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Are Italian consumers afraid of hydroponic agriculture? The role of food technology Neophobia, information, and dietary habits

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A B S T R A C T

Hydroponics is a soilless cultivation technique that promises increased agricultural yields while minimizing resource usage. However, its full potential may be limited by consumer acceptance barriers. This study examines how Food Technology Neophobia (FTN) affects willingness to pay (WTP) for hydroponic lettuce and whether environmental or health-related information, along with healthy eating and dietary sustainability orientations, shape consumers' preferences. Data were collected through an online survey completed by 750 Italian respondents assigned to one of three information conditions. The FTN Scale measured neophobia level, while consumers' WTP was elicited through a Choice Experiment. Results revealed that, although on average consumers did not discriminate between hydroponic and conventional lettuce, FTN significantly reduced WTP for the hydroponic alternative. Surprisingly, providing information on either environmental or health benefits did not yield statistically detectable influence on WTP, nor did consumers' interest in healthy eating or dietary sustainability orientation moderate preferences for hydroponic products. The findings suggest that successful market penetration depends on achieving price competitiveness with conventional products and building familiarity through experiential marketing. Moreover, hydroponic production under organic regulations could improve credibility and widen the hydroponic market.

1. Introduction

In recent years, the global agri-food sector has faced the pressing challenge of producing more food using fewer resources in response to a population projected to reach 9.8 billion by 2050 (United Nations UN, 2017). This task is aggravated by climate change, which exacerbates soil degradation, reduces both fertility and productivity, and further undermines global food security (IPCC, 2019; IPCC, 2023). Within this scenario, hydroponics, a soilless, high-tech cultivation method, has emerged as a promising alternative to traditional farming (Martin & Molin, 2019; Naresh et al., 2024). By growing crops in a controlled, highly automated environment using nutrient-enriched water solutions (Sambo et al., 2019), hydroponics drastically reduces water consumption (Naresh et al., 2024), minimizes pesticide usage (Chen et al., 2024), and eliminates the need for arable land (Naresh et al., 2024). Moreover, studies have shown that hydroponics can achieve higher yields and faster crop growth compared to conventional farming (Touliatos et al., 2016). These features make it an attractive option from both an environmental and food security perspective (Graamans et al., 2018). This production method is already widespread in countries such as the Netherlands, France, and the United States (Aires, 2018; Naresh et al., 2024; Son & Hwang, 2023), where it is increasingly calling for investments (USDA, 2024).

However, the success of hydroponics depends not only on its technical advantages but also on consumer acceptance, especially in countries where new food technologies tend to face greater resistance. As hydroponics represent an innovative and therefore unfamiliar agri-biotechnological methodology, this resistance might be rooted in the deep psychological trait known as Food Technology Neophobia (FTN), which is negatively related to the acceptance of new agri-food technologies (Califano et al., 2024; Siegrist & Hartmann, 2020; Wendt & Weinrich, 2023). FTN is defined as consumers' fear, dislike, or avoidance of novel food technologies (Cox & Evans, 2008), which differs from the concept of food neophobia. While the latter refers to the generalized hesitation to try unfamiliar foods and the reactions directed mainly towards the product itself (Pliner & Hobden, 1992), FTN specifically involves scepticism towards the processes and the techniques adopted behind food production (Wendt & Weinrich, 2023). Therefore, it is

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essential for the industry to address consumer acceptance early in product development processes (Siegrist, 2008) as the anticipated resistance towards innovative food among consumers could hinder the environmental and social advantages that hydroponics offers, including reduced greenhouse gas emissions and strengthened food system resilience (Martin & Molin, 2019).

While the literature shows that FTN negatively affects the acceptance of innovative foods (Zamparo et al., 2023), appropriately targeted information can help counteract this effect. According to the Knowledge-Attitude-Behaviour (KAB) theory (Kallgren & Wood, 1986), providing relevant information can shape consumer attitudes and behaviour. Consistent with this framework, prior research has shown that emphasizing the benefits of food technologies likely increases acceptance (Boncinelli et al., 2021a; De Magistris et al., 2015; Gilmour et al., 2019). Furthermore, understanding how to effectively communicate these benefits is critical for encouraging consumer openness to innovation (Siegrist, 2008).

Cultural factors also significantly influence consumers' responses to novel technologies (Ares et al., 2021; Perambalam et al., 2021). In Italy, where food culture remains intrinsically tied to territory and tradition (Boncinelli et al., 2024), FTN may be particularly influential in determining which products have success on the market and which do not. Wendt and Weinrich (2023) stressed that a notable part of the studies that investigated the FTN trait were conducted in Italy.

Although FTN constitutes a significant barrier to the adoption of innovative food technologies (Wendt & Weinrich, 2023), its specific influence on Italian consumers' acceptance of hydroponic products remains unexplored. Given the high-tech nature of soilless systems, consumer resistance to food innovations, and Italians' strong attachment to culinary traditions, investigating FTN's role becomes particularly relevant. While previous studies explored hydroponics' acceptance in Italy (e.g., Celeste et al., 2023; D'Amico et al., 2024; Gallè et al., 2025), this is the first study focusing on the role of FTN in shaping the monetary preferences for hydroponic products, as captured by the willingness to pay (WTP). Additionally, this study investigates the role of information, providing consumers with targeted information regarding the environmental and health benefits of hydroponics, which could mitigate consumer scepticism and increase WTP for hydroponic products. Finally, we also evaluate whether consumers' inherent dietary habits, including their engagement in healthy eating and focus on dietary sustainability, affect their WTP for hydroponic products.

By exploring the interaction between FTN, information framing, and purchase intentions through choice experiments, this research provides actionable insights for producers, retailers and policymakers seeking to expand hydroponic farming in a traditionally food-conservative market.

2. Literature review and study hypotheses

Key determinants of food consumer preferences and purchasing behaviour include perceived benefits (Fahlevi et al., 2024a; Loh & Hassan, 2022), perceived risks (Feng et al., 2025; Loh & Hassan, 2022), beliefs and values (Homer & Kahle, 1988), and trust in its various facets (Dhir et al., 2021; Hobbs & Goddard, 2015). These dimensions are particularly relevant in shaping consumer acceptance of novel foods and new technological applications in the food sector (Al Mamun, 2023; Cattaneo et al., 2019; Gao et al., 2024).

In line with the objectives of this study, it is essential to review consumer perceptions of soilless agriculture, identifying both primary concerns and key drivers of acceptance. Numerous studies exploring this topic are available. Above all, the inherently ambiguous concept of naturalness plays a central role in shaping consumer preferences, thereby directly impacting the acceptance of innovative agricultural technologies like hydroponics. Although conventional agriculture itself, involving animal breeding, fertilization, and monocropping, is far from natural (Muller et al., 2017), the romanticized view of food production linked to nature and rural life hinders the acceptance of these innovations (Specht et al., 2019). Indeed, several authors stress that consumers perceive hydroponically grown food as "unnatural" or too futuristic (Celeste et al., 2023; Csordás & Füzesi, 2023; Jaeger et al., 2022; Son & Hwang, 2023). Additionally, limited public knowledge of innovative technologies contributes to hindering food technology innovations (Siegrist & Hartmann, 2008).

The market uptake of unfamiliar products is also typically constrained by biased perceptions concerning their quality and sensory characteristics (Jaeger et al., 2023a). Soilless-grown products are often expected to be paler and have less intense flavour, although blind tastings reveal no sensory differences between those and organic vegetables (Jaeger et al., 2023a). Moreover, when consumers are asked whether they would pay a premium for hydroponic vegetables, responses are often negative (Ares et al., 2021; Huang, 2019; Jaeger et al., 2023a; Jaeger et al., 2023b). Califano et al. (2024) indicated that, although consumers are willing to consume the product from hydroponics, they are not willing to pay premium prices. In addition, the associated high energy consumption issues represent another perceived drawback regarding hydroponics (Ares et al., 2021; Son, 2023; Zhou et al., 2025).

Despite these concerns, soilless cultivation does not elicit exclusively negative reactions. A multi-country study conducted in the United States, Germany, China, and Singapore reveals generally positive attitudes towards vertical farming products (Ares et al., 2021). Moreover, several attributes of hydroponics are widely appreciated. Many consumers value the reduced pesticide and herbicide use derived from the use of such techniques (Jaeger et al., 2023b; Califano et al., 2024). Additionally, perceived sustainability and carbon emission reduction characteristics are generally positively valued (Celeste et al., 2023; Piracci et al., 2024b; Shao et al., 2022). In line with this, Gilmour et al. (2019) found that communicating the diverse benefits of hydroponic agriculture, including environmental benefits, is likely to increase consumers' monetary valuation of hydroponically produced lettuce. Perceived health benefits are another positive driver for acceptance of soilless cultivated vegetables, particularly among health-conscious consumers. Consumers are more likely to purchase hydroponic products when the benefits they perceive align with their health values (Fahlevi et al., 2024b). Product freshness and higher yields are also perceived as positive attributes (Ares et al., 2021; Jaeger et al., 2022).

Overall, literature indicates that the acceptance of hydroponics depends on how consumers weigh its perceived drawbacks against its environmental and health advantages. However, despite rationality playing a central role in human behaviour, certain decision-making processes deviate from basic logical principles (Shafir & LeBoeuf, 2002; Tversky & Kahneman, 1974) and the full adoption of innovations is strongly mediated by consumer psychology (Siegrist, 2008). Specifically concerning food, individuals are increasingly aware of its content and often hold a negative perception of the methods used to produce it (Cox & Evans, 2008). In this context, FTN represents one of the major psychological obstacles to the broader adoption of these innovations (Siegrist & Hartmann, 2020). The success of new food technologies in the market heavily relies on public perception and consumer acceptance. High failure rates and limited market penetration of novel technologies are partially attributed to FTN, which inhibits consumer acceptance by definition (Wendt & Weinrich, 2023).

While the literature review reveals that consumers have mixed feelings towards hydroponics, a generally widespread finding is that perceived sustainability and health benefits of this technology are highly valued attributes. This presents a strategic opportunity to make hydroponics appealing to consumers. If properly communicated, these attributes might counterbalance neophobic concerns and increase consumer acceptance. As the KAB theory states, information provision can shape attitudes and behaviour. Supporting this framework, some researchers have found that highlighting the benefits of food products can increase consumer acceptance and willingness to buy (De Magistris et al., 2015; Napolitano et al., 2007).

Values are also crucial drivers of consumer choice, strongly influencing attitudes and behaviour (Homer & Kahle, 1988). This has been proven in studies about pro-environmental behaviour (Govaerts & Olsen, 2023) and healthy eating habits (Kang et al., 2015). Therefore, investigating consumers' involvement in healthy eating and dietary sustainability can offer a comprehensive understanding of the values driving acceptance of hydroponics.

Given these premises, this study aims to answer three critical questions: (1) How does FTN influence Italian consumers' WTP for hydroponic products? (2) Can targeted information about environmental and health benefits increase WTP and mitigate neophobic barriers? (3) How do consumers' dietary habits influence their WTP for hydroponic products?

Building on the existing literature, five key hypotheses are developed to address these questions and are subsequently tested in this research:

H1: FTN negatively influences WTP for hydroponic products.

H2: Providing additional information about environmental benefits positively influences WTP for hydroponic products.

H3: Providing additional information about health benefits positively influences WTP for hydroponic products.

H4: Consumers' healthy eating habits positively influence WTP for hydroponic products.

H5: Consumers' dietary sustainability positively influences WTP for hydroponic products.

Finally, we explore the heterogeneous effects of informational treatments considering FTN, sustainable eating, and healthy eating. In other words, we test if the effect of messages can be heterogeneous according to the attitude towards FTN, sustainable eating, and health.

3. Materials and methods

3.1. Data collection

Data were collected through an online survey conducted in Italy. The survey was created and administered through the Pollfish platform. Responses were collected during November 2024. The questionnaire was written in Italian and administered to 750 adult Italian respondents. Participants were asked to complete a Choice Experiment (CE) and answer questions assessing their prior knowledge, information about their purchasing behaviour, perceived importance of key hydroponics' attributes, and three psychometric scales. To measure FTN levels and categorize consumers based on their acceptance or rejection of novel food technologies, the Food Technology Neophobia scale by Cox and Evans (2008) was employed. To assess consumers' dietary habits, specifically their engagement in healthy eating and focus on dietary sustainability, the Involvement in Healthy Eating and the Subjective Sustainability of the Diet scales (Pieniak et al., 2010, revisited by Van Loo et al., 2017) were administered. Finally, sociodemographic data were also collected.

This non-invasive study, involving only consenting adult volunteers, gathered data anonymously. No psychological, physical, or emotional interventions were used, and no sensitive personal data was collected. Informed consent was obtained from all participants. Formal ethics committee approval was not required under Italian research standards for this non-clinical behavioural study, which fully complied with the Declaration of Helsinki, ensuring voluntary participation, privacy, and anonymity.

3.2. Informational treatments and choice experiment

To begin, participants were randomly assigned to three groups and exposed to different informational treatments (Table 1): one “Control” treatment and two informational treatments named “Environmental benefits” and “Health benefits”.

All treatments included a brief definition of hydroponics. The “Environmental benefits” treatment added information about reduced chemical, water, and soil usage. The “Health benefits” treatment emphasized reduced risk of chemical residues and pathogen contamination. Texts for all treatments were kept concise, under 70 words, to avoid tiring respondents with overly lengthy content. They were written using conversational language, avoiding technicalities. To ensure that participants read and understood the assigned text, they were then asked to mention words they felt positive about, as an engagement task rather than a formal manipulation check.

Table 1
Texts of the three informational treatments administered to respondents.

Treatment	Text
Control	Hydroponics is a “soilless” cultivation technique in which vegetables grow in direct contact with a solution of water and nutrients. A type of cultivation that makes use of the hydroponic method is the so-called vertical farming[a]. [38 words in Italian]
Environmental benefits	Hydroponics is a “soilless” cultivation technique in which vegetables grow in direct contact with a solution of water and nutrients. A type of cultivation that makes use of the hydroponic method is the so-called vertical farming. Compared to conventional agriculture, hydroponics has environmental benefits, because it reduces the use of water, fertilizers and pesticides. Furthermore, if implemented in vertical structures, it allows to reduce the consumption of agricultural land. [68 words in Italian]
Health benefits	Hydroponics is a “soilless” cultivation technique in which vegetables grow in direct contact with a solution of water and nutrients. A type of cultivation that makes use of the hydroponic method is the so-called vertical farming. Compared to conventional agriculture, hydroponics has benefits for human health, because it reduces the risk of chemical residues in the final products and their contact with external pathogens. [67 words in Italian]

Note: the texts are a translation of the original ones, which were written in Italian.

[a] The term “vertical farm” was mentioned in the texts because many hydroponically grown vegetables in Italian grocery stores use such phrasing on the label.

The informational treatments were followed by a labelled CE. CEs represent a survey-based method designed to measure consumer preferences (Amaya-Amaya et al., 2008). By simulating purchase situations, respondents are presented with a series of choice sets, and for each set, they are asked to elicit the preferred alternative, making trade-offs between similar products differing in attributes and attribute levels. The selected product for this experiment was lettuce in bags (100 g), as it is one of the most widely available hydroponic vegetables in Italian supermarkets. In the CE, participants were offered two alternatives for each purchasing scenario: hydroponics and conventional lettuce. The alternatives varied for two selected attributes, namely price and “zero pesticide residues” logo, each defined according to the levels reported in Table 2. The inclusion of this specific certification logo is justified by the intrinsic characteristics of hydroponic production systems, which inherently require lower or no chemical inputs compared to conventional agricultural approaches, and indeed recall the frequently used claim on real market hydroponics products. Its inclusion in the experimental design serves a twofold purpose. First, it introduces additional attribute variation within the choice sets, thereby enhancing the discriminatory power of the choice experiment. Second, and more substantively, it allows for the identification of consumer preferences for

Table 2
Alternatives and attribute levels in the Choice Experiment.

Alternative specific constants	
Conventional lettuce	
Hydroponic lettuce	
Attribute	**Levels**
Price	0.70€, 1.30€, 1.90€, 2.50€
“Zero pesticide residues” logo	Absent, Present

vertical farming products that extend beyond purely environmental motivations, capturing food safety and quality-related dimensions of consumer valuation. Regarding the price levels included in the CE, they reflect real market prices collected from major Italian supermarket websites between September and October 2024.

The experimental design was generated using Ngene and consists of a fractional factorial orthogonal design comprising 8 choice sets, blocked into two group of 4 tasks each. Each respondent was randomly assigned to one of the two blocks, ensuring that the full design space was covered across the sample while limiting individual cognitive burden to 4 choice tasks. This is a deliberate strategy consistent with best practice recommendations for DCEs, where the number of attributes per task is the primary driver of response error variance (Caussade et al. 2005; Lizin et al. 2022). The D-error of the design is 0.69.

To minimize the combination of choice sets, the CE followed a fractional factorial design, which was estimated using Ngene software, resulting in the creation of eight choice sets in total. To further reduce cognitive fatigue, the experimental design was divided into two blocks of four purchase scenarios each. Participants were randomly assigned to one of the two blocks. Fig. 1 illustrates an example of the two product alternatives presented in a choice set, while the opt-out option, present in the survey's radio button interface, is not shown in the figure. The inclusion of a "no-choice" option reflects well-established methodological practice in choice experiments (Louviere et al., 2000), grounded in the recognition that preference realism is best preserved when the experimental setting mirrors real-world market conditions, wherein consumers retain the option of forgoing all offered alternatives when none satisfies their minimum utility threshold (Batsell & Louviere, 1991). This design feature is broadly acknowledged in the discrete choice modelling literature as instrumental in mitigating hypothetical bias and strengthening the behavioural validity of the elicited preference estimates (Caputo & Scarpa, 2022).

Notes: The example is a translation of the original choice set, which was written in Italian.

The opt-out option, which was included in each choice set, is not depicted in this Figure.

Because CEs are hypothetical, a major concern is hypothetical bias: respondents may overestimate their WTP for certain attributes since they are not making actual purchases. To counteract this, we employed a clear cheap talk script in the instructions for each choice set (Cummings & Taylor, 1999; Penn & Hu, 2019). Additionally, we included a repeated opt-out reminder (Alemu & Olsen, 2018), which provided respondents with the option to choose none of the alternatives in the choice sets.

By reinforcing the necessity of treating their choices as if they were genuinely required to pay for the products, these strategies ensured respondents understood their limited budget, thus mitigating potential overestimation of the attributes' WTP (Schmidt & Bijmolt, 2020).

3.3. *Consumer purchasing behaviour, attitudes, and psychometric scales*

After the CE, respondents were asked about their prior knowledge of hydroponics, their habits regarding fresh vegetable purchasing, and whether they had ever bought or would consider buying hydroponic products.

Then, to inspect consumer preferences and identify which attributes of hydroponic vegetables were valued most, participants were asked to rate the importance of the following attributes for choosing to buy hydroponic products: absence of pesticide use, reduced water usage, superior or similar quality or taste compared to soil-grown products, curiosity to try products grown with innovative cultivation methods, freshness, and availability in stores. These attributes were selected because they are typically associated with hydroponic products, but can also apply to other vegetables commonly found in supermarkets. Respondents rated the importance of these attributes on a five-point Likert scale from "not important at all" to "extremely important".

Next, to gain deeper insight into consumer attitudes, potential barriers or concerns that might discourage consumers from purchasing hydroponic vegetables were investigated. Respondents indicated their level of agreement with four negative statements: "I believe that vegetables should be grown in soil and sunlight", "I believe that hydroponic vegetables are of lower quality or worse flavour", "I believe that hydroponic vegetables are harmful to health", and "I believe that hydroponic vegetables are unnatural". Rating was done using a five-point Likert scale from "totally disagree" to "totally agree".

Subsequently, the psychometric scales were administered, starting with the FTN scale (Cox & Evans, 2008). This scale has been widely used in high- and middle-income countries in relation to genetic modification, insect production, cultivated meat, upcycling technologies, and food preservation methods (Wendt & Weinrich, 2023). It has also been applied to assess consumer acceptance of soilless cultivation systems by Ares et al. (2021), Califano et al. (2024), Jaeger et al. (2022), and Perambalam et al. (2021). In this study, we utilized the original FTN

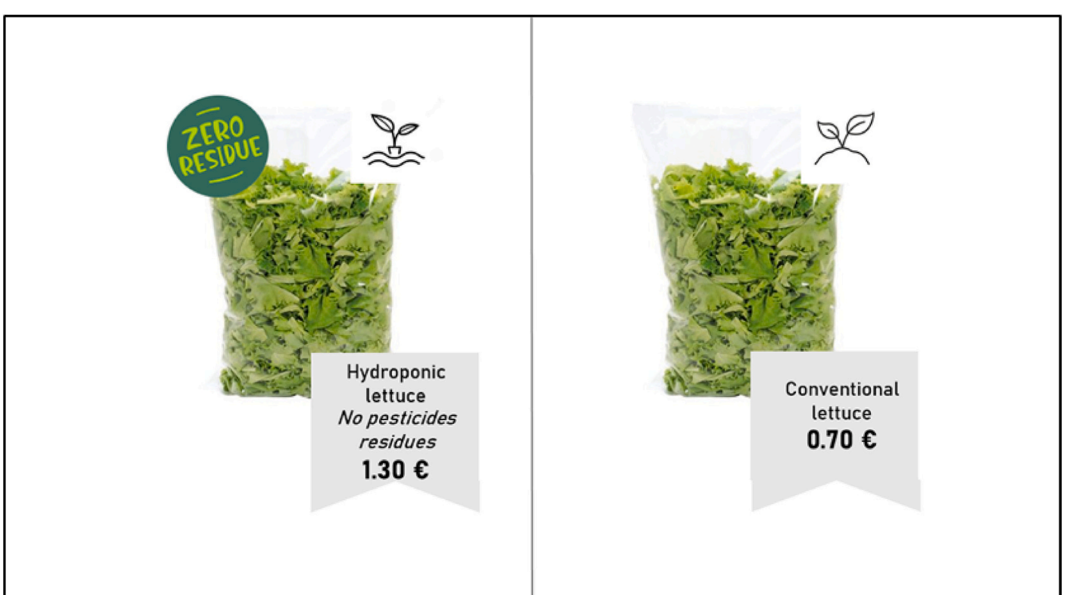

Fig. 1. Example of product alternatives included in a choice set.

scale, consisting of four factors comprising thirteen items (Table 3) to which respondents stated their level of agreement.

Then, respondents were asked to rate items from the Involvement in Healthy Eating scale (Van Loo et al., 2017), used to assess their interest in a healthy diet. The items were: “Healthy eating is very important to me”, “I care a lot about healthy eating”, “Healthy eating means a lot to me”, and “I am very concerned about the health-related consequences of what I eat”.

Lastly, respondents answered questions regarding their perceived dietary environmental consciousness. To evaluate this, the items of the Subjective Sustainability of the Diet scale (Van Loo et al., 2017) were administered. The items were: “My eating behaviour is as sustainable as that of anyone I know of a similar age”, “My eating habits are excellent with respect to good sustainability compared to those of other people of a similar age”, and “I consider myself to be very sustainable-conscious when it comes to food and eating habits”.

For consistency, all scales' items were evaluated on a five-point Likert scale from “totally disagree” to “totally agree”. Internal consistency of the psychometric scales was assessed in consideration of the Cronbach's alpha value. A good consistency was assumed when the alpha was greater than 0.70 (Nunnally, 1975).

3.4. Data analysis

Data from the CE were analysed with the Generalized Multinomial Logit (GMNL) model in WTP space, allowing the marginal WTP estimates to be directly interpreted in monetary terms (Piracci et al., 2022; Train & Weeks, 2005). This model accounts for heterogeneity in respondent preferences and scale parameter (Fiebig et al., 2010). CEs are grounded in the Random Utility Theory (McFadden, 1972). The latter assumes that individuals act as rational decision-makers seeking to maximize their utility and that their choices are probabilistic rather than deterministic. Accordingly, the utility U_{nj} of the n-th consumer for j alternative can be broken down into two parts, being a component defined as a function of alternative attributes $V(X_{nj})$ and a random unobserved component (ε_{nj}) accounting for unobserved variations in preferences:

Table 3
Factors and items of the Food Technology Neophobia Scale by Cox and Evans (2008).

Factors	Items
New food technologies are unnecessary	1. There are plenty of tasty foods around, so we don't need to use new food technologies to produce more. 2. The benefits of new food technologies are often grossly overstated. 3. New food technologies decrease the natural quality of food. 4. There is no sense trying out high-tech food products because the ones I eat are already good enough. 5. New foods are not healthier than traditional foods.
Perception of risk	6. New food technologies are something I am uncertain about. 7. Society should not depend heavily on technologies to solve its food problems. 8. New food technologies may have long term negative environmental effects. 9. It can be risky to switch to new food technologies too quickly. 10. New food technologies are unlikely to have long term negative health effects. (R)
Healthy choice	11. New products produced using new food technologies can help people have a balanced diet. (R) 12. New food technologies give people more control over their food choices. (R)
Information/media	13. The media usually provides a balanced and unbiased view of new food technologies. (R)

Notes: (R): reverse-scored item. The Italian translation of the scale from Cattaneo et al. (2019) was adopted.

$$U_{nj} = V(X_{nj}) + \varepsilon_{nj} \tag{1}$$

Within this framework, individual n will choose alternative j only if its associated utility U_{nj} is higher than the utilities associated with all other available options. Therefore, the utility U_{nj} in each choice situation t could be written as follows:

$$U_{njt} = ASC_j + \beta Pestfree_{njt} + \alpha Price_{nij} + \varepsilon_{njt} \tag{2}$$

where ASC_j is the alternative-specific constant that represents the utility for conventional and hydroponic lettuce; β is the parameter of the attribute “zero pesticide residues” and *Pestfree* is a dummy variable equal to 1 if the product shows the logo; and α is the parameter related to the price attribute. To account for both preference and scale heterogeneity, consumer preferences were modelled using the GMNL model proposed by Fiebig et al. (2010), estimated with 1000 Halton draws. Taste heterogeneity was specified by assuming normally distributed random parameters for all attributes. While the standard mixed logit model captures preference heterogeneity through a mixing distribution over taste parameters, it confounds preference heterogeneity with scale heterogeneity, that is, individual differences in the consistency with which preferences govern choices. This conflation is particularly consequential in treatment-comparison designs. Indeed, the differences in WTP across groups can reflect genuine shifts in preferences, differences in choice consistency induced by information exposure, or both. Since the central objective of this study is to test whether information treatments affect consumer preferences, a model that separately identifies the two sources of heterogeneity is required. The GMNL model addresses this by introducing an individual-specific scale parameter σ_i, allowing WTP comparisons across treatment groups to be made holding scale constant. The model is estimated in WTP space, following Train and Weeks (2005) and Scarpa et al. (2008), so that WTP parameters are estimated directly as primary model outputs rather than derived as ratios of preference-space coefficients, an approach that guarantees finite moments for the WTP distribution (Daly et al., 2012) and yields more stable welfare estimates (Balcombe et al., 2009).

To verify what information impacted consumer preferences in a statistically different manner than the absence of information and the role of consumers' dietary habits, we followed a procedure already applied in several studies (see among others, Boncinelli et al., 2021b; Piracci et al., 2024a). To test the hypothesis about the negative influence of the FTN on WTP for hydroponic products (H1), we interacted the mean-centered FTN scale score with the CE attributes and inserted these terms in specification (3). Similarly, the effects of pro-environmental and health information (H2 and H3) and dietary habits (H4 and H5) were tested using ad hoc interaction terms. To test H2 and H3, we estimated two separate models in which the control group was combined with each informational treatment in turn. We interacted the attributes with a specific treatment dummy variable equal to 1 for the specific informational treatment and 0 otherwise. The sign and significance of parameters associated with the interaction terms enabled us to test the effect of the informational treatment in changing consumer's utility for hydroponic lettuce with respect to the control group. To test H4 and H5, we interacted the mean-centered scores of the Involvement in Healthy Eating and Subjective Sustainability of Diet scales with CE attributes and we inserted them in two models.

With 750 respondents each completing 4 choice sets, the dataset comprises 3000 choice observations, providing a panel of sufficient size for stable estimation of the GMNL model. Identification of the random parameters relies on cross-respondent distributional variation across the 750 sampled individuals, for which 4 within-person observations per respondent are adequate to contribute to the simulated log-likelihood. The interaction terms included in the model specification are interactions between design attributes and respondent characteristics; their identification depends on cross-sectional heterogeneity in the sample rather than on within-respondent variation across choice tasks, a condition well satisfied by the present dataset.

Moreover, we estimated a Latent Class Model (LCM) (Train, 2009). It is an econometric model designed to capture unobserved heterogeneity among decision-makers by segmenting the population into a finite number of discrete groups or "latent classes", an approach that has become central to studies seeking deeper and more actionable marketing insights (e.g., Boncinelli et al., 2019; Dominici et al., 2020). Each latent class groups together individuals with similar preferences that are not directly observable from the data. The LCM allowed us to estimate the probability of each individual belonging to each class and then to model the choice behaviour specific to each class. Therefore, we could estimate a vector of class-specific parameters for the observed attributes.

To identify significant differences within the latent groups, a Chi-Square test was utilized.

All statistical analyses were performed using RStudio software version 4.4.2 with the GMNL package (Sarrias & Daziano, 2017).

4. Results

4.1. Purchasing behaviour and attitudes towards hydroponics

Sample characteristics are reported in the Appendix (Table A1). As shown in Table 4, approximately 95% of respondents reported purchasing fresh vegetables at least once a week.

Respondents' prior knowledge of hydroponics was evenly distributed, with approximately half being unfamiliar with the concept and the other half possessing some prior knowledge. Despite this, only a small proportion indicated that they had previously purchased hydroponically grown vegetables (16.1%). Moreover, many participants expressed openness to purchasing them in the future (68.3%). A smaller percentage remained uncertain about buying such products (14.4%), and only a very small minority (1.2%) declared that they would not consider purchasing them.

We tested whether there were differences across the sub-samples defined by the informational treatments using the Chi-square test. The results (Table A1) confirmed successful randomization in the informational treatment across sociodemographic variables and respondents' attitudes and purchasing habits (all p-values were greater than 0.05).

To investigate preference, respondents rated six attributes of hydroponic vegetables based on the importance they assigned to each, as reasons to potentially purchase them. Fig. 2 summarizes their answers. The absence of pesticide use emerged as the most favourable trait, with most respondents rating it as either very important or extremely important. Similarly, freshness and quality were highly valued, with approximately 90% of participants assigning these attributes a high level of importance, followed by reduced water usage. Conversely, attributes such as curiosity and availability received fewer responses, with a noticeable portion of participants rating them as neutral or slightly important.

Table 4
Sample Purchasing behaviour and attitudes towards hydroponics ($N = 750$).

Category	Pooled sample	
	N	%
Prior knowledge of hydroponics (yes)	360	48.0
Intention to purchase hydroponic products		
Yes, I have already bought them	121	16.1
No, but I would buy them	512	68.3
I don't know	108	14.4
No, I wouldn't buy them	9	1.2
Vegetable Purchase Frequency		
Daily	75	10.0
A few times a week	385	51.3
Weekly	249	33.2
Monthly	24	3.2
Rarely	17	2.3

To assess barriers and potential concerns about hydroponic products, respondents were asked to indicate their level of agreement with four negative statements, as reasons not to purchase them. As shown in Fig. 3, the statement that received the most agreement was the belief that vegetables should be grown in soil and under sunlight, with 40.5% of respondents agreeing or strongly agreeing. Conversely, statements related to poorer quality, health implications, and unnaturalness saw higher levels of disagreement. For example, 38.1% of respondents disagreed with the notion that hydroponic vegetables are of lower quality or taste, and 42.4% rejected the idea that hydroponic vegetables are harmful to health. Notably, the perception of unnaturalness was quite moderate, with 42.1% of respondents disagreeing with the statement, 22.7% remaining neutral, and only 9.2% expressing agreement.

Statistics related to scales are reported in Tables A2, A3, and A4 in the Appendix for each relative score.

4.2. Choice experiment and latent class model

The choice experiment results provide multifaceted insights into consumer preferences for hydroponic and conventional lettuce, shedding light on the role of food technology neophobia, information provision, and attitudinal factors in shaping WTP. As is common in hypothetical choice experiments estimated in WTP space, the absolute WTP values reported should be interpreted as indicative of the relative strength and direction of consumer preferences rather than as precise market valuations, given the well-documented tendency of hypothetical settings to inflate stated WTP relative to actual market behaviour (Penn & Hu, 2018). With this interpretive caveat in mind, the following results offer meaningful evidence on the preference structures underlying consumer acceptance of vertical farming products. Table 5 shows the results of GMNL estimates in WTP space applied to the control subsample, examining the interaction between FTN[1] and product attributes. The interaction term between hydroponic lettuce and FTN showed a negative and statistically significant coefficient (−1.61), indicating that as consumers' FTN levels increase, their WTP for hydroponic products decreased substantially. In contrast, the corresponding interaction with conventional lettuce was not statistically significant, suggesting that neophobic consumers specifically discriminated against soilless cultivation methods. Therefore, the data strongly supported hypothesis H1, confirming that FTN negatively influenced consumers' WTP for hydroponic products.

SE: Standard error. "Neophobia" refers specifically to "Food Technology Neophobia".

The main effect WTP estimates (without neophobia interaction) showed high and significant coefficients for both cultivation methods, conventional and hydroponic, indicating that consumers generally valued both product methods positively. Notably, the baseline WTP for hydroponic lettuce exceeded that for conventional lettuce, suggesting that in the absence of neophobic tendencies, consumers preferred hydroponic products. Nevertheless, the baseline model's WTP estimates should not be viewed as independent measures of market value; instead, they serve as a parametric benchmark, with the main conclusions deriving from the model's interaction structure. The "zero pesticide residues" logo and its interaction coefficient with the FTN were both non-statistically significant, indicating that neophobic consumers did not differentially respond to pesticide-free labelling compared to non-neophobic consumers.

The standard deviation parameters provided insights into preference heterogeneity. The statistically significant standard deviation for the zero-residue logo confirmed substantial variation in consumer preferences for this attribute. The non-statistically significant standard

[1] As above-mentioned, each psychometric scale has been standardised prior to its inclusion in the model specifications, so that the baseline WTP estimates correspond to a respondent at the sample mean of each scale.

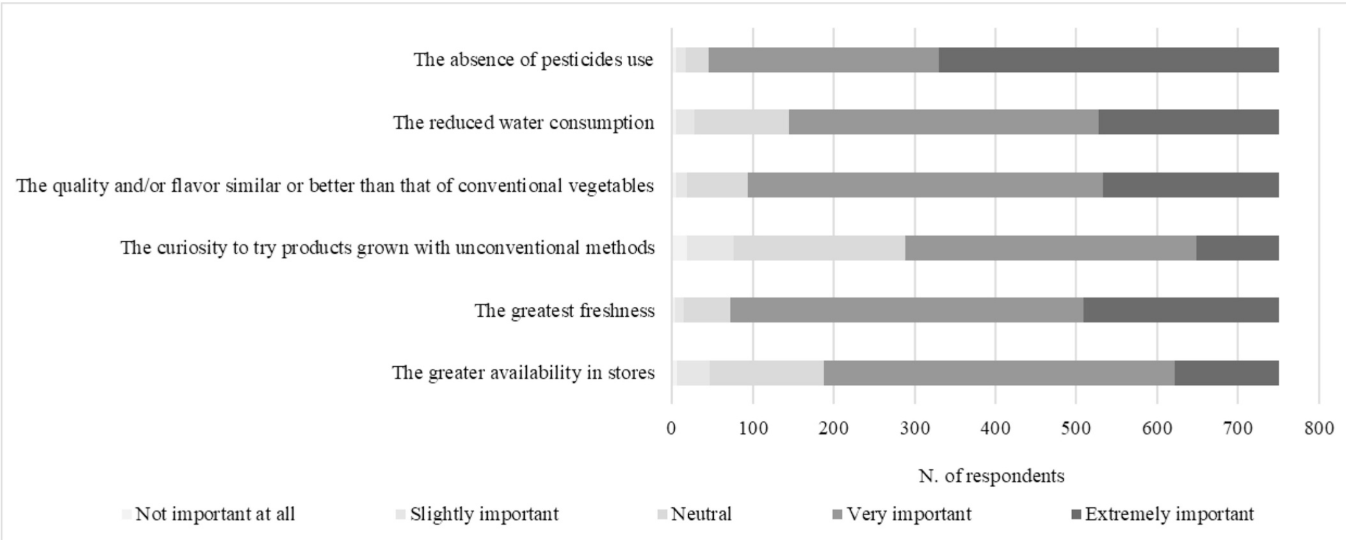

Fig. 2. Respondents' ratings of attributes of hydroponic vegetables.

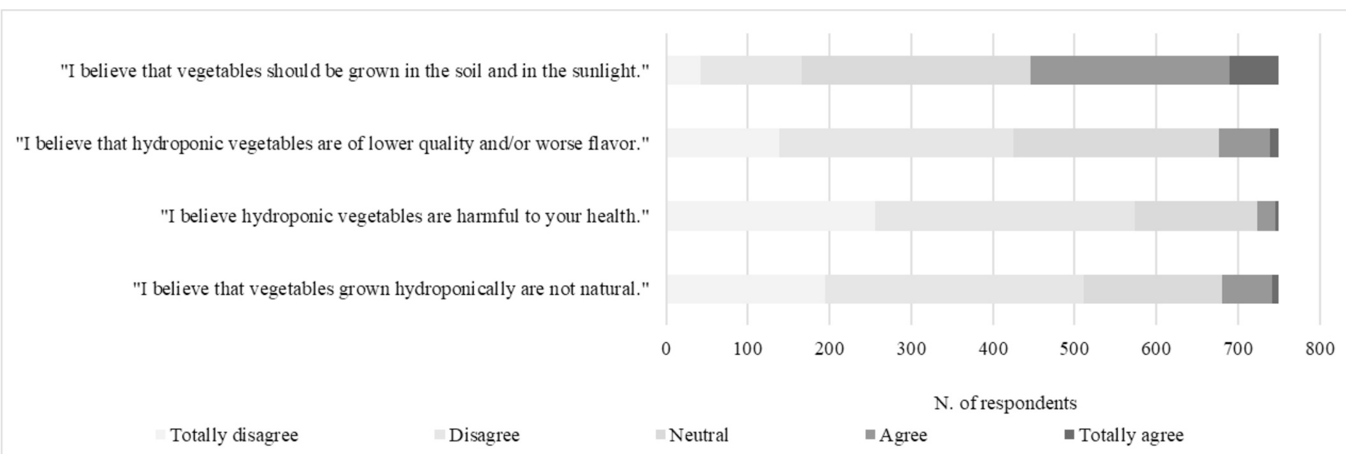

Fig. 3. Respondents' agreement with negative statements regarding hydroponics.

deviations for the cultivation method interactions suggested that the WTP for the hydroponic and conventional lettuce were relatively consistent across consumers, rather than varying widely within the sample.

Table 6 shows that hydroponic and conventional lettuce were valued similarly among consumers in the control informational treatment.

Pairwise comparison of treatments revealed no statistically significant WTP differences for cultivation methods. The pesticide-free attribute coefficient had a positive sign and was statistically significant across all treatments. Concerning the interaction terms related to the two informational treatments, neither was found to be statistically significant, suggesting no evidence of a measurable influence of the environmental and health information treatments on consumers' WTP for hydroponic products. Consequently, hypotheses H2 and H3 were not supported by the data. These findings are further corroborated by the treatment-specific mixed logit models, the associated WTP estimates, and Poe's test results (Poe et al., 2005) reported in Appendix Tables A6 and A7, respectively. Here, WTP for the hydroponic alternative did not differ significantly from the Control group for either the Environment or the Health treatment, at the 95% confidence level.

The standard deviation parameters associated with the presence or absence of the pesticide-free logo were statistically significant at 99%, suggesting consumers' heterogeneous preferences. Instead, the standard deviation for the preference for the hydroponic alternative was not significantly different from zero, thus informed consumers had more homogenous tastes.

We then interacted each construct from the FTN scale (FTN), Involvement in Healthy Eating (HEALTH) and the Subjective Sustainability of the Diet (ENV) scales with the choice of the two lettuce alternatives and the pesticide-free logo. The results from the pooled sample (Table 7) showed no significant effects, since all p-values were equal to or greater than 0.05. Therefore, we rejected hypotheses H4 and H5, concluding that individuals with a predisposition for healthier or more sustainable diets were not inclined to pay a premium for hydroponic lettuce. It should be noted, however, that the null effect observed for the Subjective Sustainability of the Diet scale warrants particular caution in interpretation, as it may partly reflect measurement unreliability stemming from the relatively low internal consistency of the scale rather than a genuine absence of association. By contrast, FTN significantly and negatively influenced the WTP for hydroponic lettuce (-0.81), supporting the robustness of previous results.

The results of the baseline model (without interaction terms) are presented in the Appendix (Table A5).

Looking at Tables 8 and 9, which examine the effect of psychological factors on WTP in both informational treatments, emerged that the informational treatments were ineffective across different consumer

Table 5
Impact of Food Technology Neophobia on Willingness to Pay for hydroponic and conventional lettuce (only Control sub-sample).

	Baseline model		Interaction model	
Variable	Coefficient (SE)	Pr(>|z|)	Coefficient (SE)	Pr(>|z|)
Conventional	4.05 (0.51)	<0.001	4.13 (0.53)	<0.001
Hydroponic	4.42 (0.53)	<0.001	4.50 (0.55)	<0.001
Pesticide-free	0.49 (0.12)	<0.001	0.48 (0.12)	<0.001
Conventional×Neophobia			−0.78 (0.55)	0.15
Hydroponic×Neophobia			−1.61 (0.56)	0.01
Pesticide-free×Neophobia			−0.04 (0.21)	0.83
Standard deviation				
Conventional	0.66 (0.69)	0.34	0.63 (0.61)	0.30
Hydroponic	0.63 (0.73)	0.39	0.41 (0.91)	0.65
Pesticide-free logo	0.74 (0.30)	0.01	0.75 (0.29)	0.01
Tau	0.63 (0.18)	<0.001	0.59 (0.17)	<0.001
Statistics				
AIC	1338.06		1316.51	
BIC	1371.52		1364.31	
Log Likelihood	−662.03		−648.25	
Number of observations	880		880	

Note: The model was estimated using 1000 Halton draws.

segments. The reported models tested whether dietary habits moderated the treatment effects on WTP for conventional and hydroponic lettuce. Notably, none of the interaction terms between treatments and psychological scales proved to be statistically significant across any of the models in either treatment condition. Moreover, again, the interaction terms between the informational treatment and the hydroponic alternative specific constant were not significant across both informational treatments, indicating that in any case, the information was effective in shifting WTP, regardless of consumers' habits. Even individuals with strong health consciousness or environmental concerns about their diet (who might theoretically be more receptive to sustainability or health-related information about hydroponics) showed no differential response to either treatment. The main effects for production methods remained highly significant in both treatments, confirming baseline preferences for hydroponic over conventional produce and preferences for pesticide-free options. However, these preferences appeared resistant to modification through information provision across all consumer psychological profiles.

Subsequently, a three-class LCM was estimated using the belonging to the treatment group as the class membership predictor. The optimal number of classes was determined by jointly considering statistical fit criteria and model parsimony (Table A8). While the AIC decreases monotonically across all tested solutions and the BIC reaches its minimum at four classes, the marginal gains in fit diminish substantially beyond three classes. Specifically, moving from two to three classes yields reductions of 1.73% in AIC and 0.99% in BIC, whereas the improvement from three to four classes is considerably smaller (0.98% in AIC and 0.24% in BIC). Consistent with established guidance on latent class identification (Nylund et al., 2007; Vermunt & Magidson, 2002),

Table 6
Impact of informational treatment on Willingness to Pay for hydroponic and conventional lettuce. For each treatment group comparison, the results from both a baseline model (without interactions) and a model including interaction terms are presented.

Variable	**Control vs. Environment**				**Control vs. Health**			
	Baseline model		**Interaction model**		**Baseline model**		**Interaction model**	
	Coefficient (SE)	Pr(>|z|)	Coefficient (SE)	Pr(>|z|)	Coefficient (SE)	Pr(>|z|)	Coefficient (SE)	Pr(>|z|)
Parameters								
Conventional	4.22 (0.39)	<0.001	4.11 (0.42)	<0.001	4.01 (0.39)	<0.001	4.37 (0.49)	<0.001
Hydroponic	4.63 (0.40)	<0.001	4.48 (0.43)	<0.001	4.61 (0.40)	<0.001	4.74 (0.50)	<0.001
Pesticide-free logo	0.49 (0.08)	<0.001	0.49 (0.08)	<0.001	0.43 (0.08)	<0.001	0.43 (0.08)	<0.001
Environment Treatment×Conventional			0.24 (0.41)	0.56				
Environment Treatment×Hydroponic			0.32 (0.41)	0.43				
Health Treatment×Conventional							−0.65 (0.43)	0.14
Health Treatment×Hydroponic							−0.24 (0.43)	0.58
Standard deviation								
Conventional	0.80 (0.40)	0.05	0.84 (0.29)	<0.001	0.94 (0.37)	0.01	0.91 (0.38)	0.02
Hydroponic	0.30 (1.05)	0.77	0.13 (1.63)	0.93	0.33 (1.04)	0.75	0.34 (1.01)	0.74
Pesticide-free logo	0.73 (0.21)	<0.001	0.73 (0.21)	<0.001	0.61 (0.23)	0.01	0.61 (0.23)	0.01
Tau	0.66 (0.12)	<0.001	0.66 (0.12)	<0.001	0.74 (0.12)	<0.001	0.74 (0.12)	<0.001
Statistics								
AIC	2898.65		2901.87		2933.03		2929.52	
BIC	2937.64		2952.00		2972.02		2979.66	
Log Likelihood	−1442.3		−1441.9		−1459.5		−1455.8	
Number of observations	1940		1940		1940		1940	

Notes: Control: "Control treatment"; Environment: "Environmental benefits treatment"; Health: "Health benefits treatment."
Coefficients are estimated in WTP space and are therefore directly interpretable as WTP estimates, expressed in €.
Interaction coefficients represent the differential WTP of respondents in each information treatment group relative to the control group (no information), which constitutes the reference category.

Table 7
Effect of psychological factors on Willingness to Pay (entire sample, no treatment distinction).

Variable	FTN		HEALTH		ENV	
	Coeff. (SE)	Pr(>|z|)	Coeff. (SE)	Pr(>|z|)	Coeff. (SE)	Pr(>|z|)
Interactions with psychological factors						
Conventional	−0.01 (0.33)	0.98	−0.18 (0.28)	0.52	−0.13 (0.31)	0.68
Hydroponic	−0.81 (0.33)	0.01	0.28 (0.29)	0.32	0.45 (0.31)	0.15
Pesticide-free	−0.24 (0.12)	0.05	0.37 (0.11)	<0.001	0.30 (0.11)	0.01
Main effects						
Conventional	4.05 (0.30)	<0.001	4.22 (0.34)	<0.001	4.34 (0.37)	<0.001
Hydroponic	4.58 (0.31)	<0.001	4.77 (0.35)	<0.001	4.89 (0.37)	<0.001
Pesticide-free	0.46 (0.07)	<0.001	0.46 (0.07)	<0.001	0.47 (0.07)	<0.001
Standard deviation						
Conventional	0.80 (0.32)	0.01	0.83 (0.31)	0.01	0.79 (0.12)	<0.001
Hydroponic	0.29 (0.83)	0.73	0.24 (1.05)	0.83	0.01 (1.52)	0.99
Pesticide-free logo	0.69 (0.17)	<0.001	0.63 (0.18)	<0.001	0.62 (0.18)	<0.001
Tau	−0.68 (0.10)	<0.001	−0.75 (0.10)	<0.001	−0.79 (0.09)	<0.001
Statistics						
AIC	4442.46		4469.31		4456.69	
BIC	4502.52		4529.37		4516.75	
Log Likelihood	−2211.20		−2224.70		−2218.30	
Observations	3000		3000		3000	

Note: FTN: Food Technology Neophobia; HEALTH: Involvement in Healthy Eating; ENV: Subjective Sustainability of the Diet; SE: Standard Error.

which recommends balancing statistical fit against model complexity and interpretability, the three-class solution was selected as it offers the best compromise between parsimony and goodness of fit, while yielding three substantively distinct and interpretable consumer segments.

Table 10 presents the characteristics of the identified clusters. Treatment parameters are all non-significant, confirming that treatment assignment does not predict class membership. Class 1 was the largest, with 46.88% respondents. Individuals belonging to this group showed a higher preference for hydroponic lettuce (4.02) compared to conventional lettuce (2.79). Additionally, they had a strong preference for the "zero pesticide residues" logo, as indicated by the statistically significant positive coefficient for this attribute. Given these characteristics, Class 1 was named "Certification seekers", as respondents in this group valued hydroponic but, mostly, pesticide-free products, and showed a modest sensitivity to price.

The second segment represented 45.88% of respondents. Individuals in this class strongly liked low prices, as indicated by the highest coefficient in absolute terms among the three groups. They showed a high preference for both hydroponic and conventional lettuce, with no clear preferences for either product type, as both had high and statistically significant coefficients. The presence of the pesticide-free logo did not affect their preferences, with the coefficient for this attribute being not statistically significant. Given these characteristics, Class 2 was named "Neutral buyers", as respondents in this group showed balanced preferences, indifference to pesticide-free labelling, and high sensitivity to price.

Class 3 was the smallest segment, comprising 7.24% of respondents. In contrast to the other two classes, this group exhibited no statistically significant preference for either hydroponic or conventional lettuce, nor for the pesticide-free logo. The only significant driver of choice was price, with a large negative coefficient (−1.06), indicating that purchasing decisions within this segment are governed almost exclusively by economic considerations. These consumers appear largely indifferent to cultivation method and product attributes, responding primarily to price signals. Accordingly, this group was labelled "Price-driven

Table 8
Interaction between environmental treatment and psychological factors on Willingness to Pay (Reference: Control treatment).

Variable	FTN		HEALTH		ENV	
	Coeff. (SE)	Pr(>|z|)	Coeff. (SE)	Pr(>|z|)	Coeff. (SE)	Pr(>|z|)
Environmental Treat. × Conventional	0.22 (0.40)	0.57	0.26 (0.42)	0.54	0.28 (0.44)	0.52
Environmental Treat. × Hydroponic	0.29 (0.40)	0.46	0.34 (0.42)	0.41	0.38 (0.44)	0.38
Environmental Treat. × Conventional×Scale	−0.36 (0.63)	0.56	0.61 (0.54)	0.26	0.90 (0.60)	0.14
Environmental Treat. × Hydroponic×Scale	0.37 (0.63)	0.56	0.25 (0.54)	0.64	0.25 (0.60)	0.68
Main effects						
Conventional	4.04 (0.41)	<0.001	4.12 (0.43)	<0.001	4.17 (0.44)	<0.001
Hydroponic	4.41 (0.41)	<0.001	4.48 (0.43)	<0.001	4.53 (0.44)	<0.001
Pesticide-free	0.49 (0.08)	<0.001	0.49 (0.08)	<0.001	0.49 (0.08)	<0.001
Standard deviation						
Conventional	0.78 (0.38)	0.04	0.79 (0.40)	0.04	0.76 (0.38)	0.05
Hydroponic	0.23 (1.21)	0.85	0.27 (1.14)	0.82	0.20 (1.41)	0.89
Pesticide-free	0.75 (0.21)	<0.001	0.73 (0.21)	<0.001	0.72 (0.21)	<0.001
Tau	0.63 (0.12)	<0.001	0.66 (0.12)	<0.001	0.68 (0.12)	<0.001
Statistics						
AIC	2888.91		2900.04		2887.65	
BIC	2950.19		2961.31		2948.92	
Log Likelihood	−1433.50		−1439.0		−1432.80	
Number of observations	1940		1940		1940	

Note: FTN: Food Technology Neophobia; HEALTH: Involvement in Healthy Eating; ENV: Subjective Sustainability of Diet; SE: Standard Error.

Table 9
Interaction between health treatment and psychological factors on Willingness to Pay (Reference: Control treatment).

Variable	FTN		HEALTH		ENV	
	Coeff. (SE)	Pr(>|z|)	Coeff. (SE)	Pr(>|z|)	Coeff. (SE)	Pr(>|z|)
Health Treat. × Conventional	−0.63 (0.42)	0.13	−0.65 (0.44)	0.14	−0.69 (0.46)	0.13
Health Treat. × Hydroponic	−0.22 (0.42)	0.59	−0.23 (0.44)	0.60	−0.25 (0.45)	0.58
Health Treat. × Conventional×Scale	−0.75 (0.58)	0.19	0.68 (0.44)	0.12	0.37 (0.45)	0.42
Health Treat. × Hydroponic×Scale	0.10 (0.57)	0.86	0.08 (0.45)	0.85	−0.16 (0.45)	0.73
Main effects						
Conventional	4.31 (0.47)	<0.001	4.41 (0.51)	<0.001	4.46 (0.52)	<0.001
Hydroponic	4.68 (0.48)	<0.001	4.78 (0.51)	<0.001	4.83 (0.52)	<0.001
Pesticide-free	0.43 (0.08)	<0.001	0.42 (0.08)	<0.001	0.43 (0.08)	<0.001
Standard deviation						
Conventional	0.82 (0.43)	0.06	0.89 (0.34)	0.01	0.85 (0.41)	0.04
Hydroponic	0.47 (0.74)	0.53	0.29 (1.34)	0.87	0.31 (1.11)	0.78
Pesticide-free	0.61 (0.23)	0.01	0.61 (0.23)	0.01	0.59 (0.24)	0.01
Tau	0.72 (0.12)	<0.001	0.75 (0.12)	<0.001	0.77 (0.12)	<0.001
Statistics						
AIC	2914.47		2921.09		2923.88	
BIC	2975.75		2982.36		2985.16	
Log Likelihood	−1446.20		−1449.50		−1450.90	
Number of observations	1940		1940		1940	

Note: FTN: Food Technology Neophobia; HEALTH: Involvement in Healthy Eating; ENV: Subjective Sustainability of Diet; SE: Standard Error.

Table 10
Results of the Latent Class Model and class membership model. Standard errors are reported in parentheses.

Variable	Class 1	Class 2	Class 3
	Certification seekers	*Neutral buyers*	*Price-driven buyers*
Choice model parameters			
Price	−0.61*** (0.11)	−1.26*** (0.15)	−1.06*** (0.27)
Conventional lettuce	2.79*** (0.42)	5.10*** (0.40)	0.26 (0.50)
Hydroponic lettuce	4.02*** (0.33)	4.73*** (0.31)	0.91 (0.51)
Pesticide-free	1.04*** (0.22)	−0.02 (0.18)	0.15 (0.29)
Class size	46.88%	45.88%	7.24%
Class membership model			
Intercept		0.23 (0.43)	−1.76*** (0.41)
Treatment (ref. = Control)			
Environmental info		−0.22 (0.27)	−0.42 (0.47)
Health info		−0.51 (0.28)	0.04 (0.42)

Note: Class 1 (Certification seekers) is the reference category in the class membership model. $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

buyers".

5. Discussion

The results of this work revealed that while Italian consumers generally held positive attitudes towards hydroponics, FTN emerged as a significant psychological barrier that reduced WTP for hydroponic products. Indeed, across multiple model specifications, higher FTN scores were associated with lower WTP for hydroponic lettuce. The effect was specific to hydroponic products, as the interaction between FTN and conventional lettuce was not statistically significant. This indicates that neophobic consumers specifically discriminated against the novel cultivation method, as expected.

Interestingly, despite the negative influence of FTN on WTP, the baseline coefficients for both cultivation methods were positive and significant, with hydroponic lettuce showing higher WTP than the conventional alternative in the control group. This suggests that consumers without neophobic tendencies exhibit a preference for hydroponic vegetables. Indeed, respondents generally expressed appreciation for such products, particularly for their freshness and pesticide-free characteristics. The absence of pesticides use is already well established in the literature as one of the most valued attributes among consumers (Jaeger et al., 2023b; Califano et al., 2024). Moreover, the negatively framed statements designed to capture concerns about hydroponics received overall low levels of agreement. Surprisingly, the perception of hydroponic vegetables as being "unnatural" received very low agreement, in contrast with previous studies (Celeste et al., 2023; Csordás & Füzesi, 2023; Jaeger et al., 2022; Son & Hwang, 2023; Specht et al., 2019). In addition, respondents did not exhibit the common misconceptions about the quality and sensory properties of hydroponic products that have been reported in earlier research (Jaeger et al., 2023a). These results underscore generally positive attitudes towards hydroponic cultivation and highlight the importance of addressing psychological neophobic barriers rather than changing or improving product attributes per se, which are already appealing to consumers.

The most unexpected finding was the ineffectiveness of informational treatments. Neither environmental nor health benefit information was found to significantly influence WTP for hydroponic products at conventional statistical thresholds, providing no support for H2 and H3. The observed effects of informational messages on WTP are negligible in magnitude and do not reach conventional thresholds of statistical significance, suggesting that brief environmental or health-framed messaging is unlikely to substantially shift consumer preferences for hydroponic products in the Italian market. This held true even when examining potential moderating effects of health consciousness or environmental awareness in eating habits. However, these findings should be interpreted as the absence of a detectable average treatment effect within the specific constraints of a hypothetical labelled choice experiment with a minimally informed control condition, rather than as general evidence against the effectiveness of information provision in shifting preferences for novel food technologies. Several context-specific factors may account for the null results and are discussed below.

The ineffectiveness of the informational treatments yet contrasts with evidence from incentive-compatible experimental settings. Gilmour et al. (2019) applied a real choice experiment on hydroponic lettuce and found that informational treatments emphasizing the various benefits of hydroponics significantly increased consumer valuation. This discrepancy may be attributed to lower cognitive engagement in hypothetical choice experiments, which reduces respondents' ability to discriminate and effectively process informational cues, compared with incentive-compatible experimental settings (Haghani et al., 2021). This finding is also not in line with the KAB model about information processing (Kallgren & Wood, 1986). A possible explanation can be that the information treatments provided may have been generic or may have been insufficiently differentiated from the baseline information already conveyed in the control condition and that a single brief exposure to the treatment stimuli may have been inadequate to overcome deeply rooted psychological negative predispositions (Lusk & McCluskey, 2018). Text complexity is indeed known to affect respondents' answers, as shown by previous research (Baum et al., 2021; Jaeger et al., 2022). Another plausible explanation relates to the inclusion of the pesticide-free logo as a choice attribute. To the extent that respondents interpreted this attribute as already conveying the primary health and environmental benefit associated with hydroponic production, the incremental informational content of the treatment stimuli may have been perceived as redundant, thereby attenuating any treatment-induced preference shift.

Moreover, given that approximately half of the respondents had already heard about hydroponics before, the treatments may have offered little novel information. Although prior exposure to a specific product or label may influence WTP (Liu et al., 2025) and, therefore, responsiveness to informational treatments, the null average treatment effects observed in this study are unlikely to reflect systematic heterogeneity in prior familiarity or knowledge across treatment conditions. Indeed, we have a homogeneous distribution across treatment groups in terms of both prior knowledge of hydroponic production and previous purchase experience. Nevertheless, future research could shed further light on the respective contributions of prior familiarity and purchase experience in shaping consumer demand for innovative food production methods. Finally, the single-exposure design may be insufficient for changing attitudes towards novel technologies, which can require repeated exposure and experiential learning (Siegrist, 2008). Therefore, in contrast to studies suggesting that greater knowledge fosters more favourable attitudes towards a specific product (De Magistris et al., 2015; Dhir et al., 2021; Napolitano et al., 2007), the present findings align with research revealing a controversial role of information in influencing consumer choices (Broad et al., 2022; Caputo et al., 2020; Coyle & Ellison, 2017). The ineffectiveness persisted even among theoretically receptive subgroups. Health-conscious consumers showed no differential response to health messaging, and environmentally engaged food consumers were unmoved by sustainability information. This suggests that barriers to acceptance might operate at a more fundamental level than rational information processing (Rozin et al., 2004).

The interaction between the Involvement in Healthy Eating scale scores and hydroponic choice was not statistically significant. Similarly, dietary environmental consciousness did not significantly affect WTP for hydroponic lettuce. These null findings, in contrast with H4 and H5, were unexpected, given that many previous studies have shown health and environmental concerns to drive acceptance of novel agricultural technologies (Ares et al., 2021; Celeste et al., 2023; Gallè et al., 2025; Govaerts & Olsen, 2023; Perambalam et al., 2021; Shao et al., 2022; Zhou et al., 2025). On the other hand, the lack of a significant effect suggests that attention to a healthy diet or focus on dietary sustainability is not sufficient to overcome the barrier of paying a premium price for hydroponic products. Moreover, these results indicate that general consumer attitudes may not necessarily translate into specific product choices when other psychological barriers, such as neophobia, are present, as highlighted by Baum et al. (2021).

The LCM revealed three distinct consumer segments, with important implications for marketing strategy. The respondents' pool was dominated by two large segments, each accounting for nearly half of the sample, with only a small residual group driven exclusively by price considerations. Both these segments show some preference for hydroponic lettuce. The largest segment, the “Certification seekers”, showed a strong preference for the pesticide-free logo regardless of cultivation method, while displaying relatively modest price sensitivity. This group's emphasis on third-party certification over production technology suggests that certification schemes may be more influential than production methods in shaping purchasing decisions. Consistent with this, a recent study reported that Italian consumers' WTP increases when hydroponic tomatoes carry certification labels (D'Amico et al., 2024). Similarly, a study in the United States found that consumer preferences for hydroponic products are driven not by attitudes towards the cultivation method itself, but by the presence of an organic label on the packaging (Gilmour et al., 2019). The “Neutral buyers” showed high and significant positive coefficients for both cultivation methods and strong price sensitivity, but remained entirely indifferent to the pesticide-free logo, suggesting that this segment engages with the product category on broadly favourable terms without requiring specific quality signals. Finally, the smallest segment, the “Price-driven buyers”, exhibited no statistically significant preference for either hydroponic or conventional lettuce, nor for the pesticide-free logo, with price as the sole significant determinant of choice.

Feil et al. (2020) further highlighted that organic certification can strongly motivate purchase intentions and positively influence consumer attitudes. Regrettably, the current European regulatory frameworks that exclude hydroponics from eligibility for organic certification may inadvertently hinder the adoption of this method. Therefore, policymakers should implement new certification schemes for soilless products or allow these products to qualify for organic labelling. This could greatly enhance consumer trust and support hydroponics' market expansion and competitiveness.

The second largest group identified by the LCM application, the “Neutral buyers”, displayed high price sensitivity and no differentiation between cultivation methods, indicating a purely economic decision-making process. Practically, this implies that maintaining competitive prices will be essential for hydroponic market penetration, as unsurprisingly, most consumers are reluctant to pay a premium (Ares et al., 2021; Califano et al., 2024; Huang, 2019). Price sensitivity affects the purchase of not only hydroponic products but also other food categories (Peschel et al., 2016).

Overall, these findings suggest that producers can benefit more from investing in cost reduction than from focusing their marketing efforts primarily on informing and educating consumers about environmental or health benefits. In addition to this, stakeholders could work on building familiarity with their product with experience, as previous research found that familiarity increases WTP for hydroponic products (D'Amico et al., 2024) and fosters more favourable attitudes towards soilless agriculture (Al Mamun et al., 2023). For instance, implementing training courses and promotional activities to raise awareness of hydroponic technology could be beneficial for industry players (Al Mamun et al., 2023).

As with most studies, it is important to acknowledge certain limitations of this research. First, being based on a hypothetical questionnaire, this study inevitably carries some degree of bias due to the absence of financial consequences after the choices, which likely results in WTP overestimations compared to incentive-compatible methodologies (Liu & Tian, 2021; Piracci et al., 2025). Future research could enhance the validity of these results by employing incentive-compatible methodologies such as experimental auctions. At the same time, an average sample size of approximately 250 respondents per treatment arm may not capture small treatment effects, and future research drawing on larger samples would contribute to a more robust assessment of the informational effects documented here.

Additionally, the online administration of the questionnaire inherently filtered the participant pool, likely resulting in a sample with a more receptive and open perspective on technology. Secondly, eco-conscious consumer segments deserve further investigation. This study focused solely on sustainability awareness from a dietary habits point of view. Yet, other subjective norms and environmental values may also be significant. This is particularly relevant given the vast previous research indicating that these factors encourage the acceptance and willingness to buy soilless-grown products (Fahlevi et al., 2024b; Perambalam et al., 2021). Finally, as the informational treatment proved ineffective in this study, future research should explore alternative intervention strategies beyond information provision, such as experiential learning, social norm manipulation, or repeated exposure protocols. It is also worth acknowledging that the partial convergence in the connotative content of the two informational treatments, whereby the environmental message may carry health connotations and vice versa, may complicate the precise attribution of observed preference changes to a single motivational domain. Moreover, investigating how FTN develops and whether it can be reduced through early exposure or education could guide long-term strategies for increasing acceptance of agricultural innovations.

6. Conclusions

Hydroponics represents an innovative cultivation system aimed at maximizing yields with minimal resource inputs. Despite its objective advantages, consumer “fear” of novel food technologies may limit its adoption. This study provides a comprehensive analysis of how FTN, information, and dietary habits influence Italian consumers' WTP for hydroponic products. The results revealed a complex framework where positive baseline attitudes coexist with psychological barriers that reduce WTP for hydroponic vegetables. The central finding, that FTN negatively influences the WTP, demonstrates that psychological traits represent meaningful barriers to sustainable agricultural innovation. In practical terms, this suggests that a large share of consumers may require price discounts or other incentives to choose hydroponic over conventional produce. However, it is worth mentioning an experimental design-related limitation. In particular, WTP estimates and their implications should be interpreted with caution as the binary structure of the choice experiment may constrain their external generalisability beyond the specific perceptual and framing conditions examined here. Moreover, it should be noted that the sample size available for each treatment group, while sufficient for the primary analyses, may have limited the statistical power to detect small but potentially meaningful effects in the interaction models.

Equally important are the factors that did not influence consumer choice. The absence of detectable average treatment effects, even among theoretically receptive consumer segments, challenges conventional approaches to promoting this innovation. Neither health-conscious nor environmentally aware consumers responded to targeted messaging, suggesting that information provision alone is insufficient to overcome neophobic barriers. Given this limited impact, increasing consumers' familiarity through direct experience, such as tastings or farm visits, may be a more effective marketing strategy than communication campaigns. Additionally, the strong consumer responsiveness to certification points to third-party verification as another promising route to market expansion. Policy-level intervention is therefore warranted; specifically, establishing appropriate standards or incorporating the soilless sector into organic certification is essential to encourage consumer trust and support market growth.

In conclusion, while hydroponic agriculture offers a promising approach towards sustainable food production, its success in the Italian market depends on addressing psychological barriers through competitive pricing, certification schemes, and an appropriate marketing strategy. The challenge exists, but it is worth tackling, as the wider adoption of hydroponics could offer healthier products for consumers, new urban job opportunities, and environmental sustainability. Lastly, promoting this farming technique can enhance food security and strengthen system resilience, while leading a way for mitigating the climate change crisis.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work, the authors used ChatGPT and Claude to improve the clarity and flow of the text. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

CRediT authorship contribution statement

Federica Cantoni: Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Elena Radicioni:** Writing – review & editing, Visualization, Validation, Supervision. **Fabio Boncinelli:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Ethical statement

No interventions were involved, and no sensitive personal data were collected. All participants provided informed consent. According to Italian research standards, formal ethics committee approval was not required for this non-clinical behavioural study, which complied with the Declaration of Helsinki and ensured privacy and anonymity.

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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.

Appendix A. Appendix

Table A1
Sample characteristics. The last column on the right report the results of the Chi-Square test for the differences in sociodemographic characteristics between the three treatment groups (“Control”, “Environmental benefits”, and “Health benefits”).

Category	Pooled sample (N = 750)		Control Group (N = 220)		Environment Treatment Group (N = 265)		Health Treatment Group (N = 265)		Chi-Square test results	
	n	%	n	%	n	%	n	%	χ^2	*p*-value
Sex									1.41	0.842
Male	340	45.3	101	45.9	124	46.8	115	43.4		
Female	404	53.9	118	53.6	138	52.1	148	55.6		
Not specified	6	0.8	1	0.5	3	1.1	2	0.8		
Age									3.50	0.479
18–34 years	165	22.0	49	22.3	64	24.2	52	19.6		
35–54 years	334	44.5	100	45.5	107	40.4	127	47.9		
≥55 years	251	33.5	71	32.3	94	35.5	86	32.5		
Educational level									4.17	0.384
Primary/Lower secondary school	76	10.1	24	10.9	29	10.9	23	8.7		
High school diploma	410	54.7	117	53.2	154	58.1	139	52.5		
University degree/Postgraduate	264	35.2	79	35.9	82	30.9	103	38.9		
Household income									6.08	0.808
< €10,000	59	7.9	15	6.8	23	8.7	21	7.9		
€10,000-22,000	143	19.1	34	15.5	58	21.9	51	19.3		
€22,000-44,000	335	44.7	100	45.5	112	42.3	123	46.4		
€44,000-70,000	135	18.0	46	20.9	47	17.7	42	15.9		
> €70,000	44	5.9	14	6.4	15	5.7	15	5.7		
Not specified	34	4.5	11	5.0	10	3.8	13	4.9		
Employment status									5.82	0.830
Employed	481	64.1	146	66.4	170	64.2	165	62.3		
Retired	100	13.3	25	11.4	38	14.3	37	14.0		
Homemaker	66	8.8	23	10.5	20	7.6	23	8.7		
Unemployed	62	8.3	16	7.3	21	7.9	25	9.4		
Student	31	4.1	7	3.2	14	5.3	10	3.8		
Not specified	10	1.3	3	1.4	2	0.8	5	1.9		
Prior knowledge about hydroponics										
Yes	360	48.0	102	46.4	132	49.8	126	47.6		
No	390	52.0	118	53.6	133	50.2	139	52.5		
Have you ever purchased or would you purchase hydroponically grown vegetables?									4.36	0.629
No, I would not buy them	9	1.2	4	1.8	4	1.5	1	0.4		
No, but I would buy them	512	68.2	143	65.0	179	67.6	190	71.7		
Yes, I have purchased them	121	16.1	39	17.7	43	16.2	39	14.7		
I don't know	108	14.4	34	15.5	39	14.7	35	13.2		
Vegetables purchase frequency									12.94	0.114
Daily	75	10.0	28	12.7	23	8.7	24	9.1		
Several times a week	385	51.3	110	50.0	137	51.7	138	52.1		
Weekly	249	33.2	66	30.0	96	36.2	87	32.8		
Monthly	24	7.5	12	5.5	2	0.8	10	3.8		
Rarely	17	2.3	4	1.8	7	2.6	6	2.3		

The FTN scale yielded a mean score of 2.72 ± 0.56, with a median of 2.69 and an interquartile range (IQR) of 0.69. Internal consistency was excellent (Cronbach's α = 0.83). Items with the mean highest agreement included: “The benefits of new food technologies are often grossly overstated” (Mean = 2.94 ± 0.97), “New foods are not healthier than traditional foods” (Mean = 2.84 ± 0.94), and “New food technologies are something I am uncertain about” (Mean = 2.82 ± 0.97). The Involvement in Healthy Eating scale yielded 4.07 ± 0.61, median 4, IQR 0.75, with acceptable internal reliability (Cronbach's α = 0.78). All items were rated highly, with medians of 4 for all items. The Subjective Sustainability of Diet scale yielded 3.46 ± 0.65, median 3.33, IQR 1, but showed low internal consistency (Cronbach's α = 0.59), similar to the original study (Van Loo et al., 2017: α = 0.65).

Table A2
Scores of the Food Technology Neophobia Scale items (Cronbach's α = 0.83).

Item	Mean (±SD)	Median	IQR
There are plenty of tasty foods around so we don't need to use new food technologies to produce more.	2.56 (±1.01)	2	1
The benefits of new food technologies are often grossly overstated.	2.94 (±0.97)	3	2
New food technologies decrease the natural quality of food.	2.77 (±0.97)	3	1
There is no sense trying out high-tech food products because the ones I eat are already good enough.	2.65 (±0.96)	3	1
New foods are not healthier than traditional foods.	2.84 (±0.94)	3	1
New food technologies are something I am uncertain about.	2.82 (±0.97)	3	2
Society should not depend heavily on technologies to solve its food problems.	2.90 (±1.13)	3	2

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Table A2 (*continued*)

Item	Mean (±SD)	Median	IQR
New food technologies may have long term negative environmental effects.	2.56 (±0.95)	3	1
It can be risky to switch to new food technologies too quickly.	2.86 (±1.01)	3	2
New food technologies are unlikely to have long term negative health effects. (R)	2.77 (±0.95)	3	1
New products produced using new food technologies can help people have a balanced diet. (R)	2.38 (±0.84)	2	1
New food technologies give people more control over their food choices. (R)	2.40 (±0.82)	2	1
The media usually provides a balanced and unbiased view of new food technologies. (R)	2.96 (±0.95)	3	2

Note: (R): reverse-scored item; SD: Standard deviation; IQR: interquartile range.

Table A3
Scores of the Involvement in Healthy Eating scale items.

Item	Mean (±SD)	Median	IQR
Healthy eating is very important to me.	4.21 (±0.75)	4	1
I care a lot about healthy eating.	4.11 (±0.73)	4	1
Healthy eating means a lot to me.	4.15 (±0.81)	4	1
I am very concerned about the health-related consequences of what I eat	3.82 (±0.88)	4	1

Note: SD: standard deviation; IQR: interquartile range.

Table A4
Scores of the Subjective Sustainability of the Diet scale items.

Item	Mean (±SD)	Median	IQR
My eating behaviour is as sustainable as that of anyone	3.23 (±0.91)	3	1
My eating habits are excellent with respect to good sustainability compared to those of other people of a similar age	3.44 (±0.86)	3	1
I consider myself to be very sustainable-conscious when it comes to food and eating habits	3.71 (±0.85)	4	1

Note: SD: Standard deviation; IQR: interquartile range.

Table A5
Baseline model results (without interaction terms) for the full sample, without distinguishing between treatments.

Variable	Coefficient (SE)	Pr(>|z|)
Conventional	4.17 (0.33)	<0.001
Hydroponic	4.71 (0.34)	<0.001
Pesticide-free	0.45 (0.07)	<0.001
Standard deviation		
Conventional	0.89 (0.30)	0.01
Hydroponic	0.26 (0.99)	0.79
Pesticide-free	0.66 (0.17)	<0.001
Tau	−0.68 (0.18)	<0.001
Statistics		
AIC	2296.27	
BIC	4538.31	
Log Likelihood	−2241.10	
Number of observations	3000	

Table A6
Estimated mixed logit models for each treatment subsample (Control, Environment, and Health).

Variable	Control		Environment		Health	
	Coefficient (SE)	Pr(<|z|)	Coefficient (SE)	Pr(<|z|)	Coefficient (SE)	Pr(<|z|)
Parameters						
Conventional	3.77 (0.30)	<0.001	3.49 (0.24)	<0.001	3.41 (0.27)	<0.001
Hydroponic	4.18 (0.33)	<0.001	3.95 (0.26)	<0.001	4.30 (0.31)	<0.001

(*continued on next page*)

Table A6 (*continued*)

Variable	Control		Environment		Health	
	Coefficient (SE)	Pr(<|z|)	Coefficient (SE)	Pr(<|z|)	Coefficient (SE)	Pr(<|z|)
Pesticide-free logo	0.58 (0.13)	<0.001	0.50 (0.10)	<0.001	0.42 (0.12)	<0.001
Price	−1.28 (0.13)	<0.001	−1.05 (0.10)	<0.001	−1.30 (0.12)	<0.001
Standard deviations						
Conventional	0.92 (0.27)	<0.001	0.84 (0.26)	0.01	1.18 (0.25)	<0.001
Hydroponic	4.18 (0.33)	<0.001	0.52 (0.36)	0.15	1.26 (0.22)	<0.001
Pesticide-free logo	0.58 (0.13)	<0.001	0.89 (0.24)	<0.001	1.06 (0.25)	<0.001
Statistics						
AIC	1338.75		1586.29		1602.26	
BIC	1372.21		1621.05		1637.02	
Log Likelihood	−662.38		−786.15		−794.13	
Number of observations	880		1060		1060	

Table A7
Mean and median willingness to pay (WTP), 95% confidence intervals (CIs), and Poe's test results for the comparison between the Control and Informational Treatment Groups.

	Mean (€)	Median (€)	95% C.I. (€)	Informational Treatment Group	Mean (€)	Median (€)	95% C.I. (€)	H0 H1	p-value
Control Group	3.29	3.28	[2.93, 3.71]	Environmental	3.79	3.77	[3.35, 4.31]	H0: $WTP_C = WTP_E$ H1: $WTP_C < WTP_E$	0.06
				Health	3.33	3.32	[3.00, 3.69]	H0: $WTP_C = WTP_H$ H1: $WTP_C < WTP_H$	0.44

Notes: The mean, median, and 95% confidence intervals for WTP were obtained through Krinsky–Robb simulations.
WTP_C, WTP_E, and WTP_H denote the WTP for the hydroponic alternative in the Control Group, the Environmental Information Treatment Group, and the Health Information Treatment Group, respectively.

Table A8
Summary of the information criteria of the Latent Class Model.

Number of classes	AIC	BIC
2 classes	4468.230	4519.051
3 classes	4390.980	4474.141
4 classes	4348.073	4463.574
5 classes	4319.869	4467.711
6 classes	4310.051	4490.234

Data availability

Data will be made available on request.

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