 12 combinations were divided into 3 blocks, and each participant completed four choice tasks, for a total of 12 choice tasks distributed among the respondents. In each task, participants had to express their preference among three multi-attribute alternatives (labelled options A, B, and C) (Hensher et al., 2015). The proposed alternatives differed based on the levels of the attributes considered, thus allowing a direct comparison between different product configurations and the assessment of individual preferences. The no-option was excluded to implement a forced-choice design, consistent with the objective of eliciting trade-offs among product attributes rather than modelling market participation. In the context of insect-based foods, including an opt-out alternative may lead to systematic avoidance driven by neophobia, thereby reducing the informational content of the choice data. Our design assumes a scenario in which consumers are already considering available alternatives, allowing us to capture relative preferences more efficiently. This approach is consistent with prior discrete choice studies (Charbonnier et al., 2015; Skouw et al., 2023; Manipis et al., 2023).

Participants were thereafter given the traits and their respective levels to be evaluated during the choice experiment, which formed the essence of the questionnaire. A representative example of the choice set used is shown in Figure 1.

Fig. 1 Example of a choice set used in the present study.



3.2 Empirical model

In the framework of the choice experiment, participants were asked to evaluate and compare several alternatives and to select the option that maximized their utility (Di Santo et al., 2024; Nazzaro et al., 2024). In line with Lancaster's (1966) theory, consumer utility is assumed to derive primarily from the specific attributes of a product rather than from the product as a whole.

Although insects were not presented in their whole form, information about the insect species was explicitly communicated to respondents within the experimental scenario. Previous research has shown that even when insects are incorporated as ingredients (e.g., flour or powder), the declared insect species can still influence consumer perceptions, attitudes, and willingness to pay, as different species evoke varying levels of familiarity, perceived naturalness, and cultural acceptance.

Consumer preferences for various product alternatives were examined with the Random Utility Model (RUM) framework established by McFadden (2001), with parameter estimation conducted by the mixed logit method (Kershaw et al., 2019; De Salvo et al., 2020).

3.3 Survey design and data collection

A questionnaire was created for a sample of young Italians aged 18 to 40, chosen to reflect the possible marketing target for novel food producers. The questionnaire started with an introduction segment detailing privacy information and elucidating the study aims, to provide participants with optimal conditions for completion.

The survey subsequently included two psychometric scales: the Food Neophobia Scale (FNS) (Pliner and Hobden, 1992) and the Environmentally Consciousness Consumer Behavior (ECCB) (Ghali-Zinoubi, 2022) scale. Participants were asked to express their degree of agreement with each statement on a 5-point *Likert* scale (1 = "*strongly disagree*"; 5 = "*strongly agree*").

Table 2 presents the items of the two psychometric measures, together with their descriptive statistics (mean and standard deviation). Additionally, Cronbach's alpha was computed for each scale to evaluate its internal consistency.

Tab.2 Measurement items.

Construct	Item	Mean	St. Dev.	Cronbach's α
Food Neophobia Scale (FNS) (Pliner and Hobden, 1992)	I am constantly sampling new and different foods.	3.06	1.30	0.77
	I don't trust new foods.	2.31	1.20	
	If I don't know what a food is, I won't try it.	3.00	1.41	
	I like foods from different cultures.	3.25	1.34	
	Ethnic food looks too weird to eat.	2.15	1.23	
	At dinner parties, I will try new foods.	3.08	1.22	
	I am afraid to eat things I have never had before.	2.30	1.31	

	I am very particular about the foods I eat.	3.21	1.30	
	I will eat almost anything.	3.25	1.33	
	I like to try new ethnic restaurants.	2.95	1.37	
Environmentally consciousness consumer behavior (ECCB) (Ghali-Zinoubi, 2022)	When there is a choice, I always choose the product that contributes to the least amount of pollution.	3.26	1.31	0.93
	Whenever possible, I buy products packaged in recyclable containers.	3.68	1.30	
	When I purchase products, I make a conscious effort to buy those products that are low in pollutants.	3.47	1.29	
	When I have a choice between two equal products, I always purchase the one less harmful to the natural environment.	3.54	1.31	
	I do not buy a product if the company that sells it is environmentally irresponsible.	3.21	1.32	
	I have switched products for ecological reasons.	2.94	1.35	

The concluding component focused on gathering sociodemographic data, including gender, age, educational attainment, family income, and sports involvement (Ren et al., 2023; Khalil et al., 2025). The poll was conducted online with Google Forms from January to March 2025, employing a convenience sample method (Sogari et al., 2024). The poll link was originally sent over social media platforms, including Facebook, LinkedIn, and WhatsApp.

Although acknowledging that convenience sampling does not provide statistical representativeness of the whole population—due to participant selection based on accessibility rather than

randomization—this approach was deemed suitable in this instance. Due to the challenges in directly accessing the specified study target, homogeneous convenience sample was used, considered more suitable and dependable than conventional convenience sampling (Jager et al., 2017).

This study involved adult participants and was conducted through an anonymous online survey. Prior to participation, respondents received information about the study and provided informed consent. Participation was voluntary, and no sensitive or personally identifiable data were collected. Given the non-invasive nature of the research and the exclusive use of anonymous data, the study was considered to pose minimal risk. Therefore, in line with common practices in social science research, all procedures complied with the principles of the Declaration of Helsinki and internationally accepted ethical standards for research involving human participants.

4. Results

4.1 Descriptive statistics of the sample

A total of 775 respondents participated in the survey; the sample was stratified and it is representative of Italian population as regards gender and age. Descriptive statistics for the sample are reported in Table 3.

Regarding gender, a slight majority of women (53.42%) consistent with the national distribution. In terms of age, the sample includes two generational cohorts: Generation Z (born in 2000 or later) and Millennials (born from 1985 onward) (García-Rodríguez et al., 2022; De Pascale et al., 2024). Generation Z accounts for 32.13% of the sample, while Millennials represent 67.87%, a distribution consistent with data from Italian Statistics Institute (ISTAT, 2025). To capture potential intra-generational differences, the Millennial cohort was further divided into two sub-groups: early and late Millennials (Brazil and Candipan, 2025). This distinction allows for a more nuanced analysis, as differences may emerge within the same generation (Guillot-Soulez and Soulez, 2014). Specifically, younger Millennials (aged 26–33) represent 29.94% of the sample, while older Millennials (aged 34–

40) account for 37.94%. This segmentation was introduced to assess whether willingness to pay (WTP) varies across subgroups within the same cohort.

In terms of education level, 43.35% reported having a university degree, 31.23% a high school diploma, 17.29% postgraduate education, and only 8.13% an elementary or middle school diploma. In terms of income, 47.10% report a monthly household income between €15,000 and €30,000, 28% below €15,000, 18.32% between €31,000 and €50,000, and 6.58% above €50,000. Finally, more than half of the respondents (54.06%) report regularly engaging in sports.

Table 3. Descriptive statistics of the sample (n = 775)

Variables	*Categories*	*Freq.*	*%*
Gender	Male	361	46.58
	Female	414	53.42
Education	Primary and secondary school	63	8.13
	High school	242	31.23
	Graduate	336	43.35
	Post-graduate	134	17.29
Family income	≤ €15,000	217	28.00
	> €15,000 and ≤ €30,999	365	47.10
	≥ €31,000€ and ≤ €50,000	142	18.32
	> €50,000	51	6.58
Sport	No	356	45.94
	Yes	419	54.06
Age classes	18-25 (Gen Z)	249	32.13
	26-33 (Early Millennials)	232	29.94

	34-40 (Late Millennials)	294	37.94

4.2 Mixed logit estimates

The results of the mixed logit model (Table 4) show the results of the mixed logit regressions without and with interaction terms. Specifically, interaction terms were integrated in the second model to assess the role of socio-demographics and psychological traits toward consumers choices. Starting with the model with no interaction terms, the results indicate that price has a significantly negative impact on the probability of choice (β = -.327; $p < 0.001$). Furthermore, products containing 15% cricket flour (β = -.421; $p < 0.001$) and 10% *Tenebrio* flour (β = -.313; $p < 0.001$) are less preferred than wheat flour indicating that on average consumers are not interested in insect flours. However, the random effects values (standard deviations) highlight significant heterogeneity in preferences: in particular, cricket flour shows significant variability among respondents (SD = .753; $p < 0.001$), while for *Tenebrio* flour the heterogeneity is even more marked (SD = 1.178; $p < 0.001$). Therefore, it is possible to understand from these results that the total WTP can be affected by consumer heterogeneity when these characteristics are integrated in the models.

Similar results emerge for packaging color: both green (β = -.168; $p < 0.05$) and yellow (β = -.157; $p < 0.05$) are less appreciated than red packaging suggesting that colour can be used for product differentiation and to get consumers attention. However, the analysis of random effects (standard deviations) shows strong variability in preferences for the color green (SD = .899; $p < 0.001$), indicating significant heterogeneity among consumers. In contrast, no significant variability in preferences for the color yellow is found (SD = 0.041; $p > 0.10$).

The Italian origin of the flour has a positive and highly significant effect on the likelihood of choosing (β = .260; $p < 0.001$). However, the associated standard deviation indicates only marginally significant heterogeneity among consumers (SD = -.304; $p < 0.10$).

Regarding biodegradable packaging, a positive, albeit weak, effect is observed on the preference for single-serving crackers ($\beta = .089$; $p < 0.10$), and the random effects do not reveal any significant heterogeneity among participants (SD = -.040; $p > 0.10$).

Finally, the mixed logit model shows that the presence of surface salt significantly reduces the likelihood of choosing the product ($\beta = -.203$; $p < 0.001$), with no indication of variability in preferences.

Focusing on the results of the mixed logit model, the interaction between product attribute levels, two psychometric scales—the Food Neophobia Scale (FNS) and the Environmentally Consciousness Consumer Behavior (ECCB)—and sociodemographic variables was analyzed. The table integrates interaction terms allowing detection of which predictor can affect willingness to pay for product attributes and suggesting if the WTP can be considered an intrinsic property or derived by individual characteristics. The analysis of results will focus over the interaction terms with the insect flours that represent the focus of the work.

The results highlight a significant interaction between the Food Neophobia Scale (FNS) and *Tenebrio* flour (10%). In particular, as food neophobia increases, a more pronounced decrease in the effect associated with *Tenebrio* flour (10%) is observed compared to wheat flour ($\beta = -0.143$; $p < 0.10$). This indicates that more neophobic consumers tend to express a less favourable attitude toward this ingredient.

With regard to the age variable, the results reveal a significant interaction effect between late millennials and the two types of insect flours analysed. In particular, compared to the 18–25 age group, individuals aged 34–40 show a reduction in the effect associated with the presence of cricket flour (15%) ($\beta = -0.414$; $p < 0.05$). Similarly, within the same age group, an even more pronounced decrease is observed in the effect related to *Tenebrio* flour (10%) ($\beta = -0.278$; $p < 0.10$) compared to younger individuals. Overall, this suggests that older consumers tend to exhibit a less favorable attitude toward products containing these types of flours.

Gender also has a significant impact; women show a lower propensity to choose products containing cricket flour (15%) than men ($\beta = -.295$; $p < 0.05$).

Although neither cricket flour (15%; $\beta = -0.305$; $p > 0.10$) nor *Tenebrio* flour (10%; $\beta = -0.407$; $p > 0.10$) have a significant effect, the high standard deviations are significant (SD = 0.652, $p < 0.001$ for cricket flour; SD = 1.101, $p < 0.001$ for *Tenebrio* flour), indicating substantial variability in individual evaluations. This suggests that, while they do not uniformly influence purchase propensity, insect flours elicit highly heterogeneous responses among consumers.

Green packaging reduces the likelihood of being chosen compared to red ($\beta = -0.173$; $p < 0.05$; SD = 0.889; $p < 0.001$), suggesting a moderately negative effect on the product's attractiveness. The high standard deviation highlights substantial heterogeneity in consumer evaluations, indicating that the color green is not perceived uniformly: while it may be less appealing for some segments, for others the negative impact is weaker or absent, reflecting differences in individual preferences and symbolic associations related to the color.

Similarly, yellow packaging shows a slightly lower probability of being chosen compared to red, although the effect is smaller in magnitude ($\beta = -0.139$; $p < 0.05$). The non-significant standard deviation ($p > 0.10$) suggests greater consistency in consumer evaluations, indicating that responses to this color are more uniform. Therefore, while it reduces the product's attractiveness, yellow exerts a more stable and predictable influence compared to green, making it less polarizing in consumer perceptions.

The Italian origin of the product increases the likelihood of being chosen compared to a product of foreign origin ($\beta = 0.264$; $p < 0.001$). The non-significant standard deviation ($p > 0.10$) indicates that this positive perception is shared fairly uniformly among consumers, highlighting broad consensus regarding the quality and reliability associated with "Made in Italy".

Biodegradable packaging increases the likelihood that the product will be chosen compared to non-biodegradable packaging ($\beta = 0.117$; $p < 0.05$), highlighting how sustainability can significantly contribute to enhancing the product's perceived value. This reflects the growing consumer attention

toward eco-friendly solutions, suggesting that the use of sustainable materials not only aligns with ethical values but also enhances perceived value, boosting the overall appeal of the product. Conversely, the presence of salt on the surface reduces the likelihood that the product will be chosen ($\beta = -0.201$; $p < 0.001$). This suggests that this characteristic may be perceived negatively, likely due to taste, health considerations, or individual sensory preferences, highlighting how attributes perceived as "excessive" can undermine the overall appeal of the product.

Table 4. Mixed logit model

Model type	Choice	Coefficient	SD
No interaction	Price	-0.327***	N.A
model	Cricket flour (15%)	-0.421***	0.753***
	Tenebrio flour (10%)	-0.313***	1.178***
	Green packaging	-0.168**	0.899***
	Yellow packaging	-0.157**	0.041
	Italian origin	0.260***	-0.304*
	Biodegradable packaging	0.089*	-0.040
	Salt on the surface	-0.203***	-6.51e-06
Goodness of fit	LR $\chi2$ = 137.34***	Log likelihood = -3210.62	
Interaction model	Price	-0.318***	N.A
	Sport × Cricket flour (15%)	-0.058	N.A
	Sport × *Tenebrio* flour (10%)	-0.019	N.A
	Education × Cricket flour (15%)	0.004	N.A
	Education × *Tenebrio* flour (10%)	-0.016	N.A
	ECCB × Cricket flour (15%)	0.016	N.A
	ECCB × *Tenebrio* flour (10%)	0.059	N.A
	FNS × Cricket flour (15%)	0.083	N.A

	FNS × *Tenebrio* flour (10%)	-0.143*	N.A
	Income × Cricket flour (15%)	0.085	N.A
	Income × *Tenebrio* flour (10%)	0.107	N.A
	Early millenials × Cricket flour (15%)	0.151	N.A
	Early millenials × *Tenebrio* flour (10%)	0.081	N.A
	Late millenials × Cricket flour (15%)	-0.414**	N.A
	Late millenials × *Tenebrio* flour (10%)	-0.278*	N.A
	Gender × Cricket flour (15%)	-0.295**	N.A
	Gender × *Tenebrio* flour (10%)	0.054	N.A
	Cricket flour (15%)	-0.305	0.652***
	Tenebrio flour (10%)	-0.407	1.101***
	Green packaging	-0.173**	0.889***
	Yellow packaging	-0.139**	.058
	Italian origin	0.264***	-.279
	Biodegradable packaging	0.117**	-.036
	Salt on the surface	-0.201***	.016
Goodness of fit	LR $\chi 2$ = 124.36***	Log likelihood = -3189.613	

Notes: *p < 0.1; ** p < 0.05; *** p < 0.01; N.A = Not Available

4.3 Willingness to pay

Table 5 presents estimates of consumers' average willingness to pay (WTP) for various product attributes from the interaction model. The WTP was calculated for all relevant terms, with the exception of insect flours, as they form the core of this study.

The results indicate that neither cricket flour nor *Tenebrio* flour exerts a significant effect ($p > 0.10$) on consumers' willingness to pay. However, the lack of significance does not imply that these attributes do not influence consumer perceptions: the variability in responses appears largely driven by individual characteristics, such as age, gender, and levels of food neophobia, rather than by the flour attribute itself. In other words, while the average effect of insect flours is not significant, there are substantial individual differences that shape willingness to pay, indicating that the perception of these ingredients is highly heterogeneous within the sample.

Regarding packaging color, both yellow and green are less appreciated compared to red, with consumers showing a willingness to pay approximately -€0.54 for yellow packaging and -€0.44 for green packaging. This suggests that red color has a stronger positive impact on product perception.

Furthermore, the results highlight that the Italian origin of the flour is a particularly valued attribute among consumers, who are willing to pay on average about +€0.83 for a single-serving portion of crackers made with Italian-origin flour compared to a product of foreign origin.

Regarding packaging, consumers are willing to pay approximately +€0.37 for biodegradable packaging compared to non-biodegradable options, indicating a growing sensitivity to environmental sustainability.

Finally, the presence of salt on the surface of the cracker is associated with a decrease in willingness to pay of -€0.63, reflecting a clear preference for less salty or salt-free products, which are likely perceived as healthier or lighter.

Table 5. Willingness to pay.

Variable	Mean	Std. error
Cricket flour (15%)	-0.96	0.75
Tenebrio flour (10%)	-1.28	0.87
Yellow packaging	-0.54**	0.22

Green packaging	-0.44**	0.16
Italian origin	0.83***	0.18
Biodegradable packaging	0.37**	0.15
Salt on the surface	-0.63***	0.18
Late millennials × Cricket flour (15%)	-1.30**	0.48
Late millennials × *Tenebrio* flour (10%)	-0.87*	0.52
Gender × Cricket flour (15%)	-0.92**	0.39
FNS × *Tenebrio* flour (10%)	-0.45*	0.24

Notes: *p < 0.1; ** p < 0.05; *** p < 0.01.

Concerning the willingness-to-pay (WTP) estimates obtained by the interaction variable, several considerations can be done. Specifically, in the 33–40 age group (late millennials), the willingness to pay for a single-serving product containing cricket flour (15%) decreases, indicating that older consumers are less inclined to accept this type of product. On average, they show a negative WTP of -€1.30 for a product with cricket flour and about -€0.87 for a product with *Tenebrio* flour, compared to an equivalent product made entirely with wheat flour (100%).

Regarding gender, women show a lower willingness to pay for a single-serving product containing cricket flour (15%), showing a value of -€0.92 compared to the equivalent product made with wheat flour.

Additionally, food neophobia has a marginally significant negative effect on willingness to pay: consumers with higher levels of neophobia tend to avoid products containing *Tenebrio* flour (10%), affecting on average about -€0.45 the WTP over a comparable wheat-based (100%) alternative.

5. Discussion

According to the objectives of this study, the incorporation of insect flour in crackers significantly reduces consumer utility compared to wheat-based alternatives, supporting H1. Both cricket (*Acheta domesticus*) and mealworm (*Tenebrio molitor*) flours generate negative preferences, although no significant standalone effects on WTP emerge (H2). However, interaction models reveal negative marginal WTP estimates for specific consumer groups, highlighting strong heterogeneity in responses.

Consistent with the literature on entomophagy (Lombardi et al., 2019; Liu and Kim, 2024), acceptance is strongly shaped by sociodemographic and psychological factors. For mealworm flour, older and more food-neophobic individuals show significantly lower WTP, confirming that neophobia is a major barrier to insect consumption. Late Millennials also display unexpected resistance, possibly due to limited familiarity with entomophagy. For cricket flour, women and late Millennials exhibit stronger aversion, in line with studies showing higher disgust sensitivity and lower acceptance among female consumers (Roccatello et al., 2024; Castro-Alija et al., 2024).

These findings align with European evidence showing that insect-based foods face resistance due to perceived unnaturalness, disgust, and low familiarity (La Barbera et al., 2018; Mancini et al., 2019). Even when insects are incorporated invisibly as flour in familiar products such as crackers, psychological barriers persist and reduce utility and WTP.

Regarding H3, packaging characteristics significantly influence consumer preferences. Red packaging is preferred over yellow and green, confirming that color cues affect product perception (Sucaèane et al., 2021). More importantly, Italian origin exerts the strongest positive effect, likely acting as a signal of trust, quality, and safety (Kuff et al., 2023; Wilkinson et al., 2018). Biodegradable packaging also increases utility, although its effect is weaker than origin, suggesting that sustainability cues are positively recognized (Naranjo-Guevara et al., 2023; Spada et al., 2024).

Consumers also show a strong preference for crackers without visible salt, indicating growing health awareness and confirming previous findings on reduced sodium preferences in bakery products (Di

Vita et al., 2016; Codină et al., 2021). Health-oriented positioning, such as “high-protein” and “low-salt”, may therefore improve acceptance of insect-based snacks.

Results further support H4, showing that food neophobia negatively moderates WTP, particularly for mealworm flour (Fischer and Steenbekkers, 2018). The absence of a significant effect for cricket flour may reflect greater familiarity and commercial exposure in the European market (Sogari et al., 2019).

Finally, H5 is confirmed by the heterogeneous role of sociodemographic variables. Women show stronger aversion toward cricket-based crackers than men (Dagevos, 2021; Wassmann et al., 2021), while age is associated with greater reluctance toward insect-based foods. Important intra-generational differences also emerge among Millennials: younger Millennials appear more open to sustainable and innovative foods, whereas older Millennials show stronger resistance (Alqahtani et al., 2025; Mariani and Annunziata, 2025). The stronger aversion to cricket flour may partly depend on its higher inclusion level (15% vs. 10% for mealworm), consistent with evidence that WTP decreases as insect content increases (Alemu and Olsen, 2019).

6. Conclusion

This study examines young consumers’ preferences for cricket and mealworm flour crackers. Results show a general negative preference compared to wheat-based products, though this can be partly offset by familiarity, Italian origin, sustainability cues, and health claims such as low salt, which increase willingness to pay.

Consumer responses are highly heterogeneous and influenced by sociodemographic and psychological factors. Gender and age significantly affect acceptance of cricket flour, with women and late Millennials showing lower WTP. For mealworm flour, food neophobia is the main barrier, especially among older consumers.

Overall, acceptance decreases with age and varies within generations, indicating strong intra-generational differences. Findings suggest that WTP is driven more by consumer characteristics than

product attributes, pointing to a segmented market. Extrinsic cues and consumer education can help reduce resistance and improve acceptance of insect-based products.

6.1 Originality and Implications

This paper compares cricket and *Tenebrio* flours at species level and provides evidence on willingness to pay for packaging color, origin, and surface salt. Results show that extrinsic cues, substitution levels, and species familiarity strongly affect consumer acceptance.

The interaction model highlights differences within millennials, adding nuance to consumer heterogeneity in insect-based food acceptance.

From a managerial perspective, insect flour is still poorly accepted among Italian consumers, suggesting a focus on niche segments more open to innovation. Increasing awareness of environmental benefits may improve acceptance.

Marketing strategies should be tailored by gender and age, while lower inclusion levels and improved formulations can help reduce resistance among less receptive consumers.

6.2 Limitations and future studies

The main limitation of this study is the use of stated preferences, which may not reflect real purchasing behavior, potentially causing hypothetical bias and overestimating willingness to pay. The Italian context also limits generalizability to other countries.

Another limitation is the use of fixed insect flour inclusion levels based on current market products. While realistic, different levels—especially higher ones—may affect consumer acceptance. In addition, the experimental design restricted the number of attributes that could be analyzed simultaneously.

Future research should apply revealed preference methods such as experimental auctions, test different inclusion levels and sensory evaluations, and explore packaging claims and cross-country comparisons to better understand consumer behavior.

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