Agriculture and Food

AIMS Agriculture and Food, 11(3): 487–509.
DOI: 10.3934/agrfood.2026025
Received: 29 January 2026
Revised: 24 April 2026
Accepted: 26 June 2026
Published: 13 July 2026

https://www.aimspress.com/journal/agriculture

Research article

Balancing sustainability, tradition, and innovation: How neophobia shapes consumer preferences for apple varieties

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Abstract: In the Italian apple market, where consumption is deeply rooted in tradition and innovation increasingly focuses on developing climate-resilient varieties, consumer preferences are evolving accordingly. This study applies principal component analysis (PCA) and best-worst scaling (BWS) methods to identify the key factors driving apple purchasing decisions in a sample of 2,096 Italian consumers and examines how these preferences relate to attitudes towards sustainable and novel apple varieties. Particular attention was given to the influence of food neophobia and neophilia in shaping consumer responses to innovation and sustainability-related attributes. Three clusters were identified: sustainability-oriented innovators valued all three pillars of sustainability, environmental, economic, and social, and showed strong interest in certifications, local origin, and novel varieties, while being less price-sensitive. Sustainability-oriented traditionalists also prioritized environmental and economic sustainability and placed the highest importance on sensory qualities and local origin but were more conservative toward novelty. Sustainability-reluctant, in contrast, showed low interest in sustainability-related attributes, and were more price-driven, assigning relatively greater importance to brand and variety. Findings highlight the heterogeneity in consumer expectations and the central role of sustainability, particularly economic and short supply chain, in shaping preferences. Organoleptic characteristics remain crucial, especially for tradition-oriented consumers, while openness to innovation aligns with stronger engagement in sustainability. These insights have strategic implications for producers, marketers, and policymakers aiming to support sustainable innovation in the fruit sector. Targeted communication and product development strategies should align with the values of distinct consumer profiles to foster a more resilient and sustainable agri-food system.

Keywords: food; behavior; apple fruit; economic sustainability; neophilia; varieties

Abbreviation

PCA: Principal Component Analysis; BWS: Best-Worst Scaling; Ops: Producer Organisations

1. Introduction

In Italian and European culture, it is said that *an apple a day keeps the doctor away*, reinforcing its reputation as a powerhouse of health benefits. The mix of these beneficial elements varies from variety to variety, making each apple unique in its nutritional profile and aromatic composition [1]. Although apples are perceived by Italian consumers as a fruit mainly for the elderly, the last few decades have seen a new wave of interest in them, a consumption that is no longer driven primarily by health aspects, but by their versatility in culinary preparations, their taste, and their growing appeal to people of all ages [2].

Among all fruit and vegetable sectors, the apple supply chain is one where brands are most strongly recognised by Italian consumers. The main producers, with a total Italian production of almost 2,162,500 tonnes in 2024, are located in Trentino-Alto Adige and Piedmont. A considerable share of apple production in Italy is managed by producer organisations (OPs), cooperatives, or other forms of associations, reflecting a highly structured and collaborative supply chain [3]. Local production can lead consumers to perceive the product as more genuine, authentic, environmentally sustainable, or beneficial to the local economy [4,5].

The sector has developed both in terms of production volume and export growth [3], accompanied by greater product diversification. Significant production in Italy is recorded for Golden Delicious, Gala, Red Delicious, and other major varieties. Club apples are the result of breeding regulated by licences. The latter have experienced a substantial growth, reaching a new production record in the past year [6]. There has also been a notable increase in the range of apple varieties available to meet consumer preferences in terms of organoleptic characteristics [6,7], as well as colour and size [8]. Alongside this diversification, different packaging options, such as bags and trays of four apples, have become available, and price segmentation has increased. These aspects reflect the growing presence of premium products that emphasise origin, production methods, and added value, such as sustainability and traceability [9,10]. Several agronomic and genetic studies have developed apple varieties resistant to sunburn from excessive solar radiation. These varieties maintain high productivity and fruit quality under climate change and rising temperatures, promoting more sustainable water use [11–13]. In addition, these varieties have enhanced natural resistance to pathogens, helping to reduce the need for pesticide applications. Varieties such as Nicoter Kanzi® and R205 Kissabel® have demonstrated improved adaptability to changing environmental conditions [14].

Today's consumers are not only looking for food products based on taste, price or brand, but are also considering value attributes, such as sustainable production and distributions, quality and sustainability certifications, and guarantee of traceability [10]. This evolution reflects growing pro-environmental values and attitude among people, influenced by their beliefs and by the socio-cultural and political context [15]. Recent evidence suggests that consumers are increasingly likely to associate food quality with environmentally sustainable attributes. These include organic production, reducing the carbon footprint, eco-friendly practices, and sustainability certifications [16]. These attributes have become important determinants of purchase intentions and willingness to pay, though the effectiveness of sustainability information on labels varies significantly depending on label

specificity and consumer segment [17]. Organic certification, one of the most widely recognised environmentally friendly schemes, is perceived as highly reliable, offering traceability and ensuring food safety through minimal pesticide use, an important factor given that consumers often eat the fruit's skin [10]. However, research on organic consumers in Italy suggests that origin and production process information may be valued more highly than the organic label itself in some product categories, particularly among consumers who are already familiar with organic products [18]

Cognitive biases may influence apple consumption, particularly regarding newly introduced varieties or ancient cultivars reintroduced to the market. As shown in previous studies on novel foods, neophobia can play a role in shaping consumer preferences [19,20]. However, familiar foods can be used to counteract unfamiliarity and reduce neophobia [21]. Recent evidence from the agri-food sector suggests that consumer acceptance of innovative agricultural products is strongly influenced by attitudes towards innovation and familiarity with the production process. This highlights the importance of psychological and informational factors in shaping purchase intentions [22]. Numerous studies have investigated consumers preferences for these attributes, helping to identify the main drivers of purchasing behaviour. On the economic and environmental front, studies have focused on the value placed on sustainable agricultural practices and traceability. [10,23] examined the impact of packaging and price in China and in a China-UK comparison, respectively. In the Latin American context, [24,25] analysed preferences for organic or low-chemical farming methods. Interest in organoleptic attributes is well established: studies conducted in Italy [26,27] and abroad [28,29] confirmed the importance of taste, aroma, crunchiness, and visual appeal. These aspects are often associated with credibility attributes, such as certifications and ethical or environmental labels, which influence perceived quality [30,31]. Some studies have focused on local origin [32] and the acceptability of nutritional innovations [33,34]. Traceability and certification also emerged as key factors in the valuation of specific varieties, such as Fuji apples [35,36]. Finally, cultural and technological dimensions influence both willingness to pay (WTP) and product acceptance [37–39].

However, climate change and evolving consumer perceptions, partly driven by rebranding strategies, are reshaping the reference market. Despite the growing body of research on consumer preferences for apples, most studies have examined individual attributes, such as taste, origin, and certifications, without offering an integrated understanding of how these factors interact to shape purchasing behavior. Moreover, limited attention has been devoted to the cognitive dynamics influencing the acceptance of novel or club varieties in mature markets, such as Italy, where consumers are familiar with the fruit but may now perceive it through a renewed lens. Addressing these gaps, this study investigates how recent transformations in production and perception affect consumer habits and attitudes towards new apple varieties associated with sustainability values, providing insights for repositioning apples as a fruit with greater character and stronger market appeal. Unlike previous studies, which have typically analyzed either apple product attributes or food neophobia in isolation, this research takes an integrated approach, combining preference elicitation with consumer profiling based on attitudes towards novelty and sustainability. Specifically, the study examines the interaction between food neophobia and neophilia in the evaluation of sustainable and innovative apple varieties, including club cultivars. This extends current knowledge on consumer acceptance of emerging products in the apple sector.

Methodologically, the present study applies the best-worst scaling (BWS) method to evaluate consumer preferences for apples. Its proven effectiveness in capturing robust preference hierarchies and its ability to account for a large number of product attributes can help bridge the gap and contribute

to our understanding of how consumers prioritize diverse apple characteristics in real-world decision-making. Additionally, the rising interest in club varieties and novel cultivars, often unfamiliar to consumers, introduces cognitive biases that may influence acceptance and perceived value.

This study aims to investigate consumer preferences for apples by identifying and ranking the most relevant product attributes through the application of the BWS method, with a particular focus on consumer responses to novel or unfamiliar varieties. A thorough analysis of attribute relevance can guide effective product positioning and reveal consumer expectations for both new and traditional apple varieties. The profiling of different consumption patterns provides insights into varying levels of interest towards new varieties and neophobia.

To reach these aims, two research questions were formulated.

1. Can distinct consumer segments be identified based on attitudes towards novelty and interest in sustainable apple production?

2. How do food neophobia and interest in innovation influence consumer preferences for sustainable apple products?

This research, through an in-depth analysis of the cultural dynamics and motivations driving apple preferences, contributes to the scientific literature by defining different consumption profiles and advancing understanding of how the intersection of tradition, innovation, and sustainability can shape the future of the food system.

2. Materials and methods

2.1. Data collection

A total of 2,096 Italian participants completed an online questionnaire. The sample was evenly split, with 50% women and 50% men. The web-based survey was developed and distributed nationwide through a specialised agency with expertise in consumer data collection. The survey was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and was approved by the Bioethics Committee of the University of Turin (Protocol No. 0565148, September 27th 2024). Prior to completing the questionnaire, all participants provided informed consent. The estimated time for completion was approximately ten minutes. The only exclusion criterion was being under 18 years of age. To ensure data completeness for scientific purposes, only fully completed questionnaires were included in the final analysis.

A cross-sectional questionnaire was developed in three sections: i) socio-demographic characteristics (including gender, age, family size, educational level, food habits, religion, and average income); ii) measures of interest in the different externalities that new apple varieties or production approaches might have on sustainability in its three dimensions, and the level of neophobia towards new apple varieties (The scales employed are described in Table 1.); and iii) measures of declared preferences towards preference experimental design according to the BWS approach.

Table 1. Scales definition in the consumer survey.

Scale	Question and characteristics	Items
Perceived externalities of new apple varieties (Scale 1)	Interest in new varieties or new production processes [40]	1. Safeguarding biodiversity 2. Reducing land and water resource consumption 3. Preserving local cultivars 4. Protecting workers' employment 5. Safeguarding the landscape and surrounding territory 6. Protecting the income of employees and producers 7. Supporting the local community 8. Fostering interaction among the different actors in the supply chain
Food Neophobia scale (Scale 2)	Ad-hoc created food neophobia scale starting from Sogari et al. (2023) adapted for new varieties apple consumption	1. I always taste new and different varieties of apples 2. I don't trust new apple varieties 3. If I don't know what kind of apples they are, I don't taste them 4. I like apples from different regions 5. Apples I don't know seem strange to me 6. I'm afraid to taste new apple varieties that I'm not familiar with 7. When it comes to the fruit I eat, I consider myself a picky person 8. I eat almost all apple varieties

For the psychometric scale the importance assigned to each statement in the two scales was assessed using a 7-point Likert-type scale (from 1 = *not all important or completely disagree* to 7 = *very important* or *totally agree*). The self-constructed ad hoc scale, starting from the food neophobia scale (FNS) widely applied in studies on novel food acceptance [42], was revised to include items specific to the consumption of new apple varieties. The reliability of the new scale was assessed using Cronbach's alpha, which showed a value of 0.85, indicating good internal consistency [43,44].

2.2. BWS

BWS methodology is a discrete choice model in which respondents' stated preferences toward certain quality attributes are measured. BWS methodology has been adopted in various research domains, including environmental conservation [45–47], product manufacturing [48], food labelling [49], and purchasing decisions [50,51]. Stated preference methods, such as those that measure behavioural intentions, have proven to be effective predictors of actual behaviour [45]. In this research, the experimental design followed that of [52] and involved the selection of 12 apple-fruit attributes (Table 2).

Table 2. Attributes of apples employed in the BWS design.

Items	Abbreviation	References
Certification of environmental sustainability certification related to natural resource management and biodiversity protection	Environmental sustainability certification	[19,53]
Certification of social sustainability geared toward greater cooperation between industry players and the community	Social sustainability Certification	[54–56]
Certification of economic sustainability that guarantees a fair income for workers and promotes a short supply chain	Economic sustainability certification	[57]
Certification of traceability	Certification of traceability	[58,59]
Organic Certification	Organic Certification	[4,24]
Colour	Colour	[8,60]
Variety (Delicius, Gala, Fuji...)	Variety	[6,29,61]
Organoleptic characteristics (taste, crispness, texture, aroma)	Organoleptic characteristics	[7,26,29]
Local origin	Local origin	[4,62,63]
Packaging	Packaging	[64]
Price	Price	[24,28,38,62]
Brand	Brand	[61,65]

The balanced incomplete block design (BIBD) was employed to ensure an equal distribution of the 12 selected attributes in random combinations within the choice tasks [66]. Each participant completed nine sets of BWS questions, with each set containing four attributes (b) randomly drawn from the original list of 12 attributes (n) [66–69]. This approach helped reduce cognitive load and respondent fatigue, compared to simple rating scales such as the Likert scale [70]. The design was created using Sawtooth software (SSI version 8.4.6, Orem, UT, USA; http://www.sawtoothsoftware.com/), which optimised statistical efficiency and minimised order bias. Each item appeared three (t) times per respondent, and four different questionnaire versions were developed to maximise the variety of item-pair combinations. In each BWS question, respondents were asked to identify the alternative they perceived as the "best" and the "worst" from the given set (the pair of items with the greatest preference difference). Repeatedly selecting the pair with the highest preference contrast allowed for a detailed analysis of consumer preferences and the relative importance of each apple attribute. The data obtained from the BWS questions were analysed using Sawtooth Software within a discrete-choice modelling framework. The dataset was structured as an input matrix comprising n rows (n = sample size) and 18 columns arranged into nine pairs. Each pair of columns represented a single BWS question, where one column recorded the position (1–4) of the attribute selected as "BEST," while the other indicated the position of the attribute chosen as "WORST," also within the 1–4 range [47,52,71]. Additionally, an extra column identified the specific questionnaire version (1–4) completed by each participant.

To analyse the BWS responses, a hierarchical Bayesian (HB) approach was applied, utilising a logit model to estimate the likelihood of an attribute being selected as "best" or "worst" at both the

individual and population levels [49]. The HB algorithm employed Monte Carlo Markov chain (MCMC) sampling, iteratively refining estimates until convergence was achieved. This procedure generated individual-level utility scores for each attribute, which were then aggregated to compute the sample-level average raw score (ARS). The ARS values, which could be either positive or negative, ranked the 12 attributes according to their relative importance, providing a detailed insight into consumer preferences.

2.3. Data analysis

Exploratory factor analysis was conducted to identify the underlying dimensions driving attribute preferences and attitudes towards novelty. Specifically, a PCA with Varimax rotation was applied to reduce and summarise the variables related to interest in new apple varieties (Scale 1) and food neophobia (Scale 2). Component loadings greater than 0.35 were considered meaningful [73]. Subsequently, a cluster analysis was performed using the factors extracted from the PCA to segment consumers and capture heterogeneity within the sample [74]. Outliers were first screened through hierarchical clustering using the single-linkage method. Ward's method was then applied to determine the appropriate number of clusters, which subsequently informed a k-means analysis, an efficient technique for large datasets [75,76]. Based on the agglomeration schedule and dendrogram [77], a three-cluster solution was selected as best representing the heterogeneity in consumers' sustainability-related apple preferences. The 3-cluster solution was validated computing the average silhouette width 0.30, indicating reasonable cluster structure and bootstrap resampling (B = 100), yielding mean Jaccard similarity coefficients of 0.65, 0.65, and 0.58 for clusters 1, 2, and 3 respectively, suggesting moderate stability across all clusters [78]. All analyses were conducted in IBM SPSS Statistics 29.0 (version 29.0; IBM, Armonk, NY, USA). Finally, after checking that the sample is normal with Shapiro–Wilk test, ANOVA one-way was conducted on the Raw Scores (preference indexes) obtained by means of the best-worst analysis, followed by Tukey's post-hoc test for pairwise comparisons. All analyses were performed using SPSS software. The socio-demographic characterisation of the clusters was carried out using the Chi-squared test.

3. Results

3.1. Sociodemographic characteristics of the sample

Table 3 shows the socio-demographic characteristics of the sample. The participants were equally divided between men and women, with a slight percentage of non-binary individuals or those who preferred not to answer. The participants' ages ranged from 18 to 70, and they were evenly distributed across the four age ranges. The largest group was aged 55 to 70, followed by 30 to 44. More than half of the sample came from the North West, South and Islands of Italy. When the Italian population was divided by area, the sample was equally divided by geographical origin according to Nielsen area [79]. The average number of household members in the sample was three. However, a similar percentage of households consisted of two or four members.

Table 3. Socio-demographic characteristics of the sample.

Variable	Description	Number of respondents	Share of sample (%)
Gender	Men	1,051	50.1%
	Women	1,039	49.6%
	Non-binary	5	0.2%
	I prefer not to answer	1	0.1%
Age	18–29	383	18.3%
	30–44	554	26.4%
	45–54	477	22.8%
	55–70	682	32.5%
Area (Italy)	North West	567	27.1%
	North East	410	19.5%
	Centre	409	19.5%
	South and Island	710	33.9%
Employment situation	Student	172	8.2%
	Employed	1,166	55.6%
	Self-employed	247	11.8%
	Housemaker	187	8.9%
	Unemployed/Seeking employment	159	7.6%
	Other	165	7.9%
School-age children	No one	1,460	69.6%
	1 component	385	18.4%
	2 components	215	10.3%
	More than 2 components	36	1.7%
Household composition	1	261	12.5%
	2	551	26.3%
	3	624	29.8%
	4	536	25.5%
	5 or more	124	5.9%
Income range	Less than 25,000 €	623	29.7%
	25,000–40,000 €	752	35.9%
	40,001–60,000 €	334	15.9%
	More than 60,000 €	129	6.2%
	I prefer not to answer	258	12.3%

3.2. Principal Component Analysis (PCA)

PCA identified three principal components, which explained 71.9% of the total variance (see Table 4). The first component (PC1), labelled *Pro-sustainable Apple*, accounted for 40.6% of the variance and reflects a positive attitude towards sustainable apple production, encompassing all three dimensions of sustainability (environmental, social, and economic). The second component (PC2), labelled *neophobic*, explained 21.1% of the variance and was associated with a reluctance to try new products, reflecting a general fear or distrust of novelty. The third component (PC3), labelled *neophilic*, accounted for 10.1% of the variance represented the opposite tendency: a favourable disposition

towards novelty and an interest in trying new products. The three new variables were validated using the Cronbach's alpha method. The values are shown in Table 4. Cronbach's alpha values indicate high internal consistency for factors 1 and 2 (PC1 and PC2), with values of 0.944 and 0.901, respectively. Factor 3 shows lower, but still acceptable, reliability (0.765). This difference may reflect the greater heterogeneity and conceptual complexity of consumers' attitudes towards novelty, which encompass both curiosity and openness to unfamiliar products.

Table 4. PCA with Varimax rotation: components of interest and neophobia attitude towards new apple varieties (n = 2,096). Each component is named according to consumption patterns described by significance of values.

Variables	Principal components		
	PC1 (Pro-sustainable Apple)	PC2 (Neophobic)	PC3 (Neophilic)
Interest towards new apple varieties			
Safeguarding biodiversity	0.766		
Reducing land and water resource consumption	0.806		
Preserving local cultivars	0.851		
Protecting workers' employment	0.851		
Safeguarding the landscape and surrounding territory	0.841		
Protecting the income of employees and producers	0.863		
Supporting the local community	0.848		
Fostering interaction among the different actors in the supply chain	0.840		
Food Neophobia scale (adapted for new varieties apple consumption)			
I always taste new and different varieties of apples			0.801
I don't trust new apple varieties		0.847	
If I don't know what kind of apples they are, I don't taste them		0.870	
I like apples from different regions			0.766
Apples I don't know seem strange to me		0.877	
I'm afraid to taste new apple varieties that I'm not familiar with		0.900	
When it comes to the fruit I eat, I consider myself a picky person		0.720	
I eat almost all apple varieties			0.827
Cronbach's alpha	0.944	0.901	0.765

Note: Kaiser–Meyer–Olkin index = 0.92. Bartlett's sphericity test: Chi square = 23304.022; *** p-value = <0.001. Non-significant values (<±0.35) are not shown.

Three clusters were identified, as shown in Table 5. The first cluster, *sustainability-oriented innovators* (46.6% of the total sample), consisted of individuals open to trying new apple varieties and demonstrated a positive attitude towards sustainability, making them the most receptive segment for innovative and sustainable apple products. The second cluster, *sustainability-oriented traditionalists*

(28.1% of the total sample), showed low enthusiasm for novelty but a strong concern for sustainability in apple production. These individuals were traditional in attitude but motivated by environmental and ethical values. The third cluster, *sustainability-reluctant* (25.3% of the sample), appeared indifferent to both novelty and sustainability and individuals' preferences were conservative, showing minimal engagement in sustainability issues.

Table 5. Clustering of respondents according to PCA.

	Cluster analysis		
	Sustainability-oriented innovators	Sustainability-oriented traditionalists	Sustainability-reluctant
Distribution	46.6%	28.1%	25.3%
Principal components			
Pro-sustainable Apple (PC1)	0.345	0.624	- 1.325
Neophobic (PC2)	- 0.028	- 0.111	0.174
Neophilic (PC3)	0.746	- 1.08	- 0.172

From the results of the BWS (Table 6), it emerged that the *sustainability-oriented innovators* showed high interest in all three dimensions of sustainability, with higher scores compared to the other clusters, particularly for environmental sustainability certifications related to natural resource management and biodiversity protection, and economic sustainability certifications that ensure fair income for workers and promote a short supply chain. This was the only cluster with a positive interest in social sustainability certifications, which aim to foster greater cooperation between sector operators and the wider community. The individuals of this cluster placed high importance on organic certification, traceability systems, and local origin. Organoleptic characteristics were also appreciated, although to a slightly lesser extent than by the *sustainability-oriented traditionalists*. This cluster exhibited the highest inclination towards novelty and low-price sensitivity, indicating greater openness to innovative and potentially premium products. Like in the other clusters, they assigned low importance to packaging and brand and reported low scores for colour.

Sustainability-oriented traditionalists showed high scores in environmental sustainability and biodiversity, as well as in economic sustainability and support for short supply chains. However, they expressed slightly negative interest in social sustainability. Organic certification and traceability systems and Local origin were considered important attributes for this group, although to a slightly lesser extent than among the *innovators*. Organoleptic characteristics were the most important attribute across all clusters, but they held the highest value for this group. Finally, individuals of this cluster showed moderate price sensitivity. Regarding negatively rated attributes, packaging and brand received very low scores. Despite a low inclination towards novelty, this group maintained a positive orientation towards sustainability-related features.

Sustainability-reluctant exhibited negative preferences across all sustainability dimensions, particularly with regard to social and environmental certifications. They explicitly valued environmental certifications (–0.153) and social certifications negatively (–0.543), indicating an aversion to these attributes. Economic sustainability and support for short supply chains also received low scores, albeit slightly less negative. This group showed the strongest negative valuation of organic certification and traceability systems of the three clusters. They also assigned lower importance to local origin and organoleptic characteristics. In contrast, sustainability-reluctant demonstrated greater

sensitivity to price, placing more importance on variety and brand than the other clusters. Although still negative, scores for packaging and colour were less pronounced. Overall, this cluster reflects a price-oriented profile characterised by negative preferences towards sustainability-related attributes and a stronger orientation towards conventional product characteristics.

Table 6. Analysis of variance (ANOVA): differences in average raw score index of apple attribute in the three clusters.

Cluster	Sustainability-oriented innovators	Sustainability-oriented traditionalists	Sustainability-reluctant	Total	F	*p*-Value
Cluster dimension	46.6%	28.1%	25.3%			
Attributes	*Average BW raw scores*					
Organoleptic characteristics	1.373^{a}	1.648^{b}	1.239^{a}	1.416	10.053	***
Economic sustainability certification	1.157^{b}	0.976^{b}	0.176^{a}	0.858	76.853	***
Organic certification	0.985^{b}	0.799^{b}	0.265^{a}	0.750	39.493	***
Local origin	0.674^{b}	0.711^{b}	0.398^{a}	0.615	7.492	***
Price	0.152^{c}	0.673^{a}	1.348^{b}	0.602	38.068	***
Variety	0.205^{a}	0.638^{b}	0.736^{b}	0.461	15.459	***
Certification of traceability	0.647^{c}	0.495^{a}	0.026^{b}	0.447	53.253	***
Environmental sustainability certification	0.644^{c}	0.442^{a}	$–0.153^{b}$	0.385	54.030	***
Social sustainability certification	0.205^{c}	$–0.028^{a}$	$–0.543^{b}$	–0.050	52.684	***
Brand	$–1.151^{a}$	$–1.304^{a}$	$–0.448^{b}$	–1.016	28.377	***
Colour	$–2.404^{b}$	$–2.317^{b}$	$–1.305^{a}$	–2.101	68.151	***
Packaging	$–2.486^{c}$	$–2.732^{a}$	$–1.740^{b}$	–2.366	57.172	***

Note: ^{a,b,c} The preference averages (rescaled scores) within a row with the same letters are statistically different (_ = 0.05, Tukey's post-hoc test). The p-value refers to the statistical significance level: ***p-value = < 0.001. F: Fisher Snedecor F-test. Some attribute names have been shortened to make the table easier to read. The full names can be found in the Table 2.

The characterisation of the sample, in terms of socio-demographic characteristics, is reported in Table 7. *Sustainability-oriented innovators* exhibited a balanced gender distribution, with a slight female majority (51.7%). In terms of age, they were mainly concentrated in the 55–70 and 30–44 age groups, and were most prevalent in the South and Islands, where they were the most represented cluster. A majority were employees, and this group had the highest share of housewives/househusbands. Like the other clusters, most respondents had no children, but household size was slightly larger, with more households reporting four members. Income distribution was more balanced, with the highest proportion of respondents reporting incomes above €60,000, and the lowest rate of non-response regarding income. *Sustainability-oriented traditionalists* were slightly more female-dominated (55%) and had a higher concentration of individuals aged 55 to 70 years. Geographically, they were mostly

distributed in the North-West and North-East of Italy. Regarding employment, the majority were employees, with a moderate share of housewives/househusbands and self-employed individuals. Most respondents in this cluster did not have children, and the typical household size ranged from two to four members. In terms of income, they were mainly distributed across low to middle income brackets, with a slightly higher percentage declining to disclose their income compared to the other clusters. *Sustainability-reluctant* had the highest proportion of male respondents (60.3%) and a larger share of younger adults (18–44 years old), particularly in the 30–44 age group. They were more prevalent in the South and Islands, with fewer respondents from the North. A majority were employees, but this group also included the highest proportion of self-employed individuals. Compared to the other clusters, they had a higher number of single-person households, and more households with more than two children. Income levels were generally in the lower brackets, and this group reported the highest percentage of household income below €25,000.

Table 7. Differences in the sociodemographic characteristics and purchase and consumption habits between the three clusters (X-squared test).

		Sustainability-oriented innovators	Sustainability-oriented traditionalists	Sustainability-reluctant	Qui-square	Sign.	Cramér's V
Gender	Men	48.3%	44.1%	60.3%	40.705	***	0.094
	Women	51.7%	55.0%	39.5%			
	No-binary	0.0%	0.7%	0.2%			
	I prefer not to answer	0.0%	0.2%	0.0%			
Age	18-29	13.7%	20.4%	24.3%	62.355	***	0.167
	30-44	25.6%	21.9%	33.0%			
	45-54	24.0%	22.6%	20.7%			
	55-70	36.7%	35.1%	22.0%			
Area (Italy)	North West	25.0%	29.4%	28.2%	34.704	***	0.091
	North East	16.7%	25.0%	18.8%			
	Centre	19.2%	19.5%	20.2%			
	South and Island	39.1%	26.1%	32.8%			
Employment situation	Student	6.7%	10.5%	8.5%	29.779	***	0.094
	Employed	55.7%	53.0%	57.3%			
	Self-employed	10.8%	10.2%	14.5%			
	Housemaker	10.7%	8.8%	5.8%			
	Unemployed / Seeking employment	7.5%	6.8%	7.9%			
	Other	8.7%	10.7%	6.0%			
School-age children	No one	66.4%	76.7%	67.8%	27.368	***	0.106
	1 component	19.5%	15.3%	19.8%			

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		Sustainability-oriented innovators	Sustainability-oriented traditionalists	Sustainability-reluctant	Qui-square	Sign.	Cramér's V
	2 components	11.7%	7.8%	10.4%			
	More than 2 components	2.5%	0.2%	2.1%			
Household composition	1	10.0%	13.9%	15.3%	19.865	***	0.055
	2	25.3%	28.0%	26.2%			
	3	29.5%	30.2%	29.8%			
	4	29.2%	22.4%	22.4%			
	5 or more	5.9%	5.4%	6.4%			
Income range	Less than 25,000 €	28.1%	28.9%	33.7%	24.291	***	0.089
	25,000 – 40,000 €	38.5%	36.0%	30.9%			
	40,001 – 60,000 €	15.9%	14.8%	17.3%			
	More than 60,000 €	7.4%	4.8%	5.5%			
	I prefer not to answer	10.1%	15.6%	12.6%			

The p-value refers to the statistical significance level: *** < 0.001.

4. Discussion

The present results provide a comprehensive analysis of the attributes of apples that consumers consider most important when making a purchase, using a combined statistical method (PCA and BWS methodology). Particular attention was also paid to consumer attitudes regarding new or unfamiliar varieties. Apple consumers are increasingly interested in sustainability issues in all three dimensions: environmental, social and economic. However, different and sometimes conflicting attitudes emerged regarding interest in the various externalities associated with new apple varieties or production methods, as well as the level of neophobia towards varietal innovation. In particular, the PCA revealed that one of the three factors described attitudes to new varieties, while the other two were oriented in opposite directions. One of these factors described neophobia, the other described neophilia.

Based on attitudes to novelty, this study identified three clusters of consumer behaviour. The largest proportion of respondents had a favourable attitude towards new varieties, provided they were produced sustainably, demonstrating an interest in all three dimensions of sustainability. This result confirms that consumer interest in traceability and sustainability is growing, even within the apple supply chain [10], and contrasts with other studies suggesting that consumers do not perceive the potential benefits of sustainable production [80]. At the same time, two other behavioural components were identified, characterised by opposing tendencies. Some respondents expressed a certain reluctance to try new products, confirming that novelty can generate mistrust and alienation in some people [81]. Equally, a segment of consumers demonstrated a high propensity to experiment, expressing openness and curiosity about new varieties and new products. This duality between neophobia and neophilia is a well-documented aspect of consumer behaviour, particularly with regard

to novel food products [82]. It is essential to recognise and address these divergent attitudes in order to design targeted communication strategies and facilitate the market introduction of innovative apple varieties. The clusters were characterised according to individuals' preferences for key apple attributes, using BWS. The first cluster, *sustainability-oriented innovators* showed strong interest in all sustainability dimensions, including social aspects, which instead elicited negative responses in the other two groups. Members of this cluster also placed great importance on organic certifications and traceability systems, displayed greater willingness to try new varieties, and were less price-sensitive. This aligns with previous findings linking sustainability awareness with neophilia, or a greater openness to innovative or unfamiliar products, and with evidence that such consumers are generally willing to pay a premium price for ethically or environmentally responsible products [83], paying less attention to price and more attention to certifications and traceability information. This aligns with recent evidence showing that consumers who are oriented towards sustainability respond positively to detailed and transparent label information, and that their willingness to pay increases with the level of specificity of the information provided These results suggest that *sustainability-oriented innovators* could be a key target group for policies promoting new varieties of sustainable apples. In terms of sociodemographic characteristics, this profile included a significant proportion of consumers from southern Italy and the Islands, as well as individuals with a medium-to-high income. This can be attributed to the fact that consumers from these regions often exhibit a stronger emotional and cultural connection to traditional and natural food practices associated with their local areas [53], coupled with a heightened awareness of environmental vulnerability and the significance of regional sustainability [84,85]. Furthermore, individuals with higher incomes are generally more willing to try innovative products and adopt food produced using new, sustainable methods [86], as greater purchasing power reduces the impact of price on food choices.

The second cluster (*sustainability-oriented traditionalists*) showed little enthusiasm for innovation and instead had a strong focus on environmental and economic sustainability issues in apple production. Members of this group also valued organic certifications and traceability systems, although to a lesser extent than those in the first cluster. This profile contrasts with the literature, which suggests that individuals who are more motivated by the sustainability benefits of sustainable food options tend to be less fearful of trying them [87]. However, our results suggest that a propensity to experiment does not necessarily follow from environmental values and sustainable purchasing behaviour. This could be explained by this type of consumer's preference for products that are often consumed raw and are perceived as natural and local [88–90]. This suggests that even among sustainability-conscious consumers, there may be some resistance to new varieties, necessitating communication strategies that focus on reassurance and connection with tradition. This group was comprised of slightly more than half women living in North-West and North-East Italy and the composition is consistent with previous findings indicating that women tend to be more involved in making sustainable food choices and are more aware of environmental and ethical issues in food production [91]. At the same time, however, regions in northern Italy have historically been more exposed to organic markets.

The final cluster, *sustainability-reluctant*, comprised consumers characterised by negative preferences towards sustainability-related attributes and limited acceptance of environmentally and socially certified apples. This group was characterised by a lack of interest in environmental and social sustainability certifications and a very low level of attention to economic sustainability. Additionally, members of this cluster placed less importance on organic certification and the local origin of apples than other groups, while standing out for their sensitivity to price. Unlike the other clusters, they tended

to value more conventional attributes, such as variety and brand, more highly. According to the literature, this group is consistent with the profiles of conservative consumers, who are more price-sensitive and less attentive to sustainability characteristics. They are also more oriented towards traditional and familiar characteristics [92]. This cluster was characterised by a greater presence of men with lower incomes. These sociodemographic traits align with previous studies indicating that male consumers, especially those with limited purchasing power, are generally less engaged in sustainability-oriented consumption and more focused on price and fundamental product attributes [93].

Organoleptic characteristics were the most important attributes for all clusters. Therefore, size, sweetness and crispness are the qualitative traits of apples that, as demonstrated by [94], most contribute to the willingness to pay for apples. It is also important to consider regional effects, as marginal effects appear to differ depending on location [8]. The general attention given to economic sustainability by all samples was relevant, as it highlights the growing social responsibility of consumers when buying food, a finding that has also been confirmed in other studies [95–97]. This trend was evident in the apple sample and reflects growing consumer awareness, particularly with regard to local products.

The results of the study highlight the need for a more diversified set of strategies across the apple supply chain. The growing consumer interest in sustainability, traceability, and varietal innovation indicates that there are promising opportunities to introduce new sustainable cultivars aimed at discerning consumer who are willing to pay a premium price. At the same time, the presence of more traditional or price-sensitive consumers underlines the importance of clear communication and the availability of affordable options. These strategies should not, however, overlook the crucial role of organoleptic quality, which remains a decisive factor influencing consumer choice.

5. Conclusions

This study makes a valuable contribution to existing literature by combining research on apple attribute preferences with research on food neophobia and neophilia. These two areas of study have largely been examined separately until now. Combining preference elicitation through BWS with consumer profiling based on attitudes towards novelty and sustainability provides new evidence on how psychological predispositions influence the evaluation of sustainable attributes and innovative apple varieties, including club cultivars. These findings enhance our understanding of consumer decision-making in the apple market and provide guidance on positioning apples in an increasingly sustainability-focused market.

In light of the transformations affecting production systems and consumer perceptions in the apple industry, this study enhances our understanding of how consumers evaluate and prioritize key product attributes. By exploring attitudes towards sustainability and openness to new varieties, the study provides useful insights for producers and marketers who want to reposition apples as a fruit with a stronger identity and renewed appeal. The results offer valuable guidance for strategies combining innovation, environmental responsibility, and cultural heritage to help the sector adapt to changing market dynamics.

The results appear promising for the sector: most consumers display a positive attitude not only towards novel apple varieties with distinctive sensory characteristics but also for products that promote sustainable approaches. Although a minority still shows resistance, there is a clear and growing sensitivity to issues such as organic farming, environmental sustainability, economic viability, and the

promotion of short supply chains. One of the most significant findings of this study is the increasing importance attributed to economic and territorial sustainability. Many consumers recognize the added value of local supply chains and Italian-grown apples, and they reflect this in their purchasing decisions.

The implications for producers and industry stakeholders are substantial. Companies must acknowledge the social, economic, and environmental impacts of their operations, committing not only to upholding sustainability principles but also to communicate them effectively. Marketing and breeding strategies should not only continue to focus on enhancing organoleptic qualities but also increasingly highlight sustainability-related attributes. Moreover, consumer profiling emerges as a strategic tool to develop targeted communication campaigns capable of addressing the diverse preferences and values present in the market. Public policies should further support short supply chains and promote comprehensive sustainability initiatives, recognizing the role of the consumer as a conscious and influential agent in the ecological transition of the agri-food system. Based on these findings, several directions emerge for future research and strategic action within the apple value chain. From a production perspective, breeding programs should aim to develop apple varieties that combine distinctive sensory quality, resilience to climate stressors, and reduced environmental impact. Simultaneously, effective communication tools, potentially leveraging digital technologies and ethically oriented storytelling, should be employed to enhance the perceived value of such innovations.

Our study has some limitations that should be acknowledged. First, although our sample of 2,096 Italian consumers is large and geographically representative, the results may not be generalisable to countries with different agri-food or cultural systems, as the study remains limited to the national context. Second, the data were collected via a cross-sectional survey, which measures stated preferences rather than actual behaviour. Future research should integrate behavioural data, particularly through experimental approaches such as real choice experiments or incentive-compatible designs, to validate the results based on actual purchasing behaviour. Third, while the BWS method effectively reduces cognitive biases, it is based on a predefined set of attributes. Therefore, the inclusion of additional elements, such as packaging, certification types or sensory descriptors, could provide a more comprehensive understanding of preference structure. Furthermore, although the measures of neophobia and neophilia are psychometrically sound, they reflect self-reported attitudes and may therefore not fully represent implicit perceptions or contextual influences on behaviour. Again, future research could address these issues. Moreover, it should be acknowledged that the economic sustainability attribute employed in this study encompasses two distinct concepts: fair income for workers and support for short supply chains. Although both aspects were intended to reflect a broader notion of economic and social fairness within the agri-food system, presenting them together as a single attribute may have made them difficult for respondents to interpret. This potential conflation should be considered when interpreting the results relating to this attribute. Finally, although the study relies on a large-scale online survey, no formal attention checks were included to detect potential respondent inattention. This may represent a methodological limitation, as highlighted by Vecchio et al. (2020), who underline the relevance of inattention issues in online survey research.

In conclusion, future perspectives point to the necessity of an integrated approach. Stronger synergy between producers, institutions, and consumers is essential to build a more resilient, equitable, and sustainable agri-food system. Targeted policies and public incentives could facilitate the transition towards short supply chain models, reinforcing the connection between product origin, quality, and identity.

Use of AI tools declaration

During the preparation of this work, the authors used ChatGPT (OpenAI) to improve the English fluency, coherence, and grammatical accuracy of the text, as none of the authors are native English speakers. After using this tool, the authors reviewed and edited the content as necessary and take full responsibility for the content of this publication.

Conflict of interest

The authors declare no conflict of interest.

Funding

This work was supported by the European Union Next GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 D.D. 1032 17/06/2022, CN00000022). This research only reflects the authors' views and opinions, and neither the European Union nor the European Commission can be considered responsible for them.

Author contributions

Antonina Sparacino: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing—original draft, Writing—review & editing. Giulia Mastromonaco: Conceptualization, Visualization, Software, Writing—original draft, Writing—review & editing. Filippo Brun: Writing—review & editing, Visualization, Supervision; Simone Blanc: Conceptualization, Writing—review & editing, Project administration, Funding acquisition. Valentina Maria Merlino: Conceptualization, Writing—review & editing, Supervision, Project administration.

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