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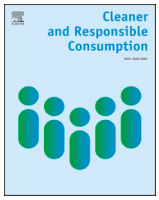

The second life of food by-products: Consumers' intention to purchase and willingness to pay for an upcycled pizza

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ABSTRACT

One of the challenges that Europe has undertaken is the transition from a linear economic system to a circular economy, where waste and resources are recovered and regenerated. The practice of upcycling in the agri-food sector represents one of the most promising solutions to the enormous problem of food waste. However, the information available to consumers about foods made with upcycled ingredients is still scarce, limiting their acceptance and creating a critical barrier to their success in the market. The objective of this study is to determine the factors that affect Italian consumers' intention to purchase and willingness to pay for a specific upcycled food enriched with a high-value vegetable by-product by applying a logit model, an interval regression, and a contingent valuation. Results show that knowledge about upcycling and the circular economy is still limited. Innovative consumers who are already aware of upcycling, who are not food neophobic, and who have a positive opinion of recycling are more willing to purchase upcycled products. At the same time, women who are already aware that the food industry produces considerable quantities of waste and who have a positive image of recycling are more willing to pay for a specific upcycled food. Finally, our sample proved to be willing to pay a premium price for an upcycled frozen margherita pizza. An informed consumer, aware of the environmental and health benefits of upcycled products, may become more willing to purchase them and to pay more compared to the same conventional products.

1. Introduction

One of the main problems of the agri-food supply chain is the production of considerable amounts of waste (Esposito et al., 2020; Garske et al., 2020). Food waste refers to losses in the early stages of the supply chain; waste generated by the food industry during the processing of raw materials is commonly referred to as by-products; and waste at the retail and consumption level is appropriately called food waste (Grasso and Asioli, 2020; Galanakis, 2012). It is estimated that, in 2020, the EU27 produced roughly 60 million tons of waste along the whole supply chain, with Germany, France, and Italy accounting for roughly 50% of the total (Eurostat, 2023). Food wastage accounts for the largest part of the food system's greenhouse gas emissions, which by themselves represent a third of the total global pollution, translating into an inefficient and irresponsible use of planetary resources (European Commission, 2023; Ardra and Barua, 2022; Kayıkcı et al., 2021; Teigiserova et al., 2020; Hagedorn and Wilts, 2019; Lemaire and Limbourg, 2019).

To minimize food loss and waste along the supply chain, it is helpful to identify and rank the possibilities according to the waste hierarchy (Papargyropoulou et al., 2014). The priority is always to prevent food from becoming waste at all stages of the supply chain, offering financial benefits, reducing the costs of handling and disposing of waste and unconsumed food, and providing environmental benefits by avoiding the use of finite resources and reducing pollution (Mittal et al., 2021). When prevention is not applicable, loss, waste, and by-products can be used for several applications, including energy production, animal feeding, and the development of functional ingredients, innovative foods, or natural additives (Andrianou et al., 2023; Jaouhari et al., 2023;

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Bentivoglio et al., 2022; Dueñas and García-Estévez, 2020; Kumar et al., 2017; Helkar et al., 2016). Such approaches could be integrated into the umbrella of the circular economy, under which materials and resources are recovered and regenerated, transforming them into new products with added value using a more sustainable, responsible, and resilient approach (Chiaraluce, 2021; Chiaraluce et al., 2021; Ghisellini et al., 2016). This regenerative economic model promotes waste reduction, repair, reuse, and recycling of materials, offering an integrated solution to the problems of resource depletion, pollution, and global warming (Ellen MacArthur Foundation, 2013).

Agriculture and the food industry have huge potential in the context of a circular economy (Osorio et al., 2021; Girotto et al., 2015), and one of the most recent solutions found to tackle the problem of food waste is upcycled food, also discussed using terms as "waste-to-value," "products with added value," "value-added surplus products," or "collateral valorization" (Coderoni and Perito, 2020; Bigliardi et al., 2020; Teigiserova et al., 2020; Aschemann-Witzel and Peschel, 2019; Bhatt et al., 2018). The Upcycled Food Association states that "upcycled foods use ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment." These ingredients could be surplus foods, by-products or side-streams, or residues and waste. In contrast to recycling, also known as downcycling, the practice of upcycling involves giving a product a higher value than the original one through a process of valorization (Aschemann-Witzel et al., 2023a; Aschemann-Witzel and Stangherlin, 2021; Moshtaghian et al., 2021). Furthermore, upcycling can lead to increased innovation in the food industry, generating new sources of income and employment. This process can also increase the resilience of food companies, as they become less dependent on limited resources and more capable of adapting to fluctuations in global markets (Liu et al., 2023; Mirosa and Bremer, 2023; Caldera et al., 2022; Gedi et al., 2020). Despite the importance given to the food industry and the research behind the development of these new products, the consumer always has the upper hand when it comes to new products on the market. To establish a new economic paradigm, consumers play a central role in the transformation towards a more circular model because their purchasing decisions and preferences can significantly influence the adoption of sustainable practices and support the launch of new products on the market, particularly in the agri-food sector (Sousa et al., 2021; Calvo-Porral and Lévy-Mangin, 2020; Coderoni and Perito, 2020; Borrello et al., 2017; Jurgilevich et al., 2016). However, the information available consumers about food products made with upcycled ingredients deriving from the agri-food supply chain is still inadequate, limiting their acceptance and posing a critical barrier to the success of these products (Hamam et al., 2021; Sousa et al., 2021; Aschemann-Witzel and Peschel, 2019). In fact, from a consumer perspective, the possibility of consuming something derived from recovered waste is not always appealing, and consumers may be reticent to ingest something containing waste (Aschemann-Witzel and Stangherlin, 2021; Grafström and Aasma, 2021; Bhatt et al., 2018; Kirchherr et al., 2018; Rizos et al., 2015). Still, it is important to keep in mind that a variety of industrial food waste and by-products, including vegetable and fruit waste, are high in bioactive substances including vitamins, phenolics, glucosinolates, and phytosterols, which may have health-promoting effects (Kusumasari et al., 2024; Nartea et al., 2023; Galanakis, 2020; Mirabella et al., 2014). If consumers become aware of the possible health benefits that these by-products may offer and become active participants in the circular transition, they will be more willing to accept, purchase, and consume food derived from waste materials.

Considering this, the present paper aims to contribute to the current literature debate about consumer willingness to purchase and pay for upcycled food. In this study, we investigated the factors that may influence consumers' purchase preferences as well as their willingness to pay (WTP) for a specific upcycled food. Several studies have already evaluated the influence of different factors on consumers' willingness to accept and buy upcycled food. We investigated the sample's personal characteristics, including socio-demographic factors, food waste production behavior, attitudes towards innovative products, and attitudes towards the circular economy.

The available literature about consumers' WTP for upcycled foods is scarce (Hellali et al., 2023; Ghazanfar et al., 2022; Asioli and Grasso, 2021; Bhatt et al., 2020) and focuses on extrinsic attributes of the products, such as messaging and claims. To the best of our knowledge, this is the first attempt to investigate how the personal characteristics of the respondents influence their WTP for a specific upcycled food.

For these purposes, a questionnaire was designed and administered online to a sample of Italian consumers. A logit model was applied to identify the possible influencing factors in consumer behavior, and interval regression was used to evaluate the determinants influencing consumers' WTP. Additionally, to elicit the WTP, a dichotomous choice contingent valuation method was used for a specific product, which is an upcycled frozen margherita pizza (330g), enriched with flour from orange cauliflower stalks, a recovered by-product from the vegetable industry, rich in nutritional compounds that may contribute to lowering cholesterol in the blood and thereby reducing the risk of coronary heart disease (Nartea et al., 2023). A vegetable by-product was chosen for this analysis as the fruit and vegetable sector is one of the most impactful in terms of the quantities of by-products produced (Chiaraluce et al., 2023). Additionally, we believe that it should be easier for consumers to accept a food containing vegetable waste instead of something of animal origin (Peschel and Aschemann-Witzel, 2020).

Compared to the available literature, our product is designed to complement the environmental benefit, due to the reduction of waste, with a health benefit due to the nutritional components of the by-product used (orange cauliflower stem flour). The remainder of the paper is structured as follows: Section 2 reports the literature background and the developed research hypotheses. Section 3 describes the methodology employed. Section 4 presents and discusses the main results of the analysis. Finally, Section 5 concludes.

2. Literature review and conceptual framework

According to the literature on consumer behavior, a variety of factors, including personal characteristics, might influence consumer preferences, purchasing behavior, and WTP.

Demographic characteristics are fundamental in identifying the proper market segments to target with upcycled foods. Studies indicate that younger consumers are generally more likely to buy and consume upcycled food (Hellali et al., 2023; Zhang et al., 2021). This trend may be explained by the fact that older individuals typically experience higher levels of food neophobia (Yilmaz and Kahveci, 2022). However, Coderoni & Perito (2021) found that neophobia can also be a hindering factor for Millennials' willingness to purchase upcycled products. Conversely, younger people, such as Millennials and Gen Z, tend to be more sensitive to environmental issues and sustainability, making them less reluctant to buy upcycled products (Aschemann-Witzel et al., 2023b). Younger consumers may also be more attentive to the nutritional characteristics of food products. Upcycled foods often highlight this aspect, as ingredients like fruit peels and seeds, which are normally discarded, are richer in valuable nutrients. Therefore, consumers might be interested in upcycled foods if the nutrient content and potential health benefits are clearly stated (Moshtaghian et al., 2023). The influence of gender on consumer behavior is varied. While Aschemann-Witzel and Peschel (2019) found that males have a more positive attitude towards waste-to-value foods, Coderoni and Perito (2020) found the opposite, as did Henchion et al. (2016), who noted that younger females are generally more disgusted by the idea of waste being used in food production. Education level can also be an indicator of consumers' purchasing intentions. People with higher education levels, who are likely more informed about current themes such as the circular economy, may experience less neophobia and be more inclined to accept and consume foods containing waste and by-products (Coderoni and

Perito, 2020; Cattaneo et al., 2019). Household income is another important aspect consider, as it could affect both WTP and the willingness to buy upcycled products. Along with age, gender, and education level, income helps assess the profile of the consumer sample. It might be useful to relate the intention to purchase and WTP to income (Dangi et al., 2020). Contrasting results can be expected: on the one hand, people with lower incomes might be willing to buy upcycled products, believing they will cost less as they contain waste (Coderoni and Perito, 2021; McCarthy et al., 2020). On the other hand, people with higher incomes might have more funds to spend experimenting with new products that offer substantial environmental and health benefits similar to the trend with organic (Nagaraj, 2021; Le-Anh and Nguyen-To, 2020) and insect-based (Orkusz et al., 2020; Liu et al., 2019) products.

Considering these findings, we propose the following hypotheses:

Hypothesis 1.1. Socio-demographic characteristics influence consumers' purchasing intentions for upcycled food. (H1.1)

Hypothesis 2.1. Socio-demographic characteristics influence consumers' WTP for upcycled food. (H2.1)

In the context of a circular economy, consumer behavior at home becomes fundamental in driving the transition (Dudziak et al., 2022). Individuals who pay attention to food preparation at home to avoid excessive discarding of products, believe that personal behavior affects global food waste generation, and are aware that the food industry produces substantial quantities of waste and by-products, might be more inclined to purchase upcycled food. This awareness is likely driven by an understanding of the problems affecting our food supply chain, such as pollution, climate change, and waste production (Stancu et al., 2016; Aschemann-Witzel et al., 2015). For these reasons, purchasing upcycled products, combined with mindful personal behavior, can represent a significant contribution to incentivizing the circular model. Additionally, individuals who are already conscious of the issue of food waste and act accordingly may recognize the environmental, health, cultural, and economic benefits of reducing and recovering food waste (Lehtokunnas et al., 2022). Therefore, their personal behavior regarding food waste awareness and production might influence their willingness to pay (WTP) for upcycled food.

Considering this, we propose the following hypotheses:

Hypothesis 1.2. Consumers' behavior towards food waste production influences their purchasing intention of upcycled food. (H1.2)

Hypothesis 2.2. Consumers' behavior towards food waste production influences their WTP for upcycled food. (H2.2)

Several factors may hinder consumers' acceptance of upcycled foods. These products are often considered innovative due to their inclusion of unusual ingredients with declared benefits, such as environmental and health advantages. As a result, food neophobia has been extensively investigated in the context of innovative food products (Siddiqui et al., 2022). Food neophobia can be described as a common trait characterized by the rejection of new food products that come from different cultures or are produced with unfamiliar ingredients. Recent literature discusses how individuals with high levels of food neophobia are more reluctant to buy and consume innovative products like insect-based foods (Erhard et al., 2023; La Barbera et al., 2021; Orkusz et al., 2020; Sogari et al., 2019; Verbeke, 2015), plant-based and meat alternatives (De Koning et al., 2020; Siegrist and Hartmann, 2020; Tsuji et al., 2012), and upcycled foods (Hellali & Koraï, 2023; Hellali and Korai, 2023; Aschemann-Witzel et al., 2022; Coderoni & Perito, 2020, 2021; Perito et al., 2020b). Addressing neophobia by informing consumers about upcycling and its benefits in combating food waste could improve acceptance.

People might be wary of highly inventive food products that they cannot fully understand; thus, approval may also depend on an individual's mindset and degree of innovation (Hellali and Korai, 2023). Innovativeness, reflecting an individual's pioneering acceptance of novelties (Figueroa and de Meneses, 2013), is likely to positively influence the purchase of innovative foods (Altintzoglou et al., 2021; Barcellos et al., 2009). To the best of our knowledge, no studies have yet investigated personal innovativeness as a factor influencing the purchase intention and WTP for upcycled food. Considering neophobia, innovativeness, and upcycling knowledge, we propose the following hypotheses:

Hypothesis 1.3. Consumers' attitudes towards innovative food products influence their purchasing intention of upcycled food. (H1.3)

Hypothesis 2.3. Consumers' attitudes towards innovative food products influence their WTP for upcycled food. (H2.3)

The concept of the circular economy is gaining momentum in academia; however, consumers still have a limited understanding of how waste and by-products can be recovered using a circular approach (Sousa et al., 2021). From a common perspective, upcycling and recycling might both be associated with the idea of recovering materials or objects to give them a second life, even though they are not synonyms. Therefore, people already engaged in recycling practices or purchase recycled materials and have a positive perception of them might also be intrigued by upcycled foods marketed as circular economy products (Boyer et al., 2021; Bigliardi et al., 2020; Calvo-Porral and Lévy-Mangin, 2020). Additionally, the circular economy encompasses the principles of sustainability, which may drive market introduction of upcycled foods and increase their consumers' WTP for them (Ghazanfar et al., 2022; Coderoni and Perito, 2020; Perito et al., 2020a, 2020b; Aschemann-Witzel and Peschel, 2019). As consumers become increasingly concerned about environmental issues affecting the planet, they may seek to understand potential solutions to these problems. Consequently, if consumers are educated about the circular economy and understand the benefits of transitioning from a linear, traditional model to a circular one, they might be more willing to purchase circular upcycled products (Kuah and Wang, 2020; Lakatos et al., 2016).

Hypothesis 1.4. Consumers' attitudes towards the circular economy influence their purchasing intention of upcycled food. (H1.4)

Hypothesis 2.4. Consumers' attitudes towards the circular economy influence their WTP for upcycled food. (H2.4)

Lastly, WTP represents a key indicator of acceptance when discussing the launch of innovative food products on the market (Hellali et al., 2023). Since we are proposing an innovative product based on a traditional Italian food, consumers are likely to compare the price of the upcycled food with the existing reference (Bhatt et al., 2020), namely a conventional frozen margherita pizza. Some studies have already investigated this aspect, obtaining controversial results. For instance, a higher price for the upcycled product compared to the conventional one was found by Ye et al. (2022) for upcycled pet food. Ghazanfar et al. (2022) discovered that consumers were willing to pay more for upcycled products when these were accompanied by a claim about the sustainability of these products. Asioli and Grasso (2021) affirmed that consumers were willing to pay more for upcycled products, but only when the nutritional and/or environmental benefits of these products were communicated. The literature underscores the importance of robust communication strategy, which is positively correlated with increased acceptance of upcycled or circular products (Pretner et al., 2021). However, consumers often perceive that products made with waste should cost less, as they are not obtained from virgin, high-quality raw materials but from what might be considered low-value inputs (McCarthy et al., 2020). Bhatt et al. (2020) found that consumers are not willing to pay more for upcycled food products when compared to conventional alternatives. Similarly, Hellali et al. (2023) and Grasso and Asioli (2020) found that consumers' WTP for circular food products is lower than for their conventional counterparts.

Hypothesis 3. The WTP for an upcycled frozen margherita pizza is

lower compared to its conventional counterpart. (H3)

According to the literature, we considered four categories of explanatory variables for the logit and interval regression models to test our hypotheses: i*)* socio-demographic characteristics (age, gender, education, income), ii*)* attitude towards food waste (attention to waste generation and quantities produced at home and industrial level), iii*)* variables referring to the individual's behavior towards innovative foods (domain specific innovativeness, neophobia, knowledge of upcycling), and iv*)* consciousness of the circular model and recycling attitude (knowledge of circular economy, perceived quality, image, safety, and benefits of recycled products). To the best of our knowledge, this is the first study that tries to combine these aspects related to the purchase and WTP of upcycled food. Fig. 1 represents the conceptual framework of the research, outlining all the hypotheses made.

3. Methods

3.1. Questionnaire design and structure

The analysis was conducted using a survey-based approach with an online questionnaire divided into five sections. The first aimed to understand consumer behavior during grocery shopping and food waste production at home. In the second section, consumers' behavior towards innovative upcycled food products was investigated using the Domain Specific Innovativeness Scale (DSI) (Barcellos et al., 2009; Goldsmith and Hofacker, 1991) and the Food Neophobia Scale (FNS) (Pliner and Hobden, 1992), with Likert agreement scales ranging from 1 to 5 (where: 1 Completely disagree; 2 Disagree; 3 Undecided; 4 Agree; 5 Completely agree). The DSI comprises six items to measure the consumer's innovativeness for a specific product category, reflecting the tendency to adopt innovations within a specific domain of interest. Food neophobia, a consumer personal trait measurable through the propensity to approach or avoid novel foods, was also assessed. Following a brief explanation of the process to respondents on how upcycled foods are made, an image showcasing some of the products currently on the market was shown. The explanation was kept as simple as possible to avoid misunderstandings. Subsequently, consumers were asked if they had ever heard of upcycled foods.

The third section focused on WTP for upcycled food. Consumers were asked if they were willing to buy a specific upcycled food, namely an upcycled frozen margherita pizza (330g), enriched with flour from orange cauliflower stalks, a recovered by-product from the vegetable industry, rich in nutritional compounds that may contribute to lowering cholesterol in the blood and therefore the onset of coronary heart disease

Fig. 2. Visual representation of the upcycled frozen margherita pizza showed to the questionnaire respondents. The image reports a clear reference to the circular economy and food waste reduction.

(Fig. 2).

A dichotomous choice contingent valuation method, based on a double-bound model, was employed to elicit consumers' WTP. This method involves estimating respondents' stated WTP for a hypothetical question regarding a non-market good or service to gauge their potential acceptance level (OECD, 2018). The flexibility of contingent valuation makes it suitable for various scenarios, allowing it to be applied to non-market goods or changes across different time periods. This method has been widely used, with numerous studies focusing on environmental issues, policy assessments, and public improvements (Carson, 2000). In contingent valuation surveys, participants are directly asked to express their preferences to understand their future intentions for a non-market good or service in a hypothetical setting. It enables direct estimation of WTP using various elicitation techniques. The choice of these techniques is crucial, as they yield different estimates. The elicitation question can be posed in several ways, including open-ended questions, payment cards, single-bounded dichotomous choice, double-bounded dichotomous choice, and different formats of bidding games. The design of the hypothetical scenario and the value elicitation questions are critical components of the contingent valuation method (OECD, 2018). The selection of elicitation technique depends on factors such as the nature of the good being studied, the cost of the survey, and the characteristics of the respondents. Firstly, a filter question was created to ask consumers whether they were willing to buy the upcycled pizza. If they answered yes, they were asked to choose three reasons why they were interested.

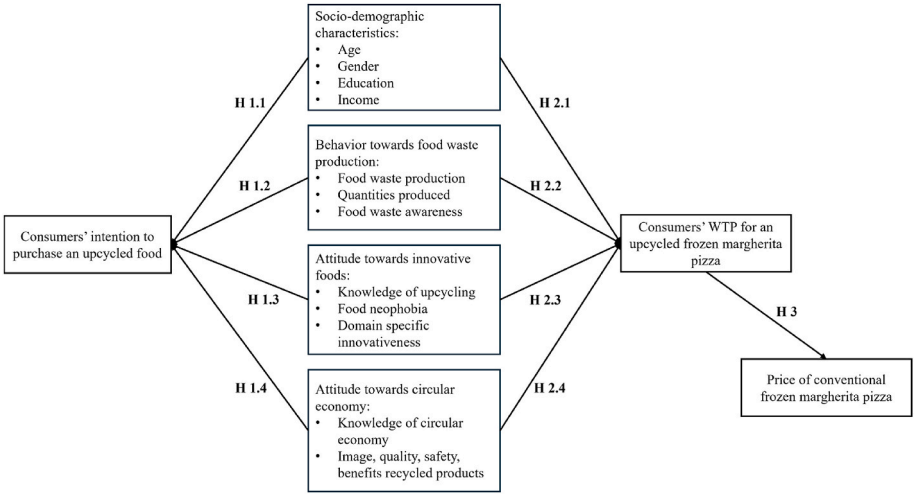

Fig. 1. Conceptual framework and hypotheses.

Otherwise, they were asked to choose three reasons why they were not interested in buying this product and, subsequently, which of some reasons could convince them to buy it. The reasons and motivations present in the questionnaire were derived from an extensive review of current literature about upcycled and innovative food products. If consumers were willing to buy the pizza, they were directed to a series of dichotomous choice questions (yes or no) to assess the WTP. To define the initial price of the upcycled pizza, a market analysis was carried out on the average selling price of a classic frozen margherita pizza or with special flours (gluten-free, with cereals, etc.). This survey was conducted from January to February 2023 at various supermarkets, superstores, and discounts located in different parts of Italy. The average price obtained for potential competitors was €4.05. WTP was estimated using an interactive bid system: the first proposed price was €4.50; if they were willing to pay this value, they were asked if they were willing to pay €5.00. If not, they were asked to pay €4.00.

In the fourth section, we evaluated the average consumer's knowledge about the concept of the circular economy and their attitude towards recycled products. After asking respondents whether they knew the concept of the circular economy, we asked them to provide their definition to understand their degree of knowledge of the concept and their interest in the topic. We then assessed the acceptance and purchase intention of recycled circular goods by consumers using the Recycled Product Scale (RPS) (Calvo-Porral and Lévy-Mangin, 2020). The scale includes fourteen items concerning the perception of quality, safety, and image of recycled products, the sustainability and environmental benefits deriving from them, and the purchase intention for these products. The items were evaluated using a 5-point Likert agreement scale (where: 1 Completely disagree; 2 Disagree; 3 Undecided; 4 Agree; 5 Completely agree).

The last section included questions related to socio-demographic data, such as gender, age, education, employment, marital status, annual household income before taxes, household size, and the number of children under 18.

The questionnaire was designed between January and April 2023 and pre-tested in May 2023. Experts from the Università Politecnica delle Marche (Ancona, Italy) and the University of Évora (Évora, Portugal) conducted the pre-test to assess general comprehension and deliberate on its efficacy, ultimately enhancing its clarity. After conducting the pre-test, some questions were revised to improve their comprehensibility. Data collection took place from June 2023 to February 2024 on a sample of 461 Italian people. The questionnaire was created using Google Forms and disseminated using various social media platforms. While using an online survey allowed us to spread the questionnaire and create a database easily and rapidly, it may have made it more difficult to reach a batch of people who do not use this kind of technology; thus, the sample may not be very representative of the reference population (Bentivoglio et al., 2021). However, we believe that, through a wide sampling, we were able to capture the main characteristics of the population.

3.2. Econometric models

A logit model was utilized to evaluate the factors influencing consumers' intention to purchase upcycled foods (Gujarati and Porter, 2009; Ramírez et al., 2021; Manski and McFadden, 1981; McFadden, 1974). The selected dependent variable is a binary (coded as 1 if consumers buy upcycled food and 0 otherwise), representing the probability of consumers purchasing upcycled foods. The specific equation of the logit model is expressed in Equation (1):

$$y = \beta_0 + \beta_1 \chi_{socio-demographic} + \beta_2 \chi_{waste} + \beta_3 \chi_{innovative\ food} + \beta_4 \chi_{circular} \quad (1)$$

The factors affecting consumers' WTP were assessed using an interval regression (Gujarati and Porter, 2009; Wooldridge, 2010; Long and Freese, 2006; Cameron, 1988; Cameron and James, 1987). This method accounts for respondents' uncertainty regarding the exact price differential due to the hypothetical nature of the question. By identifying a range (with upper and lower limits), the responses better reflect the natural uncertainty of consumers. Although the parameters are estimated with less precision compared to using a specific monetary value, the interval approach offers a more realistic depiction of consumer intentions, enhancing the robustness of statistically significant results (Shew et al., 2017). The specific equation of the interval regression model is presented in Equation (2):

$$y = x_{socio-demographic}\beta_1 + x_{waste}\beta_2 + x_{innovative\ food}\beta_3 + x_{circular}\ \beta_4 + \varepsilon_j \quad (2)$$

In this model, y is regarded as a latent continuous censored variable, representing the monetary value that consumers are willing to pay for upcycled food. It is based on the four possible answers of the respondents, and it can be included in one of the following intervals (3):

$$\Pr(yes, yes) = 1 - F\left(t_i^a\right) \quad (3)$$

$$\Pr(yes, no) = F\left(t_i^a\right) - F(t_i)$$

$$\Pr(no, yes) = F(t_i) - F\left(t_i^b\right)$$

$$\Pr(no, no) = Ft_i^b$$

The log likelihood function for this model is reported in Equation (4):

$$LogL = \sum_{i=1}^{n} I_i I_i^a \log\left[F\left(t_i^a\right)\right] + I_i\left(1 - I_i^a\right)\log\left[F\left(t_i^a\right) - F(t_i)\right] + I_i^b(1 - I_i)\log\left[F(t_i) - F\left(t_i^b\right)\right] + (1 - I_i)\left(1 - I_i^b\right)\log\left[F\left(t_i^b\right)\right] \quad (4)$$

Where t_i is the starting price (€4.50); t_i^a is the price offered in the follow-up in the case of the first affirmative answer (€5.00); t_i^b is the price offered in the follow-up in the case of the first negative answer (€4.00). The dichotomous variables I_i, I_i^a, and I_i^b take a value of one or zero depending on whether the answers to the initial question and to the corresponding follow-up have been positive or negative.

In both models, the explanatory variables (independent variables), which are the factors that might influence consumers' purchasing behavior and WTP, are listed in Table 1:

4. Results and discussion

4.1. Descriptive statistics

Out of the total of 461 responses, only 457 were considered appropriately filled out and suitable for analysis. The socio-demographic of the considered Italian sample are presented in Table 2 (n = 457).

Regarding consumers' purchasing behavior and attitude towards food waste, 41% of the sample reported always being attentive to waste production when preparing food at home, while 78% believed that purchasing behavior affects the quantities of food waste produced. Additionally, 93% were aware that the food industry produces considerable amounts of waste.

Approximately 43% of the sample declared having heard about upcycled foods. Among those surveyed, 76% expressed the willingness to buy the upcycled frozen margherita pizza. Their motivations for purchasing upcycled products were aligned with the existing literature. Respondents believe that the purchase of an upcycled product is associated with food waste reduction and recovery, as found by Aschemann-Witzel and Stangherlin (2021), Grasso and Asioli (2020), Kuah and Wang (2020), Aschemann-Witzel and Peschel (2019), and Lakatos et al. (2016). In addition, consumers believed in the environmental and health benefits embedded into the upcycled frozen margherita pizza, probably driven by the description of the product and the packaging image, thus being encouraged to buy the product (Aschemann-Witzel and Stangherlin, 2021; Coderoni and Perito, 2021; Coderoni and Perito,

Table 1
Explanatory variables of the logit and interval regression models.

Group	Variable	Acronym	Range
socio-demographic	Gender	GEND	1 = female; 0 = otherwise
	Age	AGE	age of the respondent (number)
	Education	EDU	1 = no formal education; 2 = primary school; 3 = middle school; 4 = high school; 5 = bachelor's degree; 6 = master's degree; 7 = postgraduate education
	Annual household income (before taxes)	INCO	1=<€10,000; 2 = €11,000–€20,000; 3 = €21,000–€35,000; 4 = €36,000–€50,000; 5 = €51,000–€75,000; 6=>€75,000
waste	Attention to waste generation	ATTEN	1 = respondents are attentive when preparing food at home; 0 = otherwise
	Quantities of waste produced	QUANT	1 = respondents believe that their purchasing behavior affects the quantities of food waste produced; 0 = otherwise
	Food waste awareness	AWAR	1 = respondents are aware that the food industry produces considerable amounts of waste; 0 = otherwise
innovative food	Innovativeness	DSI	1 = completely disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = completely agree
	Neophobia	FNS	1 = completely disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = completely agree
	Upcycling	UPCY	1 = respondents know upcycled foods; 0 = otherwise
circular	Circular economy	CIR_EC	1 = respondents know circular economy; 0 = otherwise
	Recycling	RPS	1 = completely disagree; 2 = disagree; 3 = undecided; 4 = agree; 5 = completely agree

A Cronbach's alpha test was conducted on the FNS, DSI, and RPS scores to assess their reliability as a summative rating scale (FNS = 0.8931; DSI = 0.9000; RPS = 0.9490). The models were run using the modules *logit* and *intreg* in STATA 15 software.

Table 2
Socio-demographic characteristics of the sample (n = 457).

Variable	% (n = 457)
Gender	
Male	44
Female	56
Age	
18–25	17
26–35	32
36–45	20
46–55	16
56–65	12
>65	3
Education	
No formal education	<0
Primary school	<0
Middle school	4
High school	26
Bachelor's degree	17
Master's degree	33
Postgraduate education	20
Employment	
Student	19
Independent worker	20
Private-sector worker	28
Public-sector worker	26
Retired	2
Unemployed	4
Other	1
Status	
Married	38
Single	37
Separated/Divorced	5
Widowed	1
Cohabitant	19
Annual household income before taxes	
Less than € 10,000	6
€ 11,000 to € 20,000	19
€ 21,000 to € 35,000	50
€ 36,000 to € 50,000	13
€ 51,000 to € 75,000	7
€ 76,000 or more	5
Household size	
One	16
Two	25
Three	23
Four	27
Five or more	9
Number of children under 18	
No children	69
One	18
Two	11
Three or more	2

2020; Kuah and Wang, 2020; McCarthy et al., 2020; Aschemann-Witzel and Peschel, 2019; Cattaneo et al., 2019; Lakatos et al., 2016).

Conversely, 24% of the respondents were not interested in buying the upcycled frozen margherita pizza. Since they do not have any similar products on the market to make any comparison, they are not willing to buy the upcycled pizza because they do not have enough information, similarly to what has been found by Aschemann-Witzel and Stangherlin (2021), Peschel and Aschemann-Witzel (2020), Savchenko et al. (2019), and Abbey et al. (2015). For the same reason, they will probably not like the taste, as they might believe that the presence of a cauliflower by-product may alter the organoleptic characteristics of the pizza. Taste could be a substantial barrier to upcycled food acceptance (Aschemann-Witzel and Peschel, 2019). Furthermore, because we chose an Italian tradition staple, customers were dissatisfied with the ingredient change in pizza, confirming that the conventional product is preferable (Aschemann-Witzel and Stangherlin, 2021; Kuah and Wang, 2020; Aschemann-Witzel and Peschel, 2019; Peschel et al., 2019). When prompted with potential motivations to incentivize the purchase of upcycled products, non-consumers expressed interest in acquiring more information about waste origin, upcycled foods, health, and environmental benefits (Cela et al., 2024; Hellali & Koraï, 2023; Aschemann-Witzel and Stangherlin, 2021; Coderoni & Perito, 2020, 2021; Goodman-Smith et al., 2021; Grasso and Asioli, 2020; Peschel et al., 2019; Savchenko et al., 2019). This underscores the importance of clear and informative communication to enhance consumer understanding and acceptance.

More than half of the sample (73%) already knew the concept of the circular economy. In the given definitions, the two most frequently used words by consumers were "reuse" and "recycling". This fact entails that consumers perceive circular economy as a practical system that ideally extends the shelf-life of a product as much as possible, connecting the idea of circular economy with closing the life cycle of the products and reinserting all the waste produced into the production chain. Participants were also resolved to assert the importance of "recovery and reduction of waste" and the necessity to explore an economic model that brings "less costs" and "less impacts", particularly on the "environment", seeking "eco-sustainability". Moreover, the use of "secondary raw materials" suggests that consumers know about the fact that waste and by-products could potentially have a second life and be reused, even in different supply chains. Surprisingly, "upcycling" was not a common word used to describe circular economy, even if the concept was introduced before in the questionnaire, and just under half of the respondents stated to know the concept. This shows how poor the knowledge of this concept is, confirming the importance of providing clear and understandable messages to communicate these new concepts that are currently being established.

4.2. Estimation results from the econometric models and WTP

The Linktest was employed to assess whether the logit model is accurately specified. To construct the model, both the linear predicted value (*hat*) and the squared linear predicted value (*hatsq*) need to be estimated (Ayenew, 2014). For the model to be correctly specified, *hat* should be statistically significant, and *hatsq* should not be significant (Chekol et al., 2022). According to the model output, these criteria are fulfilled: *hat* is significant, while *hatsq* is not. Therefore, the logit model is correctly specified since both conditions are satisfied. Additionally, in logistic regression, independent variables should not be collinear. To check for this, a multicollinearity test was conducted using the variance inflation factor (VIF). A VIF below 10 suggests a weak relationship between the independent variables. The lower the VIF, the lesser the multicollinearity. The test results show that the average VIF is 1.16, indicating that there is no multicollinearity issue in the logistic regression model.

Table 3 presents the results of the logit model, aimed at understanding the factors influencing consumers' intentions to purchase upcycled food products.

Four variables significantly influence consumers' intention to purchase upcycled products: knowledge of upcycled foods (UPCY), the domain specific innovativeness scale (DSI-representing consumer innovativeness), the food neophobia scale (FNS-representing consumer attitude towards new products), and the recycled product scale (RPS-representing consumer attitude towards recycled products).

H1.1 is not confirmed, as no socio-demographic characteristics were found to be significant in influencing the intention to purchase upcycled food.

H1.2 is not confirmed. The respondents' behavior at home and during grocery shopping shows that their attention and awareness of food loss, waste, and by-products are not significant in influencing the probability of buying upcycled food. Therefore, a future marketing strategy may not leverage this ethical aspect and sense of guilt to push the market for an upcycled product. H1. 3 is supported. Previous knowledge of upcycling positively influences consumers' intention to purchase, enforcing the fact that if consumers are well informed about what they are going to buy and eat, they are more likely to make that purchase (Yilmaz and Kahveci, 2022). Information and communication remain stable pillars to facilitate the diffusion of new products on the market, specifically if we consider that people who are more food neophobic are less willing to purchase the product (FNS is significant with a negative coefficient). As reported in the literature, food neophobia represents one of the main barriers to consumer acceptance (Grasso et al., 2023; Hellali & Koraï, 2023; Aschermann-Witzel et al., 2022; Yilmaz and Kahveci, 2022; Coderoni and Perito, 2021; Moshtaghian et al., 2021; Aschermann-Witzel and Stangherlin, 2021). People tend to be reticent when facing novelties, especially when referring to food products. This is because food consumption has an impact on a person's mood, pleasure, and health (Lyman, 1989). Addressing the problem of food waste and providing exhaustive and targeted communication about upcycling may have positive effects to try to reduce the incidence of this phenomenon. This influence of the FNS is reflected in the DSI effect, as domain-specific innovativeness has a positive influence on purchasing intention (DSI is significant with a positive coefficient). Differently from individual innovativeness, domain-specific innovation is related to a specific category, which is food. This shows that the personal innovativeness of a consumer may be low, but the one related to trying new foods is high. Therefore, innovativeness could be a strong driver for improving the upcycled food market. This trait represents a key aspect to study for companies that want to launch novel products on the market, as innovative consumers play an essential role in their success (Payini et al., 2020; Barcellos et al., 2009; Huotilainen et al., 2006). The positive incidence of personal innovativeness in influencing consumers' intentions to purchase upcycled food represents an element of novelty compared to the available studies about upcycled foods. Finally, H1.4 is partially supported. The prior knowledge of the circular economy concept does not have any significant effect on influencing the purchase of upcycled food. Thus, consumers do not correlate upcycling with the circular economy, as partially emerged from the given definition in the questionnaire. On the other hand, consumers who believe in recycling and have a positive image and opinion of recycled products (in general) are more likely to buy the upcycled frozen margherita pizza (RPS is significant with a positive coefficient) (Aschemann-Witzel, 2023b; Yilmaz and Kahveci, 2022; Kuah and Wang, 2020). If consumers are already used to buying recycled products, like electronic devices and clothes, they may be more inclined to purchase even upcycled foods. Nonetheless, the mindset of this consumer segment might be more open and prone to experiment with this alternative solution.

Table 4 presents the results of the interval regression model aimed at determining the factors affecting consumers' WTP for the upcycled pizza.

Among the factors influencing the WTP, gender (GEND), awareness of food waste production (AWAR), and recycling attitude (RPS) were found significant. H2.3 was not supported, while H2.1, 2.2, and 2.4 were partially confirmed.

Gender was the only socio-demographic characteristic found to

Table 3
Logistic regression – model results of factors affecting consumers' intentions to purchase upcycled products.

	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
GEND	0.087	0.265	0.33	0.743	−0.433	0.607	
AGE	0.001	0.01	0.15	0.881	−0.017	0.02	
EDU	−0.035	0.114	−0.31	0.757	−0.259	0.188	
INCO	0.011	0.12	0.09	0.926	−0.225	0.247	
ATTEN	−0.095	0.329	−0.29	0.772	−0.74	0.549	
QUANT	−0.092	0.307	−0.30	0.764	−0.694	0.51	
AWAR	0.021	0.491	0.04	0.966	−0.941	0.983	
UPCY	0.452	0.269	1.68	0.093	−0.076	0.98	*
CIR_EC	0.241	0.303	0.80	0.426	−0.352	0.835	
DSI	0.046	0.026	1.78	0.074	−0.004	0.096	*
FNS	−0.077	0.015	−4.98	0	−0.107	−0.047	***
RPS	0.069	0.012	5.75	0	0.045	0.092	***
Constant	−1.171	1.144	−1.02	0.306	−3.413	1.07	

Mean dependent var	0.757	SD dependent var	0.429
Pseudo r-squared	0.200	Number of obs	457
Chi-square	101.473	Prob > chi2	0.000
Akaike crit. (AIC)	431.236	Bayesian crit. (BIC)	484.857

***p < 0.01, **p < 0.05, *p < 0.1.

Table 4
Interval regression – model results determinants affecting consumers' WTP for the upcycled pizza.

	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
GEND	0.18	0.095	1.89	0.058	−0.006	0.366	*
AGE	−0.003	0.004	−0.83	0.407	−0.01	0.004	
EDU	0.008	0.042	0.18	0.857	−0.075	0.09	
INCO	0.035	0.045	0.79	0.428	−0.052	0.123	
ATTEN	0.117	0.123	0.95	0.341	−0.124	0.357	
QUANT	−0.018	0.115	−0.15	0.878	−0.243	0.208	
AWAR	−0.361	0.21	−1.72	0.086	−0.773	0.051	*
UPCY	−0.031	0.094	−0.33	0.739	−0.216	0.154	
CIR_EC	−0.08	0.125	−0.64	0.522	−0.325	0.165	
DSI	0.014	0.009	1.54	0.123	−0.004	0.031	
FNS	−0.005	0.006	−0.83	0.407	−0.016	0.007	
RPS	0.009	0.005	1.76	0.078	−0.001	0.018	*
Constant	4.59	0.463	9.92	0	3.683	5.497	***

Mean dependent var	4.647	SD dependent var	0.389
Number of obs	346	Chi-square	17.943
Prob > chi2	0.117	Akaike crit. (AIC)	855.273

***p < 0.01, **p < 0.05, *p < 0.1.

significantly influence consumers' WTP. In contrast to Hellali et al. (2023), women were more inclined than men to pay for upcycled food products. This inclination might be attributed to women typically overseeing grocery shopping, making them more aware of their purchase and better able to evaluate a product's quality relative to its price (McIntosh and Zey, 1989). Furthermore, individuals aware of the food industry's significant waste production were more willing to pay for upcycled products. This awareness might lead consumers to view waste as a resource worth utilizing further, driven by environmental concerns, health consciousness, curiosity, and ethical values. Environmental concerns prompt consumers to reduce resource waste, while health-consciousness seeks more nutritious options, often provided by upcycled foods designed to utilize otherwise wasted nutrients. Curiosity also plays a role, as the diverse ingredients and preparations of upcycled foods offer an adventurous culinary experience. Consumers may be influenced by the principles of sustainable consumption and corporate social responsibility from a social and ethical perspective. Upcycling aligns perfectly with these values, as it represents a responsible way of addressing environmental and social challenges related to the food industry (Aschemann-Witzel and Stangherlin, 2021).

Lastly, consumers already purchasing recycled products and holding positive views on recycling's environmental sustainability and safety were more willing to pay for upcycled food derived from vegetable by-products. this group recognizes the added value of circular food products, justifying premium pricing. They also understand that food by-products contain valuable nutrients, challenging the perception of lower quality in recycled products. Additionally, an upcycled frozen margherita pizza may be perceived as environmentally friendly, aligning with consumer preferences for green products that offer environmental benefits. (Calvo-Porral and Lévy-Mangin, 2020; Haws et al., 2014).

Table 5 illustrates the response combinations obtained from the group of respondents (346 individuals) willing to purchase the upcycled frozen margherita pizza and their corresponding WTP amounts.

Among these respondents, 49% indicated a willingness to pay €4.50 for the upcycled pizza and accepted the subsequent offer of €5.00. An additional 25% were willing to pay only the initial amount of €4.50. For those declined the initial price of €4.50, 16% were willing to purchase the product at a lower price, while the remaining 10% rejected both offers, unwilling to pay even the average market price of its potential competitors. Overall, the results indicate a positive response, with roughly half of the surveyed consumers expressing willingness to pay a higher price for the upcycled frozen pizza compared to a conventional one.

We were able to estimate the WTP of €4.98 for the frozen, upcycled margherita pizza, which is rich in bioactive ingredients with the use of orange cauliflower stem flour—a by-product of the industrial processing of cauliflowers. Thus, consumers recognized a premium price of €0.93, compared to the average price of the similar products already available on the market, for a product partially made with industrial processing waste. This contradicts the findings of Hellali et al. (2023), Bhatt et al. (2020), and Grasso and Asioli (2020), as Hypothesis 3 is not confirmed. The Italian sample displayed a willingness to pay more for upcycled food compared to its traditional counterpart.

The justification for this premium price of about €1 lies in consumers' perception of the product's added value beyond mere sustenance. As mentioned earlier, consumers perceive the product not only as food but as embedded with several factors justifying its added value. In fact, as reported in subsection 4.1, consumers willing to buy do so because they believe they can reduce the impact on the environment and waste production, and, especially, they perceive the product as healthier, given the intrinsic characteristics due to the nutrients present in it. Therefore, the perceived health benefits associated with the product justify the higher price tag, reflecting consumer's willingness to invest in products they perceive as beneficial to their well-being.

Table 5
Distribution of responses for the initial price offered (n = 346).

Initial price	NO/NO	NO/YES	YES/NO	YES/YES	Total
4.50€/330g	10%	16%	25%	49%	100%

5. Conclusions

In this study, we tried to address the problem of food waste and by-product generation by exploring the factors that affect consumers' intention to purchase upcycled food and their WTP, as well as the price they may be willing to pay for a specific product. The results show that knowledge of the circular economy and the practice of upcycling are still limited among consumers, but with adequate information, consumers are willing to purchase upcycled food derived from a circular system. In our analysis, we found that consumers who were initially unwilling to buy our product could be convinced if they were able to gather all the necessary and fundamental information. According to the results of the logit model, innovative consumers who are already familiar with upcycling, who are not food neophobic, and who have a positive opinion of recycling are more willing to purchase upcycled products. Simultaneously, women who are already aware that the food industry produces considerable quantities of waste and who have a positive perception of recycling are more willing to pay for a specific upcycled food, as revealed by the interval regression analysis.

As found by the descriptive analysis, information plays a central role. Consequently, after consumers have been informed and have become aware of the benefits of upcycled products, they may become more willing to purchase them and to pay more compared to the same conventional products. Indeed, the WTP of a premium price of around €1 is an important result of this study. The estimated WTP makes us understand that consumers are increasingly responsible towards the environment and towards reducing food waste. The possible health benefit obtained by adding the stem upcycled flour may justify a slightly higher price for consumers looking for a more sustainable and healthy diet. Consequently, our product innovation aims to combine the environmental aspect of waste reduction with the health benefits derived from the nutritional compounds naturally present in the orange cauliflower by-product. Thus, our product could be a practical example of upcycling while preparing a health-oriented food product. As consumers become more and more interested in health and nutritional claims, the definition of the properties of food waste and by-products may result in established information being put on labels.

5.1. Theoretical and practical implications

An important theoretical implication of this paper is the assessment of the influence of some factors on the willingness to buy and pay for upcycled food that had not been considered in previous studies. These factors are consumer awareness towards food waste production, DSI, and RPS. RPS was found to significantly influence both willingness to buy and willingness to pay. DSI has positively influenced only the probability of buying upcycled food. Awareness of waste production during food processing has had a significant impact on WTP. Thus, the factors that encourage consumers to buy upcycled food may not necessarily be the same as those that lead them to pay an increased price. Considering this, the results of this study could have significant marketing implications. The identification of the factors that influence the propensity to buy and the willingness to pay is fundamental to the definition of promotional campaigns targeted to specific market segments. In this sense, food industry stakeholders and marketers should consider the results of this preliminary study as an important starting point to enhance the presence of upcycled foods on the market.

The combination of factors influencing the purchase, the factors influencing the WTP, and the estimated value of the WTP could also be useful for pricing mechanisms. Therefore, advertising campaigns,

slogans, and general information are necessary to communicate to consumers the economic, environmental, social, and health benefits that these products have, trying to increase their awareness that resources, which are not infinite, must be exploited to their maximum. Additionally, the creation of a logo or label for the upcycling practice, which reports all the benefits and the origin of the ingredients, their nutritional content, as well as the reference to their quality, may be a strategy to increase acceptance and reduce neophobia, which is one of the main barriers to consumer acceptance.

Finally, the lack of a clear regulatory framework for food waste and by-product reuse in Italy represents a significant hurdle to overcome to enable their recovery and valorization by the food industry. It would be important for policymakers to consider their environmental and health effects to favor their production and commercialization. Despite the growing interest in sustainable food alternatives, our research underscores the need for ongoing efforts to address consumer concerns and barriers to adoption. Strategies to enhance consumer education and awareness, improve product labeling and communication, and foster partnerships across the food industry can play a pivotal role in promoting the acceptance and uptake of upcycled foods. The collaboration of consumers, food producers, policymakers, and other stakeholders may enhance the transition towards a more resilient and equitable food future that embraces innovation, sustainability, and consumer well-being.

5.2. Limitations and future research

This study is not without limitations. The distribution of the questionnaire only in Italy could limit the generalizability of our findings. Consumers' preferences are strongly influenced by the cultural heritage and lifestyle of the sample. Therefore, to mitigate the issues associated with self-selected and biased samples, future research should use a larger and more representative sample from different countries expand the scope of the study to include a more diverse sample of participants from various geographical and cultural contexts. Incorporating data from multiple regions and demographic groups would enable us to capture the breadth of consumer preferences and behaviors towards upcycled foods more accurately. Such a broader approach would enhance the external validity of our findings and contribute to a more comprehensive understanding of the complexities of consumer behavior in different contexts. Therefore, it is crucial to account for diverse perspectives and experiences to ensure the robustness and applicability of our research findings.

Self-reported data may be susceptible to biases, such as social desirability and cognitive biases, potentially affecting the accuracy and reliability of the findings. To address this limitation, future research could propose incorporating complementary methods to validate the self-reported measures of consumer intentions and willingness to pay. This could involve collecting actual purchase behavior data through observational studies or experiments conducted in real-world settings. Triangulating self-reported data with objective measures of purchasing behavior, we may enhance the validity and robustness of our findings and provide a more accurate assessment of consumer preferences and behaviors towards upcycled foods. Moreover, providing actionable insights for industry stakeholders and policymakers is crucial. By supplementing our study with empirical evidence from actual purchase behavior data, we might offer more pragmatic and evidence-based recommendations to guide decision-making in the food industry and policymaking processes.

One of the main criticisms of contingent valuation is the hypothetical bias, where individuals have been found to systematically overstate the stated WTP. To mitigate this problem, we implemented some *ex-ante* mechanisms in the survey preceding the valuation. Firstly, we provided them with a cheap talk with a brief description and a picture of upcycled foods. Secondly, we did not use a voluntary payment mechanism, as we proposed prices established through a market analysis of the potential competitors, simulating a real market situation. We acknowledge that factors such as product accessibility, pricing strategies, and marketing efforts play crucial roles in the success of upcycled food products on the market. These elements influence consumer acceptance and purchasing decisions to a significant extent. To address this oversight, we propose expanding the scope of our research to include an analysis of promotional campaigns, distribution channels, and pricing mechanisms related to upcycled food products. By incorporating these essential elements into our study, we will aim to provide a more comprehensive understanding of the challenges and opportunities associated with the commercialization of upcycled foods. Such an expanded analysis will enrich the discussion and contribute to a more robust assessment of the market dynamics surrounding upcycled food products. Future research in this area should prioritize adopting more rigorous research designs. Moreover, adopting mixed-method approaches can provide a more comprehensive understanding of consumer behavior by combining qualitative and quantitative data. Additionally, longitudinal studies would allow for the exploration of the dynamic nature of consumer preferences and market dynamics over time. Implementing these methodological enhancements can enable future research endeavors to overcome the limitations identified in our study and contribute more effectively to advancing knowledge in the field of upcycled foods.

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CRediT authorship contribution statement

Giulia Chiaraluce: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Deborah Bentivoglio:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Alessia Del Conte:** Writing – original draft, Visualization, Investigation, Data curation, Conceptualization. **Maria Raquel Lucas:** Writing – review & editing, Validation, Supervision, Project administration, Investigation, Conceptualization. **Adele Finco:** Writing – review & editing, Validation, Supervision, Project administration, Investigation, Conceptualization.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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