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Consumer Acceptance of New Sustainable Food Technologies: Upcycling Technology, Biostimulants, and Artificial Intelligence

Greta Castellini^{1,2,3}  | Guendalina Graffigna^{1,2,3}

¹Faculty of Agriculture, Food and Environmental Sciences, Università Cattolica del Sacro Cuore, Cremona, Italy | ²EngageMinds HUB – Consumer, Food & Health Engagement Research Center, Università Cattolica del Sacro Cuore, Milan, Italy | ³Faculty of Psychology, Università Cattolica del Sacro Cuore, Milan, Italy

Correspondence: Greta Castellini (greta.castellini@unicatt.it)

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ABSTRACT

Food systems have a significant impact on environmental sustainability, underscoring the need for innovative technologies to support more sustainable agricultural methods. However, the adoption of these technologies hinges on consumer acceptance, making the analysis of consumer perceptions essential. This study examines consumer acceptance of three sustainable food technologies, namely upcycling technologies, biostimulants, and artificial intelligence (AI), in agriculture through a cross-sectional online survey involving 2416 Italian adults representative of the population. It explores participants' knowledge, consumers' beliefs, and purchase intentions regarding these technologies and the novel foods treated with them. Findings indicate limited consumer knowledge, with AI applied in agriculture being relatively better known but perceived as less natural and riskier. Upcycled foods, while seen as sustainable, are associated with low levels of pleasantness. Biostimulants occupy a middle ground, being perceived as more innovative than Upcycling Technology but less artificial, risky, and reassuring compared to AI. Notably, the observed differences between technologies are small, despite statistical significance. Psychological and attitudinal factors, such as variety-seeking in food choices, food technology neophobia and food involvement, have a stronger association with purchase intentions than socio-demographic variables. Trust in actors within the agribusiness system, knowledge of new technologies, and consumers' beliefs about new foods are also positively associated with the purchase intention of foods treated with these technologies. The study emphasizes the importance of tailored communication strategies to overcome barriers, highlighting sustainability and quality while addressing perceived risks and unconscious fears. These insights are critical for advancing the adoption of innovative and sustainable food technologies in agriculture.

1 | Introduction

Food systems significantly impact environmental sustainability, necessitating global initiatives to reform how food is produced and consumed (Willett et al. 2019). Research indicates that food systems are major contributors to global environmental issues,

including greenhouse gas emissions, biodiversity decline, water use, land use changes, and chemical pollution (Willett et al. 2019). In a context where food prices are rising and food insecurity is becoming more prevalent globally (Hasegawa et al. 2021; van Dijk et al. 2021), the waste of nutrients and food highlights the inefficiencies of the existing food system. This

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issue seems particularly irresponsible when considering the sustainable development goals (European Commission 2020). To alleviate the current food system's environmental impact, technological advancements are emerging that promote more sustainable production methods and dietary choices. This includes innovations not only in what people eat but also in how food is produced, emphasizing the need for more sustainable food production technologies. However, despite their potential, these innovations often face significant challenges in terms of implementation and widespread adoption—mainly because consumers tend to be hesitant or resistant to embracing them (Banovic and Grunert 2023). In fact, the success and real-world impact of these food technologies largely depend on consumers' willingness to accept them and their intention to purchase food products derived from such technologies. For this reason, it is crucial to explore what people think about them and understand the psychological and social factors that influence consumer acceptance, to develop effective strategies for introducing these technologies and promoting their adoption.

While there has been growing attention to understanding the reasons behind the rejection or acceptance of novel food technologies and foods, significant gaps remain in the literature. Research indicates that different technologies, despite all being applied to food, can be perceived and accepted differently by consumers (Meijer et al. 2021). Consequently, research that focuses on the acceptance of specific food technologies, rather than on food innovation in general, is both necessary and urgent—particularly in the Italian context, where skepticism toward food innovation is high (Giacalone and Jaeger 2023). Moreover, comparing different technologies and their acceptance determinants using a consistent theoretical framework and a unified methodology is crucial for effectively addressing consumer concerns and tailoring communication strategies (Onwezen et al. 2021). A comparative approach, in fact, can help identify both common and technology-specific barriers to acceptance.

Among the sustainable food technologies that have sparked significant public and scientific debate in recent years—particularly in Italy—are upcycled food technologies, biostimulants, and artificial intelligence (AI).

Upcycled technology involves repurposing food by-products or waste into new products, effectively reducing waste and resource use. Upcycled food can be defined as “foods that use ingredients that otherwise would not have gone to human consumption, are procured and produced using verifiable supply chains, and have a positive impact on the environment” (Upcycled Foods Definition Task Force 2020). Biostimulants, which can be natural or synthetic, enhance plant growth and resilience, improving nutrient uptake while reducing the reliance on chemical fertilizers. This not only promotes healthier crops but also fosters more sustainable agricultural practices with lower environmental impacts (Rouphael and Colla 2020). AI plays a transformative role as well, optimizing various aspects of food production. Through predictive analytics, AI can enhance supply chain efficiency by accurately forecasting demand, thereby minimizing waste. In precision agriculture, AI can help farmers utilize resources more effectively, reducing inputs like water and fertilizers while maximizing yields (Sharma et al. 2022).

From a strategic innovation standpoint, these three technologies represent key investment domains that align with global sustainability, efficiency, and digital transition agendas. Recent reports and academic analyses highlight that the upcycled food sector is among the fastest-growing segments of sustainable food innovation, expected to reach a multi-billion-dollar market value by the end of the decade, reflecting increasing consumer and investor interest in circular economy solutions (Isaac-Bamgboye et al. 2025). Similarly, biostimulant technologies are gaining strong commercial and research momentum, as they represent a promising class of nature-derived biomolecules that enhance crop productivity and resilience while reducing chemical input dependence—an area receiving substantial EU policy and funding support (Johnson et al. 2024; Ruzzi et al. 2024).

Meanwhile, AI and digital agro-technologies are increasingly recognized as critical enablers of precision agriculture and smart food systems, attracting significant investments across Europe (Lawani et al. 2025; Pletsch et al. 2025).

Although these food technologies are among the most promising approaches for promoting sustainability and addressing environmental challenges and have been well studied individually (D'Souza et al. 2024; Lafarga et al. 2021; Ma et al. 2024), to the best of our knowledge, no studies in the literature have compared these three specific technologies using a complex and well-structured framework. Indeed, examining these three specific technologies in an integrated manner—rather than separately, as is common in most studies—is important for two main reasons.

From a psychological standpoint, studying AI, upcycling technologies, and biostimulants together is particularly relevant because each of these technologies could activate different psychological dimensions, offering a more comprehensive perspective on the mechanisms that shape the acceptance of sustainable innovations. Upcycled food can strongly engage the emotional and sensory spheres, as it challenges deeply rooted norms about food purity and edibility, often evoking emotions such as disgust, but also appealing to ethical values related to the fight against food waste (Aschemann-Witzel and Stangherlin 2021). Biostimulants could introduce a health-conscious dynamic, as they directly affect agricultural practices and food quality. Consumers could be more likely to engage with products that are perceived as healthier or that improve the sustainability of food production. AI, in turn, could activate another set of dynamics, linked to perceptions of control, transparency, and trust in institutions (Wang et al. 2025). Thus, analyzing these technologies together allows for an exploration of how various psychological factors interact in the acceptance process, providing a more nuanced framework that is useful both for theoretical development and for communication and implementation strategies.

From a technical perspective, these three technologies span different levels of the food system: from upstream agricultural practices (biostimulants), to midstream processing and waste reduction (upcycled food), to systemic optimization and data-driven management (AI). This selection allows for an exploration of sustainability-driven innovation across multiple nodes of the value chain.

Given these premises and the gaps in the literature, this study aims to:

1. Examine and compare Italian consumer perspectives, particularly their knowledge and consumers' beliefs, regarding three different food technologies: biostimulants, AI, and upcycling technology.
2. Understand and compare consumers' beliefs and purchase intentions towards novel food products on which these technologies have been applied.
3. Explore and compare the key socio-demographic and psychosocial variables, as well as Italian consumer perceptions of product characteristics, that are associated with purchase intentions for foods produced using biostimulants, AI, and upcycling technology.

2 | Literature Review and Research Contributions

Numerous studies have shown that a variety of factors can influence the acceptance of new food technologies, and in particular, the intention to purchase novel foods. In particular, socio-demographic characteristics and perceptions related to the novel food product or innovation are among the most frequently examined factors in the literature. Indeed, consumers who are younger, more educated, wealthier, and politically progressive generally tend to have more favorable attitudes toward adopting new food technologies (Cattaneo et al. 2019; Onwezen et al. 2021). Associations related to gender are less consistent, although there is a trend suggesting that males are more open to novel foods (Verbeke 2015; Wilkinson et al. 2018).

Considering variables related to consumer perceptions of new technologies, several studies have highlighted the importance of consumers' beliefs about these technologies and novel foods. Factors such as environmental impact, health effects, and the naturalness of the product significantly influence the acceptance of new food technologies and the consumption of novel foods (McComas et al. 2014). Additionally, consumers often have limited knowledge of nutrition and new food technologies, which can lead to lower acceptance due to a lack of familiarity with these innovations (McPhetres et al. 2019). However, when making decisions about new products, individuals tend to rely on experts they consider trustworthy. Thus, trust in regulatory bodies plays a crucial role in shaping people's evaluations of innovative products (Connor and Siegrist 2010; Siegrist and Cvetkovich 2000).

Although socio-demographic factors and perceptions of technology or innovative foods are important, they are not sufficient to fully explain consumer behavior (Siegrist and Hartmann 2020a).

Purchase intentions—especially in the context of novel food technologies—are influenced by a broader set of psychosocial variables, which are often underexplored in literature (Barrena and Sánchez 2013; Graffigna and Castellini 2025). Past studies have shown that individuals who are concerned about the environment tend to have more favorable attitudes toward foods treated with new technologies (Aschemann-Witzel et al. 2023). On the other hand, individuals who have a stronger belief in conspiracy theories and are more

concerned about their health are often less inclined to purchase foods treated with new technologies, as these products inspire little trust and are perceived as riskier (Du et al. 2022). Moreover, the consumers' acceptance of new food technologies is significantly affected by their fear of unfamiliar food technologies, a phenomenon referred to as food technology neophobia (Cattaneo et al. 2019). In particular, individuals with high levels of food technology neophobia are less likely to accept and purchase food products treated with new technologies (Coderoni and Perito 2020, 2021; Hellali and Korai 2023a).

However, it is important to note that these variables do not always impact acceptance of novel foods in the same way or with the same intensity. In fact, at times they act as barriers, while at other times they serve as drivers of acceptance and purchase intention for foods treated with new technologies. This effect depends on both the specific technology being considered and the type of food (Laureati et al. 2024). Some studies, for instance, have noted that AI applied to food is perceived as an abstract, invisible, and artificial technology, which generates more suspicion and fear toward AI-treated foods compared to other technologies (Yang et al. 2025). Furthermore, AI is viewed as a replacement for human judgment in the food supply chain, undermining trust in this technology and increasing fear and suspicion toward foods treated with it (Bidyakshmi et al. 2025).

Moreover, openness to trying new foods, known in psychology as variety seeking (Menon and Kahn 1995), generally has a positive impact on the acceptance and purchase intention of novel foods (Lähteenmäki and Arvola 2001). However, the more a technology is perceived as unfamiliar, distant, and completely new, the more consumer openness to new foods could play a crucial role in the acceptance and purchase intention of those foods treated with that technology (Kröger et al. 2022).

Finally, some studies have demonstrated that involvement in food can be a significant psychological aspect influencing dietary changes toward more sustainable products (Castellini and Graffigna 2024) and novel food (Graffigna and Castellini 2025). Psychological food involvement, indeed, refers to the extent to which individuals attribute emotional, symbolic, and identity-related meaning to food. People with high psychological food involvement tend to evaluate foods not only for their functional properties but also for their alignment with personal and social values—such as naturalness, sustainability, authenticity, or self-care (Castellini et al. 2023; Castellini et al. 2023; Castellini and Graffigna 2022). This psychological meaning acts as a key mechanism linking psychological food involvement to the acceptance of novel foods: individuals are more willing to embrace novel foods when these resonate with their value system and perceived identity. Conversely, when a novel or technologically processed food is unfamiliar and lacks an established psychological meaning, psychological food involvement may not play a significant role in its acceptance, as individuals have no symbolic or value-based framework through which to interpret the product (Graffigna and Castellini 2025). Consequently, we suggest that if the accounted food is unfamiliar to the individual and thus lacks a clear psychological meaning, it is possible that food involvement plays no role in the acceptance or consumption of that product.

However, only a limited number of studies have considered a comprehensive and integrative framework of determinant variables to explain the acceptance of novel foods, and none have done so with reference to the three specific technologies examined in this study—AI-based food, upcycled food, and biostimulants. Most previous research, in fact, has either not adopted any theoretical framework (Castellini et al. 2025) or has relied on well-established psychological models—such as the Theory of Planned Behavior (Chen and Chao 2025), the Technology Acceptance Model (Hellali and Korai 2023b), or the Value-Attitude-Behavior model (Huang et al. 2024)—to investigate consumers' acceptance of these products. In such cases, additional variables were often included to extend or adapt these models, yet these efforts largely remained ad hoc (Satria and Aghniarahim Punitamara 2024). To date, there is a lack of studies that have used complex models specifically designed to explain novel food acceptance, based on a thorough review of the literature and encompassing the main determinants and clusters of variables that may influence consumers' purchase intentions.

To establish a coherent theoretical framework for studying these key factors in a comprehensive and conceptually consistent manner with previous research, we relied on an extensive and up-to-date literature review aimed at identifying the variables most associated with consumer acceptance of novel foods and agricultural technologies (Castellini et al. 2025). This review served not only to select the relevant variables that can be studied in a cross-sectional work, but also to inform how they should be conceptually grouped within our model. Based on this review—consistent with previous research in the field (Laureati et al. 2024; Lu et al. 2024; Siegrist and Hartmann 2020a)—we developed a theoretical framework that distinguishes between: (I) socio-demographic variables (e.g., age, gender, education), (II) variables related to consumer consideration of product/innovation characteristics (e.g., trust, general beliefs, knowledge), and (III) psychological predispositions (e.g., food technology neophobia, conspiracy mentality, food involvement, variety seeking, health consciousness, and environmental concern). This categorization reflects commonly used distinctions in the literature between more stable individual traits and more belief-based factors and allows us to examine how these different types of variables interact in shaping acceptance of novel food technologies.

Building on these premises, this study contributes, first and foremost, to a more comprehensive understanding of sustainable food technologies, providing valuable insights for policymakers and marketing strategists. Moreover, this comparative approach allows us to identify both common and technology-specific barriers to consumer acceptance, offering insights that go beyond analysis of single technologies. This enables more precise consumer segmentation and the development of targeted communication strategies. Finally, the research provides both theoretical and practical contributions by integrating psychological constructs with food technology literature, thus informing policies, marketing efforts, and educational initiatives aimed at promoting more sustainable food consumption patterns. *il testo.*

3 | Methods

3.1 | Participants

This study employed a cross-sectional design, using an online survey administered through the Computer-Assisted Web Interviewing method, conducted between June 7 and June 28, 2024. The sample, which consisted of 2416 individuals, was recruited through a professional panel provider using stratified sampling based on official statistics from ISTAT (Italian National Institute of Statistics), as shown in the final column of Table 1. Quotas were set for key sociodemographic variables, including gender, age, education level, and geographic region, in order to ensure representativeness of the Italian adult population (18 years and older). The panel provider selected respondents from its existing online panel, matching each participant to specific quota cells corresponding to the national population distribution. The panel provider uses strict quality control measures, including attention checks, survey duration monitoring, and detection of inconsistent responses. These methods ensure participant engagement and data reliability. As a result, only high-quality data is collected. The research adhered to the ethical guidelines of the Declaration of Helsinki and obtained approval from an independent university ethics committee. Participants were fully informed about the study's goals, assured of confidentiality, and provided their consent to participate.

3.2 | Procedures and Measures

First, respondents provided their socio-demographic information, including age, gender, and education level, as well as answered questions related to psychosocial profiling (e.g., health consciousness, environmental concern, conspiracy mindset). Following this, the sample was randomly divided into three groups, each exposed to one of three different technologies: upcycling technology, biostimulants, and AI. After asking participants about their knowledge related to these technologies, a brief description was provided for each one to ensure that respondents completed the rest of the questionnaire with a clear understanding of the technologies in question. These descriptions were developed in collaboration with experts in the respective fields and present these technologies in a factual manner, consistent with common consumer-facing communication (see Supporting Information S1: A). Subsequently, participants were asked to indicate their beliefs and purchasing intentions related to the technologies presented and the novel foods to which they were applied. Below, the investigated constructs and the measures used in the questionnaire are detailed. The complete questionnaire can be found in Supporting Information S2: B.

Measures administered to all participants to gather socio-demographic and psychosocial information:

- Socio-demographic variables: Several variables, such as gender, age, education level, geographical origin, and profession, were measured to map the key socio-demographic characteristics of the participants.
- General health orientation: This construct was measured using a validated scale that assesses health consciousness (Hong 2009). The scale consists of 11 items measured on a

TABLE 1 | Demographic profiles of the sample ($n = 2416$).

	Upcycling technology ($n = 806$)		Biostimulants ($n = 808$)		Artificial intelligence ($n = 802$)		Population %
	n	%	n	%	n	%	
1. Gender							
Male	404	50.1	400	49.5	404	50.4	49.6
Female	402	49.9	408	50.5	398	49.6	50.3
2. Age							
18–29	126	15.6	136	16.8	124	15.5	16.5
30–44	195	24.2	196	24.3	192	23.9	23.7
45–54	195	24.2	183	22.6	186	23.2	21.1
55–65	143	17.7	156	19.3	158	19.7	21.1
65–75	147	18.2	137	17.0	142	17.7	17.5
3. Education							
Elementary- Junior high	270	33.5	191	23.6	242	30.2	37.8
Senior high	357	44.3	404	50	372	46.4	43.5
College or university	179	22.2	213	26.4	188	23.4	18.6
4. Geographic area							
North-West	221	27.4	213	26.4	216	26.9	26.7
North-East	158	19.6	157	19.4	160	20.0	19.5
Center	159	19.7	169	20.9	169	21.1	19.8
South and Islands	268	33.3	269	33.3	257	32.0	33.8

7-point Likert scale ranging from “strongly disagree” to “strongly agree.” Higher scores on this scale indicate a greater interest in personal health.

- Environmental concern: This construct was measured by the scale developed by Krystallis et al. (2012) that consists of five items measured on a 7-point Likert scale, where respondents express their level of agreement or disagreement (1 = strongly disagree and 7 = strongly agree) related to environmental concerns and perceptions of nature and environmental issues. Higher scores on this scale indicate a greater concern about environmental issues.
- Conspiracy mentality: This construct has been measured using the validated Conspiracy Mentality Questionnaire, developed by Bruder et al. (2013). This scale assesses the tendency of individuals to view events or situations as being influenced by hidden, malicious forces. It includes 5 items that reflect attitudes toward conspiracy theories. Respondents use a 100-point Likert scale to indicate from 0 to 100 how likely each presented event is to occur. High scores on this scale indicate a strong conspiracy mentality.
- Food technology neophobia: This construct has been measured using the namesake scale translated and validated in Italian by Cattaneo et al. (2019). This scale measures individuals' reluctance or aversion to new food technologies and innovations. It includes 13 items that capture various attitudes toward food technologies. Respondents rate their agreement with the items using a 7-point Likert scale, where 1 indicates strong disagreement, and 7 indicates

strong agreement. High scores on this scale indicate a strong aversion to new technologies applied to food.

- Food involvement: This construct is operationalized through the validated Psychological Food Involvement Scale (Castellini et al. 2023), which captures the degree to which individuals are psychologically invested in food by measuring the personal and social meanings they attribute to it. The scale assesses four key dimensions: emotional balance (the extent to which food supports emotional well-being), self-realization (the role of food in expressing personal identity and self-fulfillment), social affirmation (the use of food to communicate values and gain recognition from others), and social bonding (the role of food in fostering relationships and shared experiences). Together, these factors reflect the broader symbolic, emotional, and identity-related significance of food in individuals' lives. This scale consists of 19 items measured on a 7-point Likert scale, where 1 means strongly disagree, and 7 means strongly agree. High scores on this scale indicate a strong psychological involvement in food, meaning that the individual attributes deeper emotional, symbolic, and social meaning to eating and food-related activities.
- Variety seeking: To measure this construct, the Food Variety Seeking (VARSEEK) Scale, developed by van Trijp et al. (1992), was used. This scale measures consumers' tendencies to seek variety in their food choices. This scale assesses how much individuals enjoy trying different foods and their willingness to explore new culinary experiences. It includes 8 items that capture various aspects of this

tendency. Respondents use a 7-point Likert scale to indicate their level of agreement with each item, where 1 means strong disagreement, and 7 means strong agreement. Higher scores on this scale indicate a greater predisposition to try new foods.

- **Trust in actors of the agri-food system:** Trust has been measured using a set of five items previously utilized by Siegrist and Hartmann (2020b). These items, assessed on a 7-point Likert scale (1 = strongly disagree and 7 = strongly agree), evaluate how much individuals trust the main actors in the agri-food system. High scores indicate a strong level of trust in these actors.

Measures included in the three sections to understand consumers' beliefs and opinions about the three technologies investigated (upcycling technology, biostimulants, and AI):

- **Knowledge:** Knowledge regarding the three technologies was measured through ad hoc questions asking participants whether they had ever heard of the technologies in question. The response options included “never,” “sometimes,” and “often.”
- **Consumers' beliefs about technologies and novel foods:** Two different ad hoc item sets were used to measure consumers' beliefs about the technologies and the novel foods to which they have been applied. Specifically, a 7-point semantic differential consisting of nine opposing adjectives (e.g., negative–positive, useless–useful) was used to assess consumers' beliefs about the technologies, while another 7-point semantic differential with eight opposing adjectives (e.g., artificial–natural, unpleasant–pleasant) was created to measure consumers' beliefs about novel foods.
- **Intention to buy novel foods:** Participants were asked to rate their intention to buy upcycled food, products treated with biostimulants, and with AI tools in the next 6 months on a 7-point scale ranging from “strongly disagree” to “strongly agree,” utilizing four items created ad hoc.

For scales originally developed in English, we employed a standard back-translation method. Two bilingual researchers independently translated the items into Italian and then back into English to ensure semantic equivalence. Any discrepancies were resolved through discussion to preserve the conceptual meaning.

3.3 | Data Analysis

Data were analyzed using SPSS version 29.0 for Windows (SPSS, Chicago, IL, USA). A descriptive analysis was performed to analyze the measures included in this study. The normality of the scales was assessed using kurtosis and skewness, with cut-off values of |2| indicating acceptable normality (Hair et al. 2010). Additionally, the reliability of the scales was evaluated using Cronbach's alpha method (> 0.70 considered a good value) (Nunnally and Bernstein 1994). Reverse-worded items were identified and reverse-coded prior to analysis to maintain consistency in the directionality of the constructs.

To understand the varying levels of knowledge regarding the three technologies, contingency tables were created. Pearson's chi-square test was also conducted. Whenever the chi-square

result was significant, post hoc standardized residuals were inspected: standardized residuals are calculated as the difference between observed and expected counts of a cell divided by an estimate of its standard deviation. Since they are asymptotically normally distributed with a mean of 0 and a standard deviation of 1 under the null hypothesis of independence, as a general rule of thumb, cells with an absolute value of standardized residuals above 2 can be considered to significantly contribute to the overall chi-square value (Haberman 1973).

One-way analysis of variance was used to analyze the differences in consumers' beliefs shown by participants regarding the three technologies presented and the novel foods to which they were applied, followed by Bonferroni post hoc comparisons. This analysis was also used to compare the different purchase intentions for the foods to which these technologies were applied. The significance of results was assessed using the Benjamini-Hochberg correction for multiple comparisons. Moreover, as participants were exposed to only one technology (between-group design), individual differences in response tendencies could not be fully controlled. However, the three groups were balanced with respect to sociodemographic variables, ensuring comparable distributions and enhancing the validity of between-group comparisons. Additionally, Pearson correlations were employed to analyze the relationship between beliefs toward novel foods and the intention to purchase these products.

Finally, three hierarchical regressions were performed, one for each technology, considering the intention to purchase foods to which the three different technologies have been applied as the dependent variable. In the first block, socio-demographic characteristics were included, such as age, gender (1 = male; 2 = female), and level of education (1 = non-graduates; 2 = graduates). Subsequently, in the second block, questions regarding perceptions about novel foods' features, such as beliefs about novel foods, knowledge (1 = never; 2 = sometimes and often), and trust in the actors of the food system were added. We collapsed the original three-category knowledge variable (“never,” “sometimes,” “often”) into a binary indicator for the regression models for both conceptual and methodological reasons. Conceptually, the key distinction for our analyses was whether respondents had ever been exposed to the technology, rather than the frequency of exposure. Methodologically, collapsing the categories ensured adequate cell sizes and improved model stability, given the relatively small number of respondents in the “often” category. The resulting binary coding (never vs. sometimes/often) therefore more accurately captures the substantive contrast relevant to our study.

In the third block, variables related to the psychological dimensions of the participants—such as variety seeking, food involvement, conspiracy mentality, health consciousness, food technology neophobia, and environmental concern—were included. To assess how well the regression model fits the data, the coefficient of determination (R^2), adjusted R^2 , and F -statistics were considered and commented upon. Additionally, to test the regression coefficients, the unstandardized regression coefficients (β) were examined, considering a significance level of 0.05. Finally, since beliefs and intentions related to the three technologies were measured in a single session using similar item formats, we conducted Harman's single-factor test to verify that the results were not driven by common method variance.

4 | Results

4.1 | Characteristics of the Sample

The sample is composed of 2416 people, of whom 1208 (50.1%) are male, aged between 19 and 76 years ($M = 48.86$, $SD = 15.09$). The demographic profile is presented in detail in Table 1.

4.2 | Knowledge of Technologies Applied in the Agri-Food Sector

The results show that, in general, Italians have limited knowledge of these technologies. Indeed, 80% of participants reported that they have never heard of upcycling technology, 67% have never heard of biostimulants, and 50% have never heard of AI applied in agriculture (see Supporting Information S3: C). The contingency analysis shows a significant association between participants' knowledge levels and the type of technology ($\chi^2(4) = 165.217$, $p < 0.001$), and the standardized residuals highlight which specific cells drive this effect. "Never" responses are markedly overrepresented for upcycling technology and underrepresented for AI, indicating that participants are much less familiar with upcycling technology than expected and more familiar with AI applied in agriculture. The opposite pattern appears in the "Sometimes" and "often" category, where upcycling technology shows fewer responses than expected, and AI is applied in agriculture, among many other uses. Overall, the significant chi-square result reflects the fact that people tend to know AI applied in agriculture much better—and upcycling technology much less—than would be expected if there were no association between technology and knowledge level (Table 2).

4.3 | Consumers' Beliefs About Technologies Applied in the Agri-Food Sector and the Novel Foods

Considering the participants' beliefs about both the technologies and the foods associated with them, results show that they have predominantly medium-positive views.

However, when examining the overall beliefs about new food technologies, the results indicate that Italians have more

negative beliefs about AI tools compared to upcycling technologies and biostimulants (Table 3). This trend mirrors the consumers' feelings toward the novel foods treated with these technologies (Table 4).

Considering the specific beliefs about these new food technologies, Table 3 highlights that upcycling technologies are primarily regarded as sustainable ($M = 5.35$), positive ($M = 5.20$), and innovative ($M = 5.12$). Biostimulants are mainly viewed as innovative ($M = 5.34$), positive ($M = 5.33$), and sustainable ($M = 5.00$). Lastly, AI is predominantly seen as an innovative technology ($M = 5.53$), positive ($M = 5.21$), and useful ($M = 5.13$).

Consumer perceptions of the three technologies reveal differences. Upcycling Technology is seen as the least innovative but is perceived as the most sustainable among the three. AI is viewed as the most artificial, the riskiest, and the least reassuring. Biostimulants occupy a middle ground, being perceived as more innovative than Upcycling Technology but less artificial, risky, and reassuring compared to AI.

The effect sizes associated with these differences, measured by η^2 , range from small to moderate. For example, the perception of artificiality shows a moderate effect size ($\eta^2 = 0.095$), indicating a substantial difference in how artificial the technologies are perceived. Other dimensions, such as general beliefs ($\eta^2 = 0.007$), riskiness ($\eta^2 = 0.016$), and innovative nature ($\eta^2 = 0.010$), show small effect sizes, reflecting meaningful but less pronounced differences in consumers' beliefs. For other aspects where no significant differences emerged, perceptions of the three technologies appear broadly similar.

Considering consumers' beliefs about novel foods, Table 4 illustrates that upcycled foods are primarily perceived by consumers as sustainable ($M = 5.32$), safe ($M = 4.82$), and healthy ($M = 4.78$). Foods treated with biostimulants are mainly viewed as sustainable ($M = 5.03$), healthy ($M = 4.90$), and pleasant ($M = 4.89$). Finally, foods treated with AI are primarily considered sustainable ($M = 4.96$), pleasant ($M = 4.84$), and healthy ($M = 4.78$).

However, significant differences exist in consumers' beliefs about these novel foods. Foods produced with biostimulants are viewed as slightly more pleasant than those made with

TABLE 2 | Results of contingency table: Knowledge about technologies ($n = 2416$).

Variables	Answers	Cell	Technology			Row total
			Up	Bio	AI	
Knowledge Chi-square = 165.217($df = 4$), $p < 0.001$	Never	Observed	646	541	405	1592
		Expected	531.1	532.4	528.5	
		Std res.	5.0	0.4	-5.4	
	Sometimes	Observed	150	245	346	741
		Expected	247.2	247.8	246.0	
		Std res.	-6.2	-0.2	6.4	
	Often	Observed	10	22	51	83
		Expected	27.7	27.8	27.6	
		Std res.	-3.4	-1.1	4.5	
		CT	806	808	802	

Note: Cells with an absolute value of Std res. > 2 are marked in bold.

Abbreviations: AI, artificial intelligence; Bio, biostimulants; CT, column total; df , degrees of freedom; Std res., standard residues; Up, upcycling technology.

TABLE 3 | Specific beliefs about technologies ($n = 2416$).

Beliefs about technology	Upcycling technology ($n = 806$)		Biostimulants ($n = 808$)		Artificial intelligence ($n = 802$)		F (df)	p value	Significant after BH correction	η^2
	Mean	SD	Mean	SD	Mean	SD				
Total	4.96^b	1.31	4.97^b	1.25	4.74^a	1.18	9.11(2)	< 0.001	Yes	0.007
Negative-Positive	5.20	1.56	5.33	1.52	5.21	1.51	1.71(2)	0.181	No	—
Not Interesting-Interesting	4.91	1.76	5.08	1.64	5.10	1.64	3.07(2)	0.050	No	—
Useless-Useful	5.10	1.81	5.11	1.72	5.13	1.71	0.04(2)	0.958	No	—
Traditional-Innovative	5.12^b	1.67	5.34^a	1.65	5.53^a	1.67	11.83(2)	< 0.001	Yes	0.010
Avoidable-Essential	4.76	1.61	4.70	1.54	4.61	1.65	1.71(2)	0.181	No	—
Artificial-Natural	4.73^a	1.75	4.73^a	1.77	3.48^b	1.93	125.94(2)	< 0.001	Yes	0.095
Risky-Safe	4.76^a	1.66	4.74^a	1.61	4.31^b	1.68	19.25(2)	< 0.001	Yes	0.016
Alarmist-Reassuring	4.71^a	1.65	4.72^a	1.63	4.33^b	1.61	14.31(2)	< 0.001	Yes	0.012
Unsustainable-Sustainable	5.35^b	1.63	5.00^a	1.65	4.94^a	1.537	15.59(2)	< 0.001	Yes	0.013

Note: Bold values indicate statistically significant p -value < 0.05. Different letters (a, b, c) indicate statistically significant differences among groups (ANOVA followed by post hoc test, $p < 0.05$. Means sharing the same letter are not significantly different $p > 0.05$.

Abbreviations: BH, Benjamin-Hochberg; df, degrees of freedom; SD, standard deviation.

TABLE 4 | Specific beliefs about novel foods ($n = 2416$).

Beliefs about novel foods	Upcycling technology ($n = 806$)		Biostimulants ($n = 808$)		Artificial intelligence ($n = 802$)		F (df)	p value	Significant after BH correction	η^2
	Mean	SD	Mean	SD	Mean	SD				
Total	4.77^b	1.36	4.74^b	1.35	4.60^a	1.32	3.57(2)	0.028	Yes	0.003
Artificial–Natural	4.76	1.77	4.78	1.71	4.59	1.69	3.04(2)	0.050	No	—
Harmful–Healthy	4.78	1.63	4.90	1.56	4.78	1.53	1.64(2)	0.194	No	—
Unpleasant–Pleasant	4.67^b	1.59	4.89^a	1.49	4.84^{a,b}	1.50	4.41(2)	0.012	Yes	0.004
Avoidable–Essential	4.71^a	1.63	4.69^a	1.57	4.39^b	1.58	10.00(2)	< 0.001	Yes	0.008
Risky–Safe	4.82	1.63	4.84	1.59	4.69	1.58	2.03(2)	0.131	No	—
Altered–Unaltered	4.50	1.65	4.63	1.68	4.55	1.63	1.39(2)	0.247	No	—
Unsustainable–Sustainable	5.32^b	1.59	5.03^a	1.59	4.96^a	1.58	11.55(2)	< 0.001	Yes	0.009
Expensive–Economical	4.57^b	1.62	4.18^a	1.63	4.01^a	1.72	24.59(2)	< 0.001	Yes	0.020

Note: Bold values indicate statistically significant p -value < 0.05 . Different letters (a, b, c) indicate statistically significant differences among groups (ANOVA followed by post hoc test, $p < 0.05$. Means sharing the same letter are not significantly different $p > 0.05$. Abbreviations: BH, Benjamini–Hochberg; df, degrees of freedom; SD, standard deviation.

Upcycling Technology. AI foods seem to be perceived as the least essential, while Upcycled foods seem to be considered the most sustainable but also the most expensive.

Although these differences are statistically significant, the associated effect sizes are generally small, indicating modest differences in consumers' beliefs. The only exception is cost perception, which showed a small-to-moderate effect size ($\eta^2 = 0.020$), suggesting a somewhat stronger impact of production technology on perceived affordability. For other aspects where no significant differences emerged, beliefs among these three novel foods appear broadly similar.

4.4 | Intention to Buy

Considering the future intention to purchase novel foods, the results underline that 41% of participants express a strong intention to buy products treated with AI and biostimulants, while 38% intend to purchase upcycled foods. However, a significant portion of the sample remains in a “grey area,” uncertain about their purchasing intentions regarding these food products (see Supporting Information S3: C). When examining the mean scores, the results indicate that participants appear to be less inclined to buy upcycled foods compared to those treated with biostimulants (Table 5). However, the associated effect size is small, suggesting that differences in consumers' intention to purchase these novel foods are modest.

Given consumers' previously discussed beliefs about novel foods, one might expect that foods treated with AI would have lower purchase intentions. However, it is the upcycled food to which consumers show lower purchase intentions. As shown in Table 6, the belief most strongly correlated with purchase intention of upcycled foods is pleasantness, which is the least recognized characteristic of these foods (Table 4). In contrast, when considering consumers' beliefs about foods treated with AI, sustainability emerges as the primary characteristic associated with these products, and it is also the factor most strongly correlated with their purchase intention (Table 6).

4.5 | Hierarchical Regression Models

We first tested the assumptions of the regression models (see Supporting Information S3: C) and then conducted Harman's single-factor test to assess potential common method bias between consumers' beliefs and intentions. The test showed that the first factor accounted for 55% of the variance for upcycled food, 56% for biostimulants, and 55% for AI, indicating that common method variance is unlikely to substantially affect the results, although a minor influence cannot be completely ruled out. Following these checks, three hierarchical regression models were conducted to identify and compare the variables associated with the intention to purchase foods treated with upcycling technology, biostimulants, and AI.

Across the three models (Tables 7–9), results reveal that socio-demographic variables alone explain only a small proportion of the variance in consumers' intention to purchase foods produced through upcycling, biostimulants, or AI. Their explanatory power remains below 2% in all cases, suggesting that socio-demographic characteristics such as age, gender, and

TABLE 5 | Intention to buy ($n = 2416$).

Types of foods	Mean (SD)	F (df)	p value	Significant after BH correction	η^2
Upcycled foods ($n = 806$)	4.25 ^b (1.55)	5.583(2)	< 0.01	Yes	0.005
Foods treated with biostimulants ($n = 808$)	4.50 ^a (1.40)				
Food treated with AI ($n = 802$)	4.40 ^{a,b} (1.51)				

Note: Different letters (a, b, c) indicate statistically significant differences among groups (ANOVA followed by post hoc test, $p < 0.05$. Means sharing the same letter are not significantly different $p > 0.05$. Abbreviations: BH, Benjamini–Hochberg; df, degrees of freedom; SD, standard deviation.

TABLE 6 | Correlation between beliefs about novel foods and intention to buy ($n = 2416$).

Beliefs about novel foods	Upcycled foods ($n = 806$)	Biostimulant foods ($n = 808$)	Artificial intelligence foods ($n = 802$)
	r	r	r
Artificial–Natural	0.559***	0.571***	0.510***
Harmful–Healthy	0.577***	0.534***	0.580***
Unpleasant–Pleasant	0.621***	0.526***	0.575***
Avoidable–Essential	0.577***	0.551***	0.568***
Risky–Safe	0.567***	0.563***	0.589***
Altered–Unaltered	0.548***	0.558***	0.577***
Unsustainable–Sustainable	0.545***	0.513***	0.592***
Expensive–Economical	0.376***	0.394***	0.411***

Note: Bold values indicate statistically significant p -value < 0.05 . Different letters (a, b, c) indicate statistically significant differences among groups (ANOVA followed by post hoc test, $p < 0.05$. Means sharing the same letter are not significantly different $p > 0.05$. *** $p < 0.001$.

education play a limited role compared to attitudinal and psychological factors. In particular, for biostimulants, Model 1 did not significantly explain variance ($R^2 = 0.003$, $p = 0.432$), highlighting that socio-demographic variables do not account for purchase intention.

When beliefs about food, trust in agri-food system actors, and knowledge of the respective technologies are included (Model 2), the explained variance rises sharply in all three cases—by approximately 42%–45%—indicating that these perceptual variables are associated with the consumer intention.

The inclusion of psychological orientations (Model 3) further improves the explanatory power of the models by roughly 9%–11%, reaching total adjusted R^2 values between 0.53 and 0.56. This pattern confirms that psychological features add a meaningful layer of explanation to the intention to buy these novel foods. Considering the three final models (Model 3), the results highlight that beliefs about food, trust in agri-food system actors, knowledge about the technologies, and variety seeking are positively associated with the intention to purchase novel foods, whereas food technology neophobia has a consistently negative association with all three cases.

Despite these shared tendencies, some technology-specific differences emerge. For upcycled foods, being female is associated with higher purchase intentions, whereas for AI-based foods, higher purchase intentions are associated with males. Moreover, food involvement is positively associated with the intention to purchase foods treated with AI and biostimulants, but is not associated with the intention to buy upcycled foods. Trust and variety seeking play a strong and consistent role across all

models, but they are especially salient for upcycled food. Conversely, the intention to purchase foods treated with AI technology shows a somewhat stronger negative association with food technology neophobia, suggesting that unfamiliar, invisible, or data-driven technologies tend to provoke greater apprehension compared to the more tangible processes of up-cycling or biostimulants.

5 | Discussion

This study aims to explore and deepen the understanding of Italian consumers' knowledge, beliefs, and opinions regarding three sustainable technologies applied in agriculture: upcycled technology, biostimulants, and AI, focusing on the key socio-demographic and psychosocial variables that influence the intention to purchase novel foods treated with these technologies.

The study's findings indicate that Italian consumers have limited knowledge of these technologies, a result that aligns with previous research (Meijer et al. 2021). However, greater familiarity with AI compared to other technologies, such as upcycling and biostimulants, may reflect the broader use of AI in non-food contexts, such as consumer technology and digital services (Zhu et al. 2023). Nonetheless, this superficial knowledge may limit consumers' ability to accurately assess the benefits of these technologies.

The positive beliefs observed about the technologies analyzed, albeit with variations, confirm the crucial role of perceptions of

TABLE 7 | Hierarchical regression analysis about the intention to buy upcycled foods ($n = 806$).

Variable	Model 1			Model 2			Model 3		
	B (SE)	β	p value	B (SE)	β	p value	B (SE)	β	p value
Gender	0.283 (0.109)	0.091	0.010	0.191 (0.081)	0.061	0.019	0.154 (0.074)	0.049	0.038
Education	0.240 (0.132)	0.064	0.069	0.044 (0.098)	0.012	0.649	-0.071 (0.089)	-0.019	0.424
Age	-0.006 (0.004)	-0.057	0.103	-0.006 (0.003)	-0.059	0.024	-0.002 (0.002)	-0.017	0.476
Knowledge				0.256 (0.104)	0.066	0.014	0.241 (0.096)	0.062	0.012
Trust				0.174 (0.036)	0.134	<0.001	0.126 (0.035)	0.097	< 0.001
Beliefs about foods				0.694 (0.031)	0.607	<0.001	0.484 (0.034)	0.423	< 0.001
Health consciousness							-0.062 (0.044)	-0.038	0.158
Environmental concern							0.065 (0.037)	0.046	0.075
Variety seeking							0.367 (0.049)	0.190	< 0.001
Food involvement							0.032 (0.042)	0.021	0.444
Conspiracy mentality							0.001 (0.002)	0.017	0.515
Food technology neophobia							-0.436 (0.047)	-0.278	< 0.001
Constant	3.826 (0.304)		<0.001	-0.123 (0.301)		0.682	1.317 (0.452)		0.004
Model value	$F_{(3, 805)} = 4.179, p = 0.006, R^2 = 0.015, R^2_{\text{Adjusted}} = 0.012$			$F_{(6, 805)} = 115.970, p < 0.001, R^2 = 0.464, R^2_{\text{Adjusted}} = 0.460$			$F_{(12, 805)} = 86.527, p < 0.001, R^2 = 0.567, R^2_{\text{Adjusted}} = 0.560$		
Variation (ΔR^2; p value)	0.015; 0.006			0.449; <0.001			0.103; 0 < 0.001		

Note: Bold values indicate statistically significant p-value < 0.05.

TABLE 8 | Hierarchical regression analysis about the intention to buy foods treated with Biostimulants ($n = 808$).

Variable	Model 1			Model 2			Model 3		
	B (SE)	β	p value	B (SE)	β	p value	B (SE)	β	p value
Gender	0.069 (0.099)	0.024	0.488	0.049 (0.075)	0.017	0.516	-0.001 (0.069)	0.000	0.994
Education	0.173 (0.113)	0.054	0.126	0.137 (0.086)	0.043	0.111	-0.008 (0.079)	-0.003	0.916
Age	0.000 (0.003)	0.005	0.895	0.000 (0.003)	-0.004	0.883	0.002 (0.002)	0.017	0.508
Knowledge				0.337 (0.081)	0.113	< 0.001	0.291 (0.074)	0.097	< 0.001
Trust				0.156 (0.034)	0.129	< 0.001	0.079 (0.033)	0.065	0.017
Beliefs about foods				0.610 (0.029)	0.584	< 0.001	0.420 (0.031)	0.402	> 0.001
Health consciousness							0.006 (0.044)	0.004	0.893
Environmental concern							0.048 (0.032)	0.038	0.139
Variety seeking							0.275 (0.048)	0.153	< 0.001
Food involvement							0.184 (0.041)	0.131	< 0.001
Conspiracy mentality							0.000 (0.002)	-0.005	0.865
Food technology neophobia							-0.451 (0.048)	-0.286	< 0.001
Constant	4.159 (0.280)		< 0.001	0.262 (0.291)		0.369	1.391 (0.437)		0.002
Model value	$F_{(3, 807)} = 0.918$, $p = 0.432$, $R^2 = 0.003$, $R^2_{\text{Adjusted}} = 0.000$			$F_{(6, 807)} = 99.634$, $p < 0.001$, $R^2 = 0.427$, $R^2_{\text{Adjusted}} = 0.423$			$F_{(12, 807)} = 77.364$, $p < 0.001$, $R^2 = 0.539$, $R^2_{\text{Adjusted}} = 0.532$		
Variation (ΔR^2; p value)	0.003; 0.432			0.424; < 0.001			0.111; 0 < 0.001		

Note: Bold values indicate statistically significant p -value < 0.05.

TABLE 9 | Hierarchical regression analysis about the intention to buy foods treated with AI ($n = 802$).

Variable	Model 1			Model 2			Model 3		
	B (SE)	β	p value	B (SE)	β	p value	B (SE)	β	p value
Gender	-0.328	0.106	0.002	-0.207	0.080	0.010	-0.171	0.074	0.021
Education	0.235	0.126	0.062	0.067	0.094	0.477	-0.014	0.089	0.877
Age	-0.003	0.004	0.358	-0.001	0.003	0.576	0.001	0.002	0.799
Knowledge				0.273	0.080	< 0.001	0.246	0.074	0.081
Trust				0.102	0.036	0.005	0.079	0.035	0.025
Beliefs about foods				0.704	0.033	< 0.001	0.469	0.036	0.409
Health consciousness							0.063	0.044	0.154
Environmental concern							-0.052	0.033	0.115
Variety seeking							0.168	0.048	0.092
Food involvement							0.116	0.043	0.007
Conspiracy mentality							0.001	0.002	0.586
Food technology neophobia							-0.522	0.046	< 0.001
Constant	4.765 (0.300)		< 0.001	0.623 (0.294)		0.034	2.597 (0.446)		< 0.001
Model value	$F_{(3, 801)} = 4.944, p = 0.002, R^2 = 0.018, R^2_{\text{Adjusted}} = 0.015$			$F_{(6, 801)} = 112.760, p < 0.001, R^2 = 0.460, R^2_{\text{Adjusted}} = 0.456$			$F_{(12, 801)} = 81.204, p < 0.001, R^2 = 0.553, R^2_{\text{Adjusted}} = 0.546$		
Variation (ΔR^2; p value)	0.018; 0.002			0.442; < 0.001			0.093; 0 < 0.001		

Note: Bold values indicate statistically significant p-value < 0.05.

positivity, sustainability, and innovation. However, in general, Italians seem to have more negative beliefs about AI. It is often viewed as less natural, riskier, and more alarming, reflecting common concerns about AI as a technology detached from natural processes (Bearth et al. 2014). Furthermore, the use of AI in agriculture is frequently associated with labor-related issues, as it has the potential to replace human workers, thereby threatening jobs (Acemoglu and Restrepo 2020). Lastly, AI is often seen as a tool that could fail, leading to large-scale negative outcomes if there are not enough skilled individuals to properly operate it (Ben Ayed and Hanana 2021).

The differences in perceptions of foods derived from various technologies highlight a significant challenge for stakeholders in the food system. Foods treated with biostimulants seem to be perceived as more pleasant, likely due to their association with traditional agricultural practices. In contrast, AI-derived foods seem to be seen as innovative but less essential. For upcycled foods, the perception of low pleasantness may stem from consumers' unfamiliarity with the concept of food reuse, as suggested by Aschemann-Witzel and Peschel (2019). Additionally, the low appeal of upcycled foods may stem from how they are presented, as emphasizing their origin in by-products or waste can trigger feelings of disgust and lead consumers to perceive them as lower in quality and taste (Lu et al. 2024).

This aspect inevitably affects purchase intentions. Although AI-treated products are the least appreciated overall, upcycled foods show even lower purchase intentions. Lower perceived pleasantness may contribute to the reduced willingness to buy upcycled foods, as it shows the strongest association with purchase intention among the evaluated attributes. Consistent with previous studies, this lower pleasantness could be linked to the perception of upcycled foods as being derived from waste materials, which are often viewed as unappetizing and unsuitable for consumption (Sharma and Deutsch 2023).

Although beliefs and purchase intentions toward the three technologies and novel foods differ significantly, the small effect sizes ($\eta^2 \approx 0.01$) indicate limited practical significance. Thus, these results should be interpreted cautiously, as they reflect general trends rather than strong divisions in public opinion.

The results of the analyses highlight significant differences in the determinants of purchase intention for foods treated with upcycling technology, biostimulants, and AI tools. It is evident that socio-demographic factors have a low association with purchase intention. However, women appear to be more willing to purchase upcycled foods, while men show a greater intention to buy AI-treated foods. While our study did not directly assess the reasons behind these gender differences, previous literature allows us to hypothesize that women's greater familiarity with food-reuse practices may make them more open to upcycled foods. Conversely, men usually show a more positive attitude toward technological innovation, which could increase their acceptance of AI-applied food technologies (Castellini et al. 2025), although such explanations remain speculative.

However, the fact that age and education are not related to the intention to buy foods treated with these technologies could be explained by Italy's strong attachment to traditional culinary values and its general skepticism towards food innovation (Torri et al. 2020). In this context, cultural values related to food play a much more significant role than age or education.

In contrast, beliefs about the product and the psychological characteristics of consumers play a more significant role. This finding is confirmed by previous studies that highlight the ambiguous role of socio-demographic characteristics in the purchase of novel foods, emphasizing the importance of psychological and attitudinal dimensions (Laureati et al. 2024) instead. The inclusion of beliefs about novel food, trust in actors within the agri-food system, and knowledge of these technologies in the models leads to a significant increase in the explained variance for all three technologies, confirming previous studies (Barrena et al. 2015). Indeed, as extensively demonstrated in previous research, positive beliefs foster openness to new experiences, trust in agri-food actors reduces perceived risks and uncertainty, and greater knowledge enables consumers to better understand the benefits and safety of novel technologies (Albertsen et al. 2020).

Trust in agri-food system actors appears to show a slightly higher positive association with upcycled food purchase intention compared to AI or biostimulants. This could suggest that, because upcycled foods are less familiar and perceived as more ambiguous than other novel foods, their acceptance depends more heavily on reassurance and guarantees provided by trusted institutions and actors. In other words, consumers need credible endorsements and transparency from these entities to feel confident about the safety and value of upcycled foods.

Finally, the inclusion of psychological variables in the final model further improves the explanation of consumption intention. If willingness to try new foods, food technology neophobia, and food involvement are strongly associated with the intention to purchase foods treated with these AI, biostimulants and upcycling technologies, concerns about the environment, personal health, and conspiracy thinking do not have a significant association. The lack of relationship between purchase intention and environmental or health concerns can be explained by the fact that, for Italian consumers, deep-rooted fears about food technology outweigh the perceived sustainability and health benefits—an effect supported by previous research on the moderating role of neophobia and variety seeking (Huang et al. 2019; Lee et al. 2021). Furthermore, the lack of a relationship between levels of conspiratorial thinking and acceptance of novel foods may be due to the fact that, in the context of sustainable food technologies, other factors—such as perceived benefits, trust, and knowledge—play a more central role in shaping consumer acceptance. It is also possible that the neutral framing of the technologies provided in this study did not trigger the kind of concerns typically associated with conspiracy thinking.

On the other hand, food technology neophobia is negatively associated with the intention to buy all novel foods considered in this study, with the strongest impact on AI-treated foods. This result aligns with other studies on novel foods, which have shown that fear of food technology is one of the main drivers negatively affecting purchase intention, particularly when it comes to AI-treated foods. These are often perceived as more artificial and less natural than upcycled foods or those treated with biostimulants (Siegrist and Hartmann 2020a).

Moreover, the willingness to try new foods is positively associated with the acceptance of all novel foods considered in this study, indicating that more curious and innovative consumers

are more open to novel foods (Popa and Popa 2012). In particular, the results show that the relationship between variety seeking and the intention to purchase upcycled foods is greater than the association observed for foods treated with AI or biostimulants. This finding aligns with previous studies, which explain that upcycled foods, being among the least known novel foods, need more consumer openness to new foods for their acceptance (Grasso et al. 2023).

Finally, food involvement has a positive association with the acceptance of foods treated with AI and biostimulants, but there is no statistically significant relationship between food involvement and the intention to purchase upcycled foods. These results appear to be consistent with previous studies that have highlighted how a strong interest in food enhances the acceptance of these technologies (Giacalone and Jaeger 2023). At the same time, they show that upcycled foods are still so little known that they have not yet acquired a psychological meaning or particular symbolic value for consumers, which explains the lack of a significant role for food involvement in their acceptance. However, foods treated with biostimulants and AI are beginning to take on a psychological value for consumers, precisely because they are more familiar and recognized.

In summary, these results suggest that the acceptance of the three technologies is shaped by distinct psychological mechanisms. For upcycled foods, purchase intention is mainly driven by curiosity and openness to new food experiences, as indicated by the strong role of variety seeking. Trust in agri-food system actors also plays a crucial role, helping to reduce uncertainty about these products. This highlights that, being less familiar than other novel foods, upcycled foods require reassurance from credible institutions to foster consumer confidence in their safety and value. In contrast, the acceptance of foods treated with biostimulants and AI appears to be more strongly linked to food involvement, reflecting a deeper personal and emotional engagement with these technologies. Consequently, the emotional and social meanings attributed to these foods are more structured and defined compared to those associated with upcycled foods, as they are more familiar and less ambiguous. However, foods treated with AI face greater psychological barriers due to stronger associations with food technology neophobia. The abstract, invisible, and data-driven nature of AI tends to provoke higher apprehension, reinforcing perceptions of distance from natural food processes when compared to upcycling or biostimulants.

Despite the interesting insights derived from this study, it has some limitations. In particular, the descriptions of the technologies provided in the questionnaire may not have fully captured their complexities. Differences in the emphasis on potential benefits versus concerns—although designed to reflect typical consumer-facing communication—may have resulted in asymmetric framing, which could have influenced participants' comparative perceptions across technologies. Moreover, the findings cannot be generalized beyond the Italian context. Cultural factors, food traditions, and consumer beliefs specific to Italy may not be applicable to other countries, thus limiting the external validity of the results. Furthermore, this study did not investigate purchase intentions and beliefs about novel foods by focusing on a specific food product but rather addressed novel foods in general terms. However, as noted in other studies, beliefs may vary depending on the specific food

categorized (Barrena et al. 2015). Additionally, the research focused on these technologies as applied to agriculture, leaving us without information on how they might be perceived if implemented in other stages, such as food processing. Additionally, there is potential for common method bias, particularly due to the measurement of consumers' beliefs and purchase intentions in a single session using similar item formats. Moreover, the results of Harman's single-factor test suggest that common method bias may have partially inflated some of the relationships observed in the study, especially those involving beliefs and intentions. Future research employing multi-method or time-lagged designs would help reduce this risk. Finally, purchase intentions were measured in a theoretical context. Direct exposure to these products could elicit reactions different from those identified through surveys.

Future studies could, therefore, explore purchase intentions and beliefs about specific novel foods, analyzing how the type of food impacts consumer perceptions and testing these dynamics across different countries to assess cultural variability. It would also be valuable to examine the application of these technologies not only in agriculture but also in food processing stages. Including income as a socio-demographic factor could enhance segmentation and targeting strategies. Lastly, longitudinal studies could assess changes over time, while field experiments might provide a more realistic evaluation of consumer reactions.

6 | Practical Implications

The results of the study may offer several practical implications for the agribusiness sector and for actors involved in the promotion of foods produced using innovative technologies such as upcycling, biostimulants, and AI. First, given the generally low level of consumer awareness of these technologies, it may be useful to consider the development of targeted information campaigns aimed at explaining how these technologies work and what benefits they may bring to agricultural production. Such initiatives could potentially help reduce the perceived distance between consumers and technological innovations, particularly if information is conveyed in an accessible and audience-specific manner.

However, the findings also suggest that increasing knowledge alone may not be sufficient. Consumers' beliefs seem to be closely associated with their purchase intentions. In the case of upcycled foods, negative perceptions may arise from their association with waste, which can elicit feelings of disgust or concerns about quality. Communication strategies might therefore benefit from emphasizing the added value, quality, and environmental benefits of these products, while avoiding or carefully contextualizing references to "waste." It could also be worth exploring the adoption of alternative terminology that highlights positive attributes, although further research would be necessary to evaluate the effectiveness of such an approach.

With respect to AI in agriculture, consumer resistance may be linked to perceived risks and artificiality. Communication efforts could potentially be more effective if they focus on aspects such as efficiency, precision, and safety, while clarifying that AI is used to support agricultural processes rather than to directly alter the food product. The involvement of trusted experts from

the agri-food sector might help address consumer concerns and increase credibility. Moreover, it may remain important to clearly distinguish AI applications in agriculture from genetic modification, which continues to be viewed negatively by many consumers (Ventura et al. 2017).

Given the observed differences in acceptance across the three technologies examined, differentiated communication strategies may be warranted. While innovation-oriented and curious consumers may represent an initial target group, engaging more hesitant consumers may require a stronger emphasis on transparency, trust-building, and scientific evidence. For example, foods treated with biostimulants could be framed within broader sustainability narratives, whereas AI-based applications might be illustrated through concrete, real-world examples that demonstrate potential benefits for product quality and environmental impact.

In addition, future motivational research could help deepen the understanding of the underlying fears that may contribute to resistance toward these technologies and could support the design of more tailored interventions aimed at fostering openness. The present study suggests that unconscious fears related to food innovation and novel technologies are significantly associated with purchase intentions. Among these, fears related to the unknown or to technological uncertainty (Siddiqui et al. 2022) may play a role, particularly when consumers have a limited understanding of how such technologies function. Concerns about the loss of naturalness or food authenticity may also be relevant (Castellini and Graffigna 2022).

Finally, the positive association observed between food involvement and purchase intention may indicate the potential value of linking these products to personally meaningful values and experiences. Communication strategies that incorporate storytelling and emotional dimensions of food—such as tradition, innovation, and sustainability—could help strengthen consumers' engagement and, in turn, may contribute to greater acceptance of these emerging technologies.

We emphasize that these points should be understood as tentative suggestions rather than evidence-based recommendations, as further research is needed to assess their effectiveness.

7 | Conclusion

The introduction of new technologies in agriculture, such as AI, biostimulants, and upcycled technologies, could help mitigate the negative environmental impacts of the agricultural sector. However, it is important to understand how consumers perceive these technologies and the novel foods on which they have been applied, to forecast interventions aimed at increasing their acceptability. Through quantitative and comparative analysis, this study highlighted that Italian consumers have limited knowledge of sustainable technologies applied to agriculture. While beliefs about these technologies are generally positive, barriers remain related to perceptions of artificiality, risks, and likability, particularly for AI and upcycled foods. However, the observed differences between technologies are small, suggesting limited practical implications despite statistical significance.

Purchase intentions are more strongly associated with psychological and attitudinal factors than with socio-demographic variables, although product perceptions play a central role. Specifically, beliefs about novel foods, variety seeking, and food involvement facilitate acceptance, while technological neophobia represents a cross-cutting obstacle.

To promote the acceptance of these novel foods, an integrated approach that combines education, reassurance, and personalization of messages, adapting them to the specifics of each technology and different consumer segments, is essential. Only in this way will it be possible to overcome cultural and psychological barriers, promoting the acceptance of these sustainable food innovations.

Author Contributions

Greta Castellini: conceptualization, methodology, data curation, formal analysis, writing – original draft. **Guendalina Graffigna:** writing – review and editing, supervision. All authors have approved the final article. This paper is derived from a collaboration of the authors.

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Ethics Statement

This study has been performed in accordance with the Declaration of Helsinki, and Ethical approval for the involvement of human subjects in this study was granted by the Research Ethics Committee (CERPS), Reference number 87-23.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data are fully available upon request to the corresponding author.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

SUPPLEMENTARY MATERIAL A. SUPPLEMENTARY MATERIAL B. SUPPLEMENTARY MATERIAL C.