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Public acceptance for genetic engineering techniques: the role of food values-based information

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Genetic engineering techniques are emerging as crucial tools for addressing global food challenges. Consumer resistance however remains a major barrier to their adoption. This study explores whether framing genetical engineered foods around specific food values can increase consumers' acceptance and willingness to pay. Using a random effects interval regression model to analyze data from 1,000 Italian consumers across five staple foods, we find that food value-based messaging significantly influences attitudes and willingness to pay. This study presents an innovative approach to reducing resistance to genetic engineering techniques, highlighting the strategic role of food values in science communication and policy-making.

Keywords Food values, Biotechnology, Acceptance, Willingness to pay, European union

Foods developed through *genetic engineering techniques* (hereafter referred to as GETs for brevity) represent a diverse and rapidly evolving category of agricultural innovations[1,2]. GETs encompass a range of molecular methods aimed at modifying the genetic material of organisms in order to introduce, enhance, or suppress specific traits. Among these, *transgenesis* involves inserting genetic material from one species into another—often across kingdoms—to express novel traits[3]. In contrast, *cisgenesis* transfers genes between sexually compatible species, effectively replicating conventional breeding at the molecular level while accelerating the process[4]. *Mutagenesis*, refers to the induction of genetic mutations through chemical, physical, or targeted methods—such as CRISPR—to create desirable variation[5]. Together, these techniques offer innovative solutions to challenges related to crop productivity, climate resilience, and food security, and are collectively referred to as GETs in this analysis.

Given accelerating climate change and a projected global population exceeding 9 billion by 2050, ensuring a stable, sustainable, and nutritious food supply has become a pressing global priority. GETs hold transformative potential for developing crop varieties that are more resilient to drought, heat, and disease, while maintaining—or even improving—yield and nutritional quality[6,7]. Their precision enables the targeted modification of traits, allowing for more efficient solutions to agricultural challenges compared to conventional breeding methods. As such, GETs offer valuable tools for enhancing food security across both high- and low-income regions[8,9]. Consequently, GETs are increasingly regarded as essential components in the development of climate-resilient and equitable agricultural systems.

In recent years, foods obtained from GETs have become a focal point in policy debates within the European Union, where traditional genetically modified organisms (GMOs) are subject to strict regulations and, in practice, face de facto restrictions[10,11]. These debates have increasingly centered on the potential of GETs to address pressing challenges such as climate change, biodiversity loss, and agricultural sustainability[12,13]. Consumer acceptance is highly sensitive to policy context and upstream acceptance in the food chain[14,15], emphasizing the need for aligned regulatory and communication strategies. Recognizing that current legislation may be outdated, the European Commission has initiated consultations to revise the regulatory framework in line with scientific advancements and the evolving needs of the global food system. Particular attention is being given to new genomic techniques, which are viewed as promising tools to address climate challenges and population growth, while aligning with the principles of sustainability[16].

Despite the potential benefits of GETs-derived foods, public attitudes toward these technologies remain deeply divided[17]. Consumers in North America and parts of Asia tend to show relatively higher levels of acceptance, whereas resistance remains strong in other regions—particularly where transparency and labelling are perceived

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as insufficient[18–21]. Recent empirical evidence from Asia confirms a generally pragmatic but heterogeneous pattern of acceptance. For instance, Yamaguchi et al.[22] show that Japanese consumers differentiate between gene editing and transgenesis, with acceptance strongly depending on perceived benefits and societal relevance. Similarly, Oh and Lee[23] document in South Korea that acceptance of gene-edited agricultural products is driven by perceived usefulness and trust in regulatory oversight, rather than by technical knowledge alone. This is especially evident in the European Union, where consumer skepticism has historically been more pronounced than in other parts of the world[24,25]. Numerous studies indicate that European consumers frequently associate genetic modification with risk, unnaturalness, and ethical concerns, leading to lower acceptance levels and limited market penetration of GETs-derived products[26–28].Consumer preferences are influenced not only by perceived health and environmental risks but also by the level of trust in regulatory institutions and scientific authorities[29,30]. Trust has been identified as a central mechanism through which information about food biotechnology is processed and evaluated, particularly under conditions of uncertainty[31]. According to the Social Amplification of Risk Framework, trust in institutions can either attenuate or amplify perceived risks, shaping public responses beyond objective risk assessments[32]).

Even in the case of products obtained from GETs, early evidence suggests that public attitudes often mirror those toward traditional GMOs[33], particularly when distinctions between technologies and value-based benefits are not clearly communicated[34,35]. Recent framing studies suggest, however, that carefully designed messages emphasizing socially relevant outcomes and shared values can partially mitigate skepticism and resistance, especially when trust in science is not fundamentally compromised[36]. The communication gap between scientific communities and the general public has contributed to entrenched resistance in several countries[37,38].

Despite a growing body of research on consumer attitudes towards GETs-derived foods, significant gaps remain, especially regarding the factors that influence consumers' willingness to pay (WTP) for such products[39]. One underexplored area in the literature is the potential role of Food Values in shaping consumer opinions and trust toward GETs-derived foods. The concept of "value" was originally defined by Rokeach[40] as enduring beliefs about desirable end-states or behaviours. Building on this, Lusk and Briggeman[41] introduced the notion of "food values", referring to stable beliefs about the importance of food-related meta-attributes and consequences. While much of the existing research has focused on general acceptance levels, fewer studies have examined how specific food values (e.g. environmental impact, safety, and fairness) affect actual purchasing behaviour in real-world contexts[42–44]. Unlike many existing studies that treat food values as static preferences or segmenting variables (e.g., Lusk and Briggeman[41]), we conceptualize food values as dynamic framing tools that could potentially shift consumer evaluations. Food products are naturally associated with multiple nutritional values, and consumers tend to activate numerous values rather than evaluate foods based on a single isolated parameter. Consequently, in this study, nutritional values are conceptualized as latent dimensions that may vary in terms of relevance depending on the information provided.

While previous research, such as Hwang and Nam[45], and Marangon et al.[46], have investigated the general role of information and trust on consumer acceptance of genetically engineered foods and others food innovations, this study advances the literature by employing a more granular and value-specific framing approach. Rather than relying on broad pro-GETs messages, we test the effectiveness of messages explicitly aligned with five distinct food values—food security, food safety, food waste, environmental impact, and climate change mitigation—each applied to a different food product. This design allows us to assess not only whether information matters, but also which values resonate most with consumers and under what conditions. Moreover, consumer responses remain understudied with regard to how food value-based communication strategies might influence resistance or skepticism toward GETs-derived foods. Further research is also needed to better understand how individuals integrate ethical, environmental, and health-related information into their decisions, especially in culturally sensitive contexts like Europe where regulatory attitudes are particularly conservative.

With these premises, this study focuses on two core research questions:

RQ1 Does providing information regarding the "consequences" of using genetic engineering techniques, by linking them to certain food values, influence consumers' willingness to pay?

RQ2 When used as the basis for informational framing, are some food values more effective than others in increasing consumers' willingness to pay for foods obtained from genetic engineering techniques?

These research questions aim to investigate, first, whether food value-framed communication can increase consumers' WTP, and second, whether the effectiveness of such framing varies depending on the specific food value emphasized. Together, these questions provide a framework for understanding how targeted food system values can be strategically leveraged to influence consumer attitudes toward food innovations, such as GETs-derived products, and potentially reduce resistance.

This study contributes to the literature by shifting the analytical focus from the intrinsic importance consumers assign to food values to the communicative potential of those values when embedded in informational messages. Specifically, instead of examining whether consumers who prioritize, for example, food safety or environmental sustainability are inherently more likely to accept GETs-derived foods, this research investigates whether framing these products as supporting such values can influence WTP. This perspective conceptualizes food values not merely as static indicators of consumer preference, but as dynamic tool that can be strategically employed to shape public acceptance. Moreover, while previous studies have primarily focused on food value–based consumer segmentation[42], this study advances the field by exploring how different food values function as persuasive frames within communication strategies.

To investigate the role of the food values-based information on consumers' WTP, a treatment condition was designed. A control group with no intervention was also included for comparison. This design allowed us to isolate the effect of the informational framing linked to specific food values, which was central to our research objectives. Given the heterogeneity of food products in terms of consumption habits and baseline preferences, it is important to clarify that the aim of the study is not to compare absolute levels of WTP across products. Instead, the empirical strategy focuses on identifying treatment effects within different product category. Food products are therefore used as experimental contexts through which value-based informational treatments are implemented, allowing us to assess whether such treatments affect consumer evaluations in realistic consumption settings.

The analysis is based on survey data collected from a representative sample of 1,000 Italian consumers. To test our research questions, we employed five commonly consumed products (bananas, potatoes, tomatoes, rice, and wheat) as everyday food items. The findings confirm that food value-based information can significantly influence consumers' WTP of GETs-derived foods. Moreover, the findings offer new important implications for public policy, marketing strategies, and science communication in the context of emerging food biotechnologies.

Material and methods

Data collection

The data were collected between May and June 2024 through an online survey administered by a specialised agency to a sample consisted of 1,000 Italian consumers. The agency administered the survey using its proprietary online survey platform and recruited respondents from its established participant panel. The agency was responsible for managing the recruitment process, monitoring data quality, and preventing multiple submissions from the same respondent.

Participants were recruited to ensure broad representation of the Italian population across key socio-demographic variables, including gender, age, education, and income. Eligibility was limited to individuals aged 18 and older, ensuring that all respondents were legal adults capable of providing informed consent.

Participation in the survey was entirely voluntary. All respondents were informed about the general nature of the research prior to beginning the questionnaire. The study complied fully with Italian data protection and privacy regulations (e.g., GDPR 2016/679), and no personally identifiable information was collected or stored. Written informed consent in accordance with the Declaration of Helsinki was obtained from all participants and/or their legal guardians. Approval to conduct this study was granted by the departmental Ethical Committee of the Catania University, in accordance with its ethical review and approval procedures. In particular, they stated that for stated-preference research formal ethical approval was not required, as the study involved no risks or monetary transactions.

To ensure data quality, the survey agency excluded questionnaires completed in an unrealistically short amount of time. The online survey platform enabled efficient administration and ensured consistent delivery of the experimental treatments across participants. This method proved particularly effective for assessing consumer attitudes and stated preferences in a controlled yet scalable environment.

Experimental design

The experimental design employed a between-subjects structure, in which a total sample of 1,000 Italian consumers was randomly assigned to two independent subgroups of equal size: a control group (C) (n = 500) and a treatment group (T) (n = 500). Both groups answered the same core set of questions regarding their willingness to pay for five commonly used food products: bananas, potatoes, tomatoes, rice, and wheat. Each product was hypothetically described as being produced using GETs.

The five products selected for this study were chosen based on the availability of scientific evidence regarding the effects of GETs applied to them. These products had already been used in prior experimental research involving GETs, and documented outcomes of such modifications are available in official working papers published by the European Commission[47].

The control group was presented with a neutral description of the GETs-derived products, with no additional information provided. For example, participants in this group were asked: "*Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown?*".

The treatment group also received the same product descriptions as those given in the control group but with added information. Specifically, participants in the treatment group were exposed to information about the "consequences" of using GETs to obtain food, specifically presented as potential benefits connected to selected food values.

The following is an example of a question used in experimental treatment: "*Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown. This reduces food waste*".

Each product was associated with a specific food value relevant to public concerns (see Table 1). The selection of product-value pairs was guided by their relevance in public debates and prior literature addressing consumer concerns related to these values[36,48–51]. The goal was to integrate value-based information into realistic and familiar contexts, thus increasing the relevance and credibility of the informational treatments. The association between each product and a specific nutritional value should not be interpreted as implying that the product embodies only that value. Rather, the experimental manipulation is designed to increase the relevance of a particular nutritional value within a broader set of values already associated with the product. Other product-related values are expected to be present in both the control and treatment conditions and are therefore held constant in within-product comparisons. Since the intrinsic values related to the product are present in both the treatment and control groups, differences in willingness to pay within each product can be interpreted as the marginal effect of the increase in value induced by the information treatment. Specifically, bananas were linked to "food waste reduction", potatoes to "food safety", tomatoes to "environmental impact", rice to "climate change mitigation", and wheat to "food security". The selection of these products was primarily based on the identification of tangible effects arising from the application of GETs to each crop. Once the GETs-derived

Product (*)	Control group (n. 500 units)	Treatment group (n. 500 units) **
	Description	Description
Banana	Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown.	Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown. *This reduces "food waste".*
Potato	Would you buy 1 kg of potatoes obtained through genetic engineering techniques, in such a way as to obtain potatoes that produce less acrylamide, a carcinogenic substance that forms when they are cooked or fried at high temperatures.	Would you buy 1 kg of potatoes obtained through genetic engineering techniques, in such a way as to obtain potatoes that produce less acrylamide, a carcinogenic substance that forms when they are cooked or fried at high temperatures. *This reduces the risk of ingesting carcinogenic substances and improve the "safety".*
Tomato	Would you buy 1 kg of tomatoes obtained through genetic engineering techniques, in such a way as to obtain fruits resistant to fungal pathogens, which require fewer fungicides during cultivation.	Would you buy 1 kg of tomatoes obtained through genetic engineering techniques, in such a way as to obtain fruits resistant to fungal pathogens, which require fewer fungicides during cultivation. *This results in reduced quantities of plant defence inputs and thus reduced "environmental impact".*
Rice	Would you buy 1 kg of rice obtained through genetic engineering techniques, in such a way as to obtain plants that are more tolerant to drought and salt.	Would you buy 1 kg of rice obtained through genetic engineering techniques, in such a way as to obtain plants that are more tolerant to drought and salt. *This reduces the stress effect of "climate change".*
Wheat	Would you buy 1 kg of wheat obtained through genetic engineering techniques, in such a way as to obtain greater protein content and larger grains.	Would you buy 1 kg of wheat obtained through genetic engineering techniques, in such a way as to obtain greater protein content and larger grains. *This increases the "food security" for the world population while maintaining the amount of cultivated land constant.*

Table 1. Information provided to consumers involved in the survey. (*) To avoid an effect related to the order of the "product" proposed, we randomly order different products to different consumers (**) Marked as *italic* is the explicit mention of the Food Value-based information used for the treatment group and not in the control one

Control—Please answer the following hypothetical questions		
1. Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown, for 0€ (for free)?	o Yes	o No
1.1 (Only if the answer for the q.1 is NO) Are you sure you don't want to buy 1 kg of bananas obtained through genetic engineering techniques even if it for free?	o Yes	o No
1.2 (Only if the answer for the q.1.1 is NO) Does this mean that you don't want to purchase bananas obtained through genetic engineering techniques at all?	o Yes	o No
2. Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown, for 0.50€/kg?	o Yes	o No
2.1 (Only if the answer for the q.2 is NO) Are you sure you do not want to buy bananas obtained through genetic engineering techniques for 0.50€/kg?	o Yes	o No
3. Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown, for 0.75€/kg?	o Yes	o No
3.1 (Only if the answer for the q.3 is NO) Are you sure you do not want to buy bananas obtained through genetic engineering techniques for 0.75€/kg?	o Yes	o No
4. Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown, for 1.00€/kg?	o Yes	o No
4.1 (Only if the answer for the q.4 is NO) Are you sure you do not want to buy bananas obtained through genetic engineering techniques for 1.00€/kg?	o Yes	o No
5. Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown, for 1.25€/kg?	o Yes	o No
5.1 (Only if the answer for the q.5 is NO) Are you sure you do not want to buy bananas obtained through genetic engineering techniques for 1.25€/kg?	o Yes	o No
6. Would you buy 1 kg of bananas obtained through genetic engineering techniques, so that the fruit does not brown, for 1.50€/kg?	o Yes	o No
6.1 (Only if the answer for the q.6 is NO) Are you sure you do not want to buy bananas obtained through genetic engineering techniques for 1.50€/kg?	o Yes	o No

Table 2. Example of MPL sections of the questionnaire.

modifications were established, each was paired with a corresponding food value, drawing on established frameworks in the literature (e.g., Lusk and Briggeman[41]). The experimental design does not aim to distinguish between the effects of product value and food value, nor to compare WTP across different products. Rather, each product constitutes a separate experimental context in which the effect of a value-based information treatment is identified through a comparison between the control group and the treatment group for the same product. The use of multiple products allows us to test the robustness of treatment effects across heterogeneous food contexts, rather than inferring differences in baseline valuation across products.

Considering the existence of environmental and ethical concerns in consumer choice for innovative food investigated by Ghvanidze et al.[52], this framing was designed to test whether consumers' WTP would increase when GETs-derived foods were explicitly linked to desirable societal or ethical outcomes aligned with specific food values. To ensure internal consistency and isolate treatment effects, the assignment of each food value to a particular product was held constant across all respondents. The experimental design was not intended to compare WTP levels across different products, but rather to estimate the treatment effects within each product associated with the value-based information frame. Each product therefore constitutes a separate test of the impact of a specific message on nutritional value. The use of multiple products allows us to examine whether the direction and significance of the treatment effects are robust across different food contexts.

Each participant evaluated all five products included in the survey. To mitigate potential ordering effects, the sequence in which the products were presented was randomized for each respondent within both the control and treatment groups.

For each tested product, respondents were presented with a standardized list of prices options, expressed in €/kg. The price range began at €0.00/kg, followed by €0.50/kg, and increased in €0.25/kg increments up to a maximum of €1.50/kg, resulting in seven price points: €0.00, €0.50, €0.75, €1.00, €1.25, and €1.50 per kilogram (see Table 2).

The price levels were uniformly applied across all products to ensure comparability in assessing consumers' WTP. The uniform price range (0–1.50 €/kg) was selected to allow comparison of WTP across heterogeneous products and facilitate within-product comparisons of treatment effects. The WTP results should be interpreted in relative terms, rather than as directly comparable to market prices.

The price levels were presented always in ascending order, from lowest to highest. At each price point, participants were asked whether they would be willing to pay the specified amount. If a respondent answered "No", indicating unwillingness to pay that price, he/she was asked, "Are you sure you do NOT want to buy?". If he/she answered "Yes" to that question, the evaluation for that product was terminated, and the survey proceeded to the next item. This stepwise approach follows the Multiple Price List (MPL) method which allows precise identification of individual willingness-to-pay thresholds. It provides an effective alternative to dichotomous choice formats and also facilitates comparability across treatments and products by maintaining a consistent elicitation structure[53]. Before the WTP questions, respondents were presented with both a cheap talk script and a consequentiality script. These scripts encouraged participants to respond as if they were facing a real purchasing decision and reminded them that their answers would be used for scientific research and policy-relevant analysis, with the aim of mitigating potential hypothetical bias. In the analysis, the screening process for each item excluded respondents who answered "No" to all questions, including "Are you sure you do NOT want to buy?", and respondents who stated they did not want to purchase at €0.00 and had never purchased that item before. To perform panel data analysis, we also excluded respondents for whom four out of five items were excluded under those conditions.

Model specification and data analysis

Two models were estimated for the analysis. The first, referred to as the *basic model*, assessed the direct effect of the informational treatment on respondents' WTP. The second, the *extended model*, included interaction terms between the treatment variable (*FV dummy*) and key demographic characteristics, allowing for the estimation of heterogeneous treatment effects across subgroups.

Furthermore, by analyzing five items within a single model, we treated the data as a panel dataset. In this model, we assumed random effects to control for individual heterogeneity as in below equation.

In the basic model, the following regression specification was used:

$$WTP_{ij} = \sum_{j=1}^{5} \alpha_{1j} + \sum_{j=1}^{5} FVdummy_{ij}\beta_j + \mu_i + \varepsilon_{ij} \tag{1}$$

where: WTP_{ij} is the WTP for the *i*th observation of *j*th with covariates $FVdummy_{ij}$ and corresponding coefficients β_j. α_{1j} is a constant term set for each item. $FVdummy_j$ is a dummy variable of item j in which groups presented with food value information have a value 1. Given the nature of the question, it is important to note that the parameters of $FVdummy_j$ necessarily include item-specific interaction effects. μ_j is a random effect for individual i assumed as normally distributed—$\mu_j \sim N(0, \sigma_v^2)$. ε_j is the error term assumed as normally distributed—$\varepsilon_j \sim N(0, \sigma^2)$.

In the extended model the following regression specification was used:

$$WTP_{ij} = \sum\nolimits_{j=1}^{5} \alpha_{2j} + X_i\gamma_0 + \sum\nolimits_{j=1}^{5} FVdummy_{ij}\gamma_{1j} + \sum\nolimits_{j=1}^{5} X_i * FVdummy_{ij}\gamma_{2j} + \mu_i + \varepsilon_{ij} \tag{2}$$

In this specification, X_j of respondent characteristics including gender, age, annual income per household member, and education level. α_{2j} is the intercept term, while γ_0, γ_1 and γ_2 are the coefficients associated with the covariates, treatment, and their interactions, respectively.

Interaction terms between the treatment variable (*FV dummy*) and key sociodemographic characteristics were included in the model to examine potential heterogeneity in treatment effects across different specific population subgroups. This approach enables an assessment of whether the impact of the informational treatment systematically varies according to individual-level factors. By incorporating these interaction terms, the analysis provides more nuanced insights into how treatment effectiveness may differ across specific sociodemographic profiles, thereby offering a deeper understanding of the mechanisms driving the observed effects.

The WTP data used in this study are either interval, left-censored, or right-censored, depending on respondents' answers. For instance, if a respondent is willing to pay €1.00 but not €1.25 for a product, his/her WTP is treated as an interval [1.00, 1.25). If a respondent accepts a price of €1.50 or higher, their WTP is considered right-censored [1.50,+∞]. Conversely, if someone reports unwillingness to buy the product even if offered for free, their WTP is treated as left-censored [-∞, 0.00). Given this structure, a random effects interval regression model was applied.

We assume that WTP_{ij} for interval data ($i \in I$) is in the interval $[WTP_{1ij}, WTP_{2ij}]$. Furthermore, we assume that the observed WTP_{ij} for left-censored data ($i \in L$) is greater than or equal to WTP_{Lij}, for right-censored data ($i \in R$), it is less than or equal to WTP_{Rij}, and for point data ($i \in C$) is $WTP_{1ij} = WTP_{2ij}$.

Then, the panel-level likelihood l_i is given by:

$$l_i = \int_{-\infty}^{\infty} \frac{e^{-v_i^2/2\sigma_v^2}}{\sqrt{2\pi}\sigma_v} \left\{ \prod\nolimits_{j=1}^{n_i} F(WTP_{1ij}, WTP_{2ij}, x_{ij}\delta + v_i) \right\} dv_i \tag{3}$$

where

Variable	Control Group (n. 500 units)		Treatment Group (n. 500 units)	
	n	%	n	%
Gender				
Male	235	47.0	266	53.2
Female	265	53.0	234	46.8
Age				
18–30 y.o	59	11.8	47	9.4
31–50 y.o	202	40.4	232	46.4
> 50 y.o	239	47.8	221	44.2
Educational level				
Middle school	48	9.6	55	11.0
High school	280	56.0	264	52.8
Degree	130	26.0	149	29.8
Post-degree	42	8.4	32	6.4
Annual household income per person				
< 10 k€	250	50.0	250	50.0
10–19,9 k€	189	37.8	173	34.6
20–29,9 k€	52	10.4	63	12.6
> 30 k€	9	1.8	14	2.8

Table 3. Sociodemographic of the interviewed sample across experimental groups.

Products	Control Group	Treatment Group
Banana	0.303	0.688
Potato	0.907	1.187
Tomato	0.695	0.999
Rice	0.754	1.018
Wheat	0.345	0.810

Table 4. Mean consumers' WTP (€/kg) for GETs-derived foods across experimental groups.

$$F\left(WTP_{1ij}, WTP_{2ij}, \Delta_{ij}\right) = \begin{cases} \left(\sqrt{2\pi}\sigma_e\right)^{-1} e^{-\left(WTP_{1ij}-\Delta_{ij}\right)^2/\left(2\sigma_e^2\right)} if(WTP_{1ij}, WTP_{2ij}) \in C \\ \Phi\left(\left(WTP_{2ij}-\Delta_{ij}\right)/\sigma_e\right) if(WTP_{1ij}, WTP_{2ij}) \in L \\ 1-\Phi\left(\left(WTP_{1ij}-\Delta_{ij}\right)/\sigma_e\right) if(WTP_{1ij}, WTP_{2ij}) \in R \\ \Phi\left(\left(WTP_{2ij}-\Delta_{ij}\right)/\sigma_e\right)-\Phi\left(\left(WTP_{1ij}-\Delta_{ij}\right)/\sigma_e\right) if(WTP_{1ij}, WTP_{2ij}) \in I \end{cases}$$

where Φ() is the cumulative standard normal distribution, x_{ij} are the covariates and β are their corresponding coefficients. All estimations were performed using Stata SE 17[54].

Results

Socio-demographic characteristics

Given randomization of participants, the Control and Treatment groups are broadly comparable in their socio-demographic characteristics (Table 3). Both groups display a balanced gender and age distribution, with no substantial disparities. Education levels and annual household income per capita are also aligned across the two groups. Chi-square tests, adjusted using Holm's method to account for multiple comparisons, revealed no statistically significant differences between the control and treatment groups on any of the socio-demographic variables.

Willingness to pay results

Table 4 shows the average WTP for each product across the control and treatment groups. WTP estimates should be interpreted as relative measures that capture changes induced by information treatments, rather than as precise indicators of market prices. The conditional mean estimated by interval regression is linear, so coefficients can be interpreted as in ordinary least-squares (OLS) regression. The reported average WTP values correspond to predicted values under the control condition, as estimated by the basic model.

In the control group, mean WTP values are consistently lower across all food categories. In contrast, exposure to value-based informational messages (treatment group) is associated with higher average WTP. For example, in the case of tomatoes, the predicted WTP in the control group is €0.70/kg, compared to €1.00/kg in the group exposed to the environmental impact frame. Similar trends are observed for the other products.

Basic random effects interval regression estimates

The estimated models should be interpreted as product-specific analyses. The coefficients associated with the information treatment reflect changes in WTP within a given product induced by value-based messages, rather than differences in valuation across products. Consequently, the results are interpreted as the presence and strength of treatment effects within the context of each product not as direct comparisons of WTP levels. The basic models estimate the direct influence of the informational treatment (*FV dummy*) on consumers' WTP for GETs-derived foods, without controlling for any socio-demographic characteristics or interaction terms (Table 5). Each treatment condition emphasized a distinct food value through the information provided: food waste for bananas, food safety for potatoes, environmental impact for tomatoes, climate change mitigation for rice, and food security for wheat.

The results of the likelihood ratio (LR) test to compare the pooled model were $\rho = 0.854, \overline{\chi}^2 = 3151.27$ *P*-value = 0.000; thus, it confirmed that it was appropriate to adopt a random effects model.

About the pair Banana-Food Waste the treatment effect is positive and statistically significant at the 5% level (coefficient = 0.385; SE = 0.158). This indicates that providing participants with information about how GETs-derived bananas can reduce food waste increases their WTP by approximately €0.40/kg.

The analysis about the combo Potato-Food Safety shows a positive and weakly statistically significant treatment effect at the 10% level (coefficient = 0.280; SE = 0.175).

For the pair Tomato-Environmental Impact the treatment effect is positive and weakly significant at the 10% level (coefficient = 0.304; SE = 0.157). In monetary terms, highlighting these benefits increases willingness to pay substantially: the average WTP rises from €0.70/kg in the control group to €1.00/kg in the treatment group, representing about 50% increase.

About the pair Rice-Climate Change the treatment effect is positive and weakly statistically significant (coefficient = 0.246; SE = 0.157). The WTP in the control group was €0.75/kg and increases to €1.02/kg.

Finally, the pair Wheat-Food Security demonstrates the strongest and most statistically significant effect in the basic model, with the treatment effect significant at the 1% level (coefficient = 0.507; SE = 0.157). The food security message is highly effective in increasing willingness to pay for GET wheat. Notably, this framing doubles consumers' WTP, raising the average from €0.35/kg in the control group to €0.81/kg in the treatment group.

Overall, the results from the basic model support the central hypothesis that strategically framing information around food values can positively influence consumer attitudes toward GET-derived foods. However, the strength of these effects varies depending on the food products and the specific food values communicated. The strongest responses were observed for wheat (food security) and banana (food waste), while potato (food safety) and rice (climate change) showed weaker effects.

These findings suggest that not all food value-based messages are equally effective, highlighting the importance of tailoring communication strategies to specific products and value dimensions. It is also important to note that item-specific factors can influence the results. Additionally, while the basic model offers a clear estimate of the average treatment effect, it does not capture demographic or behavioral differences among consumers—factors that are addressed in the extended model discussed earlier.

Extended random effects interval regression estimates

Results from the extended model are presented in Table 6. These results correspond to the five food products included in the survey, each linked to a specific food value. The extended model allows for a more detailed analysis by examining how the treatment effects vary across different consumer subgroups. The result of the likelihood ratio (LR) test to compare the pooled model, were $\rho = 0.852, \overline{\chi}^2 = 3089.41, P\text{ - value} = 0.000$; thus, it confirmed that it was appropriate to adopt a random effects model.

Banana-food waste

The random effect interval regression results for GETs-derived banana provide valuable insights into how consumers' WTP is influenced by socio-demographic characteristics and exposure to food value-based information—specifically, messages related to food waste reduction.

Parameter	Banana-Food waste	Potato-food safety	Tomato-environmental impact	Rice-climate change	Wheat- Food security
FV dummy	0.385**	0.280*	0.304*	0.264*	0.507***
	(0.158)[a]	(0.157)	(0.157)	(0.157)	(0.157)
Item dummy		0.604***	0.392***	0.451***	0.042
		(0.077)	(0.076)	(0.076)	(0.076)
Constant	0.303***				
	(0.111)				
Sigma u	1.979		Sigma e	0.816	
	(0.077)***			(0.021)***	
Log-likelihood	− 5452.992		Sample size	4,559	

Table 5. Random effects interval regression estimates for the basic model. ***, ** and * denote 1%, 5% and 10% significance levels, respectively. [a]Numbers in parentheses are standard errors.

Parameter	Banana-Food waste	Potato-Food safety	Tomato-Environmental impact	Rice-Climate change	Wheat-Food security
Female[b]	0.408*	0.131	0.253	0.086	0.519**
	(0.221)[a]	(0.219)	(0.220)	(0.220)	(0.221)
Age[c]	− 0.006	− 0011	− 0.006	− 0.010	− 0.018**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
pincome[d]	0.0308**	0.051***	0.045***	0.052***	0.051***
	(0.016)	(0.015)	(0.016)	(0.016)	(0.016)
more_degree[e]	0.270	0.270	0.295	0.192	0.111
	(0.242)	(0.241)	(0.241)	(0.242)	(0.241)
FV dummy[f]	1.372**	1.215**	1.402**	1.225**	1.320**
	(0.593)	(0.594)	(0.594)	(0.592)	(0.591)
Female*i*[g]	− 0.336	− 0.648**	− 0.583*	− 0.301	− 0.877***
	(0.312)	(0.310)	(0.311)	(0.311)	(0.311)
Age*i*[g]	− 0.007	− 0.003	− 0.006	− 0.005	0.005
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
pincome*i*[g]	− 0.036*	− 0,036*	− 0.038*	− 0.045**	− 0.047**
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
more_degree*i*[g]	− 0.196	− 0.178	− 0.191	− 0.201	− 0.183
	(0.342)	(0.340)	(0.340)	(0.341)	(0.339)
Item dummy		0.813***	0.362	0.637**	0.446
		(0.288)	(0.287)	(0.287)	(0.287)
Constant	− 0.123				
	(0.418)				
Sigma u	1.942 (0.076)***		Sigma e	0.806 (0.020)***	
Log-likelihood	− 5419.1355		Sample size	4,559	

Table 6. Random effects interval regression estimates for the extended model. ***, ** and * denote 1%, 5% and 10% significance levels, respectively. [a]Numbers in parentheses are standard errors. [b]Effect of females relative to males. [c]Effect of age, as continues variable. [d]Effect of annual household income per household member, as continues variable. [e]Effect of degree or post degree relative to all others lower educational levels. [f]Effect of information provided on specific food values. [g]The trailing "*i*" indicates a cross term with the variable "FV dummy".

The coefficient for the *FV dummy* variable is positive and statistically significant at the 5% level (coefficient = 1.372; SE = 0.593), indicating that informing consumers about the potential of GETs to reduce food waste leads to a significant increase in WTP.

With respect to socio-demographic controls, personal income (*pincome* variable) exhibits a positive and marginally significant effect at the 10% level (coefficient = 0.031; SE = 0.016). This suggests that individuals with higher income levels tend to report greater willingness to pay for GETs-derived bananas. A possible explanation is that higher-income consumers may have more disposable income to support innovative or ethically framed food products, or may assign greater value to the perceived societal benefits of such innovations. Similarly, the dummy for female respondents is positive and significant at 10% level (coefficient = 0.408; SE = 0.221), indicating that, on average, women may be more favourable than men.

The variable age has a negative but non-significant effect (coefficient = -0.006; SE = 0.007), suggesting a possible, but not statistically reliable tendency for older individuals to be slightly less willing to pay. Similarly, educational (*more_degree* variable) does not show a significant influence (coefficient = 0.270; SE = 0.242), suggesting that holding a university degree or higher does not systematically affect WTP in this context.

As for the interaction terms with the treatment condition, interaction personal income (pincome*i* variable) exhibits a negative significant effect at the 10% level (coefficient = -0.036; SE = 0.021). Regarding other variables, the interaction Female*i* (coefficient = -0.336; SE = 0.312) suggests that the positive impact of food waste information may be slightly attenuated among women, but the lack of statistical significance prevents drawing firm conclusions. Similarly, interactions with age and education are likewise non-significant.

Potato-food safety

The random effects interval regression results for the GETs-derived potatoes provide a nuanced understanding of how socio-demographic characteristics and food safety-related value-based messaging influence consumer WTP.

The *FV dummy* variable, which captures the effect of communicating that GETs can enhance food safety, yields a positive value (coefficient = 1.215; SE = 0.594) and statistically significant at 5% level. Even when controlling for consumer demographic attributes and assuming an interaction term, we confirmed that food safety has a positive effect on WTP.

Among the socio-demographic variables, household income per member (*pincome*) is positively and strongly significant at the 1% level (coefficient = 0.051; SE = 0.015), suggesting that higher-income individuals show greater WTP for GETs potatoes. This pattern likely reflects their increased purchasing power and possibly a higher sensitivity to perceived product benefits when supported by scientific information.

In contrast, the effects of female (coefficient = 0.131; SE = 0.219) , age (coefficient = -0.011; SE = 0.007), and education level (*more_degree*) (coefficient = 0.270; SE = 0.241) are not statistically significant, suggesting that gender, age and education, per se, do not significantly differentiate consumers' WTP in this context.

The interaction term Female*i* is negative and statistically significant at the 5% level (coefficient = -0.648; SE = 0.310), indicating that the positive effect of safety information on WTP is actually lower for women compared to men. This might reflect greater skepticism or caution among female respondents toward technological food innovations, even when presented with safety-related benefits.

The interaction term pincome*i* is also negative and statistically significant at the 10% level (coefficient = – 0.036; SE = 0.021), similar to estimated results for banana. Higher income levels tend to be less influenced by information about food values.

The variables Age*i* and more_degree*i*, are not statistically significant.

Tomato-environmental impact

The random effects interval regression results for GETs-derived tomatoes offer valuable insights into how consumers' WTP is influenced by socio-demographic factors and food value-based information emphasizing environmental impact.

The FV dummy is positive and statistically significant at the 5% level (coefficient = 1.402; SE = 0.594), indicating that exposure to messages highlighting the environmental benefits of GETs tomatoes leads to a significant increase in WTP. The results support the notion that when the benefits of biotechnology are framed in terms of ecological improvement, consumers respond with greater valuation and acceptance.

Turning to socio-demographic variables, income (*pincome*) is again a strong and statistically significant positive predictor of WTP at the 1% level (coefficient = 0.045; SE = 0.016). This is consistent with previous results and supports the notion that individuals with higher income are more receptive to value-added product attributes, including environmental sustainability.

Conversely, *age* is not statistically significant (coefficient = -0.006; SE = 0.007), and female is also not significant (coefficient = 0.253; SE = 0.220). Similarly, education (*more_degree*) shows a positive but insignificant effect (coefficient = 0.295; SE = 0.241).

More nuanced dynamics emerge in the interaction terms. Notably, the Female*i* interaction is negative and statistically significant at the 10% level (coefficient = -0.583; SE = 0.311), suggesting that the positive effect of the environmental information treatment is significantly lower among female consumers. This again points to a pattern seen in other results: women appear less responsive to pro-biotech messages, even when these emphasize widely supported values like environmental sustainability.

The pincome*i* interaction is also negative and significant at the 10% level (coefficient = -0.038; SE = 0.021), indicating that while higher income is associated with a greater baseline WTP, the marginal impact of the treatment is lower among wealthier respondents.

Other interaction terms, such as Age*i* and more_degree*i*, are not statistically significant, suggesting limited differential responsiveness to the treatment based on age or education.

Rice-climate change mitigation

The random effects interval regression estimates for GETs-derived rice offer further insights into how consumer preferences are influenced when information emphasizes climate change mitigation, a key food value in this research.

The FV dummy is positive and statistically significant at the 5% level (coefficient = 1.225; SE = 0.592), indicating that informing consumers about the potential of GETs-derived rice to reduce climate-related impacts significantly increases their WTP even after controlling socio-demographics and interaction terms. This finding reinforces the study's central hypothesis: when the benefits of GETs are framed in terms of alignment with important societal values—such as combating climate change—consumers demonstrate greater acceptance and a higher willingness to provide economic support.

Among the socio-demographic variables, income (*pincome*) remains a strong and highly significant predictor of WTP (coefficient = 0.052; SE = 0.016; significant at the 1% level).

.The results suggest that gender, age nor educational level significantly differentiates consumers' baseline WTP for GETs rice, once income is controlled for.

Examining the interaction terms, none reach conventional levels of statistical significance except for pincome*i*, which is negative and statistically significant at the 5% level (coefficient = -0.045; SE = 0.021).

The other interaction terms are not statistically significant, indicating that the treatment effect related to climate change messaging is broadly consistent across demographic subgroups, with the exception of income.

Wheat-food security

The random effect interval regression results for GETs-derived wheat, with the informational treatment emphasizing the food value of food security, reveal key insights into consumer preferences and variability in treatment response.

The FV dummy coefficient is positive and statistically significant at the 5% level (coefficient = 1.320; SE = 0.591), indicating that highlighting the potential of GETs to obtain wheat to improve food security significantly increases consumers' WTP.

Among socio-demographic variables, age has a strong and negative effect on WTP (coefficient = -0.018; SE = 0.007), significant at the 5% level. This suggests that older individuals are consistently less inclined to accept GETs wheat. As with other models, this may reflect greater skepticism toward biotechnology among older consumers or generational differences in perception of food innovation.

Income (*pincome*) again emerges as a robust and highly significant predictor (coefficient = 0.051; SE = 0.016), reinforcing the idea that higher-income individuals are more open to paying for GETs foods when they are linked to socially desirable outcomes like food security.

The variable *female* shows a positive and significant effect (coefficient = 0.355; SE = 0.203; significant at the 5% level), suggesting that women may be slightly more receptive than men to paying for GETs wheat.

The variable education (*more_degree*) does not display a statistically significant effect (coefficient = 0.111; SE = 0.241), implying that higher education levels, on their own, are not associated with a stronger WTP for genetically engineered wheat.

The interaction terms provide further insight. The Female*i* interaction is negative and significant at the 1% level (coefficient = -0.877; SE = 0.311), indicating that the positive impact of the treatment (information on food security) is significantly lower for women compared to men.

Similarly, pincome*i* is negative and significant at the 5% level (coefficient = -0.047; SE = 0.021), pointing to diminishing marginal returns of the informational treatment among wealthier consumers, consistent with earlier models.

The other interaction terms are not statistically significant, indicating no statistically differential treatment effects by age or education level.

Robustness check

Using the same data, cross-sectional interval regression estimates were performed for each item. In this case, both the basic and extended models yielded sign conditions similar to those in Tables 5 and 6. Furthermore, the coefficients for the FV dummy in the basic model were 0.399 for banana, 0.235 for potato, 0.306 for tomato, 0.246 for rice, and 0.499 for wheat, which were close to the results in Table 5. However, the FV dummies for potato and rice were statistically insignificant at the 10% level. Thus, even without controlling for individual heterogeneity as random effects, we obtained nearly identical results overall.

Furthermore, in the extended model using random effects interval regression analysis, we estimated models by reducing the number of demographic variables (such as female and age) by one each. This allows us to determine whether specific demographic attributes vary the estimation results. As the results, in all these models, the sign conditions remained unchanged with Table 6.

Finally, for each item, we estimated the basic and extended models using 4,393 samples. These samples excluded respondents who answered “No” to the final WTP of 1.5€/kg and “No” to "Are you sure you do NOT want to buy?" Additionally, we excluded respondents with only one valid answer, because we conducted panel data analysis. Specifically, we more strictly excluded respondents identified as uncertain by the certainty-follow up question and compared the results with those of this paper. Penn and Wuyang[55] demonstrated that the certainty-follow up question can mitigate hypothetical bias, making this sub-sample analysis a suitable robustness check. The results showed the same sign conditions as in Tables 5 and 6. The variables with statistically significant coefficients were also the same, except that the wheat item dummy became statistically significant at the 10% level.

Discussion

This study makes important empirical and theoretical contributions to the literature on consumer acceptance of GETs-derived foods by examining the impact of food value-based informational framing. Overall, our findings indicate that emphasizing a specific food value through targeted informational messages within a given product context can influence consumer evaluations. Given the heterogeneity of the informational messages used in this study in terms of content, the results should be interpreted as evidence of the effectiveness of specific informational messages based on food values applied to concrete contexts, rather than as general effects of food values. Guided by two research questions—whether food value-based information influences consumers’ WTP (RQ1), and whether certain food values are more influential than others (RQ2) —the results offer clear and nuanced support for both.

Overall, the findings suggest that value-based informational strategies are effective in enhancing consumer acceptance of GETs-derived foods, although their impact varies across consumer segments. Frames emphasizing food waste reduction, food safety, environmental benefits, climate change mitigation, and food security emerge as salient drivers of willingness to pay and overall acceptance. However, the effectiveness of these value-oriented messages is not uniform. Income consistently plays a key moderating role, with the influence of information treatments either strengthening or weakening among higher-income consumers depending on the value frame. Gender-related differences further contribute to the observed heterogeneity in responses, particularly with respect to perceptions of safety and sustainability. Taken together, these results indicate that while value-based communication represents a promising approach to foster societal acceptance of agricultural biotechnologies, its effectiveness is strongly conditioned by socio-demographic characteristics. Consistently to Siegrist[56], this result underscores the need for targeted and segmented communication strategies to maximize public support for GETs-derived foods, especially when these technologies are framed as solutions to global challenges such as environmental sustainability, climate change mitigation, and food security.

The results consistently demonstrate that providing information on how GETs-derived foods contribute to specific food values significantly increases consumers’ WTP. Both the basic and extended random effects interval regression models show generally positive and significant treatment effects. These findings underscore that consumers assess GETs-derived foods not only based on the genetic techniques themselves but also on the broader societal and environmental impacts of these products. This aligns with Lancaster's[57] characteristics theory, which posits that utility derives from a product's attributes rather than the product alone; in this context, the "attributes" include ethical and societal values like sustainability and security.

Furthermore, these results contribute to the literature on information asymmetry and signaling in markets for credence goods[58,59]. Recent evidence shows that sustainability labels and value-based messaging can play a significant role in shaping purchase decisions, by influencing both perceived utility and ethical alignment[60,61]. GETs-derived foods are typical credence goods—consumers cannot directly verify claims about safety or environmental benefits and therefore rely heavily on external information. The informational treatments used in this study effectively functioned as credibility signals, increasing perceived value and reducing uncertainty associated with GETs technologies.

Regarding RQ2, the findings clearly indicate that not all food values have the same impact on consumer behaviours. Using multiple products allowed us to assess whether value-based informational effects emerge consistently across diverse food contexts. Although the extent of the treatment varies, the generally positive response to value-focused information across all products provides evidence for the robustness of the framing mechanism, rather than just the specific characteristics of individual products. The differences in treatment effects between products reflect the heterogeneity in how a specific value interacts with other product values, rather than evidence of isolated effects of individual food values. In other words, the heterogeneity should not be interpreted as a ranking of food values in absolute terms. Instead, differences in treatment effects across products highlight how the effectiveness of value-based framing depends on the specific product context in which it is embedded.

Information emphasizing food security (tested with wheat) and food waste reduction (tested with bananas) determined the strongest and most consistent increases in WTP, with statistically significant effects even after accounting for socio-demographic differences. These results align with previous research, which highlighted certain items as highly salient public concerns[35].

In contrast, messages related to food safety, environmental impact and climate change showed weaker effects. While this may suggest that food safety is perceived as a baseline expectation rather than a persuasive benefit, and that climate change may be viewed as too abstract or politically complex to strongly influence immediate purchasing decisions, these interpretations should be treated with caution. Since each food value was tested using a single product, we cannot rule out that these outcomes may also reflect product-specific effects rather than the value framing alone.

This differentiated impact of food values advances existing research, which has often treated food values as fixed consumer segments or stable preference structures[41]. In contrast, this study demonstrates that food values can act dynamically as persuasive frames that shape consumers' evaluations when linked to a specific food product. Furthermore, the variation in consumer responsiveness highlights the importance of strategically aligning the product type with the corresponding food value message to maximize engagement and acceptance.

The extended model results also reveal significant heterogeneity in consumer responsiveness. For instance, higher-income individuals tend to have a higher baseline WTP for GETs-derived foods. Similarly, female respondents often show weaker reactions to the informational treatments, despite having similar or even higher baseline WTP. These patterns align with prior research highlighting gender and income differences in attitudes toward new food technologies, often influenced by variations in risk perception and trust in science[28]. These findings highlight the need for targeted and differentiated communication strategies that take into account both consumer demographics and value orientations. It is important to emphasize that these implications should be interpreted in terms of the effectiveness of specific value-based messages in specific product contexts, rather than as general prescriptions about the relative importance of different food values.

From a policy perspective, the findings of this study convey a hopeful message: consumer resistance to GETs-derived foods are not fixed. When provided with credible, concrete information linking GETs-derived products to widely valued food attributes, many consumers respond positively. This underscores the importance of evidence-based public communication, particularly in regions like the European Union, where skepticism toward GETs has been persistent. Regulatory frameworks could benefit from incorporating food value-based impact assessments alongside traditional safety evaluations.

From an agri-food marketing standpoint, these results suggest that product positioning strategies for GETs-derived foods should go beyond technical descriptions and focus on food value-driven messaging. Labelling and marketing campaigns that highlight how GETs-derived foods contribute to waste reduction, environmental sustainability, or food system resilience could enhance both market performance and public trust in biotechnology as a viable solution to urgent food system challenges.

Conclusion

This study advances our understanding of how consumers evaluate GETs-derived foods when these products are framed not just as technological innovations, but as solutions to broader societal challenges. By linking GETs to specific food values, the findings reveal a promising pathway to enhance public acceptance of biotechnology in the food system. The results therefore highlight the potential effectiveness of information messages based on the food values associated with specific products.

The results carry both practical and theoretical implications. Practically, they suggest that strategic, value-driven communication can reshape consumer perceptions, fostering more informed, nuanced attitudes and greater trust toward food innovations. Theoretically, the study extends economic and behavioral frameworks into the agri-food biotechnology context, showing that consumers respond as much to symbolic and ethical cues as to functional attributes. Moreover, the evidence highlights that value framing's effectiveness depends on the specific food value emphasized and the demographic characteristics of the consumer.

In summary, this research demonstrates that consumer resistance to GETs is not fixed but conditional. Acceptance can be significantly shaped by how GETs-derived food are framed, especially when messages align with food values that consumers consider personally or socially important. These findings provide valuable guidance for science communication, regulatory reform, and marketing strategies aimed at bridging the gap between innovation and public trust in the evolving food system. At the same time, they highlight the need for further research into the cognitive, cultural, and institutional factors that influence consumer responses to food biotechnology.

Limitations and future research

This study has some limitations and any policy implications drawn from the findings of this study should therefore be interpreted with caution and framed in relation to specific communication strategies, rather than as general prescriptions about food values. Moreover, although the experimental design effectively tested informational treatments across five food values, it relied on hypothetical willingness-to-pay measures rather than actual purchasing behavior. This could be relevant, as previous studies have shown that consumer acceptance is often higher when genetically modified foods are presented in concrete consumption contexts[62]. Future research could enhance behavioral validity by incorporating incentivized experiments or real-world choice data.

Moreover, a limitation of this study is that each food product was paired with a single, specific food value, which constrains the ability to disentangle the individual effects of product type versus value framing. Future research should therefore test the robustness of these findings by systematically varying food value framings across different products and test multiple food values within the same product, to better isolate and understand interaction effects. In addition, it would be useful to verify whether there is heterogeneity in the results between different or specific types of GET.

Additionally, the sample was limited to Italian consumers; while stratified to reflect national demographics, the findings may not generalize to other cultural or regulatory contexts. Cross-national comparative studies would provide valuable insights into how food value perceptions interact with local trust in science, political attitudes, and media exposure. Furthermore, this study focused on socio-demographic variables but did not examine psychographic factors such as personal environmental concern, food neophobia, trust in institutions, or political ideology, all of which can influence attitudes toward biotechnology. Including these constructs in future research could improve the explanatory power of value-based communication models.

Moreover, the use of a common price range across products was consistent with the objectives of the analysis, as the focus was on within-product treatment effects rather than on absolute WTP levels, and the items considered are food products of common and frequent consumption. Nevertheless, future research could enhance the external validity of absolute WTP estimates by adopting more precise, product-specific price ranges.

Data availability

The dataset analysed during the current study is available from the corresponding author on reasonable request.

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References

1. Kumar, N. (Ed.). (2022). Biotechnology and Crop Improvement: Tissue Culture and Transgenic Approaches (1st ed.). CRC Press.
2. Wan, X., Hou, Q. & McConnell, L. L. Advances in genome editing for sustainable agriculture. *ACS Agric. Sci. Technol.* **2**(2), 165–166 (2022).
3. Zhang, H., Mittal, N., Leamy, L. J., Barazani, O. & Song, B. H. Back into the wild-Apply untapped genetic diversity of wild relatives for crop improvement. *Evol. Appl.* **10**(1), 5–24 (2016).
4. Schouten, H. J., Krens, F. A. & Jacobsen, E. Cisgenic plants are similar to traditionally bred plants: international regulations for genetically modified organisms should be altered to exempt cisgenesis. *EMBO Report* **7**(8), 750–753 (2006).
5. Oladosu, Y. et al. Principle and application of plant mutagenesis in crop improvement: a review. *Biotechnol. Biotechnol. Equip.* **30**(1), 1–16 (2016).
6. Zhang, Y., Massel, K., Godwin, I. D. & Gao, C. Applications and potential of genome editing in crop improvement. *Genome Biol.* **19**(1), 210 (2018).
7. Qaim, M. Role of new plant breeding technologies for food security and sustainable agricultural development. *Appl. Econ. Perspect. Policy* **42**(2), 129–150 (2020).
8. Podevin, N., Davies, H. V., Hartung, F., Nogué, F. & Casacuberta, J. M. Site-directed nucleases: a paradigm shift in predictable, knowledge-based plant breeding. *Trends Biotechnol.* **31**(6), 375–383 (2013).
9. FAO. *The state of food security and nutrition in the world 2022* (Food and Agriculture Organization of the United Nations, 2022).
10. EFSA. Scientific opinion addressing the safety assessment of plants developed using zinc finger nuclease 3 and other site-directed nucleases with similar function. *EFSA J.* **10**(10), 2943 (2012).
11. Eckerstorfer, M. F. et al. An EU perspective on biosafety considerations for plants developed by genome editing and other new genetic modification techniques (nGMs). *Front. Bioeng. Biotechnol.* **5**(7), 31 (2019).
12. Lassoued, R., Phillips, P. W. B., Macall, D. M., Hesseln, H. & Smyth, S. J. Expert opinions on the regulation of plant genome editing. *Plant Biotechnol. J.* **19**(6), 1104–1109 (2021).
13. Gordon, D. R. et al. Responsible governance of gene editing in agriculture and the environment. *Nat. Biotechnol.* **39**(9), 1055–1057 (2021).
14. Pakseresht, A., McFadden, B. R. & Lagerkvist, C. J. Consumer acceptance of food biotechnology based on policy context and upstream acceptance: Evidence from an artefactual field experiment. *Eur. Rev. Agric. Econ.* **44**(5), 757–780 (2017).
15. Spök, A., Sprink, T., Allan, A. C., Yamaguchi, T. & Dayé, C. Towards social acceptability of genome-edited plants in industrialised countries? Emerging evidence from Europe, United States, Canada, Australia, New Zealand, and Japan. *Front Genome Ed. August* **31**(4), 899331 (2022).
16. European Commission, (2021). Study on the status of new genomic techniques under Union law and in light of the Court of Justice ruling in Case C-528/16. Brussels. https://food.ec.europa.eu/document/download/5135278b-3098-4011-a286-a316209c01cd_en?filename=gmo_mod-bio_ngt_eu-study.pdf

17. Runge, K. K., Brossard, D., Scheufele, D. A., Rose, K. M. & Larson, B. J. Attitudes about Food and Food-Related Biotechnology. *Public Opin. Q.* **81**(2), 577–596 (2017).
18. Mielby, H., Sandøe, P. & Lassen, J. The role of scientific knowledge in shaping public attitudes to GM technologies. *Public Underst. Sci.* **22**(2), 155–168 (2013).
19. Lusk, J. L., McFadden, B. R. & Wilson, N. Do consumers care how a genetically engineered food was created or who created it?. *Food Policy* **78**, 81–90 (2018).
20. Ortega, D. L., Lin, W. & Ward, P. S. Consumer acceptance of gene-edited food products in China. *Food Qual. Prefer.* **95**, 104374 (2021).
21. Bearth, A., Otten C.D., Segrè Cohen, A. (2024). Consumers' perceptions and acceptance of genome editing in agriculture: Insights from the United States of America and Switzerland. Food Research International, 178.
22. Yamaguchi, T., Ezaki, K. & Ito, K. Exploring the landscape of public attitudes towards gene-edited foods in Japan. *Breed. Sci.* **74**(1), 11–21 (2024).
23. Oh, S. D. & Lee, K. Analysis of the public perception and acceptance of gene-editing technology and gene-edited agricultural products in South Korea. *GM Crops & Food* **16**(1), 795–810 (2025).
24. Costa-Font, M. & Gil, J. M. Structural equation modelling of consumer acceptance of genetically modified (GM) food in the Mediterranean Europe: A cross-country study. *Food Qual. Prefer.* **20**(6), 399–409 (2009).
25. Pappalardo, G., D'Amico, M. & Lusk, J. L. Comparing the views of the Italian general public and scientists on GMOs. *Int. J. Food Sci. Technol.* **56**(7), 3641–3650 (2021).
26. Bredahl, L. Determinants of consumer attitudes and purchase intentions with regard to genetically modified food—results of a cross-national survey. *J. Consum. Policy* **24**, 23–61 (2001).
27. Costa-Font, M. & Gil, J. M. Meta-attitudes and the local formation of consumer judgments towards genetically modified food. *Br. Food J.* **114**(10), 1463–1485 (2012).
28. Frewer, L. J. et al. Public perceptions of agri-food applications of genetic modification - A systematic review and meta-analysis. *Trends Food Sci. Technol.* **30**(2), 142–152 (2013).
29. de Jonge, J., van Trijp, H., Renes, R. J. & Frewer, L. Understanding consumer confidence in the safety of food: its two-dimensional structure and determinants. *Risk Anal.* **27**(3), 729–740 (2007).
30. Siegrist, M. Factors influencing public acceptance of innovative food technologies and products. *Trends Food Sci. Technol.* **19**(11), 603–608 (2008).
31. Castellini, G., Vezzoli, M., Carfora, V., Graffigna, G. & Catellani, P. Psychosocial predictors and framing effects in the acceptance of new genomic techniques-treated cheese: Evidence from a representative Italian sample. *Food Qual. Prefer.* **134**, 105675 (2025).
32. Bearth, A. & Siegrist, M. The social amplification of risk framework: a normative perspective on trust?. *Risk Anal.* **42**(7), 1381–1392 (2022).
33. Wunderlich, S. & Gatto, K. A. Consumer perception of genetically modified organisms and sources of information. *Adv. Nutr.* **6**(6), 842–851 (2015).
34. Marris, C. Public views on GMOs: deconstructing the myths. Stakeholders in the GMO debate often describe public opinion as irrational. But do they really understand the public?. *EMBO Rep.* **2**(7), 545–548 (2001).
35. Siegrist, M. & Hartmann, C. Consumer acceptance of novel food technologies. *Nature Food* **1**, 343–350 (2020).
36. Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A. (2011). Global food losses and food waste—extent, causes and prevention. Food and Agriculture Organization of the United Nations (FAO).
37. Gaskell, G. et al. GM foods and the misperception of risk perception. *Risk Anal.* **24**(1), 185–194 (2004).
38. Van Loo, E. J., Caputo, V. & Lusk, J. L. Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter?. *Food Policy* **95**, 101931 (2020).
39. Marette, S., Disdier, A. & Beghin, J. C. A comparison of EU and US consumers' willingness to pay for gene-edited food: Evidence from apples. *Appetite* **159**, 105064 (2020).
40. Rokeach, M. *The nature of human values* (Free Press, 1973).
41. Lusk, J. L. & Briggeman, B. C. Food values. *Am. J. Agric. Econ.* **91**(1), 184–196 (2009).
42. Bazzani, C., Gustavsen, G. W., Nayga, R. M. & Rickertsen, K. A comparative study of food values between the United States and Norway. *Eur. Rev. Agric. Econ.* **45**(2), 239–272 (2018).
43. Cerroni, S., Nayga, R. M. Jr., Pappalardo, G. & Yang, W. Malleability of food values amid the COVID-19 pandemic. *Eur. Rev. Agric. Econ.* **49**(2), 472–498 (2021).
44. Uddin, A., Gallardo, R. K., Rickard, B., Alston, J. & Sambucci, O. Consumer acceptance of new plant-breeding technologies: An application to the use of gene editing in fresh table grapes. *PLoS ONE* **17**(12), e0270792 (2022).
45. Hwang, H. & Nam, S. The influence of consumers' knowledge on their responses to genetically modified foods. *GM Crops Food* **12**(1), 146–157 (2020).
46. Marangon, F., Troiano, S., Carzedda, M. & Nassivera, F. Consumers' acceptance of genome edited food and the role of information. *Italian Rev. Agric. Econ.* **76**(3), 5–21 (2021).
47. European Commission, (2022). Legislation for plants produced by certain new genomic techniques. Public Consultation Factual Summary Report. Ref. Ares (2022)6392169. Available the link https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13119-Legislation-for-plants-produced-by-certain-new-genomic-techniques/public-consultation_en
48. European Commission, (2022). Farm to Fork Strategy: Public consultation on new genomic techniques. Report available at: https://food.ec.europa.eu/system/files/2022-04/sc_modif-genet_pub-cons-factsheet.pdf
49. EFSA Contam Panel (EFSA Panel on Contaminants in the Food Chain). Scientific opinion onacrylamide in food. *EFSA J.* **13**(6), 4104 (2015).
50. Wassmann, R., Jagadish, S.V.K., Heuer, S., Ismail, A., Redona, E., Serraj, R., Singh, R.K., Howell, G., Pathak, H., Sumfleth, K. (2009). Chapter 2 Climate Change Affecting Rice Production: The Physiological and Agronomic Basis for Possible Adaptation Strategies. Editor(s): Donald L. Sparks, Advances in Agronomy, Academic Press, Vol. 101, pp. 59–122.
51. Fischer, G., Shah, M., Tubiello, F. N. & van Velhuizen, H. Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. *Philos Trans R Soc Lond B Biol Sci.* **29**, 360 (2005).
52. Ghvanidze, S., Velikova, N., Dodd, T. H. & Oldewage-Theron, W. Consumers' environmental and ethical consciousness and the use of the related food products information: The role of perceived consumer effectiveness. *Appetite* **107**, 311–322 (2016).
53. Lusk, J. L. & Schroeder, T. C. Are choice experiments incentive compatible? A test with quality differentiated beef steaks. *Am. J. Agr. Econ.* **86**(2), 467–482 (2004).
54. StataCorp, (2025). Stata 19 Base Reference Manual. College Station, TX: Stata Press.
55. Penn, J. M. & Hu, W. Understanding hypothetical bias: An enhanced meta-analysis. *Am. J. Agr. Econ.* **100**(4), 1186–1206 (2018).
56. Siegrist, M. Trust and risk perception: A critical review of the literature. *Risk Anal.* **41**(3), 480–490 (2019).
57. Lancaster, K. J. A new approach to consumer theory. *J. Polit. Econ.* **74**(2), 132–157 (1966).
58. Nelson, P. Information and consumer behaviour. *J. Polit. Econ.* **78**(2), 311–329 (1970).
59. Darby, M. R. & Karni, E. Free competition and the optimal amount of fraud. *J. Law Econ.* **16**(1), 67–88 (1973).
60. Grunert, K. G., Hieke, S. & Wills, J. Sustainability labels on food products: Consumer motivation, understanding and use. *Food Policy* **44**, 177–189 (2014).
61. Grant, K. R., Gallardo, R. K. & McCluskey, J. J. Consumer preferences for foods with clean labels and new food technologies. *Agribusiness* **37**(4), 764–781 (2021).

62. Lähteenmäki, L. et al. Acceptability of genetically modified cheese presented as real product alternative. *Food Qual. Prefer.* **13**(7–8), 523–533 (2002).

Author contributions

R.S. and G.P. wrote the main manuscript text. K.Y. performed statistical analysis. R.N. validated the experimental design and the entire study. All authors reviewed the manuscript.

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Declarations

Ethical statements

All procedures were performed in accordance with relevant guidelines and regulations (e.g., Italian GDPR 2016/679 and Declaration of Helsinki). Approval to conduct this study was granted by the departmental Ethical Committee of the Catania University. They confirmed that for economic stated-preference research formal ethical approval was not required, as the study involved no risks or monetary transactions. Written informed consent was obtained from all participants prior to their inclusion in the study.

Additional information

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