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Conflicting Consumer Beliefs Influencing Eco-Innovation Adoption: Motives and Barriers for Accepting the Laser Marking of Organic Products

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ABSTRACT

In response to regulatory requirements and consumer demand for sustainable products, producers of organic products are beginning to use laser marking to reduce packaging and, thereby, packaging waste. However, the consumer responses to this "high-tech" eco-innovation remain unexplored. Using a mixed-method approach, we collected qualitative and quantitative data on responses to the laser marking of organic products from 328 French participants. Guided by the theory of consumption values and innovation resistance theory, we conducted a thematic analysis of answers to an open-ended question which probed consumers' motives for and barriers to adopting laser marking. The most frequently stated motive was ecological benefits, and the most reported barriers were risks and tradition. Structural equation modeling revealed that attitudes toward laser-marked organic products are positively impacted by social, emotional, and functional values and are negatively impacted by barriers related to images and emotions. Consumers' attitudes toward laser-marked organic products strongly affect their willingness to buy such products. To increase the acceptance of laser marking, managers and policymakers should mitigate false-negative consumer perceptions, including doubts about its eco-friendliness and safety, thereby facilitating greater acceptance of this eco-innovation.

1 | Introduction

The sale of fresh organic fruits and vegetables—the most consumed organic product category (Agence Bio 2021)—is growing slowly in Europe (USDA Foreign Agricultural Service 2024). Many consumers seem skeptical about organic products, not least due to its high prices (Fresh Plaza 2024), and are not all convinced that it is better for the environment (Dalmoro, de Matos, and de Barcellos 2020).

European consumers buy organic products mainly in supermarkets (Agence Bio 2021), where regulation requires products to be labeled as organic to differentiate them from nonorganic products. In practice, this requires (plastic, cardboard, or similar) packaging or stickers on individual items (CBI Centre for the Promotion of Imports from Developing Countries 2024). While these are intended to protect consumers from misleading practices, many dislike them (Frank and Brock 2019) because they conflict with the environmental friendliness of organic products (Agence Bio 2021). Stickers have the benefit of being smaller than packaging, but they can be difficult to remove and often end up in compost—particularly in European countries and cities where composting of bio-waste is compulsory (Euronews 2024)—and then in the soil in the form of microplastics (ATS-Tanner 2024).

In the quest to reduce the use of packaging and stickers, thus meeting consumer demand for eco-friendly products (Ismael and Ploeger 2020), the innovative practice of laser marking (sometimes called laser tattoos or natural branding) has emerged (Samoggia and Nicolodi 2017). Laser marking involves the use of a light beam to affix, for example, an organic label on the skin of the fruit or vegetable by removing a thin layer without harming the product (Puértolas, Pérez, and Murgui 2024). The technology allows retailers to sell fresh organic fruits and vegetables with labels directly on their skin, eliminating the need for additional packaging or stickers to display the label.

The production of packaging and stickers requires resources such as energy, paper, water, and chemicals like glue and ink. As laser marking replaces these environmentally harmful substances and processes, it is considered an eco-innovation (Samoggia and Nicolodi 2017). However, innovations, not least those related to food products, often face consumer resistance (Dwivedi et al. 2023; Gonzalez-Arcos et al. 2021; Phillips and Hallman 2013; Talwar et al. 2023). Food products that feature innovations can acquire new social symbolism (Samoggia and Nicolodi 2017) with the result that consumers' perceptions of them may conflict with their existing values and belief systems (Ram and Sheth 1989). This can lead to cognitive dissonance (Oshikawa 1969) and psychological barriers to accepting the innovation (Kushwah, Dhir, Sagar, and Gupta 2019). Hence, "high-tech" eco-innovations can be controversial when applied to organic food products and may negatively affect consumer purchases despite their social value (e.g., environmental benefits) (Merle, Herault-Fournier, and Werle 2016; Samoggia and Nicolodi 2017).

Consumers may also feel ambivalent about the innovation itself. On the one hand, they may associate laser-marked organic products with environmental benefits due to the elimination of packaging and stickers. On the other hand, they may perceive personal risks from the application of the laser onto the product. Functional values, such as health and safety, are important reasons why consumers buy organic products (Rana and Paul 2020). However, if the use of laser marking is associated with potential health risks, this could "wipe out" these perceived benefits (Pfiffelmann et al. Forthcoming). As laser marking may be considered to contradict a key perceived benefit of organic products—being healthful—it is an interesting case for illustrating potential consumer ambivalence toward eco-innovations (Dalmoro, de Matos, and de Barcellos 2020; Vigar et al. 2019).

Against this background, the current research aims to shed new light on the role of new technology and, more specifically, eco-innovation for sustainability (Dabbous and Aoun Barakat 2023). We investigate potential adopters' perceptions of and responses to the laser marking of organic fruits and vegetables—a field where producers are increasingly innovating to meet the challenges of sustainable development (Liu et al. 2022; Plazzotta et al. 2020). Research on consumer perceptions of laser marking is scarce, with limited focus on the perceived costs and benefits for the environment and health (Pfiffelmann et al. Forthcoming; Samoggia and Nicolodi 2017). To address this research gap, we investigate the motives for and barriers to consumer acceptance of laser-marked organic labels for fruits and vegetables. We employ a holistic conceptual framework based on the theory of consumption values (Sheth, Newman, and Gross 1991), innovation resistance theory (Ram and Sheth 1989), and the theory of reasoned action (Fishbein and Ajzen 1975).

The extant literature rarely examines the medium through which organic and other ecolabels are presented, or the critical interaction between organic products and their packaging in general despite its importance to consumers (van Herpen, Immink, and van den Puttelaar 2016). Therefore, the question of whether consumers are willing to accept innovative labeling methods such as laser marking remains unresolved both generally and specifically for organic products—another gap addressed by this research.

In the context of eco-innovation, extant research provides a less varied perspective on the technology applied to organic products. While laser marking is a technological advancement expected to bring environmental benefits (Carrillo-Hermosilla, del Río, and Könnölä 2010; Geels 2011), consumers may believe that it reduces the personal benefits of organic products. We, therefore, explore the conflict that consumers may perceive between the environmental benefits and personal costs of this technology (Merle, Herault-Fournier, and Werle 2016). Specifically, we investigate whether, in this case, consumers are willing to forgo personal benefits for the greater good of environmental sustainability.

Understanding which factors favor or impede the willingness of early adopters to accept laser marking is crucial for producers and retailers attempting to introduce this eco-innovation in the organic fruit and vegetable market. This research takes a concurrent embedded mixed-method approach (Creswell and Plano Clark 2018) to investigate consumers' perceptions of laser-marked organic fruits and vegetables, the perceptions that form their attitudes toward these products, and the motives and barriers behind their willingness to buy laser-marked organic products.

2 | Literature Review and Research Questions

2.1 | Eco-Innovation in Packaging Solutions

Eco-innovation involves creating or significantly enhancing products, processes, organizational changes, or marketing strategies that minimize the consumption of natural resources and reduce the emission of harmful substances throughout their entire life cycle (EIO [Eco-Innovation Observatory] 2012). An innovation merits the label "eco-innovation" if it adds value for consumers and businesses by significantly reducing environmental impacts (Smol, Kulczycka, and Avdiushchenko 2017).

In the food industry, an important area for eco-innovation is the development of more sustainable packaging which causes less environmental harm without sacrificing food preservation (Afif, Rebolledo, and Roy 2022; Keränen et al. 2021; Rameshbhai Patel 2023). Solutions include optimizing the size of packaging

to reduce waste and maximize space efficiency (Eberhart and Naderer 2017; Liang et al. 2022) and transitioning to sustainable materials, such as biobased, recycled, and compostable options like paper and cardboard (Allegra, Zarbà, and Muratore 2012; Drago et al. 2023). Innovative design strategies focus on functionality and recyclability using minimalist and modular approaches (Steenis et al. 2018). Improved waste management systems, such as take-back programs and comprehensive recycling instructions, facilitate effective recycling and reuse (Bhardwaj 2019; Lewis and Stanley 2012). Cutting-edge technologies, including laser marking, intelligent packaging with freshness sensors, and nanotechnology for superior barrier properties, have the potential to revolutionize the industry, improving packaging efficiency and reducing environmental impact (Gautam 2023; Puértolas, Pérez, and Murgui 2024). Table 1 offers examples of actions to improve packaging sustainability.

Research has demonstrated that cutting-edge packaging technology can increase food quality, decrease food waste, and promote eco-sustainability (Cristofoli et al. 2023; Drago et al. 2023). For instance, nanotechnology provides more hygienic materials with enhanced mechanical and antibacterial qualities, extending product shelf life, and improving food safety (Gautam 2023). Another example is laser-marking technology, which is a potential game-changer for the organic food sector. It offers a sustainable solution for labeling organic fruits and vegetables without the need for packaging or plastic stickers (Puértolas, Pérez, and Murgui 2024; Samoggia and Nicolodi 2017).

2.2 | Laser-Marking Technology as an Eco-Innovative Packaging Solution for Organic Products

In the EU and many other countries, to be sold as organic, fruits and vegetables must have an organic certification, often known as an ecolabel.[1] Ecolabels give consumers information about the environmental quality of a product or service at the point of purchase, enabling them to choose environmentally acceptable options (Thøgersen, Haugaard, and Olesen 2010). They promote environmental sustainability without limiting consumer freedom of choice and they reduce information search costs, making consumers more likely to use the information provided (Grunert and Wills 2007). However, conflicting with its ecological intent, ecolabeling can contribute to packaging waste when stickers or packaging are needed to display the ecolabel (Pfiffelmann et al. Forthcoming).

High consumer expectations drive producers to come up with increasingly creative ways to improve their products (Sumrin et al. 2021), for example, in terms of their economic, social, and environmental performance (Welch, Swaffield, and Evans 2021). This is true even in the production of traditional products like fruits and vegetables (Plazzotta et al. 2020). As laser marking of organic fruits and vegetables, where labels are created directly on the surface of the product, eliminates the need for stickers and reduces packaging waste, it is considered a packaging eco-innovation (Pfiffelmann et al. Forthcoming; Samoggia and Nicolodi 2017). This presents a market opportunity, as organic food consumers generally prefer

TABLE 1 | Examples of actions to improve packaging sustainability.

Action category	Description	Action examples	References
Packaging size	Adjusting the size of the packaging to optimize space and reduce waste.	Reducing excess packaging material; custom-sizing packaging to fit product dimensions; using compact designs.	Eberhart and Naderer (2017); Elgaaïed-Gambier (2016); Liang et al. (2022); Magnier and Crié (2015).
Packaging material	Using sustainable, recyclable, or biodegradable materials to replace traditional plastics.	Switching to biobased materials; using recycled content; employing compostable materials like paper and cardboard.	Allegra, Zarbà, and Muratore (2012); Bhardwaj (2019); Cristofoli et al. (2023); Drago et al. (2023); Herbes, Beuthner, and Ramme (2020); Lewis and Stanley (2012); Magnier and Crié (2015); Nguyen et al. (2020).
Packaging design	Innovating design to enhance functionality, reduce material use, and improve recyclability.	Minimalist design; modular packaging for multiple uses; easy-to-separate components for recycling.	Magnier and Crié (2015); Steenis et al. (2018).
Packaging waste management	Enhancing systems for recycling, reusing, and composting packaging waste.	Establishing take-back programs; providing clear recycling instructions; implementing closed-loop systems.	Bhardwaj (2019); Herbes, Beuthner, and Ramme (2020); Lewis and Stanley (2012); Magnier and Crié (2015); Scott and Vigar-Ellis (2014); Young (2008).
Packaging technology	Implementing advanced technologies to improve packaging efficiency and reduce environmental impact.	Intelligent packaging with sensors for freshness; use of nanotechnology for barrier properties; laser marking for labeling.	Gautam (2023); Herbes, Beuthner, and Ramme (2020); Pfiffelmann et al. (Forthcoming); Puértolas, Pérez, and Murgui (2024); Scott and Vigar-Ellis (2014).

environmentally friendly products (Grunert, Hieke, and Wills 2014; Thøgersen 2011) and many consider the sustainability of product packaging when making purchasing decisions (Fogt Jacobsen, Pedersen, and Thøgersen 2022). Indeed, there is a general view that plastic packaging is unnecessary and environmentally unfriendly (Fernqvist, Olsson, and Spendrup 2015), and it is therefore perceived to be unsuitable for organic products (Ismael and Ploeger 2020).

Australia and New Zealand have been using laser marking widely since 2009, and European authorities approved the practice in 2013. Some laser-marked products are currently distributed in Europe, for example in the Netherlands (e.g., Jumbo), the United Kingdom (e.g., Marks & Spencer), Germany (e.g., Edeka), Sweden (e.g., ICA), and Belgium (e.g., Carrefour), but it is still uncommon and in a very small share of the organic market (compared to packaged organic products and products labeled with plastic stickers or without any form of packaging). No comprehensive data is available on the supply or sale of laser-marked organic products, but market data from leading European companies that import, export, pack, or distribute fresh laser-marked organic fruits and vegetables in Europe is reported in Appendix A. The data shows the supply of laser-marked organic products varies considerably across products, with avocados and mangos being the most-supplied fruits, and ginger and sweet potatoes leading the vegetable category. The supply of laser-marked organic products increased between 2017 and 2020 and then declined. While this decline is likely to be attributed to external factors (see Appendix A for details), there is a need to better understand consumers' motives for and barriers to adopting this technology.

2.3 | Theory of Consumption Values and Consumer Motives for Adopting Laser Marking

Before fully adopting an innovation, a typical adopter progresses through several stages: initial exposure to the innovation or information about it; developing an understanding and a positive attitude toward it; and, finally, trying it out (Thøgersen, Haugaard, and Olesen 2010). Low-risk incremental innovations are often adopted via a "low-effort" process, in which a trial occurs immediately after awareness of the innovation without the need for prior information gathering or thorough evaluation (Hoyer, MacInnis, and Pieters 2023). However, the adoption of an eco-innovation often follows a "high-effort" path involving understanding, liking, and trial, before continued use (Hoyer, MacInnis, and Pieters 2023; Thøgersen, Haugaard, and Olesen 2010). Adopters follow a "high-effort" path when they are involved in the decision-making and perceive alternatives to be highly differentiated (Hoyer, MacInnis, and Pieters 2023; McGuire 1985), for example, due to the novelty of the innovation (Kotler and Roberto 1989). Laser marking of organic products has novelty, and as consumers seem to associate it with environmental and/or health-related outcomes, we assume a "high-effort" adoption path in this case.

To obtain a deep understanding of the reasons why consumers adopt or reject the laser marking of organic food, we investigate how its application influences motives for organic food consumption. By capturing the complexity of motivations for accepting or rejecting laser marking, this study distinguishes itself from most research in the field, which primarily focuses on individual consumer motives in isolation. We conduct an in-depth examination of the different consumer motives for preferring organic food and evaluate their impact on the demand for such foods to obtain a more comprehensive perspective on organic food preferences. The theory of consumption values (Sheth, Newman, and Gross 1991) categorizes the motives of consumer choice into five consumption values—functional, emotional, social, conditional, and epistemic—each assumed to contribute independently to shaping consumer preferences and behavior. The different motives for consuming organic products identified by empirical research can be classified into these five consumption values (Chae, Kim, and Roh 2024; Kushwah, Dhir, Sagar, and Gupta 2019), thereby helping to obtain a comprehensive overview of the motives that drive consumer adoption of organic food.

According to Sheth, Newman, and Gross (1991), a product's functional value generally has the biggest influence on consumer choices. Functional value refers to the perceived functional, utilitarian, or physical performance of a product. Systematic literature reviews find that organic food consumption is mainly driven by functional value (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020) or "benefits for oneself" (Merle, Herault-Fournier, and Werle 2016). The functional values related to organic food include product quality (e.g., Hashem et al. 2018; Janssen 2018; Vukasovič 2016), absence of harmful ingredients (e.g., Sobhanifard 2018), sensory aspect (e.g., Hasselbach and Roosen 2015; Sobhanifard 2018), food safety (e.g., Hasselbach and Roosen 2015; Roitner-Schobesberger et al. 2008; Vukasovič 2016), nutritional value (e.g., Vukasovič 2016), naturalness (e.g., Hasselbach and Roosen 2015; Janssen 2018; Sobhanifard 2018), freshness (e.g., Vukasovič 2016), and healthfulness (e.g., Hashem et al. 2018; Hasselbach and Roosen 2015; Janssen 2018; Sobhanifard 2018). Healthfulness is a primary food consumption motive (Rana and Paul 2020) and there is much evidence that organic food is generally perceived to be healthier than conventional food (Dalmoro, de Matos, and de Barcellos 2020; Vigar et al. 2019). Important health-related beliefs of organic food include the absence of chemical residues, antibiotics, hormones, genetically modified organisms, and pathogens (Hamzaoui Essoussi and Zahaf 2009).

Although research often finds that consumers primarily value the health and nutritional advantages of organic products, their perceived eco-friendliness is also important (Tanner and Wölfing Kast 2003; Wood et al. 2023). Systematic literature reviews have found that organic product consumption is driven by both its functional and its social values (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020) or "benefits for others" (Merle, Herault-Fournier, and Werle 2016). Organic food production preserves biodiversity and natural resources (Ruiz De Maya, López-López, and Munuera 2011), helping to attenuate the daunting problems facing humanity (Essiz and Mandrik 2022). The social value of organic food is also associated with motives related to identity, such as consumers' self-image, self-identity, and social approval (Chae, Kim, and Roh 2024; Puska et al. 2018), and with the product's ability to

enhance the buyer's societal image (Mohd Suki, Majeed, and Mohd Suki 2022). Hence, identification with organic food consumption may promote self-transformation toward a sustainable consumer identity, characterized by a desire to adopt sustainable and ecological behaviors (Fernandes and Saraiva 2022). In sum, the social value of organic food consumption lies in care for the self, nature, and the community (Fernandes and Saraiva 2022; Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020).

Emotional value refers to the potential of a product to provoke favorable feelings in consumers (Sheth, Newman, and Gross 1991). Emotional value, including the happiness and moral satisfaction experienced from consuming eco-friendly products, plays a role in orienting green consumption choices (Khan and Mohsin 2017). This emotion stems from the anticipated self-rewarding feelings linked to environmentally friendly behaviors (Talwar et al. 2022) and is true for organic food consumption, where past research has found that drivers include enjoyment, perceived hedonism, and pleasure (Bauer, Heinrich, and Schäfer 2013; Janssen 2018). Emotional forecasts are found to influence green consumption behavior (Onwezen, Bartels, and Antonides 2014), and positive emotions positively affect attitudes toward green consumption (Talwar et al. 2022). Emotional rewards linked to organic food consumption enhance positive evaluations of organic products and perceived social approval, serving as a motivator for consumers to align their behaviors with environmental aspirations and societal norms (Chae, Kim, and Roh 2024; Talwar et al. 2022).

Specific situational and various external factors can influence the conditional value of organic food consumption. Conditional value refers to the choice of the product being contingent on the context and circumstances faced by the consumer (Sheth, Newman, and Gross 1991). Monetary incentives and product accessibility positively influence organic food consumption, although the impact of conditional value varies by situation (Gleim et al. 2013). Increasing consumer awareness about organic foods and demonstrating the ease of adopting an organic lifestyle effectively enhance conditional value (Chae, Kim, and Roh 2024). The conditional values that drive the consumption of organic food include convenience, current health issues or concerns, a focus on maintaining good health, and considerations about local pollution and carbon footprint (Aschemann-Witzel and Niebuhr Aagaard 2014; Pham et al. 2018).

Epistemic value refers to the perceived ability of a product to spark interest, give novelty, or satisfy a demand for knowledge (Sheth, Newman, and Gross 1991). A completely new consumption experience or even a minor change in habits enhances epistemic values. Boredom with current products, curiosity, or a desire to learn can all drive epistemic value. Novelty and variety-seeking motives are important factors that activate product search, trial, and switching behaviors in food consumption (Murray, Jin, and Martin 2022; Tuorila and Hartmann 2020), including organic food consumption (Chae, Kim, and Roh 2024). As consumers gain knowledge and understanding of sustainable products, their environmental concerns increase, leading to greener consumption choices (Tezer and Bodur 2020). By providing specific and detailed information about organic food, it is possible to enhance the epistemic value to consumers (Chae, Kim, and Roh 2024). While there has been little focus on this value in research on organic food consumption, a few studies have highlighted the impact of nostalgia, fashion, knowledge, and familiarity with organic food (Kushwah, Dhir, and Sagar 2019; Lin and Huang 2012).

Overall, extant research suggests that the most important motive for organic food consumption is to obtain its functional value, followed by its social value (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020). This sets the scene for what happens when an eco-innovation like laser marking is applied to organic products. This eco-innovation creates social value by removing the need for plastic to communicate that the product is organic (Samoggia and Nicolodi 2017). While it may primarily be considered a technique to protect the natural integrity of the food, the laser-marked organic label does not change the nutritional characteristics of the product (Puértolas, Pérez, and Murgui 2024; Samoggia and Nicolodi 2017) or other functional values. Therefore, we expect that consumer motivations to accept laser marking of organic food are primarily driven by social value rather than functional value. Epistemic value may also play a role in the acceptance of laser marking because this technology is relatively new and may intrigue consumers, particularly those interested in novelty. As there is little scientific knowledge about consumer perceptions of laser marking and as qualitative research is particularly suited to under-investigated issues (Crick 2021), we use a qualitative approach to obtain a detailed understanding of consumers' motives for evaluating laser-marked organic labeling. We therefore follow an open, explorative approach to address the following research question:

RQ1 *Which motives are most salient for consumers when evaluating laser-marked organic labeling of fruits and vegetables?*

2.4 | Innovation Resistance Theory and Consumer Barriers to Adopting Laser Marking

Most of the prior research assumes that new sustainable products are perceived as superior to existing ones—pro-innovation bias (Acuti, Pizzetti, and Dolnicar 2022). However, while new technologies usually bring greater benefits, they often increase the risks perceived by consumers and their fear of a negative experience, sometimes referred to as the paradox of technology (Frank, Chrysochou, and Mitkidis 2023). Research on consumer resistance to innovations finds that numerous issues can emerge during the introduction and readaptation phase and that most consumers become receptive to innovations only after these issues are resolved (Ram and Sheth 1989). This research investigates the underlying reasons for consumer resistance to innovative organic food products using innovation resistance theory to provide a comprehensive understanding of the barriers involved. First, we map the functional and psychological barriers to buying organic food identified by previous research. Then, we discuss how the laser-marking technology for organic labels can alter consumers' perceptions of various aspects of a product, including perceived barriers to adopting them.

Innovation resistance theory (Ram and Sheth 1989) was developed to understand consumer resistance to new products and to classify the barriers that restrict the adoption of innovative

products or services. By highlighting the factors that explain consumer resistance, the theory helps to ascertain the success or failure of innovations. Past research has identified barriers to the consumption of organic food that correspond to classifications suggested by innovation resistance theory (Kushwah, Dhir, Sagar, and Gupta 2019). Therefore, innovation resistance theory seems to be a suitable framework for investigating possible barriers to the adoption of eco-innovations related to organic food, such as laser marking of organic fruits and vegetables. The theory proposes five barriers related to usage, value, risk, image, and tradition. It divides these into two broader categories—functional barriers and psychological barriers.

Functional barriers appear when consumers perceive that adopting an innovation entails a significant change in their consumption patterns in terms of usage, value, or risk. A usage barrier appears when there is perceived incongruence between an innovation and the consumer's existing practices or habits (Ram and Sheth 1989). A value barrier appears when the consumer fails to perceive that the added value justifies the cost of the new product compared to existing alternatives (Ram and Sheth 1989). For example, research has found that many consumers experience a value barrier for organic products due to their higher price compared to conventional products (e.g., Torres-Ruiz, Vega-Zamora, and Parras-Rosa 2018; Yazdanpanah, Forouzani, and Hojjati 2015), which negatively influences the purchase of organic products (Leonidou et al. 2022; Wu et al. 2019). Nevertheless, many consumers are willing to pay more for organic products because they worry about the environmental consequences of conventional agriculture (Bradu, Orquin, and Thøgersen 2014; Katt and Meixner 2020). Risk barriers can arise from the consumer's perceived uncertainty about a new product (Ram and Sheth 1989). In the context of organic food, the three main risk barriers identified by previous research are uncertainty about label authenticity, doubt about certification and labeling agencies, and skepticism about the processes involved (Roitner-Schobesberger et al. 2008; Sondhi 2014; Torres-Ruiz, Vega-Zamora, and Parras-Rosa 2018). The perceived risk of being misled when buying organic food may lead to more effort being invested in the adoption process of these products (Fazio 1990; Hoyer, MacInnis, and Pieters 2023). A similar scenario has been proposed in the case of laser-marking adoption (Samoggia and Nicolodi 2017).

Psychological barriers arise when there is a perceived conflict between important consumer beliefs and innovation. Ram and Sheth (1989) further classify psychological barriers into tradition and image barriers. For example, previous research reveals that deviation from traditional, well-known products that offer sensory experiences, such as smell, taste, and sight, can have a detrimental impact on customers' perceptions of the product's quality (Kushwah, et al. 2019). Image barriers are likely to arise if a product's inherited identity, including brand, place of manufacture, or product category, has negative connotations (Ram and Sheth 1989). Regarding organic products, prior research mostly focuses on consumer skepticism and a lack of distinction from conventional products (Misra and Singh 2016).

The biggest barriers to consumer adoption of organic products appear to be the value barrier followed by the usage barrier (Kushwah et al. 2019). It is not clear whether laser marking of organic fruits and vegetables should create additional barriers related to product usage or value. However, it may increase concerns about food safety and health risks (Pfiffelmann et al. Forthcoming), despite no negative side effects for consumer health having been identified (Puértolas, Pérez, and Murgui 2024). Clearly, if laser-marking technology increases consumers' concerns about potential health risks, understanding their reactions to this eco-innovation is crucial for its future success (Samoggia and Nicolodi 2017). Given the lack of prior research, we also take a qualitative approach to gain a deeper understanding of the barriers that may lead consumers to resist laser-marked organic labeling, thereby attempting to answer the following research question:

RQ2 *Which are the most salient barriers that may lead consumers to resist laser-marked organic labeling of fruits and vegetables?*

2.5 | Impacts of Motives and Barriers on Attitude Toward Laser-Marked Organic Products

Eagly and Chaiken (1993) define an attitude as a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor. In our context, a consumer's attitude toward laser-marked organic products is that consumer's positive or negative overall evaluation of organic fruits and vegetables labeled with laser-marking technology. The theory of consumption values (Sheth, Newman, and Gross 1991) posits different consumption values that positively influence consumers' attitudes and choices. Supplementing this, innovation resistance theory (Ram and Sheth 1989) suggests various barriers that negatively influence consumers' attitudes and choices. Consistent with these two theories, empirical research has identified a range of motives for and barriers to the adoption of organic food (Kushwah et al. 2019) and other eco-friendly products (e.g., Barbarossa and De Pelsmacker 2016).

Research based on the health belief model (Hochbaum, Rosenstock, and Kegels 1952) posits that individuals strive for optimal well-being and, therefore, are more likely to engage in health-related behavior if they believe it will benefit their health and if they feel susceptible to health problems. This helps to explain why functional values, such as the perceived health benefits of organic products, are important for buying decisions (Hashem et al. 2018; Hasselbach and Roosen 2015; Janssen 2018; Sobhanifard 2018).

Other research has found that consumers buy organic food products partly based on altruistic motives, whereby they aim to contribute to the greater good by supporting sustainable practices (Barbarossa and De Pelsmacker 2016; Merle, Herault-Fournier, and Werle 2016). Yet other research indicates that people may also have ego-centric motives for buying organic products, such as enhancing their own social status (Chae, Kim, and Roh 2024; Mohd Suki, Majeed, and Mohd Suki 2022; Puska et al. 2018). These streams of research are consistent with our earlier proposition that, while functional values may be most important (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020), social values are also critical for consumers' decisions to buy organic food, both for altruistic and egoistic reasons (Barbarossa and De Pelsmacker 2016).

Consumers may also perceive negative personal outcomes from engaging in organic food consumption (Barbarossa and De Pelsmacker 2016; Dawes 1980), particularly due to its higher price (Torres-Ruiz, Vega-Zamora, and Parras-Rosa 2018; Yazdanpanah, Forouzani, and Hojjati 2015). Most research emphasizes that this is the biggest barrier to organic food consumption (Kushwah, Dhir, Sagar, and Gupta 2019).

As organic products are generally perceived to be healthier than conventional ones (Dalmoro, de Matos, and de Barcellos 2020; Vigar et al. 2019), previous research rarely identifies barriers associated with risks to health (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020). Nevertheless, consumers may associate new technologies such as laser marking with risks of contamination, especially if the skin of the product is edible, creating fear and doubt about the products (Pfiffelmann et al. Forthcoming). Contagion theory (Nemeroff and Rozin 1989) suggests that the perceived health risk is greater for products that are ingested because of their passage into the body, which implies a transfer of physical, behavioral, or moral properties from the product to the body. This perceived risk of contamination may become a significant barrier to the adoption of laser-marked organic products if consumers fear that the technology compromises the safety and healthfulness of the product. The introduction of laser marking could, therefore, create a negative health halo (Sundar et al. 2021), which could impede consumer acceptance. Thus, while organic products are typically associated with health benefits, any perceived risk associated with laser marking could be a barrier to adoption and create a negative attitude toward this eco-innovation.

Consistent with the basic tenets of the theories of consumption values (Sheth, Newman, and Gross 1991) and innovation resistance (Ram and Sheth 1989), we expect that the salient motives for adopting this innovation (as reflected by how frequently they were stated in response to an open question) positively influence consumers' attitudes toward laser-marked organic products and that the salient barriers negatively influence these attitudes. Due to the lack of previous research, we restrict ourselves to formulating hypotheses about the general impacts of salient motives and barriers but abstain from predicting which specific motives and barriers drive attitudes toward this eco-innovation.

H1 *Attitude toward laser-marked organic products is positively influenced by the salient consumer motives for accepting this eco-innovation, as reflected in responses to an open question about the advantages of using laser-marking technology for this purpose.*

H2 *Attitude toward laser-marked organic products is negatively influenced by the salient consumer barriers to accepting this eco-innovation, as reflected in responses to an open question about the disadvantages of using laser-marking technology for this purpose.*

2.6 | The Mediating Role of Attitude Toward Laser-Marked Organic Products

According to social cognitive theories such as the theory of reasoned action (Fishbein and Ajzen 1975) and the theory of planned behavior (Ajzen 1991), consumers' attitudes toward a product are based on their salient beliefs about the product's attributes and on evaluations of these beliefs (Ajzen 1991). Because consumers are motivated to act in line with their beliefs and feelings, a positive attitude leads to a greater willingness to buy the product (Rucker and Petty 2006). In accordance with these theories, we assume that positive and negative beliefs about laser-marked organic products contribute to forming attitudes toward these products, and we assume that this is the primary determinant of consumers' willingness to buy them. Hence, consumers' motives for and barriers to accepting laser marking are primarily expected to impact their willingness to buy laser-marked organic products in an indirect way, mediated through their attitude toward such products. There is mounting evidence to support the expected positive relationship between consumers' attitudes toward and intentions to buy organic food products (e.g., Boobalan et al. 2021; Rana and Paul 2017; Sultan et al. 2020; Teixeira et al. 2022; Thøgersen and Zhou 2012). When studying the market for innovative products which are new and unfamiliar to most potential adopters, buying intentions are somewhat hypothetical and the expression "willingness to buy" is often used instead (e.g., Piha et al. 2018; Stancu et al. 2022). We focus on consumer attitude toward the product and willingness to buy as dependent variables because they are generally considered to be the primary consumer responses of interest in marketing research (Kim and Lennon 2008) and the best indicators of future behavior when investigating the market potential for an innovation (e.g., Li et al. 2021; Thøgersen and Zhou 2012). We therefore test the following hypothesis:

H3 *Consumers' attitudes toward laser-marked organic products (a) positively influence their willingness to buy them and (b) mediate the relationship between their motives for and barriers to buying laser-marked organic products.*

2.7 | The Effects of Personal Factors on the Adoption of Laser Marking

Consumers exhibit varying levels of readiness to adopt new products (Rogers 2003), including eco-innovations in food products (Thøgersen, Haugaard, and Olesen 2010). Hence, the adoption process depends on environmental and product-related factors as well as on personal factors (Grunert and Wills 2007; Hoyer, MacInnis, and Pieters 2023; Thøgersen, Haugaard, and Olesen 2010). The personal factors identified by previous research include consumer motivation, knowledge, experience, and personality (Phillips and Hallman 2013; Thøgersen, Haugaard, and Olesen 2010; Thøgersen, Pedersen, and Aschemann-Witzel 2019). To obtain a deeper understanding of consumers' beliefs and attitudes and to enable market segmentation and identification of the most likely early adopters, it is essential to understand the personal factors that influence consumers' responses to a specific innovation. This is particularly important for a radical innovation such as laser marking due to the uncertainty and perceived risks associated with it, which give rise to more reservations and even resistance than incremental innovations.

Consumers with greater concern about the issue targeted by innovation are more likely to understand and pay attention to it. Concern for the environment is an essential motivation for the

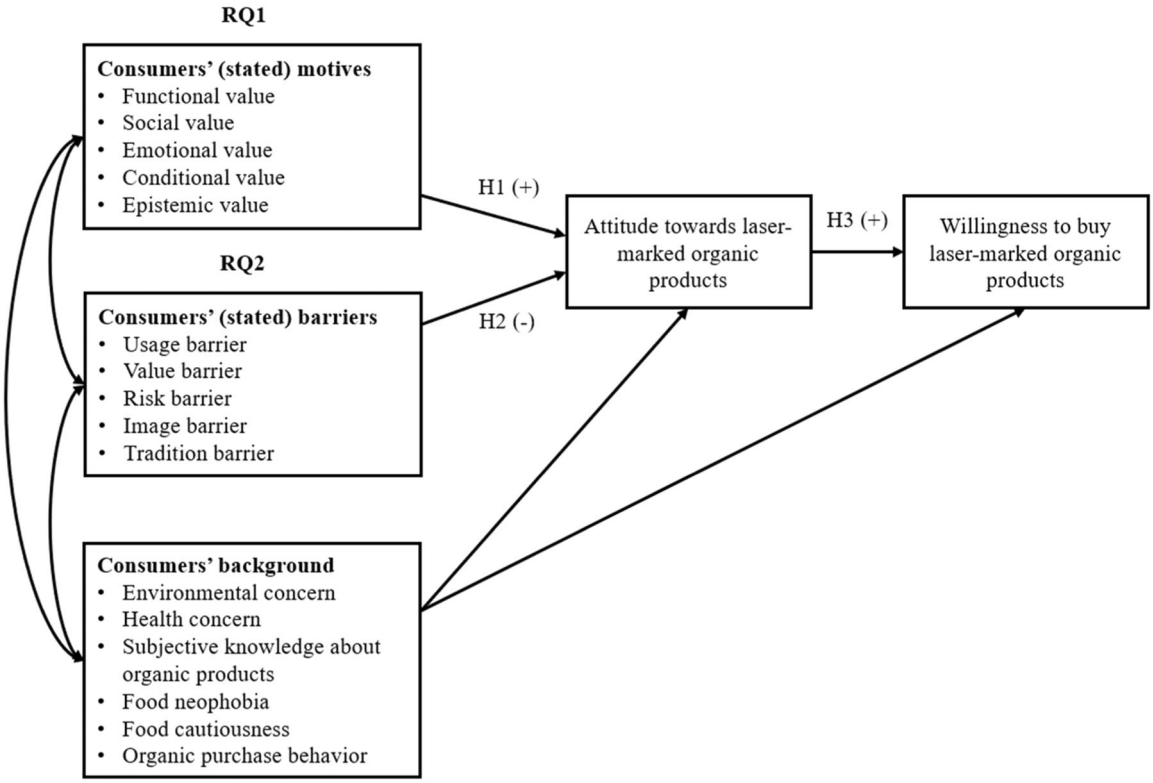

FIGURE 1 | Conceptual model.

sustainable behavior of consumers generally (Casalegno, Candelo, and Santoro 2022) and specifically for eco-innovation adoption (Thøgersen, Haugaard, and Olesen 2010). Due to the environmental benefits of laser marking, which make it an eco-innovation (Samoggia and Nicolodi 2017), it is more likely to be welcomed by environmentally concerned consumers (Tanner and Wölfing Kast 2003). However, consumers who are concerned about their health are more likely to reject it (Squires, Juric, and Bettina Cornwell 2001; Thøgersen, Pedersen, and Aschemann-Witzel 2019). Despite the absence of evidence of any health risks from laser marking, some consumers believe it to be unsafe (Gallen, Pantin-Sohier, and Peyrat-Guillard 2019; Pfiffelmann et al. Forthcoming), which may be linked to general health concerns.

Another personal factor that is important for innovation adoption is knowledge (Grankvist, Lekedal, and Marmendal 2007; Morris, Hastak, and Mazis 1995), which helps consumers to recognize, understand, try, and adopt eco-innovations (Thøgersen, Haugaard, and Olesen 2010). For example, having greater knowledge about and experience with organic products should help consumers to have a more favorable attitude toward organic product innovations such as laser marking (Phillips and Hallman 2013; Samoggia and Nicolodi 2017).

Research has also identified personality traits that influence the speed of adoption of innovations, including eco-innovation (Rogers 2003; Thøgersen, Haugaard, and Olesen 2010; Thøgersen, Pedersen, and Aschemann-Witzel 2019). Specifically regarding food innovations, important personality traits include food neophobia and cautiousness (e.g., Baker, Shin, and Kim 2016; Pliner and Hobden 1992), which may negatively influence attitudes toward the laser marking of food products and hence impede its adoption.

Given the paucity of research on the effects of these personal factors on consumers' responses to laser marking of organic products, we have no solid basis for formulating hypotheses about these effects. Instead, we address them in an explorative fashion as control variables, providing a deeper understanding of variations in beliefs, attitudes, and willingness to buy laser-marked organic products. Figure 1 illustrates this research's conceptual model, which integrates research questions, hypotheses, and control variables.

3 | Research Methodology

3.1 | General Design

To investigate the associations between beliefs (motives and barriers) about, attitudes to, and willingness to buy laser-marked organic food products, we rely on a concurrent embedded mixed-method design (Creswell and Plano Clark 2018), which is a convergent design method where qualitative and quantitative data are collected simultaneously (Kurtaliqi et al. 2024). Given the exploratory nature of our research questions, we first uncovered the general perceptions of consumers and what they associate with laser marking of organic products by using an open-ended question embedded in an online survey. Participants were encouraged to report both positive and negative perceptions and associations. Their

statements were then coded into motives and barriers using thematic analysis (Braun and Clarke 2006). This was combined with a confirmatory approach where using rating scales, we measured key outcome variables in the same survey (i.e., attitude toward and willingness to buy laser-marked organic products) and important consumer background characteristics (e.g., environmental and health concerns, subjective knowledge about organic products, food neophobia, food cautiousness). The motives and barriers were then dummy-coded, making it possible to test their influence on the dependent variables while controlling for background characteristics, allowing the qualitative and quantitative variables to interact with each other in a statistical model (Creswell and Plano Clark 2018). We used structural equation modeling (SEM) for the statistical analysis because it offers a comprehensive approach for assessing and modifying complex theoretical path models while also estimating relationships between latent variable constructs and their associated indicator variables (Hair et al. 2017).

3.2 | Participants

For the study, Bilendi (a French panel agency) recruited a sample of 328 French consumers, who were filtered through screening questions to ensure the final sample was representative of the French population in terms of gender and age. With a power of 0.80 and a significance threshold of 0.05, this sample size allowed us to detect weak but meaningful correlations (r) of 0.15−0.20 (Cohen 1988). Participants completed an online survey in exchange for virtual points that they could accumulate and use to obtain gifts from Bilendi. Their ages ranged from 18 to 85 ($M_{age} = 45.78$ years; $SD_{age} = 15.57$) and 53% were women. Participants reported buying fruit and vegetables quite frequently, with 76.5% doing so at least four times per month. On average, 48.6% of the fruit and vegetables they bought were organic. Table 2 provides a more detailed sample description.

TABLE 2 | Sample profile.

Characteristic	Category	*N*	%
Age	18−34	78	23.8
	35−54	129	39.3
	55 or more	121	36.9
Gender	Women	174	53
	Men	154	47
Tattooed	Yes	56	17.1
	No	272	83.9
Education level (highest diploma obtained)	No diploma	9	2.7
	Middle school	11	3.4
	Youth training	40	12.2
	High school	74	22.6
	Higher national diploma	54	16.5
	Bachelor's degree	34	10.4
	Master's degree	71	21.6
	PhD	35	10.7
Household composition	Single-person household	106	32.3
	Single-parent family	22	6.7
	Couple without children	88	26.8
	Couple with children	112	34.1
Monthly purchasing frequency of fruit and vegetables	No purchase	2	0.6
	Once per month	14	4.3
	Twice per month	26	7.9
	Three times per month	35	10.7
	Four times per month or more	251	76.5
Proportion of organic fruit and vegetables purchased		328	48.6

3.3 | Procedure and Measures

The questionnaire first measured respondents' concern for the environment, using three items borrowed from Thøgersen, Pedersen, and Aschemann-Witzel (2019); health, using three items from Thøgersen, Pedersen, and Aschemann-Witzel (2019); subjective knowledge about organic products, using four items from Thøgersen, Haugaard, and Olesen (2010); food neophobia, using four items adapted from Pliner and Hobden (1992); and food cautiousness, using two items adapted from Pliner and Hobden (1992). Next, we showed the participants a photo of different fruits and vegetables labeled as organic using laser marking (see Appendix A) and asked the open-ended question: "In your opinion, what are the advantages and disadvantages of using laser-marking technology to indicate organic labeling on the skin of fresh fruits and vegetables?" The responses to this question ranged from 0 to 154 words, with an average of 21.81 words. Six participants did not write anything. Finally, we measured the willingness to buy laser-marked organic products using a three-item scale adapted from Park et al. (2021) and the attitude toward laser-marked organic products using a four-item scale adapted from Holbrook and Batra (1987). All constructs were measured using seven-point Likert scales or semantic differentials in the French language. Appendix B presents the complete list of measures and scale sources.

3.4 | Thematic Analysis of Open Responses

The participants' statements about the use of laser marking for organic labeling of fresh fruits and vegetables in response to the open question were analyzed using NVivo 14 for thematic analysis (Braun and Clarke 2006). We used inductive hand-

coding to identify themes related to the research questions and followed a semantic approach to code the explicit meanings of the data without looking for anything beyond what participants had written (Boyatzis 1998; Braun and Clarke 2006). Following the guidelines of Miles, Huberman, and Saldaña (2014), we defined a word, a sentence, or more than one sentence expressing a unique thought as the unit of analysis. Because each unique word or thought was coded independently, some texts were coded as representing more than one theme. New inductive codes were added when new thoughts appeared, and the codes were revisited and revised if needed as new codes were generated.

In line with prior research (e.g., Oates et al. 2003), the two coders clustered the inductive themes into higher-level meta-themes (Hycner 1985). We used the theory of consumption values (Sheth, Newman, and Gross 1991) to classify themes into motives, and innovation resistance theory (Ram and Sheth 1989) to classify (other) themes into barriers. Two authors independently read all the open-ended responses and generated themes regarding motives and barriers. They then compared their independently generated themes, together deciding on the final coding taxonomy and the classification of the themes into meta-themes. The codes were applied to indicate the presence or absence of a motive or a barrier related to the evaluation of laser-marked organic products.

Once the themes were classified into meta-themes, we computed Cohen's Kappas for each one. The level of agreement for the motive meta-themes was moderate to strong, with $\varkappa$ values ranging from 0.713 to 0.896, whereas the level of agreement for the barrier meta-themes was weak to moderate, with $\varkappa$ values ranging from 0.374 to 0.646 (McHugh 2012). Differences between coders were identified for each theme and disagreements were resolved through discussion. We recorded 306 unique statements related to motives ($M = 0.93$, SD = 0.84) and 392 unique statements related to barriers ($M = 1.20$, SD = 1.05).

For statistical tests involving perceived motives and barriers, we used dummy variables which indicated whether participants reported (1) or did not report (0) each motive and barrier (i.e., the meta-themes). This resulted in five dummy variables for motives (i.e., functional, emotional, social, conditional, epistemic) and seven dummy variables for barriers (i.e., usage, value, risk, image, tradition, social, emotional).

3.5 | Statistical Analysis

To test H1 and H2, we used confirmatory factor analysis (CFA) and SEM to analyze the influence of the motives and barriers on attitudes toward laser-marked organic products while controlling for consumers' psychological characteristics. To test H3, we further analyzed the influence of attitude toward laser-marked organic products on willingness to buy using SEM. This included analysis of the influence of motives and barriers as well as other background factors. Figure 2 illustrates the data collection and analysis procedure.

To assess the quality of the measurement scales, we followed the two-step procedure recommended by Steenkamp and Van Trijp (1991). First, we purified the scales by removing items with inter-item correlations less than 0.30. Second, we used CFA to investigate the factor structure and to test construct reliability (CR), convergent validity, and discriminant validity. The standardized measurement weights (i.e., factor loadings), standard errors, *t*-values and *p*-values of each item are given in Appendix B. The fit indices recommended by Hu and Bentler (1998) suggest an acceptable model fit. Table 3 reports the levels of reliability, convergent validity, and discriminant validity of

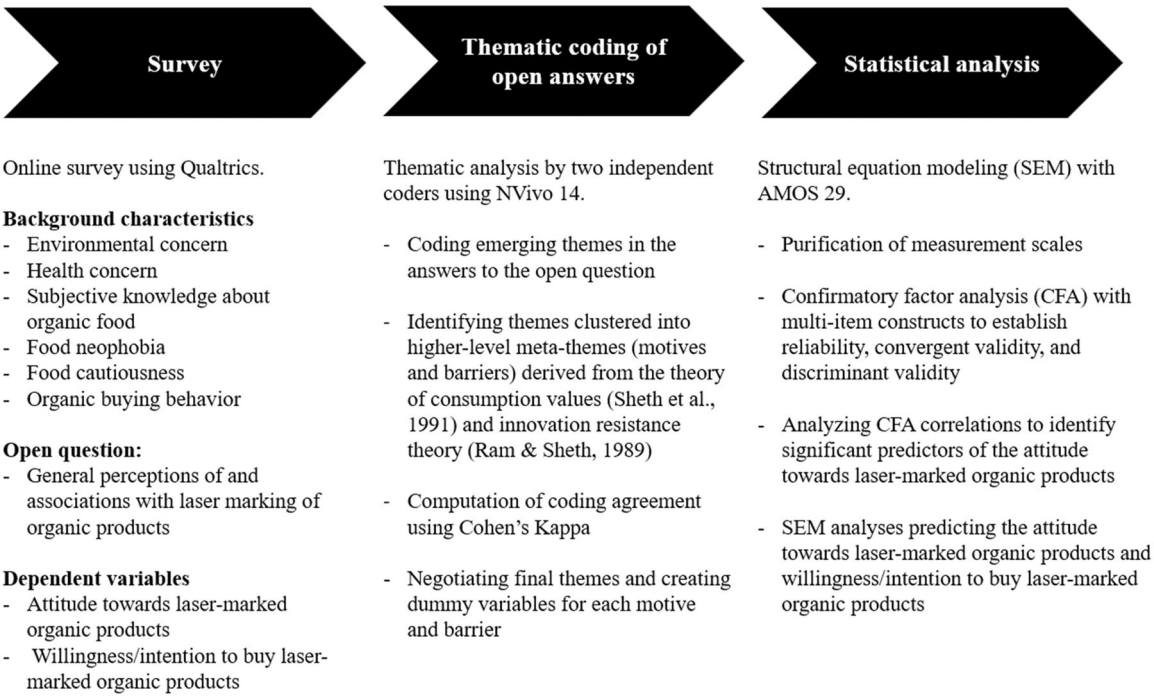

FIGURE 2 | Data collection and analysis procedure.

TABLE 3 | Reliability, convergent validity, and discriminant validity.

Constructs	CR	AVE	Correlations						
			Health concern	Environmental concern	Subjective knowledge	Food neophobia	Food cautiousness	Attitude	Willingness to buy
Health concern	0.899	0.75	*0.87*						
Environmental concern	0.920	0.79	0.48	*0.89*					
Subjective knowledge	0.930	0.77	0.35	0.49	*0.88*				
Food neophobia	0.830	0.55	0.11	−0.02	0.04	*0.74*			
Food cautiousness	0.744	0.59	0.53	0.49	0.43	0.42	*0.77*		
Attitude toward laser-marked organic product	0.912	0.72	0.28	0.26	0.26	−0.16	0.03	*0.85*	
Willingness to buy	0.963	0.90	0.31	0.31	0.27	−0.08	0.05	0.82	*0.95*

Note: The square roots of the AVE are in italics and presented on the diagonal.

the multi-item constructs in the model. The average variance extracted (AVE) values are greater than 0.50, CR values are greater than 0.70, and the square roots of the AVE from each construct surpass their correlations, demonstrating discriminant validity (Fornell and Larcker 1981). We, therefore, judge the quality of the measurement scales to be satisfactory.

4 | Results

4.1 | Thematic Analysis

To address RQ1 about the most salient motives for consumers adopting laser-marked organic labeling of fruits and vegetables, we report the meta-themes and themes in Table 4 with examples of participants' quotes in Table 5. Regarding RQ2 about the most salient barriers, we also present the meta-themes and themes in Table 6 with examples of participants' quotes in Table 7.

4.1.1 | Consumer Motives

As Table 4 shows, the most frequently expressed motive meta-theme was *social value*, with 51.6% of the thoughts expressed being classified within this meta-theme. Almost all these comments are further classified as an ecological motive. However, as a few respondents mentioned motives related to helping producers, they are also classified as social value. For example, the following comment reflects the ecological motive theme:

> *The use of a laser for the marking of fruits and vegetables is a good idea insofar as there are multiple plastic labels on these types of products. The manufacture of plastic labels requires equipment to print, glue, and treat the paper to obtain a glossy film. [...]. The use of glue on these products or the multiple packaging, therefore, does not make sense in an ecological approach.*

The second most frequently mentioned meta-theme was *functional value* (33.7%). As Table 4 shows, traceability (food safety) was the most commonly mentioned motive within this meta-theme. Other frequently mentioned motives were free from harmful ingredients, higher visibility and legibility, and sensory aspects. Less frequently mentioned functional value motives were avoidance of incongruity, cheaper alternatives, naturalness and freshness, and nutritional value. The following quote reflects both the sensory aspects and higher visibility themes:

> *This avoids having to take off the plastic label and having residues that remain attached to the food and gives more visibility of the "organic" mention than a plastic label stuck on the fruit or vegetable or a poster on the stall.*

Comments within the *emotional value* meta-theme (11.8%) related to positive emotions such as positive mood, emotion, or enthusiasm. These comments tended to use enthusiastic words or short sentences, such as "Good idea," "Great!" or "I like the concept".

TABLE 4 | Consumer motive meta-themes and themes.

Meta-theme	Theme	Theme frequency	Meta-theme total	Meta-theme percentage (%)
Social value	Ecological motive	156	158	51.6
	Social approval and identity	1		
	Willingness to help producers	4		
Functional value	Free from harmful ingredients	29	103	33.7
	Traceability (food safety)	40		
	Naturalness and freshness	6		
	Nutritional value	1		
	Sensory aspect	22		
	Higher visibility and legibility	24		
	Cheaper alternative	7		
	Avoidance of incongruity	9		
Emotional value	Positive mood/emotion	36	36	11.8
Epistemic value	Fashion/modernity	7	8	2.6
	Knowledge	1		
Conditional value	Personal health	1	1	0.3

Note: Meta-theme percentages are the percentages of total thoughts for the motives.

TABLE 5 | Consumer motive meta-themes and quotation examples.

Meta-theme	Example quotations (theme)
Social value	Saves plastic labels and therefore reduces waste (Ecological motive) Having a good conscience and not destroying our land when growing fruits and vegetables (Social approval) Lower cost for producers and distributors (Willingness to help producers)
Functional value	No labels full of glue and chemicals (Free from harmful ingredients) This provides better traceability of fruits and vegetables during purchase (Traceability) Having this little label is disturbing when you eat a fruit or when you want to wash a fruit or a vegetable it sticks everywhere (Sensory aspect)
Emotional value	Very good idea to develop (Positive mood/emotion)
Epistemic value	Innovative, stylish (Fashion/modernity) Original and distinctive (Fashion/modernity)
Conditional value	This can be interesting from every point of view for my health, my balance, and my well-being (Personal health)

Note: All quotes are presented with (minor) corrections of typographical and grammatical errors (e.g., adding punctuation).

Finally, the least stated meta-themes were the *epistemic value* (2.6%) and *conditional value* (0.3%). Epistemic value motives mostly related to fashion/modernity, and only one participant evoked a conditional value motive related to personal health.

4.1.2 | Consumer Barriers

As Table 6 shows, the most frequently mentioned barrier meta-theme was the *risk barrier* (32.7%). The most frequently mentioned barrier within this meta-theme was doubt about safety processes, which covers expressions of uncertainty about the technical process. The second most frequently mentioned barrier was concern about food safety, which captures the fear that laser marking represents a health risk. Other barriers within this meta-theme were doubt about the eco-friendliness of the process, doubt about the label, and fear of nutrient loss. An example of a quote under the theme of doubt about safety processes is:

> *I hope that no chemical element is introduced into the product with this technology. Is it really a safe technique?*

Within the *tradition barrier* meta-theme (28.6%), specific barriers included sensory cues, shorter shelf life, habit, and

TABLE 6 | Consumer barrier meta-themes and themes.

Meta-theme	Theme	Theme frequency	Meta-theme total	Meta-theme percentage (%)
Risk barrier	Doubt about the label	13	128	32.7
	Doubt about eco-friendly process	20		
	Doubt about process's safety	84		
	Food safety	31		
	Loss of nutrients	3		
Tradition barrier	Sensory cues (taste, appearance)	82	112	28.6
	Shorter shelf life	29		
	Habit	4		
	Satisfaction with conventional product	16		
Image barrier	No perceived difference between laser and conventional	15	39	9.9
	Social symbolic	24		
Value barrier	Monetary value	26	38	9.7
	Extra time involved	4		
	Damaged food	68		
Usage barrier	Limited variety/poor product range	4	19	4.8
	Low visibility and limited information	13		
	Food involvement/convenience	2		
Emotional barrier	Negative mood/emotion	36	36	9.2
Social barrier	Social approval and self-presentation	6	20	5.1
	Impact on producers	16		

Note: Meta-theme percentages are the percentages of total thoughts for the barriers.

satisfaction with conventional products. One participant wrote, "I prefer another option: no label! Like at the local street market." Another described their satisfaction with conventional products in more detail:

> *I do not see the advantages of the laser; it is enough simply to group the organic fruits and vegetables on a dedicated organic stall.*

Within the *image barrier* meta-theme (9.9%), specific barriers included social symbolism and the absence of perceived differences between laser and conventional labeling. The following quote reflects the social symbolic theme: "It is not very natural, and it seems strange to me on organic products."

In the *value barrier* meta-theme (9.7%), the specific barriers included monetary value, extra time involved, and damage to the food. For example: "It is possible that it damages the product and increases its price."

The *usage barrier* meta-theme represents 4.8% of statements, including statements about low visibility and limited information, limited variety/poor product range, and food involvement or convenience. The following statement reflects the limited information theme: "This marking is not legible enough."

Finally, two meta-themes emerged that have not previously been documented in the organic labeling literature. The first was the *emotional barrier* meta-theme (9.2%) reflected in negative or aggressive statements, such as: "Zero interest, it is ridiculous, and it does not make you want it." The second was the *social barrier* meta-theme (5.1%). The specific themes included social approval and self-presentation, and impact on producers. For example, one participant stated: "This is a more expensive technique that is not accessible to producers."

4.2 | Determinants of Attitude Toward Laser-Marked Organic Products

To examine the influence of motives and barriers on attitude toward laser-marked organic products, we used maximum likelihood CFA and SEM analysis in AMOS 29, while also controlling for basic psychological factors identified as relevant in previous research. Motive and barrier meta-themes were included as dummy variables and were coded 1 if the participant had mentioned at least one theme classified into the meta-theme and coded 0 otherwise. All other variables were represented as reflective latent variables based on two to four manifest variables each (see Appendix C).

TABLE 7 | Consumer barrier meta-themes and quotation examples.

Meta-theme	Example quotations
Risk barrier	This solution does not prove that the food is truly organic (Doubt about the label) I hope it is not polluting... Is it a guarantee? (Doubt about eco-friendly process) What technology is used? Is there ink or harmful materials in contact with the fruit or vegetable? (Doubt about safety processes) Risks of illness following ingestion of the laser-marked product (Safety food issue) Although it avoids labels and glue, personally I also eat the skin of fruits and vegetables where vitamins and mineral salts are found, among other things (Loss of nutrients)
Tradition barrier	I don't know what the impact is on the quality of the fruit other than an absolutely repulsive visual aspect (Sensory cues) Laser marking can damage the fruit or vegetable and therefore reduce its shelf life" (Shorter shelf life) The organic fruits and vegetables that I buy are not labeled. So I don't see the point of laser printing a label to replace a label that doesn't exist on the organic fruits and vegetables I eat. I buy them at the market from an organic producer for example or even at the supermarket (Satisfaction with conventional product)
Image barrier	I don't see what the added value could be (No perceived difference between laser and conventional) I would not eat fruits or vegetables with this type of tattoo since this artificial touch-up on the food makes it less natural (Social symbolic)
Value barrier	I wonder how much this will be charged to the consumer? (Monetary value) This makes us peel everything! (Extra time involved) The laser damages fruits or vegetables, especially those with very thin skins (Damaged food)
Usage barrier	The label could be difficult to read if the product is a little less fresh (Low visibility and limited information) This process does not apply to all fruits (raspberries, strawberries, etc.) (Limited variety/poor product range)
Emotional barrier	Disagree with all of this, it is bad for your health, it is shameful trickery (Negative mood/emotion)
Social barrier	I dread the fear of some people seeing this as a marking, it sometimes has bad connotations (Social approval and self-presentation) It is a gimmicky solution that risks penalizing small organic producers who will have to acquire laser machines (manufacturing cost, energy used, etc.) (Impact on producers)

Note: All quotes presented with (minor) corrections of typographical and grammatical errors (e.g., adding punctuation).

First, we analyzed the bivariate correlations between attitude toward laser-marked organic products and each of the consumer perceptions captured by our meta-themes, along with the psychological background factors, estimated by CFA, to verify their relevance for consumer attitude toward laser marking of organic products (see correlations in Appendix D). This analysis revealed that seven factors—conditional value, usage barrier, tradition barrier, value barrier, risk barrier, and social barrier—were not significantly correlated with attitude toward laser-marked organic products at the $p < 0.05$ level. This was also the case for food cautiousness. These beliefs and background factors, therefore, seemed irrelevant to consumer attitudes toward laser marking of organic food and were left out of further analyses.

Next, the remaining beliefs and personal background factors were included in an SEM analysis, which predicted attitudes toward laser-marked organic products. Table 8 shows that when controlling for all significant correlates, subjective knowledge, environmental concern, health concern, food neophobia, epistemic value, and past organic purchasing behavior do not significantly predict attitude toward laser-marked organic products. Hence, their impact on attitude seems to be captured by or mediated through other predictors. However, the analysis confirmed that attitude toward laser-marked organic products depends on stated motives (i.e., social value, emotional value, and functional value) and barriers (i.e., image barrier and emotional barrier).

Importantly, among motives and barriers, social value has the greatest positive impact, followed by emotional value and functional value. Emotional and image barriers have the greatest negative impact on attitudes toward laser-marked organic products. That the three most salient motives (Table 4) significantly predict attitude is consistent with H1. However, it is surprising and contradicts H2 that the two most salient barriers, by far, are not correlated with attitude (see Appendix C). This suggests that many consumers evaluate this new technology based more on emotions than on consideration of facts. However, many assess it based on its documented merits, as reflected in the strong positive impact of the perceived social and functional value on attitude toward laser marking of organic food.

4.3 | Determinants of Attitude Toward and Willingness to Buy Laser-Marked Organic Products

Next, we extended the SEM analysis to estimate the impact of attitude toward laser-marked organic products on willingness to

TABLE 8 | SEM analysis regressing attitude toward laser-marked organic products on meta-themes and personal characteristics.

Beliefs/constructs	Unstand. coef.	Stand. error	Coef. stand.	*t*-values	*p* values
Social value	1.07	0.17	0.32	6.276	< 0.001
Emotional value	1.37	0.26	0.26	5.381	< 0.001
Functional value	0.56	0.17	0.15	3.240	0.001
Emotional barrier	−0.76	0.27	−0.14	−2.812	0.005
Image barrier	−0.53	0.26	−0.10	−2.080	0.038
Subjective knowledge	0.11	0.07	0.10	1.554	0.120
Environmental concern	0.14	0.10	0.09	1.375	0.169
Health concern	0.14	0.09	0.09	1.460	0.144
Food neophobia	−0.08	0.07	−0.06	−1.146	0.252
Past behavior	0.00	0.00	0.05	0.863	0.388
Epistemic value	0.06	0.52	0.01	0.107	0.915

Note: Only shows the structural model. The measurement model and the rest of the AMOS output can be acquired from the authors. Goodness-of-fit measures: $\chi^2(216) = 341.375$; RMSEA = 0.042; TLI = 0.96; CFI = 0.97; $R^2 = 0.419$.

TABLE 9 | SEM analysis of the path model from meta-themes through attitude toward laser-marked organic products to willingness to buy laser-marked organic products.

Independent variables		Dependent variables	Unstand. coef.	Stand. error	Stand. coef.	*t*-values	*p* values
Attitude toward the product	→	Willingness to buy[a]	0.74	0.05	0.73	14.204	< 0.001
Social value	→	—	0.36	0.13	0.11	2.783	0.005
Functional value	→	—	0.26	0.13	0.08	2.046	0.041
Emotional barrier	→	—	−0.20	0.20	−0.04	−1.009	0.313
Image barrier	→	—	−0.19	0.18	−0.04	−1.010	0.313
Emotional value	→	—	−0.09	0.19	−0.02	−0.453	0.651
Social value	→	Attitude toward the product[b]	1.15	0.16	0.36	7.294	< 0.001
Emotional value	→	—	1.37	0.24	0.27	5.622	< 0.001
Functional value	→	—	0.63	0.17	0.19	3.839	< 0.001
Emotional barrier	→	—	−0.78	0.26	−0.15	−3.004	0.003
Image barrier	→	—	−0.42	0.24	−0.09	−1.705	0.088

[a]Willingness to buy laser-marked organic products.
[b]Attitude toward laser-marked organic products. Only shows the structural model. The measurement model and the rest of the AMOS output can be acquired from the authors. Goodness-of-fit measures: $\chi^2(38) = 38.137$, $p = 0.463$; RMSEA = 0.003; TLI = 1.00; CFI = 1.00; R^2 Attitude toward the product = 0.359; R^2 Willingness to buy = 0.687.

buy them while also controlling for its antecedents (see Table 9). Based on the fit indices recommended by Hu and Bentler (1998), the structural model (reported in the note to Table 9) has an excellent fit to the data.

As expected (H3), willingness to buy laser-marked organic fruits and vegetables is significantly and positively influenced by attitude toward the product ($\beta = 0.73$; $p < 0.001$). In addition, after controlling for attitude toward the product, social ($\beta = 0.11$; $p < 0.01$) and functional values ($\beta = 0.08$; $p < 0.05$) have weak but significant direct effects on willingness to buy. As we saw in the earlier analysis, attitude toward the product is positively and significantly influenced by social ($\beta = 0.36$; $p < 0.001$), emotional ($\beta = 0.27$; $p < 0.001$), and functional values ($\beta = 0.19$; $p < 0.001$), and is negatively influenced by emotional barriers ($\beta = -0.15$; $p < 0.01$). However, when leaving out other predictors, image barriers are no longer significant at the $p < 0.05$ level.

5 | Discussion and Conclusion

We used both qualitative and quantitative approaches for this research, employing a concurrent embedded mixed-method design (Creswell and Plano Clark 2018) on data collected in an online survey. The main aim was to obtain a better understanding of consumer responses to laser marking of organic

products by (1) identifying the most prevalent consumer motives for and barriers to accepting laser marking of organic food products; and (2) estimating the extent to which each motive and barrier influences consumer attitude toward laser-marked organic products and thereby influences consumer willingness to buy such products. In doing so, we controlled for consumers' environmental and health concerns and their knowledge and experience of organic products, as well as food-related personality traits.

The thematic analysis of responses to an open-ended question (Braun and Clarke 2006) identified five consumer motive meta-themes and seven barrier meta-themes, with *social* and *functional values* being the most salient (i.e., most frequently mentioned) motives and *risk* followed by *tradition* being the most salient barriers among participants.

The fact that most of the positive associations with laser marking of organic products included *social values* is consistent with past research (Chae, Kim, and Roh 2024; Merle, Herault-Fournier, and Werle 2016; Mohd Suki, Majeed, and Mohd Suki 2022). Also consistent with past research (Pfiffelmann et al. Forthcoming; Samoggia and Nicolodi 2017), we find that ecological benefits are the most salient *social value* associated with adopting laser-marked organic products. The finding that many consumers perceive *functional value* in this eco-innovation supplements previous research (Leonidou et al. 2022; Wu et al. 2019). Some consumers associated health benefits, such as food safety (i.e., increased traceability) or being free from harmful ingredients, with laser marking of organic products, and some associated positive impacts on food sensory aspects and naturalness.

Risk barriers are the most salient barriers or negative consumer associations with this eco-innovation. This is consistent with recent research on laser marking which reveals that some consumers are skeptical about the healthfulness of laser marking (Pfiffelmann et al. Forthcoming). We also find that consumer resistance to laser-marked organic labeling is rooted in perceived risks and doubts about the safety of the process. This may partly be due to a lack of knowledge about laser marking and organic products (Grankvist, Lekedal, and Marmendal 2007; Morris, Hastak, and Mazis 1995; Phillips and Hallman 2013). Also consistent with past research (e.g., Misra and Singh 2016; Phillips and Hallman 2013), we find that technological manipulation of organic products confuses some consumers by challenging their perceptions of the *tradition* and *image* of organic products. This *psychological barrier* arises from a perceived conflict between consumers' existing beliefs about the product and its new version (Sheth, Newman, and Gross 1991). Our research further complements past research (Pfiffelmann et al. Forthcoming; Samoggia and Nicolodi 2017) by revealing that some consumers fear that laser marking could change the sensory cues of the products or change their habits in relation to the organic products, or that they perceive no benefits from laser-marked organic products compared to conventionally labeled organic products.

The CFA and SEM analyses reveal that attitude toward laser-marked organic products is positively influenced by *social value, emotional value*, and *functional value*, and is negatively influenced by *emotional barrier* and *image barrier*. It appears that attitude toward laser-marked organic products is more strongly influenced by positive beliefs (i.e., motives) than by negative beliefs (i.e., barriers), which appear to be mostly emotional. All impacts of the personal background factors included appear to be mediated through these perceived motives and barriers. As expected, we find that willingness to buy laser-marked organic products is strongly and positively influenced by consumer attitude toward such products and that most of the impacts of perceived motives and barriers on this willingness to buy are indirect and mediated by attitude.

5.1 | Theoretical Contributions

This research contributes to the literature on consumer responses to eco-innovation in packaging solutions (e.g., Liang et al. 2022; Magnier and Crié 2015), ecolabeling (e.g., Thøgersen, Haugaard, and Olesen 2010), organic food (e.g., Kushwah, Dhir, Sagar, and Gupta 2019), and, specifically, adoption of laser-marked organic products (Pfiffelmann et al. Forthcoming; Samoggia and Nicolodi 2017). Responding to the increasing consumer demand for sustainable packaging (Fogt Jacobsen, Pedersen, and Thøgersen 2022), some retailers offer laser-marked organic fruits and vegetables in an attempt to reduce plastic waste. However, the supply of such products is growing slowly, if at all, partly due to the underwhelming response of consumers. Hence, understanding consumers' motives for and barriers to adopting laser-marking technology for organic products is crucial for the effective promotion of this eco-innovation.

The limited previous research suggests that consumers perceive laser marking as an eco-friendly labeling innovation but are concerned about health risks (Pfiffelmann et al. Forthcoming; Samoggia and Nicolodi 2017). Our study extends this previous research. Using qualitative and quantitative approaches, we add richness to the understanding of consumers' attitudes toward this eco-innovation and, subsequently, their willingness to buy laser-marked organic products (Frank, Chrysochou, and Mitkidis 2023). By applying the theory of consumption values (Sheth, Newman, and Gross 1991) and innovation resistance theory (Ram and Sheth 1989) to laser-marked organic products, we also extend the research on motives and barriers for consumer purchasing of organic food (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020).

Our research makes an important contribution by uncovering the ambivalent emotional responses of consumers to laser marking. The multi-variate SEM analysis revealed that *emotional value* has a strong positive effect and, at the same time, that *emotional barriers* have a strong negative effect on attitude toward laser-marked organic fruits and vegetables. This is in line with past research that highlights the role of emotions in attitude formation (Allen et al. 2005), including about organic products (Bauer, Heinrich, and Schäfer 2013; Janssen 2018). In addition, our analyses revealed that *image barriers* have a negative influence on consumers' attitudes toward this eco-innovation. Hence, it appears that consumers' attitudes toward laser-marked organic products are based, to a great extent, on

spontaneous emotional responses rather than on carefully balancing benefits and risks. Our qualitative analyses revealed that many consumers perceive that there are *risk barriers* to laser marking of organic products, as suggested by contagion theory (Nemeroff and Rozin 1989) and by past research which found that some consumers doubt the safety of laser marking (Pfiffelmann et al. Forthcoming). As there is no evidence of any health risks from laser marking, the perceived risk expressed by respondents may also be an emotional response. In addition, the fact that our analyses found no significant relationship between perceived risks and attitude toward laser-marked organic products suggests that the perceived risks are not considered to be very serious.

Our SEM analyses indicated that *social values* contribute more strongly than *functional values* to a positive attitude toward laser marking of organic fruits and vegetables. This is consistent with previous research which indicates that organic food consumption is primarily driven by altruistic motives (Barbarossa and De Pelsmacker 2016; Merle, Herault-Fournier, and Werle 2016), but it is contrary to research that identifies *functional values* as the primary drivers of organic food consumption (Kushwah, Dhir, Sagar, and Gupta 2019; Rana and Paul 2020). From our research, it appears that consumers have a positive attitude toward laser-marked organic products primarily because they perceive this labeling technique to be environmentally friendly rather than because it has a personal *functional value*.

In accordance with social cognitive theory (e.g., Ajzen 1991; Fishbein and Ajzen 1975), our research identifies the beliefs about laser marking that influence consumers' attitudes toward laser-marked organic products and, mostly mediated through their attitude, their willingness to buy these products. Our findings are also consistent with prior research which found a positive relationship between consumer attitude toward organic products and intention to purchase (e.g., Boobalan et al. 2021; Rana and Paul 2017; Sultan et al. 2020; Teixeira et al. 2022; Thøgersen and Zhou 2012).

5.2 | Limitations and Future Research

Our sample is representative of the French population in terms of gender and age, but not necessarily in other respects. Of the fruits and vegetables purchased by our sample, about half (48.6%) were organic, but some participants bought very few, if any, of such organic products. These consumers may care little about laser marking of organic products. However, any potential bias from this is likely to be in the direction of disconfirming our hypotheses and, therefore, does not pose a threat to our main conclusions. Furthermore, given the limited availability of laser-marked products in France, the majority of those in our sample are likely to belong to "later adopter" categories (Rogers 2003). This may again have biased our results in a negative direction, particularly regarding willingness to buy laser-marked organic products. Future research is encouraged to take account of factors such as nationality, familiarity, and prior experience of laser marking.

This research focused on the laser marking of organic food only, including all types of fruits and vegetables. Hence, future research could investigate consumer perceptions of laser marking of other types of labels, for example, to indicate Protected Geographical Indications, or to provide information such as brand names, country of origin, quality signals, or code numbers. Another promising avenue would be to investigate the moderating role of the edibility of the laser-marked skin of organic products. Contagion theory (Nemeroff and Rozin 1989) suggests that attitudes toward laser marking are likely to be more negative for products with edible skin as consumers may perceive the laser marking to be a contaminant which they might ingest.

Because participants reported their motives and barriers through responses to an open-ended question, they may have under-reported those that did not come to mind at the time of the survey. Therefore, the maxim "absence of evidence is not evidence of absence" should be considered in any future research that uncovers additional themes by conducting individual interviews, focus groups, or surveys to validate our model using self-reported measures.

Finally, this research uses willingness to buy as the final outcome variable, and it is therefore silent about the final behavior of consumers. Considering the infamous intention–behavior gap (Essiz and Mandrik 2022; Hassan, Shiu, and Shaw 2016), future research could conduct field experiments in markets where laser-marked organic products are available to study actual purchasing behavior.

5.3 | Managerial Implications

This research suggests managerial implications and actionable guidance for producers of organic fruits and vegetables, retailers, and policymakers. It demonstrates that many consumers are ready to buy organic fruits and vegetables with laser-marked labels because they appreciate and embrace the benefits of this eco-innovation. Offering such laser-marked products is an excellent way for stores to help these customers avoid the incongruity or cognitive dissonance created by the plastic packaging or sticker labeling of organic products. This solution is particularly relevant for retailers that strive to offer a sustainable variety of products, such as organic, local, national, or vegan products. However, other consumers resist this new technology, and participants in our study generally expressed more negative than positive associations with laser marking of organic products (392 unique negative statements vs. 306 unique positive statements). Furthermore, the impact of negative associations on attitudes toward laser-marked organic products is mostly emotional rather than evidence-based. This strongly suggests that it is essential to increase awareness and education to raise consumer acceptance of laser marking.

We find that positive consumer attitudes toward this eco-innovation are, to a great extent, due to its social value (158 unique statements classified within this meta-theme). However, only about half of the participants said laser marking was eco-friendly (156 unique statements classified under this theme from the 328 participants). Thus, there is still a need for campaigning to raise awareness about environmental issues related

to over-packaging and to educate consumers about how laser marking contributes to the reduction of plastic packaging and CO_2 emissions. Retailers should communicate the advantages of this eco-innovation, including providing evidence that it is more ecological than packaged food or plastic stickers. They could do so through information campaigns on their websites, social media, and other channels. For example, Tesco recently announced that, from now on, all its organic avocados will be laser-marked to reduce plastic use (Tesco 2024). Producers and retailers could also organize events or competitions to engage consumers and simultaneously increase awareness and promote laser-marked products and brands, and they could use displays or posters on fruit and vegetable shelves to inform consumers while shopping. Retailers could go even further and create "zero packaging" departments completely dedicated to products without packaging or plastic stickers, in the same way that some have departments dedicated to national products. This could be an attractive proposition for environmentally-minded consumers.

We also found that only a third of spontaneously expressed thoughts about motives for purchasing laser-marked products related to their functional value (103 unique statements within this meta-theme). Therefore, retailers and producers should also communicate information about its functional benefits, such as traceability and the absence of harmful ingredients. A trustworthy source, such as a relevant authority, nutritionist, or medical doctor, who could verify the health and safety of laser-marked products, could help to reassure consumers about the absence of harmful ingredients. These campaigns should also reassure consumers about the naturalness, freshness, and sensory qualities of the products.

Many respondents reported risk barriers (128 unique statements for this meta-theme), including doubts about its eco-friendliness (20 unique statements) and food safety (31 unique statements), which mainly reflected their lack of knowledge about laser marking. To mitigate negative perceptions of laser marking and build better understanding among consumers, trusted governmental organizations and environmental nongovernmental organizations should actively promote this technology. Such campaigns would align with laws on reducing plastic waste and plastic packaging for fruits and vegetables. A French law of February 10, 2020, on waste reduction and promotion of the circular economy demands that fruits and vegetables sold in supermarkets should no longer use plastic packaging. Laser marking is a means for retailers to comply with this regulation and to meet consumer demand for more sustainable products. Until it is broadly adopted by retailers, first-movers could use it to differentiate themselves from competitors. However, producers and retailers must demonstrate to consumers that laser marking is genuinely environmentally friendly and not just a branding tactic or greenwashing. Providing tangible evidence of the benefits, such as the amount of packaging saved, reduced CO_2 emissions, and other environmental benefits, is essential. To do so, they could use calculations that compare the annual amount of plastic waste or CO_2 emissions created by an average household buying fruits and vegetables in plastic wrapping with one that buys only laser-marked products.

Finally, many participants also mentioned barriers related to tradition (112 unique statements within this meta-theme), including fear about the sensory aspects of the products (82 unique statements) and satisfaction with conventional organic products (16 unique statements). Some also mentioned value barriers (38 unique statements for this meta-theme), including risks that the products would cost more (26 unique statements) and deteriorate faster (68 unique statements). To counter these perceptions, retailers could develop a variety of laser-marked organic fruits and vegetables that they sell, starting with those with thick skins, such as avocados, butternut squash, melons, mangos, and so forth. Once consumers have tried and become used to laser marking on these types of products, organic fruits, and vegetables with more sensitive skins, such as zucchini, apples, or pears, could be introduced into the mix. Retailers could also use laser marking to promote that it is easy to adopt an organic lifestyle, thereby enhancing the conditional value of the products. In addition, they could emphasize that laser marking does not damage the products or affect their shelf life and highlight that consumers are not being charged extra for this eco-innovation.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are openly available in OSF at https://osf.io/qr96h/.

Endnotes

[1] E.g., https://www.ecolabelindex.com.

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Appendix A

Supply of Laser-Marked Organic Products

To obtain an indication of the supply of laser-marked organic products, we collected market data from leading European companies that import, export, pack, or distribute fresh laser-marked organic fruits and vegetables in Europe (Table A1). This data gives some indication of the popularity of laser marking by type of fruit and vegetable and over time. Due to data confidentiality, we cannot disclose the exact quantities of products delivered, but we present percentages.

Among the laser-marked organic products, avocados (21.5%) and mangos (20.7%) are the most-supplied fruits, while ginger (37.1%) and sweet potatoes (12.4%) lead the vegetable category. Overall, laser-marked organic vegetables make up a larger portion of the supply (55%) than fruits.

The supply of laser-marked organic products saw significant growth between 2017 and 2018, increasing by 61.8%. The demand for fruits continued to rise through 2019 and 2020 before experiencing a sharp decline until 2023. Conversely, the demand for vegetables saw a steep drop in 2019 and continued to decrease through 2023.

Annual comparisons are challenging due to varying retailer supply-demand changes. Some retailers are required by their headquarters to purchase both organic and nonorganic products from a single supplier, leading them to drop out. Some retailers also decided to stop buying laser-marked produce because of the difficulties in differentiating between organic and nonorganic at the cash register. External factors, such as weather, also impact the quantity of produce that distributors receive from producers. In addition, the market share of pre-ripped avocados or ready-to-eat avocados and mangos has grown and is still growing in sales volume, and those products are not laser-marked. Also, many retailers prefer to sell a few products in a combined package instead of one single product (to increase the sales volume), while laser marking is used for bulk produce. This could explain the decline in the demand for laser-marked organic fruits since 2021. All these reasons may explain why the supply of laser-marked organic produce has declined, which is not related to consumers' choices and preferences.

TABLE A1 | Percentage of sales delivered, by kilograms, by laser-marked organic fruits and vegetables.

	2017	2018	2019	2020	2021	2022	2023	Total[b]
Fruits								
Avocados	10.2	3.6	9.2	29.9	32.9	33.5	34.7	21.5
Lemons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pomegranates	0.0	1.2	1.4	1.4	0.4	0.9	0.4	0.9
Grapefruits	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.1
Kiwis	0.0	0.0	0.0	0.0	0.4	0.3	0.2	0.1
Coconuts	0.6	3.2	0.0	0.0	0.0	0.0	0.0	0.7
Limes	0.0	0.0	0.8	0.6	0.4	2.9	3.9	1.0
Mangos	3.3	13.5	17.4	33.7	23.4	19.2	24.9	20.7
% Fruits[a]	14.1	21.6	29.3	65.7	57.5	56.7	64.1	45.0
Evolution of the volume of fruits sold (in %)		+75.1	+17.2	+61.3	−31.2	−40.4	−19.2	
Vegetables								
Zucchinis	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ginger	36.9	48.5	60.8	25.4	25.1	30.9	24.9	37.1
Cucumbers	1.4	6.8	0.3	0.4	0.0	0.0	0.0	1.5
Pumpkins	15.2	6.7	4.8	1.3	1.6	1.5	1.5	4.0
Sweet potatoes	32.2	16.3	4.8	7.1	15.8	10.9	9.5	12.4
% Vegetables[a]	85.9	78.4	70.7	34.3	42.5	43.3	35.9	55.0
Evolution of the volume of vegetables sold (in %)		+58.1	−24.3	−79.2	+7.6	−36.2	−62.3	
Evolution of the volume of fruits and vegetables sold (in %)		+61.8	−12.2	+13.1	−14.7	−38.6	−34.7	

[a]Percentage of the total of laser-marked organic fruits and vegetables.
[b]Percentage of the total of laser-marked organic fruits and vegetables between 2017 and 2023.

Appendix B

Illustration of Organic Fruit and Vegetables With the Laser-Marked Label

We are presenting you with a labeling technique applied to the skin of fruit and vegetables from organic farming. As shown in the photograph below, the indication that the product is organic is marked by a laser inscription on the outer layer of the skin of fruit and vegetables.

Note: “Bio” means “Organic” in English.

In your opinion, what are the advantages and disadvantages of using laser-marking technology to indicate organic labeling on the skin of fresh fruit and vegetables?

Your response can take the form of keywords or written sentences, the important thing for us is to obtain your spontaneous opinion on the positive and negative aspects of this practice of laser-marked organic fruits and vegetables.

Appendix C
Table C1.

TABLE C1 | Results of the confirmatory factor analysis measurement model.

Codifications	Wording	Stand. coef.	*t*-values	*p* values
Environmental concern (Thøgersen, Pedersen, and Aschemann-Witzel 2019)				
EC3	I am willing to be inconvenienced to take actions that are more environmentally friendly.	0.856	—	—
EC2	I consider the potential environmental impact of my actions when making many of my decisions.	0.886	21.145	< 0.001
EC1	My purchase habits are strongly affected by my concern for our environment.	0.927	22.459	< 0.001
Health concern (Thøgersen, Pedersen, and Aschemann-Witzel 2019)				
HC1	I try to prevent health problems before I feel any symptoms.	0.770	—	—
HC2	I am concerned about health hazards and try to take action to prevent them.	0.919	17.731	< 0.001
HC3	I try to protect myself against the health hazards I hear about.	0.899	17.479	< 0.001
Subjective knowledge about organic products (Thøgersen, Haugaard, and Olesen 2010)				
SK1	I know quite a lot about organic food.	0.940	—	—
SK2	I feel well-informed about organic food.	0.888	26.252	< 0.001
SK3	I am one of the experts on organic food among my acquaintances.	0.826	22.013	< 0.001
SK4	Compared with others I know more about organic food.	0.850	23.509	< 0.001
Food neophobia (Pliner and Hobden 1992)				
PHOBI1	I am afraid to eat things I have never had before.	0.695	—	—
PHOBI2	I don't trust new foods.	0.768	11.728	< 0.001
PHOBI3	At dinner parties, I will not try a new food.	0.769	11.739	< 0.001
PHOBI4	I am not interested in food products different from those I already know.	0.734	11.344	< 0.001
Food cautiousness (Pliner and Hobden 1992)				
CAUTION1	I am very cautious about the foods I will eat.	0.804	—	—
CAUTION2	If I don't know what is in a food, I won't try it.	0.734	10.888	< 0.001
Willingness to buy laser-marked organic products (Park et al. 2021)				
PI1	I would be likely to buy laser-marked organic fruits and vegetables if they were available for purchase.	0.954	—	—
PI2	I would plan to buy laser-marked organic fruits and vegetables if they were available for purchase.	0.935	35.084	< 0.001
PI3	I would actively seek out this product in a store to purchase it.	0.951	37.836	< 0.001
Attitude toward laser-marked organic products (Holbrook and Batra 1987)				
AP1	I like (vs. dislike) these products.	0.888	—	—
AP2	I react favorably (vs. unfavorably) to these products.	0.857	21.356	< 0.001
AP3	I feel positive (vs. negative) toward these products.	0.892	23.836	< 0.001
AP4	These products are good (vs. bad).	0.755	16.995	< 0.001

Note: Goodness-of-fit measures: $\chi^2(209) = 391.25$; RMSEA = 0.052; TLI = 0.963; CFI = 0.969.

Appendix D
Table D1.

TABLE D1 | Correlations between attitudes toward laser-marked organic products and (1) beliefs extracted from open answers and (2) other potential antecedents, reported in Appendix C.

Beliefs/constructs	Correlations	*t*-values	*p* values
Social value	0.43	6.770	< 0.001
Emotional barrier	−0.33	−5.441	< 0.001
Emotional value	0.30	5.012	< 0.001
Health concern	0.28	4.321	< 0.001
Functional value	0.27	4.529	< 0.001
Environmental concern	0.26	4.205	< 0.001
Subjective knowledge	0.26	4.229	< 0.001
Image barrier	−0.24	−3.979	< 0.001
Organic purchase ratio	0.21	3.552	< 0.001
Food neophobia	−0.16	−2.430	0.015
Epistemic value	0.14	2.359	0.018
Risk barrier	−0.11	−1.875	0.061
Value barrier	−0.09	−1.553	0.120
Tradition barrier	−0.07	−1.218	0.223
Usage barrier	0.07	1.131	0.258
Conditional value	−0.04	−0.678	0.497
Food cautiousness	0.03	0.460	0.646
Social barrier	0.02	0.408	0.684

Note: Correlations estimated by means of CFA. Goodness-of-fit measures: $\chi^2(337) = 524.405$; RMSEA = 0.041; TLI = 0.94; CFI = 0.96.