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Consumer heterogeneity in the acceptance of genome-edited wines: evidence from information treatments and preference segmentation

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1. Introduction

In recent years, the European wine sector has faced increasing pressure to reduce the environmental impact of agricultural practices and to ensure greater sustainability throughout the entire value chain. Within this context, Italy represents a particularly relevant case study, as it is one of the world's leading wine producers and exporters. National production has fluctuated around 45–50 million hectolitres annually, accounting for approximately 20% of global output, with exports exceeding €7 billion per year. The sector represents a key pillar of the Italian agri-food economy and plays a crucial role in rural employment and regional development (ISMEA, 2024).

Given the economic and territorial importance of the sector, environmental pressures, including recurrent drought periods, rising temperatures, extreme weather events, biodiversity loss, and increasing restrictions on chemical inputs, have intensified the need for innovative and environmentally sustainable cultivation strategies (Baltazar et al., 2025; Qaim, 2020; Borrello et al., 2021). In this context, New Breeding Techniques (NBTs) are generating growing interest among policymakers, research institutions, and wine producers as tools capable of combining genetic innovation, sustainability, and regulatory compliance (EFSA Panel on Genetically Modified Organisms, 2021; Zezza and Vassallo, 2024).

Indeed, NBTs can contribute positively to sustainable wine production, as demonstrated by numerous publications (Nogué et al., 2024; Moffa et al., 2025) and by genome-edited crop varieties that have already reached commercial stages in several non-European countries (Ishii and Araki, 2016; Bonea, 2024).

The success of NBTs lies in their speed, simplicity, and precision. This precision is what distinguishes NBTs from traditional genetically modified organisms (GMOs). With CRISPR, it is possible to modify a specific genomic site without necessarily inserting foreign DNA. The type of mutation introduced is indistinguishable from one that could occur naturally. For this reason, in several countries — including the United States, Canada, Australia, China, and India — plants obtained through NBTs are not classified as GMOs and are therefore not subject to GMO-specific regulations.

This enables a faster pathway from development to adoption, better aligned with the needs of producers and consumers at a time when climate change requires urgent responses (Matinvafa et al., 2023).

The absence of regulatory constraints places NBTs in a distinct regulatory and perceptual category, with potential social implications (Vives-Vallés and Gangjee, 2025). However, despite this seemingly favorable framework, consumer acceptance remains a crucial factor for the adoption and commercial success of wines obtained through such technologies.

In the European Union, the regulatory treatment of New Genomic Techniques remains under active debate. Recent policy proposals, including the distinction between NGT-1 and NGT-2 categories, reflect an evolving legal framework in which NBTs and organic production are currently positioned as institutionally distinct approaches (Molitorisová et al., 2025). This regulatory transition highlights the relevance of examining how consumers perceive these attributes when presented jointly in a hypothetical market context, as public evaluations may not necessarily mirror formal institutional classifications.

While NBTs offer significant agronomic and technical advantages, their market diffusion ultimately depends on consumer acceptance. A growing body of empirical research conducted across North America, Europe, Latin America, and Asia indicates that public responses to genome editing technologies are neither uniformly positive nor uniformly negative, but rather heterogeneous and context-dependent (Cummings and Peters, 2022; Ballco et al., 2025; Gatica-Arias et al., 2019; Ishii and Araki, 2016). Consumer evaluations have been shown to depend on perceived benefits, pricing implications, institutional trust, and cultural framing. In several studies, acceptance increases when clear environmental or consumer-oriented advantages—such as reductions in

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pesticide use—are explicitly communicated, while low baseline awareness often generates uncertainty or conditional support (Stofer et al., 2023; Gao et al., 2024; Paudel et al., 2023; Beghin and Gustafson, 2021). For instance, evidence from Spain suggests that consumer support for CRISPR-edited products becomes more favorable when substantial sustainability improvements are demonstrated (Ballco et al., 2025).

However, most existing investigations focus on staple crops and vegetables, with limited attention devoted to products characterized by strong symbolic, territorial, and regulatory dimensions. Wine represents a particularly distinctive case, as it is closely associated with notions of terroir, authenticity, and Protected Designations of Origin (PDO), as well as with premium positioning and cultural tradition. These features may amplify the salience of technological interventions and shape consumer interpretations in ways that differ from other agri-food categories. Against this background, examining consumer responses to NBT-derived wines within sustainability and geographical indication contexts addresses an important and currently underexplored research gap.

In addition to these perceptual dimensions, it is also important to consider how NBTs differ from other innovation pathways currently discussed in viticulture.

Unlike PIWI grape varieties (Pilzwiderstandsfähig), which are developed through crossbreeding between *Vitis vinifera* and fungus-resistant species, NBTs can be applied directly to varieties registered under Protected Designation of Origin (PDO) schemes, enabling the development of disease-resistant vines while preserving the varietal, territorial, and sensory traits (Casanova-Gascón et al., 2019). This characteristic offers extraordinary potential for protection consortia and producers seeking to innovate without compromising typicity (Andersen et al., 2015).

From an agronomic perspective, NBTs offer greater versatility than PIWI hybrids, allowing not only resistance to fungal pathogens but also improvements in tolerance to abiotic stress, water-use efficiency, and oenological quality (Gisi, 2022). Their application could therefore help address the challenges posed by climate change and phytosanitary restrictions, without conflicting with the legislative constraints that limit the use of hybrids in many European PDOs.

In parallel with scientific and regulatory advances, there has been a growing interest among consumers in sustainably produced wines, which ensure transparency, traceability, and low environmental impact throughout the supply chain (Galati et al., 2022; Fernqvist et al., 2022a). It is precisely at this intersection, between biotechnological innovation and the increasing demand for sustainable wines, that the present study is positioned. The aim is to investigate whether, and to what extent, new genetic techniques are accepted by consumers and valued as a positive attribute in their wine purchase decisions.

To the best of our knowledge, current scientific literature does not yet offer a study specifically focused on this topic within the wine sector. Most existing research has examined the impacts of NBTs in other agri-food domains, such as fruits and vegetables (Götz et al., 2022), vegetable oils (An et al., 2019), soy (Son and Lim, 2021), fruits (Uddin et al., 2021), potatoes (Muringai et al., 2020), animal products (Ortega et al., 2020), rice (Hao et al., 2024), or generic food categories (Ortega et al., 2022; Fernqvist et al., 2022b), while largely overlooking the wine domain.

Understanding consumer acceptance is essential because the commercial success of genome-edited products ultimately depends not only on technological feasibility and regulatory approval, but also on market legitimacy. Wine represents a particularly relevant case study in this context due to its strong symbolic, territorial, and regulatory dimensions, which may amplify consumer sensitivity to technological interventions compared to staple crops. Despite the economic and cultural importance of the wine sector, empirical evidence on consumer responses to NBT applications in wine remains extremely limited, thereby justifying the need for targeted investigation.

To address this research gap, it is essential to consider a variety of factors that may directly or indirectly influence the impact of genetic innovations on consumer behavior. Acceptance may be shaped by cognitive, cultural, and perceptual variables, such as familiarity with biotechnologies, prior knowledge, trust in science, orientation toward sustainability, and openness to new information (Lusk et al., 2018; Onwezen et al., 2013; Albertsen et al., 2020; Frewer et al., 2003). Moreover, a key role in fostering acceptance is played by how these technologies are communicated: the type of information provided, narrative framing, and transparency of the message can significantly affect risk perception and acceptance levels (Santeramo et al., 2021).

These considerations support the hypothesis that the impact of NBTs in the wine sector will depend not only on their technological attributes, but also on the informational context to which consumers are exposed, their level of knowledge, and their attitudes toward sustainability. In light of this, the present study aims to address four main research questions (R1, R2, R3, R4), consistent with the assessment of consumer impacts related to the application of genetic editing technologies in wine production:

- (R1) Do NBTs significantly influence wine purchase decisions at the aggregate level?
- (R2) Can distinct consumer segments be identified based on their preferences for wines obtained through NBTs, and how are these segments characterized in terms of attitudes toward environmental sustainability and genetic innovation in agriculture?
- (R3) Does prior knowledge or familiarity with new genetic techniques affect the likelihood of choosing a wine made using these technologies?
- (R4) How does information about NBTs influence consumer wine choices, and what effect does it have among individuals unfamiliar with these technologies?

To answer these research questions, a Discrete Choice Experiment (DCE) was designed, initially estimated using a Mixed Logit Model and subsequently refined through a Latent Class Choice Analysis, which allowed segmentation of consumer preferences in relation to the perceived impact of genetic innovations, initial knowledge levels, and exposure to specific information. To formally test the role of information framing in shaping consumer preferences, we embed a randomized informational treatment within the survey design. This experimental component allows us to identify the effect of alternative communication framings on wine choice behavior and to assess whether exposure to different framings systematically affects latent class membership probabilities.

This paper is structured as follows: the first section outlines the state of the art, focusing on previous research addressing how environmental sustainability, genetic innovation, and food neophobia influence wine consumer behavior. The following section presents the methodological framework, the results of the analysis, and finally a discussion of the findings.

2. State of the art on sustainability, genetic modification, and food neophobia in wine consumer behavior

The literature on consumer responses to genetic innovations in food has evolved from early studies on GMOs (e.g., Frewer et al., 2003; Siegrist, 2008) to more recent analyses of genome-editing technologies (e.g., Bearth et al., 2024; Han et al., 2025). Within this broader debate, environmental sustainability has emerged as one of the main drivers of food choices, particularly in product segments with high symbolic and cultural value, such as wine (D'Amico et al., 2016).

European consumers are increasingly attentive to factors such as carbon footprint, responsible vineyard management, and label transparency (Martínez-Navarro and Sellers-Rubio, 2024; Schaufele and Hamm, 2017). Sustainability is progressively perceived as a distinctive product value, capable of influencing purchasing decisions even when associated with a premium price, especially among younger and more educated consumers (Pomarici and Vecchio, 2014). Willingness to pay for sustainable attributes emerges as a dynamic variable, which depends on the clarity of the message conveyed, the experiential context, and the credibility of information sources (Vecchio et al., 2021; Sogari et al., 2015). While the concept of sustainability has traditionally focused on production techniques, packaging, and transportation (Scozzafava et al., 2024), new genetic technologies offer promising opportunities to increase plant resistance to biotic stressors and improve resilience to climate-related challenges (Vives-Vallés and Gangjee, 2025).

The issue of consumer responses to genetic innovations in agriculture is the subject of a broad and multifaceted debate, which has so far only marginally involved the wine sector. Studies in agri-food contexts reveal that genome editing technologies are often perceived ambivalently: on the one hand, they are associated with promises of sustainability, higher productivity, and reduced pesticide use; on the other, they raise concerns regarding food naturalness, transparency, and health safety (Meerza et al., 2024; Caputo et al., 2020; Han et al., 2025; Marette et al., 2021; Bearth et al., 2024; Ding et al., 2023). Consumer attitudes are strongly influenced by the type of information provided, the narrative framing, and the emotions elicited (Marette et al., 2021; De Marchi et al., 2021). Detailed, scientifically grounded, and sustainability-oriented communication has been shown to significantly alter consumer preferences and reduce information asymmetry (Caputo et al., 2025; Borrello et al., 2021). In the case of genetic innovation, narratives focusing on environmental benefits, compatibility with tradition, and traceability can increase acceptance, even among more skeptical consumer segments (Orivri et al., 2024; Ferrari et al., 2021). Nevertheless, Vecchio et al. (2022), in their analysis of PIWI grape variety acceptance, highlight that the introduction of genetic innovation in viticulture is far from straightforward. Wine is a product with high symbolic value, deeply tied to notions of tradition, naturalness, and terroir. Within this cultural framework, consumer reactions to new technologies are often shaped by ideological stances, low scientific literacy, and high levels of food neophobia (Sogari et al., 2018; Giacalone and Jaeger, 2023; Baum et al., 2023; Parrella et al., 2024).

Food neophobia, in particular, has been identified as a key predictor of resistance to the adoption of biotechnological innovations (Bearth et al., 2024), especially in markets where the product carries strong identity and cultural connotations (Pliner and Hobden, 1992; Siegrist, 2008).

However, several studies suggest that factors such as personal orientation toward sustainability, trust in science, and openness to new information can mitigate the effects of neophobia and foster greater acceptance of genomic techniques (Nawaz and Satterfield, 2022; Martin-Collado et al., 2022), including in the wine sector (Capitello and Sirieix, 2019; Ristic et al., 2016). In this context, a relevant contribution comes from research exploring the role of trust as a central psychological lever in consumer decision-making. Specifically, trust in science, regulatory authorities, and agribusiness companies is considered a key factor in the acceptance of genome editing, particularly when these innovations are communicated in ways that align with perceived values such as environmental responsibility, traceability, and transparency (Paudel et al., 2023; Kajale and Becker, 2014).

The reviewed literature shows that consumer reactions to the introduction of genetic technologies are far from uniform, and are shaped by a complex interplay of cognitive, emotional, and informational factors. For this reason, a deep understanding of these dynamics is essential, as consumer behavior represents the main barrier (or conversely, a potential driver) for the diffusion of such innovations (Sikora and Rzymski, 2021). Identifying the key drivers that influence wine purchasing decisions thus becomes a strategic step toward supporting the responsible adoption of genetic technologies in viticulture.

3. Methodology

3.1. Choice experiment design

Consumers' preferences were investigated using a Discrete Choice Experiment (DCE), a widely adopted method for assessing the value attributed to product attributes. This approach has been extensively applied in consumer studies on food products in general (Alfnes et al., 2006), and wine in particular (Bazzani et al., 2024; Mazzocchi et al., 2019; Costanigro et al., 2019). The experimental design involved administering a structured questionnaire aimed at capturing consumers' psychographic profiles and their preferences regarding the purchase of a bottle of red wine for a special occasion. This specific context was selected to emphasize the symbolic and reputational dimensions of the product, thereby making participants more sensitive to qualitative, identity-related, and innovative variables (De Toni et al., 2022).

The questionnaire consisted of multiple sections. The first section served as a screening phase, excluding respondents who had not purchased or consumed red wine on at least one special occasion in the past three months. This was followed by a section on wine consumption habits, alongside the choice experiment module. A dedicated section explored attitudes, perceptions, and knowledge levels regarding sustainability and genetic innovation in agriculture. The survey concluded with a demographic section. A dedicated section of the questionnaire measured respondents' attitudes toward environmental sustainability in wine production and toward genetic innovation in agriculture using 5-point Likert scales (1 = strongly disagree/not important, 5 = strongly agree/very important). Items were adapted from established literature on food technology acceptance and sustainability orientation (e.g., Frewer et al., 2003; Lusk et al., 2018; Sogari et al., 2018).

Prior knowledge of New Breeding Techniques (NBTs) was measured through a dichotomous self-reported familiarity indicator (0 = no prior knowledge; 1 = prior knowledge).

Socio-demographic variables included gender, age, education level, employment status, income bracket, and macro-regional residence.

The objective was to include both the main drivers traditionally associated with wine choice for special occasions and the innovative attribute under investigation, the application of new genetic techniques in viticulture. The selected attributes and corresponding levels used in the choice profiles are as follows:

- **Price** (€18, €24, €30, €36) – levels chosen to reflect a realistic premium price range, consistent with high perceived-value wines;
- **Organic certification** (present/absent);
- **Vite TEA** (present/absent) – described as *"wine produced using NBTs"* in the Italian version of the questionnaire;
- **DOCG denomination (Barolo/Brunello) -** two of the most prestigious and internationally celebrated Italian wine appellations, selected for their strong territorial identity, symbolic capital, and established premium market positioning. These denominations, traditionally associated with the emblematic grape varieties Nebbiolo and Sangiovese respectively, represent benchmark quality signals within the Italian wine sector. Moreover, previous scientific research has explored advanced biotechnological techniques in these cultivars, including protoplast regeneration in Sangiovese (Bertini et al., 2019; Gambino et al., 2024), which constitutes a technical prerequisite for genome-editing applications.
- **No choice option** – included to capture respondent behavior in scenarios where neither alternative is considered preferable, thus enhancing the model's realism and robustness.

The selection of attributes and levels was informed by a structured review of the wine marketing and food choice experiment literature, ensuring theoretical relevance, empirical consistency with prior DCE applications, and contextual appropriateness for the Italian premium wine segment.

Price was included as a standard economic attribute allowing the estimation of willingness to pay and reflecting established practice in wine DCE studies (González-Juárez et al., 2022; Tait et al., 2019; Costanigro et al., 2019). The inclusion of the DOCG denomination reflects the documented role of geographical indications as symbolic and quality cues in wine purchasing decisions (Beckert et al., 2017; Scozzafava et al., 2016). Organic certification was selected as a benchmark sustainability attribute, given its well-established relevance in shaping consumer preferences for environmentally friendly wines (Ruggeri et al., 2020; Pomarici and Vecchio, 2014; Schäufele and Hamm, 2017; Scozzafava et al., 2021). Finally, the "Vite TEA" attribute was introduced as the focal innovation variable, consistent with emerging literature examining consumer responses to genome editing in agri-food contexts (Caputo et al., 2020; Bearth et al., 2024). Attribute levels were defined to reflect realistic market conditions and to ensure managerial and policy relevance, particularly within the premium segment associated with wine purchases for special occasions.

The inclusion of both organic certification and the NBT (Vite TEA) attribute does not imply regulatory compatibility between the two production approaches. Rather, their joint presence in the experimental design allows the exploration of consumer trade-offs and perceived coherence between sustainability signals and technological innovation within a hypothetical market context. Given the evolving European regulatory framework and ongoing policy discussions, testing these attribute combinations provides empirical insight into consumer perceptions independently from current institutional classifications. Discrete Choice Experiments are particularly suited to investigate such hypothetical combinations, as they allow the isolation of attribute effects even in contexts where institutional alignment is still under development. Importantly, our econometric specification estimates the main (marginal) effects of each attribute on choice; we do not model interaction effects between organic and NBT attributes, and thus we do not make claims about combined or synergistic effects.

The experimental design was developed using Ngene software, adopting a labeled D-optimal efficient design (Street and Burgess, 2007) consisting of 12 choice sets (reported in Appendix 1). Fig. 1 presents an example of how the choice sets were displayed to respondents.

Data were collected in June 2025 through the professional online panel provider Toluna (https://www.toluna.com/it/). Participants were recruited using quota-based sampling procedures to ensure alignment with national demographic patterns of Italian wine consumers. Quotas were defined according to official statistics assessed by Italian National Institute of Statistics (ISTAT) with respect to gender, age distribution, and macro-geographical residence (North, Centre, South and Islands).

To ensure relevance to the research context, respondents were required to meet a screening criterion consisting of having purchased or consumed red wine for a special occasion within the previous three months. Individuals who did not satisfy this condition were excluded from participation. A total of 1050 valid responses were retained for analysis after excluding incomplete questionnaires and observations failing quality control checks (e.g., unrealistically short completion times or inconsistent response patterns). The final sample reflects the demographic structure of Italian wine consumers in terms of gender composition, age classes, and regional distribution, thereby supporting the external validity of the study (please see Annex 2).

Participants were randomly assigned to three different informational treatments prior to completing the choice experiment (350 consumers per treatment group, with identical demographic distributions across age, gender, and region). The full text of the treatments is provided in note.[1] Two of these treatments included information regarding the meaning of the attribute "Vite TEA", while the third contained no information (baseline). The aim was to examine how different informational framings affect consumers' perceptions when choosing wine. The two information treatments, while sharing a common factual base, differed in tone, wording, and potential perceptual impact on the recipients.

The first message presented a more detailed narrative, using technical yet accessible language, and framed NBTs as a natural evolution of traditional cross-breeding techniques. The technology was described as a tool to accelerate existing practices, with explicit references to "natural mutants" and the use of enzymes, aiming to reassure the reader about the naturalness and safety of the intervention. This version emphasized the emergency context of climate change and the need for faster responses to plant health and environmental challenges. Agronomic and ecological benefits, such as stress resistance and reduction in chemical inputs, were clearly highlighted. The symbolic framing aimed to position NBTs as a continuation of tradition, rather than a rupture from it.

The second message, by contrast, adopted a more concise and assertive communication style. The key feature here was the use of more technical and neutral terminology, explicitly referring to the technique as "genetic engineering", while clarifying that no foreign DNA is introduced, in order to prevent consumers from associating the method with transgenic technologies. As in the first message, agronomic and ecological benefits were mentioned (e.g., stress resistance and reduced

Fig. 1. Example of a choice set shown to participants.

[1] **Treatment 1:** No Information – Baseline.

Treatment 2: The label VITE TEA – Tecnica di Evoluzione Assistita indicates that the wine in the bottle was produced from plants obtained through a new breeding technique. This technique allows for the development of a plant that could have been obtained using traditional cross-breeding methods, although the latter would require much longer timeframes—no longer compatible with the challenges posed by climate change. This new technique uses enzymes to deactivate certain genes, in the same way that natural mutations occur, thereby increasing the plant's resistance to diseases, pathogens, and adverse environmental conditions (such as drought). As a result, it is possible to reduce chemical inputs (pesticides and fungicides), water usage, and fertilizer application.

Treatment 3: The label VITE TEA – Tecnica di Evoluzione Assistita indicates that the wine in the bottle was produced from plants obtained using a new genetic engineering technique which, by modifying the genes of the vine without introducing any external DNA, enables the selection of plants that are more resistant to diseases, pathogens, and adverse environmental conditions (such as drought). This allows for a reduction in the use of chemical inputs (pesticides and fungicides), water, and fertilizers.

chemical inputs), but without references to tradition or naturalness.

The two information treatments thus reflect distinct communication models. The first emphasizes continuity with traditional viticultural practices and includes ecological appeals. The second favors a purely technical-scientific tone, omitting any cultural or ideological framing. The comparison between these two approaches enables an analysis of how information framing may steer consumer sensitivity toward the identity-related, qualitative, or innovative dimensions of the product, ultimately shaping individual preferences and stated choice behavior**.**

4. Statistical power and sample size assessment

To address the adequacy of the sample size and the statistical power of the Latent Class Choice Model (LCCM), a formal two-step assessment was conducted.

First, a design-based benchmark was computed following recent methodological guidance for discrete choice experiments (Assele et al., 2023). Under a multinomial logit (MNL) approximation, the minimum required sample size depends on the number of choice tasks per respondent (T), the number of alternatives per task (A), and the number of parameters to be estimated (K).

A commonly used heuristic consistent with the design-based logic (also related to Johnson & Orme's rule) is:

$$N \geq \frac{500 \cdot K}{T \cdot A}$$

and considering T = 12 choice sets, A = 2 product alternatives (excluding the opt-out for a conservative calculation), and K = 8 parameters in the corresponding MNL specification, the minimum required sample size is approximately 167 respondents. Even under more conservative assumptions (e.g., K = 12), the required sample remains below 250 observations. The actual sample size (N = 1050) substantially exceeds these design-based benchmarks.

Second, and more importantly, a parametric Monte Carlo power analysis was performed to evaluate statistical power within the latent class framework. The simulation replicated the observed experimental structure (1050 respondents; 12 choice tasks; two product alternatives plus opt-out; five retained latent classes with shares of 33%, 27%, 22%, 8%, and 6%). For each of 1000 replications, parameters were drawn from asymptotic normal distributions centered on the estimated coefficients, using the estimated variance–covariance matrix. Choice probabilities were generated according to the logit specification, and hypothesis tests were recomputed for both class-specific utility parameters and membership covariates. Empirical power was calculated as the proportion of replications rejecting the null hypothesis at $\alpha = 0.05$.

The results indicate high statistical power for attributes with moderate to large estimated coefficients, including in smaller latent classes (6–8% of the sample). Instances of low empirical power correspond to parameters with near-zero estimated effects, indicating that non-significant results reflect small effect sizes rather than insufficient sample size. Full simulation results are reported in Appendix 3.

5. Data analysis framework

Consumer choices were analyzed within the framework of Random Utility Maximization (RUM), which assumes that individuals derive utility from the attributes of the alternatives presented in each choice set (McFadden, 1974). The utility that individual i derives from choosing alternative j in choice situation t can be expressed as:

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} \tag{1}$$

where Vijt represents the deterministic component of utility, specified as a function of observed attributes and parameters to be estimated, and ε_ijt is a stochastic error term capturing unobserved influences.

The deterministic component of utility is specified as:

$$V_{ijt} = \beta_i' X_{ijt} \tag{2}$$

where Xijt is a vector of alternative attributes and the opt-out. The vector βi captures individual-specific taste parameters.

5.1. Mixed Logit Model

To account for unobserved preference heterogeneity across respondents, a Mixed Logit (MXL) model was first estimated. In this specification, parameters are allowed to vary randomly across individuals according to specified distributions:

$$\beta_i = \overline{\beta} + \eta_i \tag{3}$$

where $\overline{\beta}$ represents the population mean parameters and η_i captures individual-specific deviations.

Under this framework, the choice probability is obtained as:

$$P_{ijt} = \int \frac{\exp(\beta_i' X_{ijt})}{\sum_k exp(\beta_i' X_{ijt})} f(\beta_i \mathrm{I}\theta) \mathrm{d}\beta_i \tag{4}$$

where f (β_i |θ) denotes the density function of the random parameters. Estimation was conducted using simulated maximum likelihood procedures.

The Mixed Logit model serves as a diagnostic step to assess the presence and magnitude of preference heterogeneity. The statistical significance of parameter standard deviations provides empirical support for adopting a segmentation-based approach. Preference heterogeneity is an inherent feature of discrete choice models within the Random Utility framework. The objective of the present analysis is therefore not to demonstrate the existence of heterogeneity per se, but to identify structured and economically interpretable forms of variation in consumer preferences across latent segments.

5.2. Latent Class Choice Model

To identify structured and interpretable forms of heterogeneity, a Latent Class Choice (LCC) model was estimated (Vermunt and Magidson, 2021). Unlike the MXL model, which assumes continuous heterogeneity, the LCC model assumes that the population consists of a finite number of latent classes, each characterized by homogeneous preference parameters.

For each class c, the deterministic utility component is specified as:

$$V_{ijtc} = \beta_c' X_{ijt} \tag{5}$$

Conditional on class membership, the probability that individual i chooses alternative j follows a standard logit formulation:

$$P_{ij\mathrm{I}c} = \frac{\exp(\beta_c' X_{ij})}{\sum_k \exp(\beta_c' X_{ik})} \tag{6}$$

The unconditional probability is obtained by weighting across classes:

$$P_{ij\mathrm{I}c} = \sum_c \pi_{ic} P_{ij\mathrm{I}c} \tag{7}$$

5.3. Active covariates in class membership

Class membership probabilities are modeled as:

$$\pi_{ic} = \frac{\exp(\gamma_c' Z_i)}{\sum_m \exp(\gamma_m' Z_i)} \tag{8}$$

where Z_i includes active covariates. In our case (i) prior knowledge of NBTs (binary indicator) and (ii) informational treatment assignment (categorical experimental variable).

These covariates enter directly into the class membership function and are estimated jointly with class-specific utility parameters. This specification allows formal statistical testing of whether prior familiarity with genome-editing technologies and exposure to different informational framings systematically influence the probability of belonging to segments characterized by positive, neutral, or negative preferences toward NBT-derived wines.

The statistical significance of these effects is evaluated using Wald tests, both at the class-specific level and jointly across classes. Therefore, prior knowledge and informational treatments are not treated as descriptive background variables, but as active determinants of preference segmentation within the discrete choice framework.

This modeling strategy allows the segmentation structure itself to be partially explained rather than purely data-driven, linking cognitive and informational variables to observed heterogeneity in preferences, while remaining within a Random Utility framework.

5.4. Model selection and estimation

Models with an increasing number of latent classes were estimated to determine the optimal segmentation structure. The selection of the optimal number of latent classes was guided by established statistical and informational criteria from the literature (Greene and Hensher, 2003), such as log-likelihood values, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), entropy measures, and economic interpretability of class profiles. The selected model represents the best balance between statistical fit, parsimony, and substantive interpretability. All models were estimated using maximum likelihood procedures. It is important to clarify that the objective of the analysis is not causal identification in a structural econometric sense. Rather, the study investigates structured preference heterogeneity and the association between cognitive variables, informational treatments, and class membership probabilities within a discrete choice modeling framework.

6. Results

6.1. Model 1 - mixed logit

The initial estimation was conducted using a Mixed Logit (MXL) model to assess aggregate attribute effects while accounting for unobserved heterogeneity in individual choices. Table 1 reports the estimated mean coefficients and standard deviations of the random parameters. Significant standard deviations indicate the presence of preference heterogeneity across respondents.

The results indicate that several attributes exert a statistically significant influence on choice. Price, estimated with a fixed coefficient, shows the expected negative and highly significant effect, confirming sensitivity to price across the sample. The “organic” attribute exhibits a large and highly significant mean coefficient, indicating that environmental sustainability positively affects choice. The associated standard deviation is also significant, suggesting considerable heterogeneity in preferences. The central attribute related to R1 (“Vite TEA”) presents a non-significant mean coefficient, indicating no significant aggregate effect. However, its standard deviation is large and statistically significant, revealing substantial variation in individual-level preferences.

Table 1
Mixed Logit model estimates (mean coefficients and standard deviations).

Attributes	Mean coef.	z-value	p-value	S.D.	z-value (σ)	p-value (σ)
Price	−0.0349	−19.02	<0.001	0.1002	—	—
Organic	0.7749	15.20	<0.001	1.3396	25.63	<0.001
Vite TEA	0.0251	0.81	0.421	0.5865	13.87	<0.001
DOCG	0.0200	0.77	0.442	0.4053	10.52	<0.001
No choice	−3.7812	−21.01	<0.001	2.5761	—	—

The geographical indication (“denomination/DOCG”) displays a non-significant mean coefficient and moderate variance. The “no choice” parameter is negative and highly significant, confirming respondents’ active engagement in the choice tasks. The presence of significant variance components across several attributes indicates heterogeneity in consumer preferences, which is further explored through Latent Class analysis.

6.2. Model 2 - Latent Class Choice

To address R2, a Latent Class Choice (LCC) model was estimated to identify distinct segments of consumers based on their choice patterns. A series of models with an increasing number of classes was estimated using LatentGold software (see Table 2), and the optimal specification was selected based on model fit criteria. With respect to R3 and R4, prior knowledge of NBTs and informational treatment were included as active covariates in the class membership function. This specification allows the estimation of how the probability of belonging to each segment varies according to cognitive familiarity and exposure to different informational framings.

Among the estimated specifications, a 5 + 1 class solution was selected based on model fit and parsimony criteria. In all models, an additional class was included to capture respondents with less structured choice patterns. Although the log-likelihood improves as the number of classes increases, the Bayesian Information Criterion (BIC) indicates diminishing informational gains beyond the 5 + 1 specification. The selected model shows an increase in explained variance (pseudo-R^2 from 0.3936 to 0.4308) and maintains high classification quality (entropy >0.88). Table 3 reports the estimated attribute coefficients and covariate effects for each latent segment in the 5 + 1 class model. Wald statistics confirm the statistical significance of the main attributes and active covariates.

6.3. Class 1 – Symbolic Consumers Open to innovation

This group, the largest segment (33% of the sample), is characterized by a relatively balanced weighting of attributes, without a clear dominance structure. All attribute coefficients are statistically significant and of similar magnitude, with the exception of price, which assumes a positive and significant value (β = 0.0306; z = 8.68). This indicates a deviation from the expected negative relationship typically associated with a cost attribute. In this segment, price appears to function as a quality signal rather than as a financial constraint, consistent with previous literature on symbolic wine consumption (Palma et al., 2016; Lo Monaco et al., 2020).

Such effects are consistent with findings in symbolic markets, where perceived value is influenced not only by intrinsic product characteristics but also by external cues such as price and geographical denomination (Beckert et al., 2017; De Toni et al., 2022). Evidence of a Veblen-type effect in the wine sector has also been documented (Simeone et al., 2023).

Within this class, price operates alongside denomination cues: this is the only cluster exhibiting a significant preference for Barolo (β = 0.1161; z = 3.28). Positive and statistically significant coefficients are also observed for both “Vite TEA” (β = 0.1531; z = 3.74) and organic certification (β = 0.1924; z = 3.90).

From a socio-demographic perspective, this class aligns closely with the sample average in terms of gender (62% male) and age (mean age 41), with slight overrepresentation in the North-West and underrepresentation in Southern regions. Educational attainment is above average, with a higher share of university graduates. Employment levels are high, with relatively low shares of unemployed respondents and students. Individuals in this class, together with those in Class 6, report the highest income levels in the sample (approximately 35% above the overall average).

Table 2
Comparative model fit statistics for Latent Class Choice models.

Model	Log-likelihood	AIC	BIC	R^2 Overall	R^2 (0)	Entropia	LMR (p-value)
1 + 1 classes	−11068,14	22.171,06	22.146,28	0.0576	0.1940	1.0000	—
2 + 1 classes	−9608,45	19.314,29	19.244,90	0.2426	0.3521	0.8809	0.0332
3 + 1 classes	−8904,86	17.969,72	17.855,72	0.3357	0.4318	0.9044	0.0350
4 + 1 classes	−8611,12	17.444,84	17.286,23	0.3936	0.4813	0.8809	0.0603
5 + 1 classes	**−8385,04**	**17.055,30**	**16.852,08**	**0.4308**	**0.5132**	**0.8864**	**0.0642**
6 + 1 classes	−8213,72	16.775,27	16.527,44	0.4627	0.5404	0.8816	0.0747
7 + 1 classes	−8087,25	16.584,95	16.292,51	0.4808	0.5559	0.8833	0.0772

6.4. Class 2– eco-innovators

The second segment (27%) is characterized by strong positive coefficients for organic certification ($\beta = 2.7025$; $z = 22.00$) and for “Vite TEA” ($\beta = 0.5421$; $z = 6.39$), indicating a structured preference profile in which sustainability and genetic innovation are positively valued. The price coefficient is negative and statistically significant ($\beta = -0.0163$; $z = -2.14$). Estimated willingness to pay is particularly high for organic certification and positive for the genetic innovation attribute.

Socio-demographically, gender (57% male) and age (mean 40) are close to the sample average. This segment is underrepresented in the North-West and overrepresented in the North-East and Central regions. Educational attainment is above average, with a high concentration of Bachelor's and postgraduate degrees. Unemployment rates are low, and income distribution is concentrated in middle-income brackets (€15,000–€30,000).

6.5. Class 3 – Price-Sensitive Pragmatists

Class 3 (22%) is characterized by a strong and negative price effect ($\beta = -0.2183$; $z = -14.95$), while other attributes—including “Vite TEA,” organic certification, and denomination—are not statistically significant. The “no choice” parameter is strongly negative ($\beta = -8.6978$; $z = -22.46$), indicating active participation in the choice tasks. This segment includes the highest proportion of male respondents (65%) and reflects the average sample age (42 years). It is overrepresented in the North-West and underrepresented in the North-East and Central regions. Educational levels are below average, with a higher share of high school diplomas and lower representation of postgraduate degrees. Income distribution closely mirrors the sample average.

6.6. Class 4 – Selective Environmentalists

This class (8%) shows a positive and significant coefficient for organic certification ($\beta = 0.4789$; $z = 2.98$) and a strong negative price effect ($\beta = -0.2580$; $z = -13.17$). The “Vite TEA” attribute is not statistically significant. Gender distribution aligns with the sample average (59% male), and this class has the highest average age (47 years). It is overrepresented in the North-East and underrepresented in Central and Southern regions. Educational attainment is generally below average, although the proportion of PhD holders is slightly above average. This class includes the highest proportion of retirees and relatively higher unemployment rates. Income distribution is concentrated in the €15,000–€30,000 range, with overrepresentation in the lowest income bracket (<€15,000).

6.7. Class 5 – Traditionalists Opposed to innovation

Class 5 (6%) is the only segment in which the “Vite TEA” attribute shows a strongly negative and statistically significant coefficient ($\beta = -3.5090$; $z = -13.24$). Organic certification and denomination are not statistically significant, while price has a moderately negative effect ($\beta = -0.0637$; $z = -4.53$).

The “no choice” parameter remains negative ($\beta = -2.3595$), indicating continued engagement with the choice tasks. This class includes a relatively higher proportion of female respondents and has an average age of 45 years. It is overrepresented in Central and Southern Italy and underrepresented in the North-West. Educational attainment is below average, with a higher share of respondents without formal degrees. Income levels are generally lower than the sample average.

6.8. Class 6 – No effect

Class 6 (4%) is characterized by the absence of statistically significant attribute effects, suggesting a limited and weakly structured utility specification within the set of observed attributes. This segment likely reflects unobserved decision criteria not explicitly modeled in the experiment.

The analysis of consumer attitudes toward sustainability (Table 4a, Question Q5) and genetic innovation (Table 4b. Question Q8) reveals statistically significant differences across the identified latent segments. ANOVA results comparing the five latent classes with respect to the perceived importance of sustainable production methods (1 = not important, 5 = very important) and attitudes toward genetic innovation in agriculture (1 = strongly opposed, 5 = strongly in favour), lead to rejection of the null hypothesis of attitudinal homogeneity across segments ($F = 32.75$, $p < 0.001$ for Q5; $F = 15.39$, $p < 0.001$ for Q8). These findings indicate systematic differences in value orientations and perceptions among the identified classes.

Tables 4a and 4ba and 4b report the mean values and within-cluster variance of attitudinal responses for each segment, together with the ANOVA statistics comparing latent classes.

The Tukey post-hoc analysis confirms statistically significant differences across the latent classes for both variables under consideration. Regarding the importance attributed to sustainability in wine selection for a special occasion, Classes 1 and 2 exhibit the highest mean scores and differ significantly from Classes 3, 4, and 5, which report lower values. Class 5 records the lowest mean score and differs significantly from the more sustainability-oriented segments.

With respect to attitudes toward genetic innovation in agriculture, distinct patterns also emerge. Classes 1, 2, and 3 report higher mean evaluations and differ significantly from Classes 4 and 5, which show lower levels of support. Class 5 records the lowest mean score, while Class 4 occupies an intermediate position but remains significantly different from the first three segments.

Overall, the post-hoc results indicate that both sustainability orientation and attitudes toward genetic innovation vary systematically across the identified consumer segments.

7. The role of prior knowledge of NBTs in class membership probability

The inclusion of the dichotomous variable “prior knowledge of new genetic techniques” directly addresses Research Question 3 (R3), which seeks to determine whether familiarity with these technologies influences the likelihood of choosing a wine produced through NBTs. This variable was introduced as an active covariate in the Latent Class Choice (LCC) model to assess its contribution to the latent structure of preferences and, specifically, to class membership.

Table 3
LCC Estimated coefficients.

Variable	Class 1 - Symbolic Consumers Open to Innovation	Class 2 - Eco-innovators	Class 3 – Price-sensitive Pragmatists	Class 4 – Selective Environmentalists	Class 5 - Traditionalists Opposed to Innovation	Class 6 - (no effect)	Wald χ^2 (p)
DOCG	0.1161 (3.28) ***	−0.0059 (−0.08)	−0.0464 (−0.65)	−0.1606 (−1.14)	0.1792 (1.09)	0.0000 (.)	13.82 (p = 0.017)
Organic	0.1924 (3.90) ***	2.7025 (22.00) ***	0.1027 (0.85)	0.4789 (2.98) ***	0.6933 (3.38) ***	0.0000 (.)	528.84 (p < 0.001)
Vite TEA	0.1531 (3.74) ***	0.5421 (6.39) ***	0.0678 (0.87)	0.0070 (0.05)	−3.5090 (−13.24) ***	0.0000 (.)	259.88 (p < 0.001)
Price	0.0306 (8.68) ***	−0.0163 (−2.14) **	−0.2183 (−14.95) ***	−0.2580 (−13.17) ***	−0.0637 (−4.53) ***	0.0000 (.)	651.49 (p < 0.001)
No Choice	−3.6255 (−13.03) ***	−3.7110 (−13.75) ***	−8.6978 (−22.46) ***	−4.8953 (−12.10) ***	−2.3595 (−5.28) ***	0.0000 (.)	1047.97 (p < 0.001)
NBTs Knowledge	−0.0000 (.)	−0.5817 (−3.09) ***	−1.2066 (−5.82) ***	−1.8683 (−5.18) ***	−2.6037 (−4.26) ***	−0.8505 (−0.14)	63.95 (p < 0.001)
Information Treatment 1	0.0000 (.)	−0.0000 (.)	−0.0000 (.)	−0.0000 (.)	−0.0000 (.)	−0.0000 (.)	20.90 (p = 0.022)
Information Treatment 2	−0.0000 (.)	0.3227 (1.44)	0.5154 (2.21) **	0.5022 (1.60)	1.4676 (2.90) **	−0.1862 (−0.45)	
Information Treatment 3	−0.0000 (.)	0.0606 (0.27)	0.3920 (1.73)	0.1477 (0.45)	1.6040 (3.27) ***	−0.7878 (−1.59)	

z-values in parentheses; ***$p < 0.01$; *$p < 0.05$.

Table 4a
Differences across classes in attitudes toward environmental sustainability.

Attitudes toward environmental sustainability (Q5)				
Cluster	*Count*	*Sum*	*Mean*	*Variance*
1	338	1426	4,218935	0,581005
2	289	1297	4,487889	0,340999
3	235	879	3,740426	1,030624
4	86	327	3,802326	0,7487
5	59	232	3,932203	1,133255

Variance analysis						
Source of variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between groups	86,89323	4	21,72331	32,75458	1,08E-25	2,380813
Within groups	664,5407	1002	0,663214			
Total	751,434	1006				

Table 4b
Differences across classes in attitudes toward genetic innovation.

Attitudes toward genetic innovation (Q8)				
Cluster	*Count*	*Sum*	*Mean*	*Variance*
1	338	1054	3,118343	1,250048
2	289	920	3,183391	1,150279
3	235	737	3,13617	0,94719
4	86	233	2,709302	0,985089
5	59	126	2,135593	0,774401

Variance analysis						
Source of variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between groups	67,77878	4	16,94469	15,39537	3,16E-12	2,380813
Within groups	1102,837	1002	1,100636			
Total	1170,616	1006				

The results indicate a significant effect of prior knowledge (Wald $\chi^2 = 63.95$; $p < 0.001$), with the associated coefficients being negative for all classes relative to the baseline (Class 1 – Symbolic Consumers Open to Innovation). This suggests that, ceteris paribus, individuals reporting familiarity with NBTs are more likely to belong to Class 1 than to any other segment. Knowledge of NBTs therefore appears more strongly associated with this segment, which includes consumers who rely on symbolic attributes such as extrinsic product characteristics, use price as a quality cue, and express a positive attitude toward genetic innovation. While the decrease in the probability of belonging to other classes as knowledge increases may be expected for segments such as Class 5 (Traditionalists Opposed to Innovation), which displays strong rejection of NBTs, it is less intuitive for Class 2 (Eco-Innovators), which shows the highest positive coefficient for the “Vite TEA” attribute ($\beta = 0.5421$; $p < 0.001$). This pattern suggests that support for innovation in Class 2 may be shaped less by technical familiarity and more by broader value orientations, such as environmental concern and openness to innovation. More generally, knowledge does not automatically imply agreement or acceptance. Individuals may be familiar with a technology yet evaluate it differently depending on their underlying values and perceptions.

For Class 5, the negative and statistically significant coefficient associated with prior knowledge ($\beta = -2.6037$; $z = -4.26$; $p < 0.001$) indicates that respondents familiar with NBTs are less likely to belong to this segment. This result suggests that limited familiarity may be associated with more precautionary or defensive attitudes toward genetic innovation in the wine sector.

Classes 3 (Price-Sensitive Pragmatists) and 4 (Selective Environmentalists) also display negative and statistically significant coefficients, although of smaller magnitude. In these cases, the probability of class membership decreases as prior knowledge increases.

Overall, prior knowledge appears to be associated with more structured and differentiated preference patterns toward genetic innovation. Unlike short-term informational exposure, familiarity with NBTs may provide a more stable interpretative framework through which consumers evaluate technological attributes.

8. The role of information in the segmentation of preferences

The second active covariate included in the model refers to the informational treatment provided to participants prior to the choice experiment and directly addresses Research Question 4 (R4). The overall effect of information is statistically significant (Wald $\chi^2 = 20.90$; $p = 0.022$), though it displays heterogeneity across classes.

Model results indicate that informational treatments exert statistically significant effects—albeit in different directions—on certain segments. Specifically, the technical-popularized message (Treatment 2), which contextualized NBTs as an evolution of traditional varietal crossing methods, has a significant effect on Class 3 – Price-Sensitive Pragmatists ($\beta = 0.5154$; $z = 2.21$; $p < 0.05$) and on Class 5 – Traditionalists Opposed to Innovation ($\beta = 1.4676$; $z = 2.90$; $p < 0.01$). The message emphasizing scientific transparency and technological efficiency (Treatment 3) shows a statistically significant effect only for Class 5 ($\beta = 1.6040$; $z = 3.27$; $p < 0.001$).

Information about NBT methodologies is therefore associated with an increased probability of belonging to Class 5, particularly under the more technical framing (Treatment 3). For Class 3, the effect is significant only under Treatment 2, while for the remaining classes no statistically significant changes are observed.

These findings suggest that informational interventions do not operate uniformly across consumer segments and may interact with pre-existing attitudes. This pattern is consistent with research in risk perception (Siegrist and Hartmann, 2020), which shows that information is often interpreted through existing cognitive and value-based frameworks. In some cases, technical or regulatory messages may reinforce prior skepticism rather than modify it.

9. Discussion

The results highlight the complex and value-driven nature of consumer acceptance of NBTs in the wine sector, consistent with evidence showing that responses to food technologies are shaped more by symbolic and perceptual dimensions than by purely technical considerations (Idris et al., 2023; Hu et al., 2022; Siegrist and Hartmann, 2020). The Mixed Logit model indicates that the average effect of NBTs on wine choice is not statistically significant. However, the significant standard deviation reveals substantial preference heterogeneity, confirming a polarized structure of consumer responses. Rather than a homogeneous consensus, reactions to genetic innovation in viticulture are highly differentiated, in line with evidence on PIWI grape varieties (Vecchio et al., 2022) and broader international studies on genome-edited food, where acceptance patterns are segmented and influenced by socio-demographic characteristics, cultural orientations, and trust in institutions (Verma et al., 2023; Bullock et al., 2021).

The Latent Class analysis further clarifies this heterogeneity by identifying structured and economically meaningful segments. A majority of respondents display either positive or neutral attitudes toward the “Vite TEA” attribute, while only a small minority expresses strong opposition. This distribution mirrors patterns observed in other agri-food contexts, where acceptance of genome editing tends to be higher among younger, male, and highly educated consumers (Caputo et al., 2020, 2025), traits that characterize the most innovation-oriented clusters in our sample.

The identification of an “Eco-Innovators” segment (Class 2) is particularly relevant. These consumers coherently associate environmental sustainability with genetic innovation, suggesting that technological progress is not necessarily perceived as incompatible with sustainability values. This finding aligns with Castellini et al. (2025), who show that strong environmental concern and trust in science significantly increase openness to emerging food technologies.

At the same time, the role of prior knowledge is nuanced. While familiarity with NBTs increases the likelihood of belonging to more accepting segments (Lindberg et al., 2023), support for innovation in Class 2 appears to be driven less by technical literacy and more by broader attitudinal orientations and value systems, consistent with Costa et al. (2025). This suggests that pro-innovation preferences may emerge even in the absence of detailed scientific knowledge, provided that the technology resonates with pre-existing worldviews, such as sustainability or progress orientation.

In contrast, the “Traditionalists opposed to innovation” (Class 5) display strong and ideologically rooted resistance to NBTs. Their profile is consistent with patterns associated with food neophobia (Pliner and Hobden, 1992; Sogari et al., 2018) and heightened risk perception among individuals with lower educational attainment and socioeconomic vulnerability (Bearth et al., 2022). For this segment, opposition appears less linked to specific technical concerns and more to symbolic interpretations of naturalness and technological intrusion.

The impact of informational treatments further reinforces this interpretation. The more technical framing (Treatment 3) increased the probability of assignment to the most resistant class, suggesting a potential backfire effect in line with risk communication literature (Orivri et al., 2024; Siegrist and Hartmann, 2020). This finding highlights that communication strategies centered exclusively on technical explanations may fail to address underlying value-based concerns and may even intensify resistance when they lack cultural resonance.

This dynamic is closely related to how consumers cognitively frame the distinction between traditional GMOs and NBTs. Even though respondents’ knowledge of both technologies was measured and one informational treatment explicitly clarified that NBTs do not involve the insertion of foreign DNA, consumer evaluations may still be influenced by broader associations linked to the concept of “genetic modification.” Therefore, resistance toward NBT-derived wines may not simply reflect insufficient technical understanding, but rather deeper symbolic and normative attitudes toward human intervention in natural processes. At the same time, the significant role of prior knowledge suggests that lower familiarity may lead some consumers to implicitly assimilate NBTs to more controversial notions of genetic modification.

The organic attribute emerged as a consistent and shared driver of choice, reaffirming the primacy of perceived sustainability in wine purchasing decisions, in line with previous research (Sogari et al., 2015; Scozzafava et al., 2021).

The relevance of sustainability-oriented attributes observed in our results is consistent with broader evidence showing that environmental concerns increasingly influence food purchasing decisions. In particular, research on meat consumption highlights how information about environmental impacts can shift preferences toward lower-impact alternatives (Poore and Nemecek, 2018). Our findings suggest that similar sustainability considerations are also embedded in consumer choices within culturally symbolic categories such as wine. At the same time, unlike staple foods such as meat, wine carries additional identity and territorial dimensions, which may moderate or interact with environmental motivations in shaping consumer responses. Notably, even among organic-oriented consumers (Class 4), there is no automatic transfer of trust toward genetic techniques. This confirms that a preference for sustainability does not necessarily translate into unconditional openness to technological innovation (D'Amico et al., 2016; Vecchio et al., 2022).

An additional point concerns the empirical relationship between the

NBT attribute and organic certification within the experimental framework. Organic certification and New Genomic Techniques are currently treated as institutionally distinct within the EU regulatory framework. At the same time, the inclusion or exclusion of NGTs in organic production remains part of an ongoing scientific and policy debate (Molitorisová et al., 2025).

The present study does not take a normative position on this debate. Rather, it estimates the independent marginal effects of organic certification and NBT attributes in consumer choice.

The results show that both attributes exert statistically significant effects on utility, but the econometric specification does not include interaction terms. Therefore, the analysis does not test complementarity or substitution patterns between the two production approaches.

The attitudinal evidence further indicates that sustainability orientation and acceptance of genetic innovation represent partially distinct evaluative dimensions. While some segments display positive coefficients for both attributes, others combine relatively high sustainability attitudes with rejection of the NBT attribute. This confirms that environmental concern does not automatically translate into openness to technological innovation.

In a symbolically dense sector such as wine, where territorial identity and perceived naturalness are central to value construction, consumer responses to innovation are shaped by multiple value-based considerations (Idris et al., 2023).

10. Conclusion and policy implications

This study provides novel evidence on consumer heterogeneity in the acceptance of genome-edited wines within a premium and symbolically dense product category. Using a Random Utility Maximization framework and Latent Class analysis, the results show that New Breeding Techniques do not exert a uniform effect on wine choices. While the average impact is statistically neutral, this masks substantial heterogeneity across consumer segments.

With respect to R1, NBTs act as a polarizing attribute rather than a universally accepted innovation. A majority of consumers exhibit either positive or neutral responses, whereas a small but clearly identifiable segment expresses strong opposition.

Regarding R2, the segmentation analysis reveals economically meaningful clusters, ranging from "Eco-Innovators" who positively integrate sustainability and technological progress, to "Traditionalists" characterized by ideological resistance.

The results indicate that organic certification and the NBT attribute exert independent marginal effects in consumer choice. The study does not test perceived regulatory compatibility between organic production and genome-editing technologies. Rather, the findings highlight the multidimensional nature of consumer evaluations, showing that sustainability orientation and acceptance of genetic innovation represent distinct attitudinal dimensions across segments.

Concerning R3, prior knowledge of NBTs significantly influences class membership. Familiarity reduces the likelihood of belonging to strongly resistant segments, suggesting that scientific literacy plays a moderating role in shaping acceptance.

Finally, with reference to R4, informational treatments produce heterogeneous and sometimes counterproductive effects. Technical framing may reinforce opposition among skeptical consumers, highlighting the importance of culturally aligned communication strategies.

The results indicate that uniform communication approaches are unlikely to be effective. Instead, segmentation-based strategies are required. For innovation-oriented and sustainability-driven consumers, communication emphasizing environmental benefits and climate resilience may enhance acceptance. For more conservative segments, messages should stress continuity with tradition, varietal identity, and territorial heritage.

In a regulatory context characterized by ongoing institutional developments, clarity in communication and labelling will likely play a key role in shaping consumer understanding. Given the long production cycles in viticulture and the experimental stage of NBT applications in wine, understanding how consumer perceptions evolve alongside regulatory frameworks will be crucial.

Overall, the market potential of genome-edited wines depends not only on technological performance, but on the dynamic alignment between innovation, consumer values, regulatory clarity, and communication strategies. The findings have differentiated implications across stakeholder groups. For policymakers, the segmented nature of consumer responses suggests that regulatory communication should avoid binary framings of acceptance versus rejection. For producers and consortia, the presence of innovation-oriented segments indicates a potential early-adopter niche, while traditionalist consumers require more cautious positioning. For retailers, segmentation-based strategies appear more appropriate than uniform market launches. Finally, the significant role of prior knowledge highlights the importance of long-term educational initiatives over short-term technical communication campaigns.

11. Limitations and future research

Despite the methodological robustness of the study, several limitations should be acknowledged. First, the analysis relies on stated preferences derived from a discrete choice experiment and may therefore be subject to hypothetical bias. Second, the focus on Italian consumers limits the external validity of the findings, particularly in contexts characterized by different cultural attitudes or regulatory frameworks. Third, the experimental design estimates only main attribute effects and does not model interaction terms, such as those between organic certification and genome-editing technologies, which could further clarify potential complementarity or substitution dynamics. Fourth, the informational treatments capture short-term framing effects and do not account for longer-term processes of knowledge formation or shifts in public discourse. Fifth, although the study conceptually distinguishes between GMOs and NBTs, it does not directly measure the extent to which consumers cognitively differentiate between these technologies. Future research could employ dedicated psychometric measures to better assess perceived similarities, symbolic associations, and risk attributions. Finally, the cross-sectional nature of the data prevents dynamic analysis of evolving consumer attitudes, particularly in light of ongoing EU regulatory developments such as the NGT-1 and NGT-2 distinction. Longitudinal and cross-country studies would provide valuable extensions of the present findings.

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

During the preparation of the revised manuscript, the authors used generative AI tools (ChatGPT, OpenAI) solely to assist with the translation of the text into English and with minor language editing. After using this tool, the authors carefully reviewed, revised, and edited the content as needed, and take full responsibility for the accuracy, originality, and integrity of the published article.

CRediT authorship contribution statement

Gabriele Scozzafava: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft. **Manuela Campa:** Validation, Visualization, Writing – review & editing. **Enrico Marone:** Conceptualization, Data curation, Formal analysis, Resources, Validation, Writing – review & editing.

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. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clrc.2026.100420.

Data availability

Data will be made available on request.

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