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# From Plant-Based Alternatives to Front-of-Pack Labels: Exploring Consumer Perception and Strategies for Healthy and Sustainable Diets

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## Abstract

The transition toward healthier and more sustainable food systems is a pressing challenge of our time, driven by the need to ensure safe, nutritious, and environmentally responsible food for future generations. To support this transition, the present dissertation focuses on two emerging strategies that have shown great potential in fostering healthier and sustainable diets. Specifically, this thesis dives into the promotion of plant-based alternatives, with a focus on meat substitutes, and the implementation of interpretative front-of-pack labeling systems. The research included in this manuscript explores both tools to investigate their potential to influence consumer behavior, improve dietary choices, and support the larger goal of transforming global agrifood systems.

Given the widely recognized environmental and health impact of meat production, plant-based alternatives have emerged as a viable solution to reduce meat consumption. Promoting such products could thus contribute to lowering global greenhouse gas emissions and mitigating public health concerns, while also meeting consumers' growing demand for more ethical and safer production methods. However, to guarantee the potential of plant-based alternatives, consumers' acceptance and adoption of such foods is key. In this scenario, this dissertation deepens the understanding of consumer perceptions, motivations, and sensory expectations related to plant-based analogs and examines how these factors can shape purchasing decisions and behavior changes. Special attention is paid to how consumers interpret the sensory qualities of these products and how these perceptions can vary depending on the specific type of product being replaced – whether it is a burger or a hot dog replacement – and on the different consumer segments. The research shows that while consumers may expect plant-based alternatives to be healthy and environmentally friendly options, their motivations for adopting such foods often extend beyond health and sustainability concerns to include the need to meet their sensory expectations. Recognizing these diverse motivations is essential for stakeholders aiming at promoting plant-based alternatives through targeted product development and marketing strategies.

On the other side, front-of-pack labels, particularly interpretative systems such as the Nutri-Score and Eco-Score, represent another key tool for influencing consumer behavior and fostering healthier and more sustainable food choices. Interpretative front-of-pack labels simplify nutritional and environmental information and provide consumers with the necessary information to make timely decisions at the point of purchase. In the context of this dissertation, front-of-pack labels are explored as tools to improve consumers' understanding and also shape their sensory expectations and purchase intentions for plant-based meat alternatives when compared to traditional meat products.

In combining the analysis of the available literature and of novel empirical studies on plant-based alternatives and front-of-pack labels, this PhD dissertation uncovers important insights into the complex relationship between consumer behavior, understanding, sensory perceptions, and visual attention. By enhancing consumer acceptance and understanding, this dissertation also emphasizes the importance of consumer empowerment in driving decisive changes. When provided with the right tools – whether in the form of transparent, accessible information or appealing alternatives to traditional meat products – consumers are better equipped to make food choices that benefit both human health and the environment. Ultimately, as the world seeks to address the challenges posed by climate change, resource scarcity, and public health, promoting plant-based alternatives and effective front-of-pack labeling systems emerges as a promising pathway for aligning consumer behavior with health and sustainability goals. Therefore, by investigating the factors influencing consumer perceptions, acceptance, and behavior, this PhD dissertation supports policymakers, industry stakeholders, and researchers focused on fostering the transition toward healthier and more sustainable food systems.

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# Introduction

## Global Food Challenges

Food plays a central role in every society, not only by satisfying nutritional needs but also by contributing to economic, social, and environmental progress (Dury et al., 2019). Food systems should ensure the availability, affordability, and diversity of nutritious foods (FAO et al., 2023). They shape the quality of diets through production, distribution, and marketing, and have the potential to promote food security and healthy diets. Yet, today's food systems are facing numerous challenges requiring new adaptation. Beyond the impact on public health, food systems also have a significant effect on the environment by contributing to climate change. Specifically, agrifood systems account for nearly one-third of global greenhouse gas emissions (GHGs), with livestock alone responsible for roughly 15% of anthropogenic emissions (Dury et al., 2019; European Commission, 2020a). Additionally, traditional farming practices impact natural resources, affecting land and freshwater depletion and contributing to biodiversity loss (European Commission, 2020a). Therefore, with the global population rising and the rapidly growing concerns around ethical issues related to food production, agrifood systems are required to adapt and evolve to meet new demands while still providing nutritious, safe, and sustainable food (FAO, 2022). This adaptation requires innovative approaches, as current food production methods are not sufficient to address emerging global issues (Dury et al., 2019). To facilitate this transition, national and international authorities are actively exploring strategies that could support a shift toward healthier and more sustainable food systems (WHO, 2019, 2021). However, no one-size-fits-all solution exists and a multifaceted, cooperative effort involving all actors in the food chain – from producers to consumers, from farm to fork – is crucial to address both current and future challenges (European Commission, 2020b).

In this context, the present dissertation emphasizes the empowerment of consumers as a pivotal part of this transition. Specifically, the research included in this manuscript aims at deepening our understanding of consumer perceptions related to novel food sources and to evaluate strategies that

could influence dietary behaviors. By focusing on consumers, this work recognizes that individual food choices can cumulatively have significant environmental, health, and social impacts.

## Alternative protein sources

One approach explored in this dissertation is the potential incorporation of new food sources into daily diets as a means to reduce reliance on animal-based products. Examples of novel protein sources include plant-based alternatives, cultured meat, edible insects, mycoproteins, and algae. While uncertainties remain regarding the benefits of specific alternative protein sources – for instance, there is no broad consensus on the best approach to assess the environmental impact of plant-based and cultured meat (Andreani et al., 2023; Onwezen et al., 2021) – the scientific community agrees on the potential positive effects these foods could have on global food systems (Smetana et al., 2023). Specifically, projections on alternative protein sources show that a dietary shift towards these foods could reduce the environmental pressure of food systems by mitigating climate change and by requiring less space and water resources (Smetana et al., 2023).

In addition to the environmental benefits, alternative protein sources could also facilitate a transition toward healthier diets (European Commission, 2020a). Along with generally having good protein contents, many of these alternative proteins are a valuable source of micronutrients (Ahmad et al., 2022; Andreani et al., 2023; Kim et al., 2019). However, certain limitations remain; for instance, controlling the micronutrient composition and the risk of inadequacies of specific micronutrients (especially vitamin B12) remains a research challenge for many alternative proteins, such as cultured meat and plant-based meat alternatives (Andreani et al., 2023; Chriki & Hocquette, 2020). Despite these issues and the need for further research, alternative protein sources have a strong potential to replace red and processed meats, making them key players in promoting healthier food choices.

Furthermore, the rise of novel protein sources also aligns with the growing consumer concerns over food safety and with the increasing demand for more ethical production systems (Fonseca & Sanchez-

Sabate, 2022; Liguori et al., 2022). Thus, alternative proteins not only offer a response to the urgent challenges of sustainability and health, but they could also address issues related to food safety, food security, and animal welfare (Ahmad et al., 2022; Andreani et al., 2023; Chriki & Hocquette, 2020). Finally, novel protein sources offer a path toward a more resilient and ethical future for food systems, potentially reshaping the global food landscape in the coming decades.

Among these emerging food sources, plant-based alternatives stand out as a sector with significant growth potential, with their market projections indicating a continued expansion in the next years (McClements & Grossmann, 2021; Nils-Gerrit Wunsch, 2022). These alternatives are food products designed to mimic traditional animal-based food (i.e., meat, fish, dairy, and egg) while incorporating plant-based ingredients only (McClements & Grossmann, 2021). Given their potential to steer consumers' choices toward more plant-based diets, this dissertation contributes to the scientific literature by exploring the current state of the art on plant-based alternatives from a marketing and consumer perspective**.** In addition, this PhD thesis provides new experimental insights into consumers' acceptance of plant-based alternatives, with a focus on plant-based meat substitutes.

## Front-Of-Pack Labeling

In addition to exploring consumer perceptions of new food sources, it is also critical to develop and test strategies that can encourage the adoption of healthy and sustainable products. The complexity of today's food environments, combined with marketing strategies and the widespread availability of processed foods, poses significant challenges to consumers (Fernqvist et al., 2024; Pitt et al., 2017). Many individuals also lack the time or resources to thoroughly evaluate the nutritional or environmental impact of their purchases, underscoring the need for tools that can simplify the decision-making process and enable consumers to make healthy and sustainable food choices more easily (Dongo, 2022; Fernqvist et al., 2024).

One key tool to address this issue is front-of-pack labeling, which offers clear, timely information directly on food packaging (Dongo, 2022). Front-of-pack labels have the potential to inform consumers about the healthfulness and environmental sustainability of products at the point of purchase and help them to make decisions aligned with their values and goals. Research shows that consumers are more likely to choose healthier options when provided with simplified, visible information rather than relying on lengthy ingredient lists or nutrition tables (Shrestha et al., 2023). Moreover, front-of-pack labels can be particularly helpful in encouraging behavior change by nudging consumers toward better choices without requiring significant cognitive effort (Shrestha et al., 2023). In The introduction of standardized labeling systems has the potential to further streamline this process. When these labels are consistent across products and countries, consumers can develop familiarity and trust in the information they receive, enhancing the likelihood that they will use the labels to guide their choices (Nohlen et al., 2022; WHO, 2017).

However, for front-of-pack labels to be effective, they must not only be accessible but also backed by rigorous research to ensure they significantly influence purchasing decisions toward healthier and more sustainable choices. Therefore, along with investigating consumer perceptions of plant-based alternatives, this dissertation also explores the use of front-of-pack labels to steer consumers' diets. Specifically, the works included in the present thesis focus on two labeling schemes – the Nutri-Score and Eco-Score – which are potential candidates for mandatory implementation across the European Union (Boone et al., 2023; Hercberg et al., 2022). These labels provide consumers with insights into both the nutritional and environmental impacts of their food choices, potentially influencing their decisions in favor of healthier and more sustainable options. Through a combination of literature review and experimental methodologies, including eye-tracking, this dissertation examines the effectiveness of the Nutri-Score and Eco-Score as tools for steering consumers toward healthier and more sustainable food choices.

## Structure and General Aim

Given the above-described overview, the content of this dissertation is structured to further investigate and understand how consumers perceive and respond to plant-based alternatives and front-of-pack labels, with the final objective of providing valuable insights that can inform policy and industry practices. As consumer behavior plays a pivotal role in the transition to healthier and more sustainable diets, it is essential to explore the factors influencing their food choices.

Finally, the content of this dissertation is structured as follows:

- **Chapter 1**: This chapter provides a comprehensive review of the literature surrounding the two main topics of this dissertation: plant-based alternatives and front-of-pack labels. It includes three key works. The first two articles review the existing literature on plant-based alternatives, examining these products from nutritional, technological, and environmental perspectives, with an emphasis on consumer perceptions and market analysis. The third article uses a systematic approach to reviewing the recent literature on the impact of the Nutri-Score and Eco-Score on consumer understanding and behavior.
- **Chapter 2**: This chapter presents three original studies that build on the themes introduced in the first chapter. The first study applies the means-end chain approach, a cognitive model previously adopted in consumer studies, to investigate consumer motivations for purchasing plant-based burgers. The second work employs a sensory analysis to compare consumer expectations and actual sensory experiences of a plant-based meat alternative versus its animal-based counterpart. The final study included in this chapter combines eye-tracking data and self-reported measures to explore the role of visual attention to the Nutri-Score and Eco-Score labels in shaping consumer sensory expectations and willingness to purchase plant-based and pork hot dogs.
- **Conclusion**: The dissertation concludes with a synthesis of the key findings, implications for policymakers and industry stakeholders, and suggestions for future research. It emphasizes

the importance of continued research into both consumer behavior and food labeling strategies as key drivers for the transition toward more plant-based diets.

By examining both the consumer acceptance of plant-based alternatives and the role of front-of-pack labels in influencing food choices, this dissertation contributes to the broader conversation on how to achieve healthier and more sustainable food systems. Through a combination of literature review and innovative experimental research, it offers valuable insights into strategies that can empower consumers and promote diets that are beneficial to human health but also address broader societal concerns, such as animal welfare and environmental sustainability.

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# Chapter 1:
# State of the art

## 1.1 Study 1

# Consumer perceptions and market analysis of plant-based foods: A global perspective

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## Abstract

Plant-based alternatives have gained increased attention during the past decades, from both industries and consumers. The present chapter aims at highlighting the current market situation of these products and at providing a comprehensive picture of the role of consumers in the plant-based alternative sector. Specifically, this chapter investigates the present knowledge of both consumers' perception and the sensory evaluation of plant-based foods that strive to mimic animal products – i.e., meat, dairy, seafood, and eggs – and identifies research gaps that should be addressed to enhance plant-based alternatives and enable them to become a practical tool toward a sustainable plant-forward transition.

**Keywords:** sustainability; health; food systems; flexitarians; animal products.

### 1.1.1 Introduction

Nowadays, there is a growing interest in the environmental, ethical, and health effects of our food choices (McClements & Grossmann, 2021), and a global transition toward sustainable diets has been promoted at both national and international levels to lower the impact of our eating habits. In order to attract interest and sensitize stakeholders, many events and educational campaigns have been implemented over the past decade and the concept of "sustainable diets" has become an integral part of governments' priorities (Jones et al., 2016).

Sustainable and healthy diets have been defined by the Food and Agriculture Organization (FAO) as "dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe, and equitable; and are culturally acceptable" (FAO and WHO, 2019). By reading this definition, we are distinctly dealing with a comprehensive concept that covers an umbrella of different aspects. There is no "silver bullet" to achieve the goals outlined by the FAO, and a lot of effort is required from several actors and sectors of the food system. Among possible solutions, shifting social norms toward plant-based diets – which do not require to permanently abolish meat – and away from the overconsumption of foods of animal origin is a key element (FAO, 2022b).

*But why is it necessary to reduce animal-based food consumption?*

The challenge of feeding a projected world population of nearly 10 billion people by 2050 along with the growing demand for meat products in industrialized countries is alarming if we consider the competition for agricultural land and resources (de Bakker & Dagevos, 2012; FAO, 2017). The industrial livestock sector is a relatively unsustainable process and is responsible for many environmental issues, such as deforestation, pollution, and biodiversity loss; in addition, animal products have a higher environmental impact per calorie (or gram) than most plant-based foods do (Aiking, 2011; Godfray et al., 2018). Along with these ecological aspects, food of animal origin is associated with animal welfare concerns (Godfray et al., 2018; Marescotti et al., 2020) and with

increasing awareness among consumers regarding unethical practices of factory farming, including pigtail docking, poultry debeaking, calves' separation, and mistreatment in slaughterhouses (Grandin, 2018; Profeta et al., 2021). Finally, animal products lead to an increased risk of noncommunicable diseases (NCDs), such as cardiovascular diseases, cancer, diabetes, and obesity (Godfray et al., 2018; Willett et al., 2019). Current estimates show that the global adoption of a low-meat diet (and not necessarily a meat-free diet) that covers nutritional recommendations for fruits, vegetables, and caloric requirements, is estimated to lower diet-related greenhouse gas emissions by nearly 50 percent and reduce premature mortality by nearly 20 percent (Barnard & Leroy, 2020; Bryant, 2022).

These data could be a solid driver by itself for many consumers to reduce their consumption of foods of animal origin. However, many individuals still require and desire the specific appearance, flavor, texture, and feeling associated with animal products (Siddiqui et al., 2022). These sensory elements, along with the growing importance of adopting plant-based diets, have led to propelling advancements in the plant-based alternatives industry, with the development of several plant-based substitutes mimicking animal products (FAO, 2022b; McClements & Grossmann, 2021). During the last decade, plant-based dairy and meat alternatives have become quite popular and widespread in various regions of the world (Andreani et al., 2023). More recently, plant-based options for eggs and seafood are also gaining attention and spreading in the global market (Boukid et al., 2022; Rondoni, Millan, et al., 2021a).

Although the market of plant-based food is showing impressive growth figures in recent years – as highlighted in the following sections of this chapter – it still remains a fraction compared to the size of the meat and dairy markets – markets which are also projected to keep on growing in the near future (OECD-FAO, 2022; Parlasca et al., 2022). Moreover, recent studies hint that plant-based foods are first and foremost complementary to conventional animal products rather than competitive and threatening to meat and dairy market shares (Andreani et al., 2023; Neuhofer & Lusk, 2022; Tonsor et al., 2022).

To provide a comprehensive picture of the current role of consumers in the plant-based alternative sector, this chapter investigates the present knowledge on consumers' perception of several types of plant-based foods (i.e., meat alternatives, hybrid meat, dairy alternatives, and egg and seafood analogs) and the latest market trends of these products.

### 1.1.2 Why do people choose to reduce animal-based foods? A general perspective

Although the landmark study *Livestock's long shadow* was almost completely focused on meat production in its modest attention to the demand side, it already highlighted – more than a decade and a half ago – that a consumer segment was reducing its meat intake due to "growing concerns about health, the environment, ethical, animal welfare and development issues" (Steinfeld et al., 2006). This early observation summarizes what scholarly work has extensively corroborated about the most relevant consumer concerns motivating dietary shifts away from (excessive) meat consumption. In other words, the question raised in the title of this section could be simply answered with the quoted phrase of Steinfeld and colleagues.

Multiple motivations can shape consumers' demand, including socio-demographic factors (e.g., income, age, sex), food product characteristics (e.g., price, safety, convenience, sensory properties, appearance, freshness, nutritional values), cultural aspects (e.g., social norms, eating conventions and traditions, religious beliefs), as well as human health considerations, environmental issues, and animal ethics. Strikingly, the last three (i.e., human health, environmental concerns, and animal welfare) are the foremost reasons why consumers choose to reduce the consumption of foods of animal origin, and limit or abstain from eating meat particularly. It has been consistently shown that ethical considerations about environmental sustainability and agricultural animal welfare, as well as reasons related to personal health, are important and common consumer motives to (intend to) limit the quantity of meat consumed and/or restrict the frequency of eating meat (Cooney, 2014; Hanras et al., 2022). Meat disgust is another identified reason to avoid or curtail meat that may count as an

animal welfare-derived motive, whereas weight control could be considered a health-derived reason to cut down on meat (Hopwood et al., 2021). Generally, consumer motives to reduce the intake of food of animal origin are on par with the broad agreement in academia that consuming less meat and dairy products benefits the environment, human health, and animal welfare. Hence, the main line that can be drawn in the research domain of meat-reducing (flexitarian) and meat-avoiding (vegetarian/vegan – hereafter: veg*n) food styles is clear: ecological impacts, health concerns, and ethical aspects of animal-based products are pivotal to answering the question on why contemporary Western food consumers limit their meat consumption, restrict their intake of animal-sourced products, or even entirely refrain from eating food of animal origin (Kemper et al., 2023; Müssig et al., 2022; North et al., 2021).

However, research on this topic continues, and the latest available scientific knowledge gains in detail and differentiation. This resonates in linking different categories of motivations to specific dietary positions. Food consumers have several motivations for engaging in meat reduction behaviors; for instance, ethical concerns about agricultural animals are strong motives for veg*ns to adopt and maintain a meat-free diet in comparison to flexitarians, whereas taste- and health-related product characteristics of plant-based foods are more relevant to flexitarians when reducing their intake of animal-based food products (Hopwood et al., 2021; North et al., 2021). A recent research project (Smart Protein Project, 2021) showed that, for flexitarians, the five most crucial motives to opt for plant-based foods were all product-related (i.e., taste, health, fresh, no additives, and cheap, respectively). Environmental sustainability ($6^{th}$ place) and animal welfare concerns ($7^{th}$ place) followed as minor factors that influence flexitarians' choices for plant-based foods. By the same token, omnivores' behaviors are more likely driven by egocentric motives, such as price, convenience, product familiarity, and personal health; whereas veg*ns' are motivated by ecocentric elements in which the perceived benefits or costs of behavioral consequences to the ecosystem are of decisive importance (Boukid, 2021; Hanras et al., 2022; Müssig et al., 2022; North et al., 2021). Nevertheless, ethically- and environmental-sustainability-oriented veg*ns can also be distinguished from personal

health-motivated veg*ns (Cooney, 2014; Leenaert, 2017). Closer scrutiny in the field of flexitarianism reveals that – also within the heterogeneous dietary group of flexitarians – different motives prevail for different segments. Committed meat reducers – "heavy" flexitarians or "semi-vegetarians", to borrow a term from earlier research – are close to meat abstainers and share strong motivators with meat-avoiding consumers for rejecting meat: health benefits, environmental concerns, and animal welfare considerations are the main drivers. On the other end of the spectrum, avid meat eaters and flexitarian fractions that are more attached to meat consumption indicate that affordability (price), safety, and/or sensory appeal (taste) are driving motivations when considering reducing food of animal origin (Verain et al., 2022; Verain & Dagevos, 2022; compared to: (Kemper et al., 2023; Malek & Umberger, 2021a, 2021b, 2023; Spendrup & Hovmalm, 2022).

Although recent studies – as the ones just mentioned – indicate that a segment of today's food consumers is uninterested in or indifferent to plant-based alternatives, minority groups of veg*ns and the emerging segment of flexitarians may be considered the main target groups of plant-based alternative products (Andreani et al., 2023; Dagevos, 2021; Lehto et al., 2023) if only for the simple reason that their meat-free/low-meat diets are facilitated by plant-based foods as affordable, accessible, appealing, and nutritious options to animal-based counterparts.

### 1.1.3 Market Trends of Plant-Based Alternatives

The market of plant-based protein alternatives has grown rapidly since the beginning of the 21st century, with the global plant-based food market expected to reach 77.8 billion U.S. dollars in 2025 and double by 2030 (Nils-Gerrit Wunsch, 2022d). Impossible Foods Inc. (Redwood City, CA, USA), with The Impossible™ Burger, and Beyond Meat Inc. (El Segundo, CA, USA), with the Beyond Burger®, are among the first companies gaining popularity in this sector thanks to their successful products mimicking beef burgers (van der Weele et al., 2019). More recently, other large companies

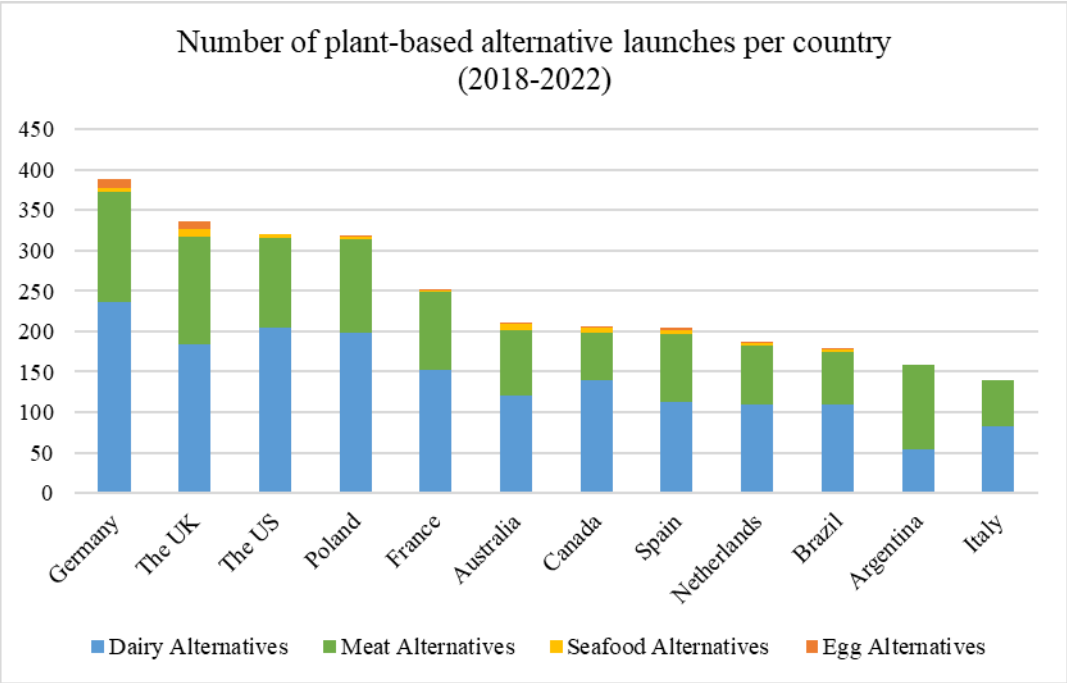
519 (e.g., Tyson, Perdue Farms, Nestlé, and JBS) have also joined this promising market (Sha & Xiong,
520 2020; Witte et al., 2021).
521 To analyze the latest trends, the present section explores the data on new plant-based alternatives
522 retrieved from Mintel's Global New Product Database (GNPD) (Solis, 2016). This online tool allows
523 researchers to review and analyze information about new product activities on the market. Data were
524 extracted in February 2023 based on the following search strategy:

525 • The *Category* matches one or more of: "Processed Fish, Meat & Egg Products"; "Dairy".
526 • The *Date Published* is within the last five complete years (i.e., 2018-2022).
527 • The *Claim* matches one or more of: "Plant-Based"; "Vegan/No Animal Ingredients".
528 • The *Launch Type* matches "New Product".

529 The research returned 5904 new plant-based alternative products launched on the global market over
530 the 2018-2022 period. Data were downloaded as an Excel file and the results of the analysis carried
531 out by the authors are presented hereinafter.
532 The nearly 5900 new launches extracted from GNPD refer to products designed to imitate food of
533 animal origin in taste, texture, smell, and appearance, and can be in the form of meat, dairy, fish, or
534 egg analogs. More than half of these new product launches were dairy substitutes (62%), followed by
535 meat (35%), seafood (2%), and egg (1%) alternatives.
536 The most involved countries in this sector are European countries, with Germany, the UK, Poland,
537 and France as leading actors, along with the US (
538

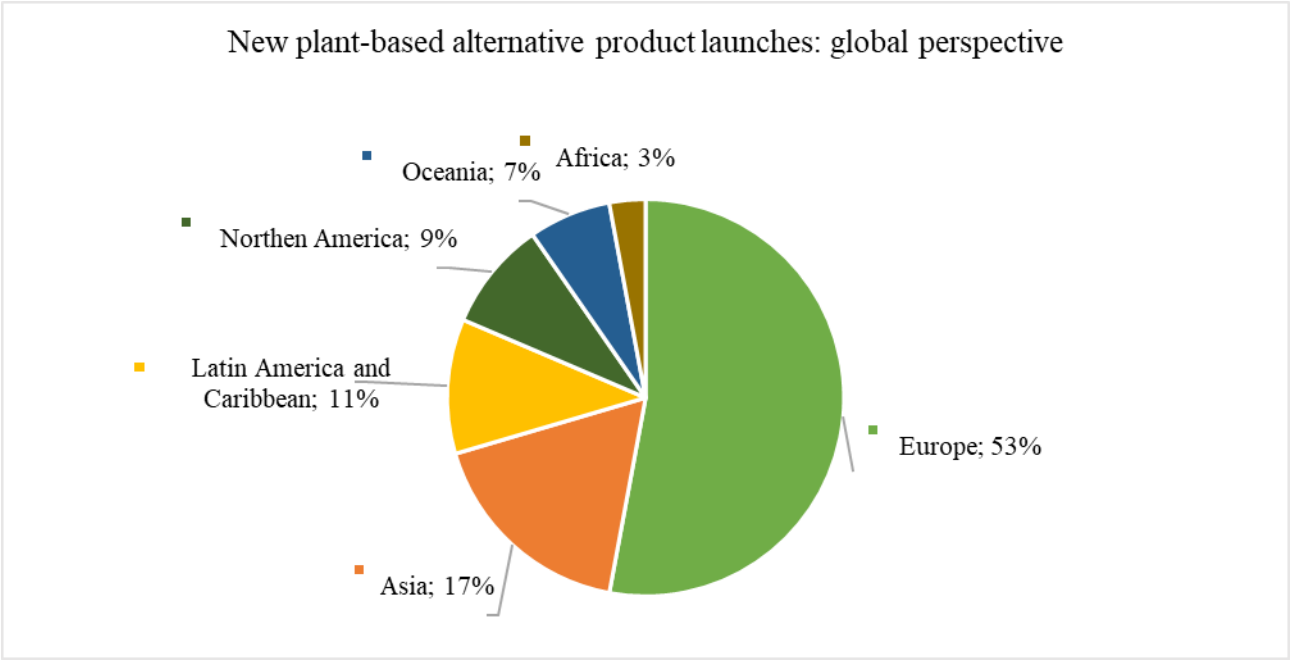
539 **Figure *1***). A general overview of the global market is represented in Figure 2, which depicts that
540 Europe and Asia together account for nearly 70% of the global launches of plant-based analogs over
541 the 2018-2022 period (
542 Figure ***2***).
543
544

**Figure 1**. Twelve most active countries involved in the launches of plant-based alternatives over the 2018-2022 period.




Source: own elaboration.

**Figure 2.** Distribution of geographic regions involved in the launches of plant-based alternatives over the 2018-2022 period.

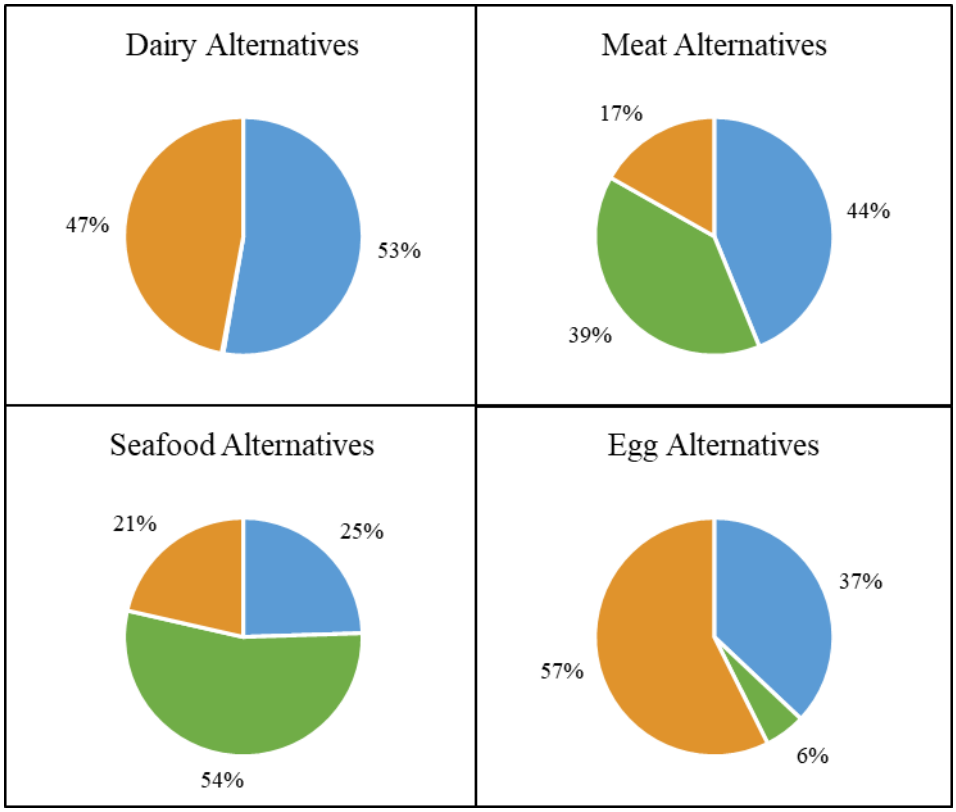



Note: Africa = Algeria, Cameron, Morocco, Egypt, Ethiopia, Ghana, Ivory Coast, Kenya, Nigeria, South Africa, Tanzania, and Tunisia; Asia = Bangladesh, Cambodia, China, Hong Kong, India, Indonesia, Israel, Japan, Jordan, Kuwait, Laos, Lebanon, Myanmar, Oman, Pakistan, Philippines, Puerto Rico, Qatar, Saudi Arabia, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, Turkey, UAE, and Vietnam; Europe = Austria, Belgium, Belarus, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Holland, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the UK; Latin America And Caribbean = Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Panama, Peru,

559 and Venezuela; North America = Canada and the US; Oceania = Australia, Malaysia, and New Zealand *(United Nations,*
560 *2022)*. Source: own elaboration.
561

562 Considering these launches of new plant-based alternatives, dairy substitutes have an average price
563 of 14.96€/kg and the storage method mostly employed is either chilled or shelf stable. Meat analogs,
564 which are usually sold frozen or chilled – but in some cases can also be shelf-stable (e.g., canned
565 products) – have an average price of 23.07€/kg. Egg and seafood alternatives are the most and second-
566 most expensive categories, with 35.10€/kg and 32.96€/kg, respectively. Whereas seafood analogs are
567 sold either frozen (54%), chilled (25%) or shelf-stable (21%), egg substitutes are rarely sold frozen
568 (< 1%). To have a graphical representation of the storage method, please refer to Figure 3.

569 **Figure 3.** Storage methods of plant-based alternatives launched over the 2018-2022 period.

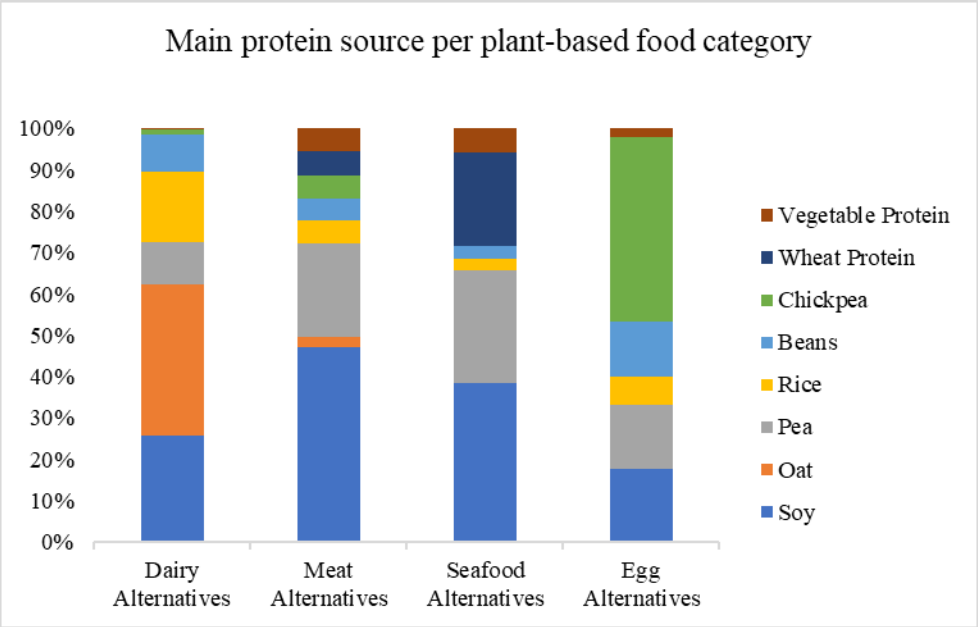



570 Note: Orange= shelf-stable; Blue= chilled; Green= frozen. Source: own elaboration. Source: own elaboration.
571

572 One relevant aspect for both consumers and manufacturers when considering the market of plant-
573 based foods is the ingredients employed in the production process. As we are dealing with products
574 that should be high in protein, it is no coincidence that soy is the leading source of plant-based food

ingredients, usually followed by rice, oat, and pea proteins. As a matter of fact, in 2020, sales of plant-based food employing soy as the main source were valued at nearly 2.4 billion U.S. dollars, and it is expected to grow and reach 4.1 billion U.S. dollars by 2026 (Nils-Gerrit Wunsch, 2022c, 2022a). Referring to the four food categories separately (i.e., dairy, meat, seafood, and egg alternatives), proteins derived from oat, soy, and rice are mostly used in dairy alternatives, whereas soy, pea, and wheat proteins are frequently employed in meat and seafood analogs. As for egg alternatives, chickpea proteins are the most commonly used. A more detailed overview of frequently used ingredients as the main protein source is represented in Figure 4**Error! Reference source not found.**.

**Figure 4.** Top-8 most employed ingredient as the main protein source for the new plant-based alternatives launched over the 2018-2022 period divided by category.




Source: own elaboration.

The recent success of plant-based alternatives, and their positive market trends, also draws attention to a critical aspect that can influence consumers' food choices: the way these products are labeled. Even if it is not in the scope of the chapter, it is worth mentioning that labeling and product names are critical elements when considering consumers' perceptions and motivations (Asioli et al., 2023; Demartini et al., 2022). Preferences for shopping behaviors appear to be related to preferences for the

592 labeling of plant-based alternatives; specifically, consumers who are inclined to prefer foods of
593 animal origins over plant-based substitutes would usually allow the use of animal-sounding names
594 (e.g., “beef” or “steak”) only on animal products (Van Loo et al., 2020). Marshall et al., (2022)
595 showed that, for meat-free dishes, consumers preferred meat-related names (e.g., cauliflower steak)
596 over non-meat-sounding labels (e.g., cauliflower slice) (Marshall et al., 2022). If we focus on the
597 current legislative situation in the European Union (EU), many stakeholders are demanding
598 governmental interventions to regulate the labeling system of novel foods (Amato et al., 2023;
599 Demartini et al., 2022). Since 2017, the Court of Justice of the European Union does not allow the
600 market of plant-based dairy substitutes with designations such as ‘milk’, ‘cream’, ‘butter’, ‘cheese’
601 or ‘yogurt’, which are reserved by the EU law for animal products only (Court of Justice of the
602 European Union, 2017). The same legislation does not apply to products mimicking meat or other
603 categories, for which no official law is currently in place at the EU level. As a matter of fact, the
604 adoption of animal-sounding names – e.g., “vegan burger” or “plant-based bacon” – is a major
605 debating point when considering the sector of plant-based alternatives. Producers’ and consumers’
606 associations are discussing opposite views at global levels and the intervention of regulators is needed
607 to solve this issue. However, different rules apply in different countries. For instance, in 2018, the
608 French government outlawed the use of animal-related terminologies to describe plant-based foods
609 (Assemblée Nationale, 2018). On the other hand, the draft guidance of the Food and Drug
610 Administration (FDA) “Labeling of Plant-based Milk Alternatives and Voluntary Nutrient Statements:
611 Guidance for Industry” suggests that plant-based milk alternative products that mention the term
612 “milk” in their name (e.g., “almond milk”), and that have a nutrient composition that differs from
613 traditional milk, include a voluntary statement that conveys how the product nutritionally differs from
614 animal milk (e.g., “Contains lower amounts of Vitamin D and calcium than milk”) (Food and Drug
615 Administration, 2023). Therefore, a unique view on how to label plant-based products that mimic
616 animal-based foods does not exist yet. Further research should focus on testing possible solutions to

protect both consumers and producers and reach harmonized guidance that could provide consumers with clear labeling and give them the information needed to make informed purchasing decisions. While the dispute on how to label these products is still under discussion, the increased awareness of sustainable and health concerns is shifting consumer interests toward plant-based lifestyles, and, consequently, manufacturers are employing claims on food packaging to capture consumers' attention. It is no surprise that the number of new packaged goods launched with a "plant-based" claim has grown by nearly 700% over the 2015-2021 period and accounted for around 12% of 2021 total launches. If we focus the attention on the new product launches that are the subject of this section (plant-based alternative launches over the 2018-2022 period), the five most employed claims are "Plant-Based", "Low/No/Reduced Allergen", "Vegan/No Animal Ingredients", "High/Added Protein", and an ethical claim to stress an environmentally friendly package. When considering single categories, claims mostly differ for dairy substitutes – i.e., "Dairy Free", "Low/No/Reduced Lactose", and "Vitamin fortified" – which stresses the importance of being products suitable for lactose intolerant consumers other than for individuals who seek plant-based options.

Finally, advancements in food technology on the one hand, and increasing consumer concerns about health and climate change on the other, have fueled the global plant-based food market to reach a remarkable spike worldwide. Future growth is also expected (Andreani et al., 2023; OECD & FAO, 2020). Within the context of this projection, the next sections highlight strengths and weaknesses when it comes to consumers' preferences and sensory evaluation of plant-based product alternatives.

### 1.1.4 Consumer Perception & Sensory Evaluation of Meat Alternatives

Nowadays, several plant-based meat alternatives containing either pulse- or cereal-based proteins have been developed and introduced into food markets to either fully replace meat (Andreani et al., 2023; Boukid, 2021) or combine animal- and non-animal-based ingredients, i.e., the so-called "hybrid meat products" (S. Grasso & Jaworska, 2020).

642 Using plant-derived protein products, such as tofu and tempeh from soybeans, has been a traditional
643 practice for centuries in Asian countries. However, these products are not considered meat
644 alternatives (Andreani et al., 2023; Giacalone et al., 2022), and, due to their sensory differences
645 compared to meat, they have not become popular in Western countries, especially among meat-eaters
646 (Fiorentini et al., 2020). For this reason, during the past years, the food industry has focused on
647 developing meat-like substitutes that could mimic the sensory characteristics of animal products
648 (Giacalone et al., 2022). Barone et al., (2021) employed online focus groups to co-create healthier
649 new meat products (Barone et al., 2021). Results showed that partial meat substitution with plant-
650 based ingredients could be accepted by consumers when these products resemble regular meat in
651 terms of sensory features, especially in their flavor.
652 Today, the terms plant-based "meat alternatives" or "meat analogs" typically indicate a new
653 generation of products that try to imitate the taste, texture, odor, flavor, and appearance of processed
654 meat, such as burgers, patties, sausages, and nuggets (He et al., 2020; Sha & Xiong, 2020). To reach
655 these specific high-quality characteristics (e.g., "the bleeding burger"), various colorants – such as
656 leghemoglobin, red beets, and red cabbage – are employed in the production process of meat
657 alternatives (Andreani et al., 2023). These and other elements (e.g., vegetable oils) contribute to a
658 long list of unfamiliar ingredients (Cutroneo et al., 2022) that could lead consumers to perceive the
659 product as unnatural (Hartmann et al., 2022).
660 Given that low sensory appreciation, especially for taste and appearance, is a strong barrier to the
661 adoption of meat substitutes (Giacalone et al., 2022), and considering the crucial role of ingredients
662 in modifying these aspects, sensory attributes and overall consumer acceptance are strongly
663 influenced by the types of plant protein sources employed in the production process (Caputo et al.,
664 2022; Lemken et al., 2019). For instance, some legume proteins can negatively influence the sensory
665 characteristics of meat analogs by providing the final product with a beany off-flavor (Andreani et
666 al., 2023).

667 The most investigated meat category in consumer studies, including sensory tests, is burgers
668 (Andreani et al., 2023; Michel et al., 2021; Onwezen et al., 2022; Slade, 2018); however, little is
669 known about consumers' sensory evaluation of plant-based meat products (Fiorentini et al., 2020;
670 Martin et al., 2021). The first consumer and sensory tasting studies focused on the "first generation"
671 of plant-based foods – i.e., not specifically developed to mimic foods of animal origin (Caparros
672 Megido et al., 2016; Schouteten et al., 2016). More recently, some studies investigated the "new
673 generation" of meat analogs (Caputo et al., 2022; S. Grasso et al., 2022; Smetana et al., 2021) and
674 tested the impact of information provision (e.g., "conventional 100% beef burger" *vs* "plant-based"
675 or "hybrid" burger) on consumers' perception and sensory evaluation. Results showed that
676 respondents generally prefer traditional meat products over their plant-based counterparts.
677 Interestingly, S. Grasso et al., (2022) found that – both under blind and informed conditions – hybrid
678 burgers were the most appreciated ones, followed by beef and plant-based burgers (S. Grasso et al.,
679 2022). Focusing on plant-based options, the texture was a critical aspect under the blind condition,
680 followed by the taste, aroma, and appearance. Nevertheless, these attributes significantly increased
681 in liking, especially for appearance and taste, in the informed condition.
682 Another sensory study, one of the few employing pork meat substitutes, evaluated the role of
683 information (health and environmental benefits of using plant proteins) on consumer preferences for
684 a plant-based sausage. Results showed that information (both health- and environmental-related)
685 significantly increased the purchase intention for the plant-based option. However, consumers' higher
686 preference for traditional pork sausages was not reversed, even after providing the information
687 (Martin et al., 2021). These results suggest that the no-conventional sensory attributes of plant-based
688 meat alternatives are more easily accepted when the information about its characteristics is disclosed;
689 however, this impact is not strong enough to overturn consumers' preferences, which remain in favor
690 of traditional meat food (Caputo et al., 2022; Cordelle et al., 2022; Martin et al., 2021).
691 In line with previous results, studies exploring consumer responses toward plant-based meat burgers
692 in terms of demand changes (i.e., purchasing behaviors) indicated that individuals usually prefer

traditional meat products (Caputo et al., 2022; Profeta et al., 2020; Van Loo et al., 2020). However, Van Loo et al., (2020) showed that providing consumers with information on the environmental and animal welfare benefits of meat alternatives could positively affect preferences for plant-based burgers without impacting the demand for conventional meat (Van Loo et al., 2020). Caputo et al., (2022) also observed that the willingness to pay for the plant-based alternative was higher in the informed condition (i.e., consumers knew the product did not include ingredients of animal origin) than in the blind condition (i.e., no information on product characteristics was provided) (Caputo et al., 2022).

Another crucial aspect influencing the acceptance of food is product familiarity. Consumers are usually more familiar with meat products than they are with their vegetarian counterparts (Boukid, 2021; Caputo et al., 2022; Smetana et al., 2021) and, as a consequence, the situational appropriateness differs between the two options (Elzerman et al., 2021). For instance, consumers usually prefer a traditional steak over a vegetarian one when preparing a "special meal" (Elzerman et al., 2021).

Ultimately, the market success of plant-based meat alternatives will vastly rely on understanding consumers' perceptions and beliefs, which are influenced by both non-sensory attributes (e.g., information included on the packaging about the ingredients or products' benefits) and product-specific sensory characteristics (e.g., taste, appearance, texture, smell), which require specific features to avoid negatively impacting plant-based meat products (Banovic & Sveinsdóttir, 2021). Moreover – and in accordance with the second section of this Chapter – individual-related factors, such as age, gender, culture, and more specific health and environmental behaviors, are strong determinants in the acceptance of plant-based meat products (Giacalone et al., 2022; Profeta et al., 2020; Vural et al., 2023).

### 1.1.5 Consumer Perception & Sensory Evaluation of Hybrid Meat

Along with plant-based alternatives mimicking foods of animal origins, hybrid meat products – which combine animal and non-animal ingredients (e.g., hybrid burgers, hybrid meatballs) – are an elegant

719 strategy to ease the transition from a meat-centered diet to more nuanced products that offer
720 environmental and health benefits and a familiar taste (Banovic, Barone, et al., 2022; S. Grasso &
721 Goksen, 2023). Hybrid meat products are foods containing an amount of plant-based ingredients that
722 usually varies between 25% to about 50% (S. Grasso & Jaworska, 2020).
723 From 2019, hybrid products have been launched in the European and the US market (e.g., Danish
724 Crowns' 50/50 burgers, Denmark; Applegate's Well-Carved beef/veggie burger, the UK) (Aidan
725 Fortune, 2019; Flora Southey, 2021). It has been estimated that, if 50% of meat is replaced with plant
726 proteins, this novel alternative could promote both human and animal health and reduce greenhouse
727 gas emissions by nearly 32% (Baune et al., 2021). The reported advantages of these products are
728 related to higher sensory acceptance due to their familiar meaty taste (S. Grasso et al., 2022) – even
729 by consumers who are attached to meat (Banovic et al., 2022). However, even though hybrid meat is
730 becoming more popular, consumer acceptance is not yet well-defined.
731 The current situation is that many people have values (or abstract, situation-specific aggregated
732 cognitive categories) toward hybrid products as citizens, where they express altruistic, self-
733 transcendent principles, whereas as consumers, they manifest more selfish, self-interest values
734 (Banovic & Barone, 2021). The effect of these on the acceptance of hybrid alternatives depends on
735 the level of self-construal or on how people see themselves in relation to others. Self-transcendent
736 goals (i.e., adopting sustainable behaviors) are dominant in non-committal interdependent situations
737 (e.g., professing self-environmental identity). On the other hand, self-interest goals (i.e., adopting
738 healthy behaviors) have a stronger effect on the acceptance of hybrid products when it comes to real
739 choices, where independent self-construal is activated (e.g., higher levels of health consciousness).
740 In line with the other plant-based alternatives, environmental concerns are not always the top purchase
741 motive for hybrid products, thus self-interest goals are usually more influential and health concerns
742 are often prioritized (Asioli et al., 2023). Whether people reveal their self-transcendent or self-interest
743 principles when buying hybrid products is further mediated by the perceived product quality, which
744 has been identified as a decisive factor in the acceptance of hybrid meat (Lang, 2020).

Hybrid meat is often perceived as a plant-based alternative by consumers who are attached to meat (Banovic, Barone, et al., 2022; Circus & Robison, 2019). However, the ambiguous nature of these products (part animal, part plant) could also make it difficult for omnivore and flexitarian consumers – who are the main target of hybrid foods – to distinguish between hybrid, animal-based, and plant-based options (van der Meer et al., 2023). Thus, better market positioning and differentiation strategies should be implemented to ensure that hybrid alternatives could be clearly distinguished at the point of purchase.

In terms of sensory characteristics, research has shown that hybrid meat performs better than plant-based alternatives in terms of both expected and actual taste (S. Grasso et al., 2022; Neville et al., 2017; Tarrega et al., 2020), which led to higher acceptance rates over plant-based alternatives (Sogari et al., 2022). Exploring the sensory quality of hybrid meat products with consumers and investigating their motives and barriers are key elements to steer both reformulation and marketing efforts in the right direction. However, studies were primarily carried out in Western countries (e.g., the US, Denmark, Spain, the UK, and Germany) and thus, additional research should focus on the sensory analysis and information provision using different meat products in different countries (S. Grasso & Goksen, 2023).

### 1.1.6 Consumer Perception & Sensory Evaluation of Dairy Alternatives

Oppositely to plant-based meat alternatives, plant-based dairy substitutes have been less explored in terms of consumers' acceptance and sensory evaluation. Most of these studies focused on milk and beverage alternatives, whereas research on cheese, yogurt, and other dairy alternatives (e.g., butter) is still scarce (Adamczyk et al., 2022; Yang & Dharmasena, 2020).

Regarding plant-based beverages, curiosity, the need for diversity in the diet, familiarity, health aspects (e.g., different fat contents), and being suitable for lactose intolerant people are the main motives for consumers to look for these alternatives (Adamczyk et al., 2022). Usually, individuals

who are primarily concerned with nutrition, environmental aspects, health, and animal welfare are more likely and more frequently willing to consume plant-based milk substitutes, as well as flexitarians and veg*ns (Boaitey & Minegishi, 2020). Conversely, the main barrier to the consumption of these products is their taste, as consumers are seeking plant-based beverages that have similar sensory characteristics to their dairy counterparts. Research on the sensory evaluation of these products strongly confirms that dairy-based beverages are more appreciated by consumers, especially if full-fatted (ca 3% fat), whereas unsweetened plant-based drinks are usually the least preferred (McCarthy et al., 2017). Consumers usually seek products that resemble the animal counterpart – e.g., "white appearance" and "milk-like flavor" – and avoid characteristics that are not typical of dairy-based food, such as "grain/wheat flavor" and "cardboard-like" (Cardello et al., 2022; Chung et al., 2022; Collier et al., 2023). Food technologists and developers have also tested several strategies to improve the sensory aspects of plant-based beverages; for instance, blending different types of nuts or adding vanilla or cocoa extracts to the product has shown promising results (Jonas da Rocha Esperança et al., 2022). This methodology can lead to a positive impact on both the taste and the color of the final product (Felberg et al., 2009).

Along with the above-mentioned product characteristics, consumers are also influenced by the packaging and the claims displayed on it. For instance, the illustration of the main ingredient (e.g., cashew) can steer consumers' preferences, and claims – especially nutritional and functional ones (e.g., "lactose-free", "cholesterol-free", "prebiotic", "source of protein") – can positively impact individuals' perception and purchasing intentions of plant-based beverages (Cabral Rebouças et al., 2020; Rebouças et al., 2019).

As for milk alternatives, plant-based cheese substitutes are also facing several challenges in terms of sensory characteristics, especially for their flavor and textural properties. Although some cheese alternatives are appreciated for their softness, buttery taste, and smoothness, consumers – mainly omnivore consumers – express dislike and unhappiness with the sensory attributes of these products (Falkeisen et al., 2022; Pointke et al., 2022). However, given the paucity of literature, more studies

should investigate these aspects to better evaluate the sensory profile, consumers' segments, and their acceptance of plant-based cheese (Short et al., 2021).

When it comes to plant-based yogurts, the scientific literature on the topic is significantly smaller compared to the other dairy alternatives. Technological efforts are leading to products with improved sensory characteristics and the small corpus of research has shown that some of these goods can be considered similar to dairy yogurts in terms of sensory acceptability, especially for their texture (N. Grasso et al., 2020; Gupta et al., 2022). However, Greis et al., (2023) showed that yogurts with a higher dairy content were more appreciated than samples with lower dairy contents, which indicates that consumers still require improved sensory features that would likely increase the market share of this product category – such as sweet, moist, soft, and smooth (Brückner-Gühmann et al., 2019; Greis et al., 2023; Jaeger, Cardello, et al., 2023). As providing information about the environmental and health benefits of plant-based yogurts did not show impactful results on consumers' acceptability (Jaeger, Giacalone, et al., 2023), advancements in food technology and increased awareness of the sustainable and health impact of reducing food of animal origin are needed to allow these products to become mainstream in the global market.

Overall, plant-based milk is by far the most developed and studied category of plant-based dairy products, and it currently accounts for 15% of the total retail milk worldwide (Giacalone et al., 2022). Also considering the other categories (i.e., plant-based cheese and yogurt), the global market and the demand for plant-based dairy alternatives are expected to grow (Nils-Gerrit Wunsch, 2022b), but there are still critical challenges that need to be faced to promote their consumption. First, negative sensory characteristics are a relevant issue as consumers generally prefer the dairy counterpart over the plant-based option (Giacalone et al., 2022; Jonas da Rocha Esperança et al., 2022). Second, most people are not willing to entirely renounce dairy products. Finally, consumers are not fully aware of the environmental benefits related to plant-based dairy substitutes, although they are usually conscious of the health and nutritional benefits of these alternatives (e.g., low-caloric contents and lactose-free features). As suggested by Adamczyk et al., (2022), people rarely associate dairy

products with animal suffering and ecological complications linked to industrial farming, and thus, these products do not feel "unpleasant" as meat does (Adamczyk et al., 2022).

In order to increase the consumption of plant-based dairy alternatives – and in line with the other plant-based substitutes – there is the need for technological advancements to improve the positive sensory experience related to these products, as well as the promotion of awareness campaigns to educate consumers on the environmental benefits of plant-based products over animal-based dairy (Clune et al., 2017).

### 1.1.7 Consumer Perception & Sensory Evaluation of Egg and Seafood Alternatives

While plant-based meat and milk alternatives are already consolidated in the global market, egg and seafood analogs represent niche sectors, and studies exploring consumers' perceptions and acceptance of these products are still scarce.

Plant-based eggs are intended to promote environmental sustainability and encourage a reduction in the consumption of animal eggs while addressing food allergy issues (Brennan et al., 2022; Rondoni, Millan, et al., 2021b). One of the first research investigating consumers' preferences for plant-based eggs was conducted in 2020. Results showed that people who do not usually consume plant-based food products tend to prefer egg replacements when the product mimics the color and taste of its animal counterpart, whereas vegans and consumers suffering from egg allergies would opt for characteristics that do not necessarily replicate animal eggs (Rondoni, Grebitus, et al., 2021; Rondoni, Millan, et al., 2021a).

Overall, a critical factor for consumers is the nutritional content of the plant-based product. The reason for this tendency is to be traced to the general understanding that traditional eggs are known for being an optimal source of proteins, vitamins, and omega 3, and thus people would expect a similar nutritional profile in egg analogs (Rondoni, Grebitus, et al., 2021; Rondoni, Millan, et al., 2021a).

847 Another relevant aspect for consumers is the packaging and the claims displayed on it. Consumers
848 believe that manufacturers should use the packaging to convey important messages, such as a “clean”
849 ingredient label (e.g., short ingredient list), health benefits (e.g., allergen- and cholesterol-free),
850 animal welfare (e.g., does not involve animals), safety aspects (e.g., it is free from contaminations
851 such as salmonella, antibiotics, etc.), and sustainability elements (Rondoni, Grebitus, et al., 2021;
852 Rondoni, Millan, et al., 2021a).
853 Consumer studies on plant-based eggs are still in their infancy and results cannot be generalized to a
854 wide population, as research was carried out in just a few countries (Italy and the UK) (Rondoni,
855 Grebitus, et al., 2021; Rondoni, Millan, et al., 2021b). Further research is needed to investigate not
856 only preferences and attitudes toward this product category but also sensory expectations and
857 perceptions, which have not been explored so far.
858 Despite consumers’ perspectives on plant-based egg alternatives being little investigated, aspects
859 covering seafood alternatives have been even less explored. In 2022, a study by Boukid et al. assessed
860 the nutritional profile of seafood analogs (e.g., tuna, calamari, fish fillets, and fish fingers) compared
861 to conventional products. The research showed that plant-based seafood alternatives have variable
862 nutrient contents, and, in many cases, they substantially differ from the nutritional profile of their
863 animal counterpart (Boukid et al., 2022). However, the study did not analyze consumers’ perception
864 of these nutritional differences, and, in terms of consumer science, it is quite laborious to find
865 scientific articles investigating consumers’ behavior, attitude, and sensory expectation for this food
866 category. The dearth of research on this topic concurs that consumers’ interest in these products is
867 still low and they are not ready to add them to their regular diets (Estell et al., 2021; Gorman et al.,
868 2023). Although messaging about the benefits of seafood substitutes and viewing the ingredient list
869 could increase the willingness to try and to pay for the product (Gorman et al., 2023; Kim et al., 2023),
870 the key factor for driving consumers’ perception is the successful replication of complex sensory
871 aspects (Gorman et al., 2023). As a matter of fact, despite being aware of the environmental benefits
872 of plant-based fish alternatives (but less conscious of their healthiness), consumers are mostly

hindered by the taste and texture seafood analogs could have (Gorman et al., 2023). Further research should expand on this topic to investigate attitudes and motives toward the consumption of seafood alternatives. Additionally, sensory evaluation is required to explore whether exposure to these products could impact consumers' perceptions.

The lack of scientific evidence for egg and seafood analogs is probably because these are still niche market sectors. Technological innovations for these product categories have recently accelerated and their market share is expected to increase in the near future. Therefore, it is not possible – as of the writing of this chapter – to provide a comprehensive overview of consumer perceptions and sensory evaluation of plant-based egg and seafood alternatives. Ample room exists for future studies to cover innovative aspects that could be of benefit to manufacturers, health professionals, and policymakers.

### 1.1.8 Discussion and Conclusions

The growing demand for plant-based foods as an alternative to animal-sourced proteins is expected to rise in the upcoming years (Andreani et al., 2023; Aschemann-Witzel et al., 2020). Given this prediction, policy and marketing strategies are needed to ensure that non-animal products are more accessible to omnivore consumers who might not be willing to entirely eliminate certain foods from their diets (i.e., becoming veg*n) (Banovic, Arvola, et al., 2022). One strategy to promote this transition is to produce plant-based alternatives that resemble their animal counterpart without compromising sensory characteristics, as many consumers still desire the specific flavor, texture, mouthfeel, and feeling of various animal-derived products (FAO, 2022b). The plant-based analogs market is a vibrant sector which merits further exploration and assessment, as emphasized by the significant growth figures it is experiencing and will likely continue undergoing in the near future. The increasing availability of these products in supermarkets and food chains (including McDonald's, Burger King, and KFC having released plant-based versions of beef burgers and chicken nuggets),

the substantial investments of the latest decades, and the remarkable efforts to improve the product qualities, all testify the influence this sector has gained for both consumers and manufacturers.

Another strategy would be to go beyond the product purchase and tackle the moment of the pre- and post-consumption to provide consumers with information, ideas, and recipes on how to use and cook new meals that can solidify the footing of plant-based products in the market (Banovic, Arvola, et al., 2022). This is one of the key gaps that most companies are not considering in today's marketplace.

However, to support this sector and promote a transition toward healthier and more sustainable eating behaviors, it is critical to assess and understand consumers' perceptions and beliefs. The fact that people express their concerns about diet, climate change, and various aspects of meat production when prompted to share their opinion is often inconsistent with their actual behavior (de Barcellos et al., 2011; ElHaffar et al., 2020). Despite the ample evidence on people's health concerns related to meat consumption (Barone et al., 2021; Macdiarmid et al., 2021), eating habits do not seem to be healthier (Eurostat, 2023). Similarly, regardless of the increased awareness of environmental issues (Circus & Robison, 2019; Pais et al., 2020), consumers' actions do not always or automatically become more sustainable (FAO, 2022). Nevertheless, changes are possible, and hybrid and plant-based options have the potential to facilitate the shift from meat-centric dishes to plant-forward dishes (Banovic, Barone, et al., 2022), thus promoting the reduction of foods of animal origin without requiring a strict shift to veg*sm (Spencer et al., 2021; Spencer & Guinard, 2018).

One relevant aspect to take into consideration when referring to consumers' views and beliefs is that drivers to reduce the consumption of meat and foods of animal origin are likely to vary between countries (Adamczyk et al., 2022; Bryant et al., 2019). Given the global perspective of the present chapter, this hypothesis is particularly relevant. At present, comparative research on consumer motives in favor of limiting the consumption of foods of animal origin that highlights country-specific traditions and circumstances represents a knowledge gap (Bakr et al., 2022; Bryant et al., 2019; Greis et al., 2023). Future research may be conducted to gain insight into how and to what extent culinary

habits, social surroundings, or (un)availability of affordable and palatable plant-based alternatives are country-specific (de)motivators of consumer acceptance.

Regardless of the type of plant-based alternative, common aspects related to consumers' responses can be identified. First, information provision often increases the interest and the attitude toward these products, and thus, communication campaigns and the use of labels (e.g., the Nutriscore and the Ecoscore) should be considered to allow consumers to make informed choices and provide them with the necessary tools to understand the health and the environmental impact of foods (S. Grasso et al., 2022; Martin et al., 2021; Smetana et al., 2021; Van Loo et al., 2020) Second, along with high prices, the relatively low familiarity/availability of these products is a critical aspect associated with consumers' preferences. To allow plant-based alternatives to become mainstream in the market, it is necessary to foster familiarity – for instance, through free tasting sessions in supermarkets. It has also been recommended to increase the availability of plant-based analogs in school canteens to familiarize younger generations with these alternatives (Profeta et al., 2020; Sogari et al., 2022). Last, even if familiarity and information about the benefits could support consumers in their choices, the sensory appeal remains a critical factor for acceptance (Caputo et al., 2022; Fiorentini et al., 2020). Limited animal-like sensory features – either expected or experienced – represent a strong barrier to replacing traditional animal products with plant-based alternatives. To further investigate this issue, studies on consumers' perceptions of plant-based substitutes should include more direct experience with such products as well as consider different contexts and purchasing situations (Elzerman et al., 2021; Sogari et al., 2022). To become successful among consumers and avoid market failure, a consumer-oriented approach to product development is required – for instance, by co-designing products with consumers, or by integrating both sensory and consumer sciences. As a matter of fact, an increasing body of literature on sensory studies stresses the importance of employing untrained panels to evaluate product characterization and provide actionable insights on product development and marketing of novel foods (S. Grasso et al., 2022; Smetana et al., 2021). This collaboration with consumers (i.e., product co-creation) could provide actionable directions not only to optimize sensory

attributes during product development but also to improve overall consumer acceptance in terms of situational and cultural appropriateness (Barone et al., 2021; Sogari et al., 2022).

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## 1.2 Study 2

# Plant-Based Meat Alternatives: Technological, Nutritional, Environmental, Market, and Social Challenges and Opportunities

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**Abstract**

There is a growing awareness that fostering the transition toward plant-based diets with reduced meat consumption levels is essential to alleviating the detrimental impacts of the food system on the planet and to improving human health and animal welfare. The reduction in average meat intake may be reached via many possible ways, one possibility being the increased consumption of plant-based meat alternatives (PBMAs). For this reason, in recent years, hundreds of products have been launched on the market with sensory attributes (i.e., taste, texture, appearance, and smell) similar to their animal counterparts; however, these products have often a long list of ingredients and their nutritional values are very different from animal meat. The present review aims to highlight the main opportunities and challenges related to the production and consumption of PBMAs through an interdisciplinary approach. Aspects related to the production technology, nutritional profiles, potential impacts on health and the environment, and the current market and consumer acceptance of PBMAs are discussed. Focusing on the growing literature on this topic, this review will also highlight research gaps related to PBMAs that should be considered in the future, possibly through the collaboration of different stakeholders that can support the transition toward sustainable plant-based diets.

**Keywords**: alternative proteins; consumer acceptance; flexitarianism; meat analogs; sustainability; SGDs

### 1.2.1 Introduction

It is broadly agreed that transitioning away from meat-intensive diets towards increasingly plant-based diets is essential to alleviating the adverse environmental sustainability impact of the food system and to improving human health and animal welfare. However, our collective meat consumption is still increasing and is projected to keep on rising in the coming decade (OECD et al., 2022). To curb the projected global rise in meat consumption, it is argued that a substantial reduction in average meat consumption levels – starting in affluent societies – is critically important.

Meat reduction can be established in various ways: (i) reducing meat portion size, (ii) replacing part of meat-based products with plant-based alternatives (so-called hybrid meats) or applying a "less but better" principle (less quantity, more quality, i.e., more environmentally and/or animal-friendly meat), (iii) leaving the meat out from the dish without a replacement, (iv) replacing meat by another protein source (ranging from animal-based foods, such as eggs or cheese, to plant-derived alternatives, such as legumes, mushrooms or tofu – not to mention alternative sources of protein with a minimal, i.e., insects and seaweed, or still non-existent market share, i.e., cultured meat), and last but not least, (v) consuming plant-based meat alternatives (PBMAs) (Dagevos, 2016; M. Verain et al., 2015). These strategies imply that a flexitarian diet should not be narrowed down to the adoption of (processed) meat substitutes because it is also about substituting meat with other (unprocessed) alternative proteins both animal- and plant-sourced. Having said this, the broad and varied dietary group of flexitarians is undeniably the key target group of PBMAs and the major group already consuming these products. From the perspective of a flexitarian diet characterized by abstaining from meat (whether this is occasionally, frequently, or often) it is obvious that flexitarians are searching for and interested in meat alternatives to practice their reduced meat foodstyle. Briefly put, there is logic in pointing to flexitarians as launching customers. From the perspective of PBMAs, the dominant market strategy hitherto is to mimic traditional meat as closely as possible in terms of flavors (meaty/savory), texture (mouthfeel), appearance (e.g., 'the bleeding burger'), nutritional value

(iron, vitamins, etc.), and even product names (using meat-related terms) – by the way, "PBMAs" may also be read as "plant-based meat analogs". The food industry's goal to develop meat-like plant-based foods unquestionably facilitates the meat-free choice of many flexitarians and vegetarians and vegans as well, who may feel aversion to the associations with meat surrounding PBMAs.

While food consumers' adoption and acceptance of PBMAs is not self-evident, as will be shown in the remainder, it seems safe to say that PBMAs facilitate the need of many of today's food consumers in various high-income countries to be supplied with tasty, affordable, and accessible alternative protein products to meet their cravings to eat beyond meat.

Currently, many factors can testify that the field of PBMAs is vibrant and worth to be further explored and critically assessed. Among these factors the remarkable success of efforts to improve the product qualities of PBMAs in the past few decades and the wide availability PBMAs on supermarket shelves and in the food service sector (including McDonald's, Burger King, and KFC having released plant-based alternative versions of beef burgers and chicken nuggets). Furthermore, the substantial investments in the PBMA market, the significant growth figures it is experiencing in frontrunning countries (like Germany, the UK, or the Netherlands), and its expected growth rates in global sales in the near future are additional elements that can attest the key role of PBMAs.

This review aims at highlighting the main challenges and opportunities, related to the production and consumption of PBMA products, taking into consideration all the pivotal aspects of designing new food products. Indeed, after a brief excursus on the formulation and production technology of PBMAs (i), the review addresses their nutrition profile and their potential impact on health (ii) and the environment (iii), as well as consumers' choices (iv) and the state of the market (v). Each of the five sections will provide a sketch of the state of affairs and overall this article aims to add to other recent reviews (Giacalone et al., 2022a; Nezlek & Forestell, 2022) by critically assessing recent studies from different disciplines, in order to highlight consensus and controversies on this topic with an interdisciplinary perspective.

### 1.2.2 Production Technology of Plant-Based Meat Alternative

Among the earliest examples of meat alternatives, vegetable protein products are traditionally produced and consumed in Asian countries – i.e., tofu and tempeh from soy and seitan from gluten. Unfortunately, these products are not able to meet the sensory attributes of meat products for Western consumers, who seek vegetable-based products that resemble meat in structure, flavor, and taste. The 21st-century meat substitutes/alternatives take up the cross-linking capacity - under certain conditions - of soy proteins from the Asian tradition. Indeed, even today, soy is the main raw material for the production of meat substitutes/alternatives (Zhang et al., 2021). This supremacy undoubtedly depends on the availability of the raw material and the techno-functional attributes of its proteins, including its solubility, its ability to absorb water and oil, and its gelling and emulsifying properties - all important aspects in defining the quality of the finished product (Nishinari et al., 2014). However, scientific research (and the market) is shifting towards the use of raw materials other than soy for issues concerning GMOs, allergies, unfavorable climate for soy cultivation, as well as the preservation and/or valorization of biodiversity. Thus, recent work explored the use of proteins from different raw materials including peas, fava beans, rapeseeds, and hemp, alone or in combination with soybean (Grossmann & Weiss, 2021). Regardless of the botanical source, protein isolates – with protein content above 75% (usually close to 90%) – are the most used raw materials (Schutyser et al., 2015).

Protein isolates are produced by wet separation techniques that are often time-consuming, costly, inefficient, and unsustainable, given also the high amount of water, alkalis, acids, or enzymes employed (Schutyser et al., 2015). Finally, since the functionality of proteins can widely vary depending on the process conditions adopted during protein isolation, the standardization of the technological properties of the isolates is challenging (Grossmann & Weiss, 2021). Thus, protein isolates are increasingly being replaced by protein concentrates (protein content between approx. 50 and 65%), without neglecting the structural properties required in the finished product (Zahari et al.,

2022). These high protein fractions are produced from dry separation processes. The latter type of process is considered more sustainable than wet techniques as it requires no water or solvent, less energy, and preserves the protein's native structure, instead of forming protein aggregates, thus, retaining their technological functionality (Grossmann & Weiss, 2021). The principle behind the air classification is the different density of the flour particles, which are richer in starch or proteins. This allows the separation of the flour into a fine protein-rich fraction and a coarse starch-rich fraction as a consequence of the centrifugal and gravitational forces applied during the operation. Therefore, the less-refined protein ingredients obtained by the air classification also contain other components, such as lipids and fibers, which are often included in the formulation of protein isolate-based products (Schutyser et al., 2015). Since the lipid and fiber content in protein concentrates may vary based on the source and processing conditions, the set-up of the air-classification conditions needs to be optimized. So far, there are few examples - albeit with encouraging results - of the application of high-protein fractions obtained by air separation from legumes in the production of meat substitutes (De Angelis et al., 2020), suggesting the need for further studies also using different sources.

In order to expand the range of raw materials suitable to be used in the production of meat substitutes and that can maintain high-quality characteristics of the finished product, various colorants (e.g., leghemoglobin, red beets, red cabbage, etc) and flavorings (e.g., herbs and spices) have been proposed to reproduce the meat color and flavor profile, as well as to mask the beany off-flavors of some legume proteins. The juiciness, tenderness, and other sensory attributes of meat-like products are also obtained by using fats/oils (such as coconut oil/butter, sunflower oil, canola oil, sesame oil, etc). However, it is increasingly common to use binding agents (e.g., oleogels, starches, hydrocolloids, fibers) as fat replacers (Zahari et al., 2022). Indeed, high amounts of fat - acting as a lubricant - could interfere with the protein denaturation process, which is the first kind of modification proteins need to undergo in order to obtain a meat-like structure.

The meat-like structure is achieved when the native globular structure of pulse proteins is transformed into a fibrous structure in which proteins are elongated and highly ordered (Grossmann & Weiss,

2021). This structure can be created by different technologies (including extrusion, flow-induced structuring using a Shear cell or a Couette cell, 3D printing, wet-spinning, and electrospinning), the advantages and disadvantages of which were recently summarized by Boukid (2021).

High productivity, low costs, versatility, energy efficiency, and scale-up potentials have extruded the most widely used technology used to produce meat substitutes. During the process, raw materials are hydrated, subject to thermal and mechanical stress applied during extrusion, and, finally, the product is cooled to room temperature (Wittek et al., 2021). As a result of the mechanical stress, the temperature, the pressure, and the final cooling, proteins undergo a series of structural modifications ranging from denaturation to unfolding, crosslinking, and alignment, resulting in a fibrous structure that mimics the characteristics of muscle tissues (Sha & Xiong, 2020). These modifications take place in a chamber containing one (i.e., single screw extruder) or – more commonly – two (i.e., twin screw extruder) co-rotating screws that convey the material towards a die that provides the final shape to the product. The extrusion chamber is subdivided into several zones in which the peculiar profile of the screws – and, thus, the applied shear – and the temperatures cause the material to undergo (from the material inlet to the finished product outlet) mixing, hydration, shearing, homogenization, compression, deaeration, heating, shaping, and expansion. During these operations, proteins are hydrated, unfolded, aligned, and texturized.

Extrusion can be performed at a low moisture level (<30%) to obtain texturized vegetable proteins (TVPs) or at a high moisture level (>50%) to directly obtain meat analogs. When extrusion is carried out at low moisture, the sudden drop in pressure at the end of the extruder causes an immediate expansion of the product, due to the rapid evaporation of water. TVPs have a spongy meat-like structure that mimics ground beef or chicken breast. TVPs can take different forms (flakes, chunks, or minced), and, after hydration (and final cooking), they are able to retain their structural integrity and the chewy texture and elasticity, which is typical of that of meat.

In the case of high moisture extrusion, a cooling die is connected at the end of the twin-screw extruder to cool down the sample at 20 °C, which prevents the expansion and promotion of the fibers'

alignment and stabilization, and is typical of the anisotropic structure desirable for this kind of products.

Although the use of technologies other than extrusion has shown encouraging results (including high-temperature inducing shearing and 3D printing), some hurdles still need to be addressed before their widespread industrial deployment: cost reduction, and/or applicability to a wide range of legume proteins.

### 1.2.3 Nutrition Profile & Health Impact of Plant-Based Meat Alternatives

Among the several reasons related to the growing demand for meat alternatives, a potential explanation is likely related to the increased knowledge about the negative impact on human health of diets high in red meats and, above all, processed meat (Afshin et al., 2019). This, together with an increased concern for the environmental impact of animal products compared to their plant-based counterparts, supports the transition towards sustainable healthy diets, which are based on a high intake of plant-based foods and moderate consumption of animal products (FAO and WHO, 2019).

However, to investigate the potential role of PBMAs on human health, it is critical to analyze the nutritional characteristics of these products, also considering that meat is an essential source of high-quality proteins, iron, vitamins, minerals, and a certain amount of saturated fats depending on the type of meat (Pereira & Vicente, 2013). A few studies analyzed the nutritional quality of meat alternatives present in different markets and compared meat alternatives and animal meat in terms of energy and nutrient content (Bryngelsson et al., 2022; Cole et al., 2022; Cutroneo, Angelino, Tedeschi, Pellegrini, Martini, et al., 2022).

In this regard, a recent study analyzed the nutritional quality of 269 commercial meat analogs currently sold on the Italian market by retrieving data reported on their food labels (Cutroneo, Angelino, Tedeschi, Pellegrini, Martini, et al., 2022). A large nutritional variability was observed among PBMAs, with plant-based steaks showing significantly higher protein, lower energy, fats, and

salt contents compared to other plant-based food categories. Comparing the nutritional information with reference animal meat products, results showed a higher fiber content in all PBMAs. Moreover, plant-based burgers and meatballs had a lower protein content than their meat counterparts, while ready-sliced meat substitutes showed a lower salt content than cured meats.

Similar results were obtained in other studies performed in the US (Cole et al., 2022), Sweden (Bryngelsson et al., 2022), and other European markets (Boukid, 2021). These studies found lower energy, total and saturated fat contents and higher total carbohydrates, sugars, and fibers in PBMAs compared to meat-based products. On the other hand, salt content showed contrasting results. Furthermore, plant-based and meat-based products generally presented a similar amount of total proteins despite large differences in the content of single amino acids. As a matter of fact, higher amounts of glutamic acid and cysteine, and a lower content of alanine, glycine, and, above all, methionine were identified in PBMAs (M. De Marchi et al., 2021).

These results support the importance of further exploring the use of plant-based protein blends to reduce differences between plant-based and animal-based meats (Gorissen et al., 2018). In addition, it is noteworthy that plant-based and animal products also differ in protein digestibility and the bioavailability of single amino acids. Indeed, animal meat showed a higher protein digestibility than PBMAs, which, in turn, have a negative impact on amino acid bioavailability. These data suggest the possibility to use specific protein sources with high bioavailability (e.g., soy isolate), and stress the importance of considering the real bioavailability of amino acids when investigating the diet quality of dietary patterns that include these products.

Another interesting aspect to be considered regards micronutrients. Data are often limited on this topic, but previous studies highlighted how PBMAs are a good source of minerals, also reporting a higher iron content compared to meat (M. De Marchi et al., 2021; Pointke & Pawelzik, 2022). However, it is important to underline that the absorption and bioavailability of iron from plant-based sources and vegetarian diets are lower compared to omnivorous diets, and this shall be considered in future investigations (Hunt, 2003).

Altogether, these results highlight the importance of carefully evaluating the nutritional impact of switching from animal meat to PBMAs in order to identify potential at-risk nutrients. With this intention, a recent study compared the omnivore diet with diets in which animal products were substituted with either traditional or novel plant-based foods by using NHANES 2017–2018 data. The risk of inadequacies for specific nutrients (e.g., vitamin B12) was highlighted, especially when novel PBMAs were used (Tso & Forde, 2021). These results support once again the need to consider the nutritional quality of PBMAs when switching to plant-based diets that exclude the consumption of animal foods.

Another area that deserves further investigation is the evaluation of the impact of replacing animal meat on human health through well-designed human intervention studies. So far, different studies compared the effects of vegetarian/vegan diets over omnivorous diets (Oussalah et al., 2020), however, trials specifically focused on PBMAs are still lacking. Yet, due to the publication of study protocols on clinical trial registries (e.g., ClinicalTrials.gov), it is reasonable to expect the implementation and publication of trials evaluating the impact of PBMAs on nutritional and health aspects in the near future. A first attempt was recently performed by Crimarco and colleagues (Crimarco et al., 2022) who assessed the effects of plant-based meats on biomarkers of inflammation through a secondary analysis of the Study With Appetizing Plant food – Meat Eating Alternatives Trial (SWAP-MEAT). Contrary to expectations, no improvements in biomarkers of inflammation following plant-based meat consumption were identified. However, further long-term studies focused on a large plethora of health markers are necessary before drawing any conclusion.

### 1.2.4 Environmental Impact of Plant-Based Meat Alternatives

Meat is a protein food with a high biological value; however, the conversion of feed and fodder into animal protein may not be sustainable due to inputs and the use of limited natural resources (Kumar et al., 2022). Currently, several farming systems of meat production exist, with the production

efficiency per unit of a product depending mainly on feeding, breeds, management, and technology employed (Rotz et al., 2010; Steinfeld, Gerber, Wassenaar, Castel, Rosales, & De Haan, 2006). Fewer resources per product unit are required for crops growing, which leads these products to represent an interesting opportunity for sustainable development while meeting the increasing demand for food (OECD and FAO, 2020). Thus, in developed countries not relying on subsistence animal breeding, PBMAs could bring environmental benefits in terms of biodiversity, land and water use, and reduced greenhouse gas emissions (GHG) (Aiking, 2011a; Tukker et al., 2011).

Nonetheless, the environmental impact of PBMAs still needs to be assessed. In this regard, the life cycle assessment (LCA) approach has been applied. It is a methodology used in various contexts to quantify the environmental impacts of a product based on the ISO 14040 (ISO, 2006a) and ISO 14044 (ISO, 2006b) standards to improve its environmental performance (Froldi et al., 2022).

Several LCA studies were conducted on PBMAs to detect hotspots in the production process and to compare environmental performances with animal-based products. Indicators such as climate change, land, water, and energy use were considered.

In this regard, Bryant (C. J. Bryant, 2022) analyzed 43 studies and concluded that the production of meat analogs is more sustainable when compared to animal products. At the same time, Detzel et al. (Detzel et al., 2022) stated that PBMAs could help reduce the environmental impact related to food consumption by overcoming the complexity of the processing stage of ingredients – which has a significant environmental impact – and by optimizing the inputs required to produce protein ingredients (i. e., legumes, trying to stabilize their yields, the main problem for their cultivation (Pulvento et al., 2015). Nevertheless, Smetana et al., (2015) reported that the technology employed (i.e., machinery and process equipment) might be a valuable opportunity to improve the sustainability of alternative protein source production. A detailed LCA study by Mejia et al. (Mejia et al., 2020) on three factories producing 57 different types of meat analogs achieved low GHG emissions, mainly due to the manufacturing process, followed by the agricultural production of food ingredients and their transportation. According to Goldstein et al. (Goldstein et al., 2017), the production stage

accounts for 80% of the environmental impact, due to the use of electricity from fossil sources; however, alternative energy solutions could mitigate this impact.

In-depth studies are needed since contrasting data are ascribed to energy consumption derived from the use of proxy processes for the implemented energy sources (C. J. Bryant, 2022). Within the meat supply chain, meat production and animal husbandry are the most impactful stages (Godfray et al., 2018). Nevertheless, manure production, subsequently applied to the soil, spares the need for chemical fertilizer, contributes to crop yield, and maintains soil fertility. On the other hand, legumes do not require nitrogen fertilization due to their ability to fix nitrogen from the atmosphere and at the root level (Stagnari et al., 2017). This leads to fewer $N_2O$ and $NH_3$ emissions due to the non-use of manure and/or synthetic fertilizers.

Several studies considered the impact of meat and meat analogs on the water used and the effects on eutrophication and acidification. In a study comparing patties with or without meat, Smetana et al. (2021) estimated lower acidification and subsequent aquatic eutrophication for PBMAs. Similar conclusions were obtained by Heller et al. (Heller & Keoleian, 2018), who showed a lower water use for plant-based patties. However, guidelines for water modeling are needed to avoid misleading interpretations based on erroneous comparisons.

Lusk et al. (Lusk et al., 2022) produced a model to study both the economic and environmental effects of the use of alternative plant products over meat in the US. Reforestation of cropland and pastureland, as well as the conversion of land for crops grown for livestock feeding to crops for plant-based products, would result in the sequestration of 0.43 megatons of $CO_2$ per year. The results imply an increase in crop yields to compensate for the reduction in available cropland. At the European level, Saget et al. (Saget et al., 2020) found a reduction in human-animal competition for land use for pea protein production and an 89% lower global warming potential. More in detail, in Germany a 5% substitution of beef with pea proteins could lead to a 1% reduction in annual $CO_2$ emissions. However, it is important to assert that agricultural activities impact 9.9% of global greenhouse gas emissions (Bager et al., 2021). There could be scenarios of increased arable land to fulfill the growth of

alternative meat products, even when deforestation is limited through environmental policies. The extensification of palm plantations in humid tropical countries could be an example, with an increased demand for coconut oil as an ingredient in plant-based beef substitutes (Goldstein et al., 2017).

It can be concluded that still few LCA studies quantified the environmental impact of meat substitutes, and many limitations related to the application of the methodology need to be addressed. Relevant considerations are: i) PBMAs are highly processed foods, thus, impacts associated with the use of different forms of energy counteract the low environmental impact associated with the production of plant-based ingredients (Mejia et al., 2020); ii) the building of databases for the productive process of complex (multi-ingredient) foods should be a relevant point to focus on; iii) a functional unit that does not consider the mass of a product but integrates primary nutrients should be implemented, along with a feature required when comparing LCA results from different studies/products (McLaren et al., 2021; Saget et al., 2020); iv) sustainability of PBMAs production must take into consideration good agricultural practices, such as crop rotation, fertilizer, plant protection, and water use (Detzel et al., 2022).

### 1.2.5 Consumer Behavior of Plant-Based Meat Alternatives

In the realm of meat alternatives, despite technological innovations and efforts to design processed plant-based products from different sources, one of the main challenges to successfully replacing animal products with plant-based ingredients is to recreate similar meat sensory properties. Moreover, communication about these new products and individual attributes (e.g., attitude and demographics) should be taken into consideration during the marketing stage – especially in those countries where meat and meat-based products have a key role in consumers' minds, in terms of habits, culinary tradition, and culture (Giacalone et al., 2022a; Sogari et al., 2021). Therefore, both sensory and consumer science can play an important role in understanding how consumers perceive PBMAs, including drivers and barriers to their acceptance.

First, past studies showed that the perceived sensory attributes and consumer acceptance are strongly influenced by the choice of plant/protein sources (Caputo et al., 2022a; Fiorentini et al., 2020). Therefore, what ingredients to use as a replacement for meat is an important factor to consider in the development of meat alternatives (Tucker, 2014). Early product developments mimicking processed meat products, for example, those from mycoproteins (Quorn®), have a low sensory acceptance in terms of taste and texture (Elzerman et al., 2011). This results in a low willingness to include such products as a real meat substitute for meat eaters (Hashempour-Baltork et al., 2020). As mentioned above, until a few years ago, the first generation of these products was mostly designed for vegetarians and vegans (Elzerman et al., 2011; He et al., 2020a; Van Loo et al., 2020). To meet acceptability from a wider audience of meat eaters, the new generation of PBMAs shall be developed in a way that texture, appearance, aroma, and taste resemble the equivalent of authentic meat products, before, during, and after cooking (Giacalone et al., 2022a; He et al., 2020). Yet, reproducing the complex and delicate sensory profile of farmed meat can be challenging (Neville et al., 2017a; Sha & Xiong, 2020). For instance, the color of plant-based products may diminish due to light or oxygen exposure, or the taste could be affected by lipid oxidation and cause undesirable characteristics (Fiorentini et al., 2020). Considering that the appearance of a product is generally the first element to be assessed, it is a critical determinant in food acceptance. Another challenge of these PBMAs is to recall the flavor of real meat while avoiding unpleasant flavors (e.g., bitterness, burnt, and earthy) caused by the high level of legume protein (Giacalone et al., 2022). Therefore, the need of mimicking meat characteristics requires the use of many additives in the development stage (Giacalone et al., 2022). As a result, the product packaging of PBMAs often includes a long list of unfamiliar ingredients (Cutroneo, Angelino, Tedeschi, Pellegrini, Martini, et al., 2022), which could convey a sense of processed and unhealthy food among consumers. Especially PBMAs that are high/ultra-processed could be associated with a certain unnaturalness of the product (Hartmann et al., 2022). Thus, while reducing the gap between the sensory profiles of PBMAs and their meat equivalent might be important for some companies, the concept of product acceptance goes beyond merely sensory

appreciation, including consumers' perception. For example, low product familiarity with PBMAs – including also the preparation/cooking method – is one of the most important product-related factors associated with consumer acceptance. This could potentially limit the expansion to the mainstream consumer market. Therefore, fully understanding consumers' acceptance of PBMAs should require individuals to have a direct experience (Nezlek & Forestell, 2022).

The most investigated meat category in consumer studies, including sensory tests, is burgers (Caparros Megido et al., 2016a; Caputo et al., 2022a; S. Grasso et al., 2022). The reason is that traditional burgers are one of the most popular meat formats due to their composition (e.g., rich in proteins and fats), market availability, convenience, affordability, and sensory qualities (Boukid & Castellari, 2021; Patinho et al., 2021). Results consistently indicate that respondents generally prefer traditional meat products over their plant-based alternatives. For example, S. Grasso et al. (2022) showed that individuals had higher sensory expectations for a beef burger than a plant-based or hybrid patty, however, in terms of acceptability and purchase intent, the hybrid one (60% beef and 40% vegetables) was the most preferred after the tasting.

In general, also product familiarity is often associated with higher acceptance. For instance, another study by Caputo et al. (2022) which included a choice experiment with a blind-informed sensory study, showed that the beef burger, which had the highest degree of familiarity, also received the largest willingness to pay (WTP) compared to two PBMAs and one hybrid burger. They also found that, in the informed group, the preference and WTP for the plant-based patty labeled as "made with animal-like protein" exceeded the hybrid burger (70% beef and 30% mushrooms) and the plant-based burger "made with pea protein". As reported by several studies, low prices of non-meat protein sources may act as a driver to accept such products (Eckl et al., 2021); however, it will probably take some years to reach price parity with traditional meat (Nezlek & Forestell, 2022).

Regarding demographics, habits, and attitudinal factors, being pro-health, pro-sustainability, and young leads to higher acceptability toward PBMAs compared to other consumer segments (Giacalone et al., 2022). For these reasons, health and environmental sustainability benefits could be included

among the main drivers to try such products (Eckl et al., 2021). For instance, in a study by [51](Sogari et al., 2021) motivations to process both sustainability and nutrition information were a strong determinant to drive the likelihood to purchase a hybrid meat-mushroom burger among US students. Other impacting factors could be the attitude toward meat analogs (Banovic & Sveinsdóttir, 2021) and, more in general, consumer attitude toward food innovation (Sogari et al., 2021). On the other hand, the main personal-related barriers to acceptability are related to food and food technology neophobia (Giacalone et al., 2022a; Nezlek & Forestell, 2022), attachment to meat, and lower situational appropriateness of consuming non-meat protein sources (Eckl et al., 2021).

Several studies showed that heavy meat eaters might be less willing to substitute meat products for plant-based alternatives than flexitarians (Dagevos, 2021a; Michel, Hartmann, et al., 2021). However, other studies suggested that the more consumers are already familiar with plant-based products, the least individuals seek such products to be similar to meat from a sensory point of view (Giacalone et al., 2022). This could be explained by the fact that vegetarians and vegans are not seeking meat sensory properties in plant-based products (Kerslake et al., 2022).

Finally, more knowledge about consumer acceptance of PBMAs is also helpful for legislators. For instance, in the EU, policymakers support the production and promotion of alternative meat substitutes and hybrid products by funding research programs towards more sustainable and alternative proteins, such as the Farm to Fork Strategy in the European Union (European Union, 2020). Thus, understanding how consumers perceive such products is challenging for the food system, and developing meat alternatives with high consumer appeal requires full integration of sensory and consumer research.

### 1.2.6 Market Analysis of Plant-Based Meat Alternatives

Given that the latest market trends of plant-based meat alternatives have not been deeply investigated, we conducted market research to identify the current direction of these products. Retailers and

industries could benefit from the data retrieved from this analysis to design new products (in terms of ingredients, claims, labeling, etc.) to better shape their market strategies.

To analyze market trends of PBMAs, we used Mintel's Global New Product Database (GNPD) (Solis, 2016) an online database for new products launched in selected countries. The same database was previously used in other research. For instance, several authors employed Mintel's GNPD to investigate front-of-package information, food labeling schemes, ingredient profiles, and new launches of alternative meat products in the global market (Boukid, Sogari, et al., 2022; Boukid & Castellari, 2021; Lawrence et al., 2018; Petersen et al., 2021).

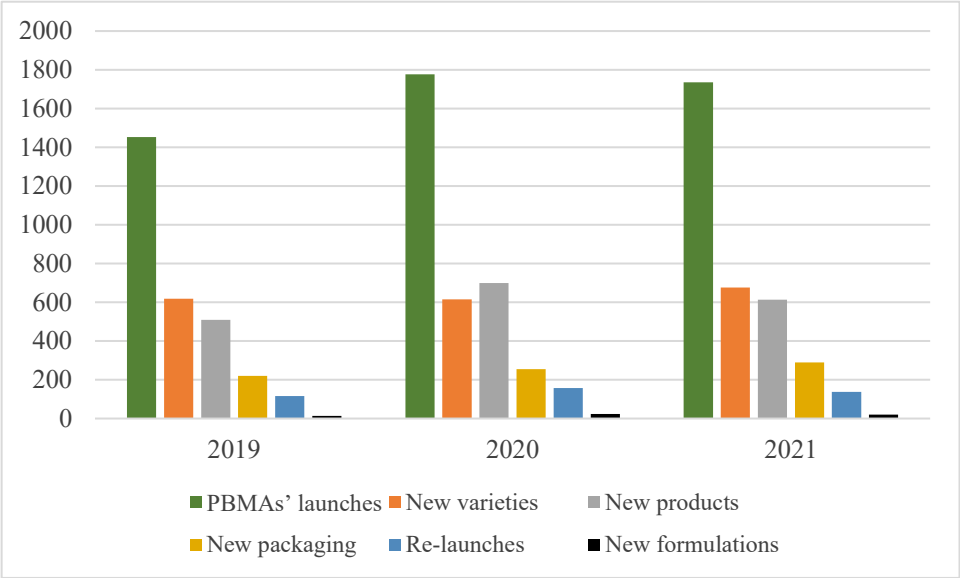
The objective of our analysis was to use the Mintel database to extract and explore different information on the latest market trends of PBMAs. In order to have an overview of recent years, we searched for new meat alternative launches over the past three years (from January 2019 to December 2021). The dataset was extracted on October 26$^{th}$, 2022, and the search strategy is described in the Appendix (Table A1).

The research returned 5,155 results in the form of a spreadsheet where each column reported different information, such as ingredients, claims, and nutritional values per 100g. After cleaning the dataset to remove non-meat alternatives (e.g., fish or egg alternatives) using keywords (e.g., seafood, salmon, tuna, egg) in the "Product" and "Description" columns, the final dataframe was analyzed using descriptive statistics.

During the past three years (2019-2021), the market of PBMAs has seen a remarkable spike in product launches with 4,965 products released worldwide. More in detail, Figure 1 shows a solid growth of PBMAs at the beginning of 2020 – when the COVID-19 pandemic broke out – and a slight drop at the end of 2021. This change could be explained by common short-term reductions in meat intake during zoonotic outbreaks – the same happened for the SARS-CoV in 2003 and the African Swine Flu in 2019 (Attwood & Hajat, 2020). Thus, this meat intake reduction could have led consumers to look for new alternatives at the beginning of the coronavirus outbreak. Nevertheless, despite the modest negative trend during the third and fourth quarters of 2021, the overall direction of PBMAs'

launches is positively growing, and this new dietary pattern could represent an opportunity to foster these products. More precisely, this positive market trend is mostly focused on the introduction of new products (n = 1,822; 36.7%) and new varieties (n = 1,910; 38.5%) of PBMAs. The remaining launches (n = 1232; 24.8%) include new packaging, re-launches, and new formulations.

**Figure 1**. Number of PBMAs' launches (n= 4,965 – green bar), new varieties (n= 1,910 – orange bar), new products (n= 1,822 – grey bar), new packaging (n= 1,822 – yellow bar), re-launches (n= 386 – blue bar), and new formulations (n= 58 – black bar) launched worldwide over the past three years (2019-2021).



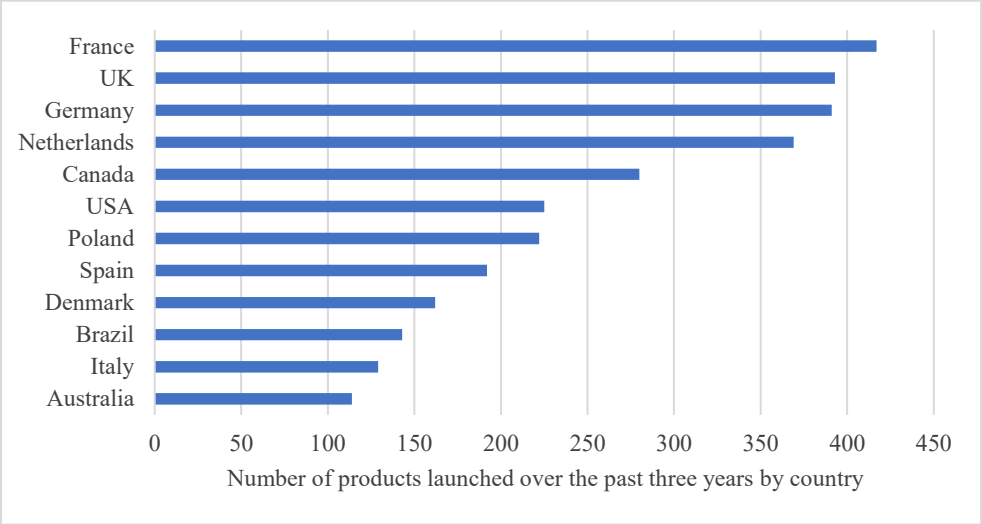

Abbreviations: PBMAs, plant-based meat alternatives. Source: own elaboration.

It is also important to highlight that, despite the market for PBMAs' products experiencing increasing growth, the global market revenue of plant-based meat substitutes is forecast to be worth 33.99 billion U.S. dollars in 2027 (Global: Meat Substitutes Market Revenue 2016-2027 | Statista, 2022), while the meat sector is expected to value at 1354 billion U.S. dollars by 2027 (Global Meat Industry Value Projection, 2021-2027 | Statista, 2022). Thus, the market share of PBMAs is, and is estimated to remain, significantly lower than the meat market.

Considering the 2019-2021 period, new PBMA products were mostly launched in France, with 417 new launches (8.4%), followed by the UK (n = 393; 7.9%) and Germany (n = 391; 7.9%). The top twelve most active markets in this sector are represented in Figure 2. This figure underlines how European and northern American countries, along with Brazil and Australia, have been more active

in launching plant-based meat alternatives during the past years, showing an increasing interest in meat substitutes in these countries.

**Figure 2**. Twelve most active countries in PBMAs' launches over the past three years (2019-2021)

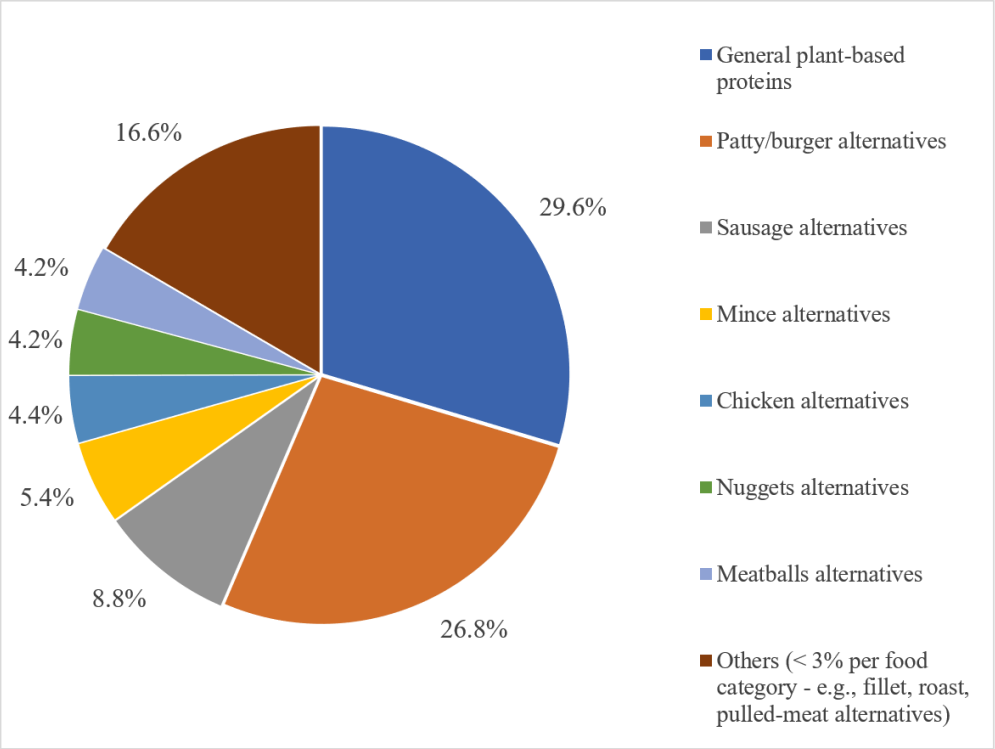



Note: Each bar represents the total number of PBMAs' launches between January 2019 and December 2021. Abbreviations: PBMAs, plant-based meat alternatives. Source: own elaboration.

In the global market, the most represented food categories were general plant-based proteins (n = 1,469; 29.6%) – meaning foods that do not intend to mimic an existing meat product (e.g., burgers, sausages, nuggets, meatballs) but can still be considered meat substitutes as they are protein-rich plant foods (e.g., "teriyaki tofu" and "fried gluten with peanuts") – and patty/burger alternatives (n = 1,331; 26.8%). Every other food category alone – such as sausage, mince, or nugget alternatives – does not represent more than 9% of the total launches, as illustrated in Figure 3.

In terms of highest sales value in € and growth rate, according to a recent study of the Smart Protein project (The Smart Protein project, 2022) using Retail Scanning Data Nielsen, the UK and Germany lead the sector of PBMAs, i.e., sausages, burger patties, and cold cuts. However, differences in the categories exist between countries; for example, plant-based sausages lead the market segment in UK whereas in Germany the top category is plant-based refrigerated meat (burger patties, nuggets, minced, etc.), followed by plant-based cold cuts and meat spreads and plant-based sausages.

**Figure 3**. Food category distribution of the PBMAs launched over the past three years (2019-2021).




Abbreviations: PBMAs, plant-based meat alternatives. Source: own elaboration.

Regarding the ingredients, we used the data from Mintel to identify which foods are most used as first ingredient. When *water* was reported to be the first element in the list (n = 1605; 32.3%), we considered the second one. Using this strategy, we identified 1,914 products (38.6%) containing *soy-based components* – e.g., soybean curd, proteins, or flour – as first ingredient. After *soy*, *wheat* (n = 520; 10.5%) and other *pulses* (n = 702; 14.1%), such as kidney beans, black beans, peas, chickpeas, and lentils, were predominantly used as first ingredient, followed by *mushrooms* (n = 134; 2.7%) and *jackfruit* (n = 86; 1.7%).

In terms of information provided on the packaging, a total of 120 different claims were identified. Out of 4,965 products, 2,849 (57%) included the "Vegan/No Animal Ingredients" claim and 2,099 (42%) reported the "Plant Based" claim. In addition, in line with Cutroneo et al. (Cutroneo, Angelino, Tedeschi, Pellegrini, Martini, et al., 2022), the most common nutrition claim was the "High/Added Protein" statement (n= 1,616; 33%). A graphic presentation of the claims is represented in Figure 4.

**Figure 4**. Word Cloud of the top 20 claims employed in PBMA products launched over the past three years (2019-2021). Abbreviations: PBMA, plant-based meat alternative.


Note: A word cloud is a visual representation of word frequency and value. The "Social Media" claim indicates the presence on the packaging of a logo/claim to entice consumers to join the company's social media community and follow its channel/website. Source: own elaboration.

Finally, Mintel's Global New Product Database has been a practical tool to obtain a global overview of PBMAs' market trends. The data retrieved and analyzed from the database showed how plant-based meat alternatives can widely differ in terms of food category, ingredients, and/or claims. However, despite these several variations, the increasing trend in product launches– especially from Western countries – highlights a promising global trend to support the transition toward a plant-based diet. However, as previously highlighted in this section, market share differences between the meat and the PBMA sector are still notable and meat revenue forecasts do not foresee any declining trend. These data underline that the growing market of meat substitutes does not significantly affect the meat market. Therefore, PBMAs are still weak substitutes for animal-based products as they are rather complementary to meat than meat replacers (Neuhofer & Lusk, 2022). Previous studies also showed that regular meat consumers are less likely to choose plant-based items over beef than people declaring to follow different diets (e.g., vegan, flexitarian, vegetarian) (Tonsor et al., 2022). Thus, in order to support a dietary shift toward meat reduction, it is critical to study and test strategies that could steer meat eaters' choices toward plant-based diets and support the growing market of PBMAs.

### 1.2.7 Discussion and Conclusions

Plant-based foods that replace animal foods, such as meat, but also dairy, and even fish and eggs, are gaining increased attention as possible substitutes that can facilitate the transition towards sustainable healthy diets. The idea of processing plant-based ingredients to obtain protein-based foods is not a new concept for consumers since many products, such as tempeh, tofu, and seitan, have been available on the market for hundreds of years (Nezlek & Forestell, 2022), especially in Asian countries. However, these products were not intended to be meat substitutes per se and have never become mainstream in Western countries. A possible explanation could be that these products have mostly been targeted at vegetarians or vegans without any explicit reference to their animal counterparts. Nevertheless, the development of the so-called “meat alternatives” sector is gaining more and more attention due to the growing concerns over the environmental impact of the food system (Giacalone et al., 2022), and the increasing awareness of the detrimental impact of high meat consumption on human health (Grosso et al., 2022).

In the last years, hundreds of meat-like substitutes, such as plant-based burgers, are developed and launched globally on the market to imitate the traditional beef burger using either 100% plant-based ingredients or a mix of both meat and plant-based ingredients, i.e., “hybrid meat products”. Although this latter category is not suitable for vegetarians and vegans, these hybrid meat alternatives could exploit consumer barriers of PBMAs (e.g., low sensory quality) and lead to the first approach to reduce meat consumption.

The growing demand for PBMAs has driven the development of ground-breaking process technologies and novel ingredients which can help to obtain products with meat-like sensory attributes that have the potential to attract non-vegetarian consumers (Fiorentini et al., 2020). However, many of these new meat alternatives are highly complex products in terms of ingredients/formulation and require technological investments (van der Weele et al., 2019). For instance, one limitation of using plant proteins as meat substitutes is the challenge of preserving the

shape while dealing with the high risk of crumbling (Hashempour-Baltork et al., 2020). For this reason, as of now, most of these proteins have been employed either as a meat ingredient substitute (e.g., in the shape of mince) or as part of food products (e.g., pizza, sauces, etc.), and have not been consumed on their own (Elzerman et al., 2011). Currently, a new line of familiar alternatives to traditional meat products or dishes, such as imitation-meat burgers, has been launched in supermarkets and restaurants (Onwezen et al., 2021).

While targeting young flexitarians and omnivores is seen as the key to ensuring growing sales of plant-meat alternatives in the future (Lemken et al., 2019; Mintel, 2020), there is still the need to investigate whether and how the sensory appeal will be a barrier for the second generation of plant-based meat alternatives among these consumers (Giacalone et al., 2022).

To achieve acceptability among non-vegetarian consumers, plant-based food should resemble the texture, flavor, appearance, aroma, and taste of authentic meat products. However, the long list of unfamiliar ingredients used to mimic meat sensory properties leads to different nutrition values of these products compared to animal meats. As a result, even if PBMAs are similar to meat in terms of sensory experience, they cannot be considered a nutritional replacement for animal products (Nezlek & Forestell, 2022). Thus, further studies are needed not only to monitor the nutritional quality of new plant-based meat products on the market but also to investigate the impact of this substitution on human health markers. In addition, adequate nutritional education programs to improve consumers' knowledge and awareness about the differences between animal- and plant-based products are required (Cutroneo, Angelino, Tedeschi, Pellegrini, Martini, et al., 2022).

Moreover, the discussion on whether manufacturers should communicate PBMA products using references to the animal counterparts (e.g., ‘tastes like meat’), which could create positive expectations for meat consumers (Giacalone et al., 2022a; S. Grasso et al., 2022), is still under debate. Specifically, after the recent commercial success of several PBMAs, a strong debate has started on how to label/name such products. For example, in the EU, a regulation clarifying whether “meat-sounding” labels for PBMAs should be allowed does not exist yet. This outcome will probably impact

consumer preferences as shown in a recent study by[83] (Demartini et al., 2022) in which consumers' perception of tastiness and healthiness and their willingness to buy plant-based meatballs were negatively affected by the vegan labeling.

As we reported, the sector of PBMAs is launching on the market products that mimic animal counterparts, and the term 'meat substitutes' seems to imply that people will stop eating meat (Nezlek & Forestell, 2022); however, it is more likely that individuals will consume both traditional and non-traditional meat alternatives. In this scenario, PBMAs may be a useful tool to reduce animal products, especially for populations that consume too much animal meat according to dietary recommendations. We might also expect PBMAs to be regarded as an intermediate phase on our way to (semi-)plant-based diets, in which unprocessed plant-based foods and recipes would take a center stage. Achieving this kind of diet would mean that our food habits have really gone beyond meat.

Finally, future studies should consider calls for collaboration, particularly among stakeholders of the food supply chain (i.e., industries and food services) and the scientific community (i.e., nutritionists and dietitians, food technologists, and consumers scientists), to facilitate the transition toward healthier and more sustainable plant-based protein sources.

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**Conflicts of Interest:** "The authors declare no conflict of interest."

## Appendix A

**Table A1**. Search criteria considered on Mintel database.

| Search Variable | Criteria |
|---|---|
| Category | "Food" |
| Sub-category | "Meat Substitutes" (with "Format Type" matching one or more of the following: ball; block/cubed; burger; sausage; fillet; shredded/minced; sliced; other) |
| Date Published | within the "last three complete years" (January 2019 – December 2021) |
| Region/Market | "Across all regions/markets" |

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## 1.3 Study 3

# Evaluating the Influence of the Nutri-Score and Eco-Score Labeling: A Systematic Review on the Effects on Consumers' Behavior

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## Abstract

The increasing socio-political interest in front-of-pack (FOP) nutrition and sustainable labels is leading to a larger body of consumer studies on the topic. The present study aims at assessing and examining the current literature on a highly discussed graded and color-coded label format at the European level: the Nutri-Score (NS) and its environmental counterpart, the Eco-Score (ES). Specifically, our systematic review investigates consumers' responses to the NS and ES in terms of consumers' perception, understanding, and purchasing behaviors. Results from the retrieved articles (n= 72) show promising results for the NS in terms of objective understanding and purchasing behaviors. More heterogeneity was identified for subjective understanding. Regarding the ES and the dual-labeling system (i.e., when both the NS and ES are displayed on the front of the food package), the restricted number of studies limits the conclusions and implications that could be drawn. Furthermore, limitations and suggestions for future research are proposed, as well as policy implications. Finally, given the current socio-politic context and debates on this FOP label format, our analysis will contribute to the discussion of the decision process to adopt a mandatory FOP nutrition label to support public health.

**Keywords**: front-of-pack labels; consumer understanding; food choices; health; sustainability.

### 1.3.1 Introduction

Unhealthy diets and lack of physical activity are among the major global risks related to death and can lead to chronic non-communicable diseases (e.g., heart diseases, cancer, and diabetes). Thus, healthy diets could prevent illnesses, promote health, and prolong life among the population (FAO and WHO, 2019).

Diversifying and modifying our eating habits can be an effective strategy to address not only health issues but also to help provide sufficient, nutritious, safe, affordable, and sustainable food to a rapidly growing global population. As a matter of fact, population growth is raising the environmental pressure on the planet's limited resources and increasing greenhouse gas emissions from the agriculture sector (OECD-FAO, 2022).

The FAO guidance for sustainable healthy diets stresses the importance of wholegrains, an abundance of fruits and vegetables, small amounts of red meat and processed food, and, specifically in high-income countries, a reduction in calories, fats, and sugars. Following these guidelines, an environmentally friendly diet could potentially reduce the pressure on both global health and the environment (FAO and WHO, 2019).

Research evaluating the environmental impact of food systems showed potential positive effects of consumers' choices and consumption patterns on sustainability (FAO and WHO, 2019). Therefore, switching towards healthier and more sustainable dietary patterns is a shared responsibility where all actors – including consumers – play a crucial role (FAO and WHO, 2019). Considering the complexity of the food system, consumers should be able to access clear, comparable, and verifiable information in a timely way in order to make informed purchases. One strategy to support consumers in their decisions is the implementation of front-of-pack (FOP) labeling, which could potentially provide them with readily and relevant information while promoting reformulations of food products (De Temmerman et al., 2021; Schruff-Lim et al., 2023). Several countries have implemented and promoted strategies to support consumers through mandatory or voluntary FOP systems (USDA, 2020; WHO, 2019) A number of different nutrition FOP labels (Table 1),

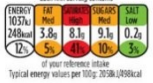
categorized based on their aggregation (nutrient-specific *vs.* summary systems) and interpretation (reductive/descriptive *vs.* interpretative/evaluative) level, are currently adopted and used in different countries (European Commission, 2020b; WHO, 2019). In this context, both national and international authorities have emphasized consumers' need for consistent and credible information on the front of food packing and the need to harmonize the labeling system to encompass both health and environmental aspects (WHO, 2019). Thus, in order to make the FOP labeling framework work, it is crucial to support label awareness, which could be facilitated by labeling systems that are widely used and adopted (WHO, 2019). In this context, the WHO recommended: "adopt, or develop as necessary, a mandatory interpretive FOP labelling system based on the best available evidence to identify the healthfulness of foods and beverages" (WHO, 2017, p. 12).

As a result, several nutrition and sustainable FOP labels have been developed and studies evaluating their effectiveness (e.g., by asking consumers to assess the nutritional quality of food products in the presence/absence of a FOP label) have increased during the last decades (An et al., 2021; De Marchi et al., 2023). In addition, systematic reviews and meta-analyses have obtained comprehensive evidence on the effectiveness of this strategy in steering consumer behavior (An et al., 2021; Bastounis et al., 2021; Kleef & Dagevos, 2015; Schruff-Lim et al., 2023; Song et al., 2021). Overall, results showed that ecolabels lead to higher willingness-to-pay premiums compared to their absence of food products. However, results vary across different types of sustainable labels and the implementation of policies shaping sustainable food systems is also necessary (Bastounis et al., 2021; Tiboni-Oschilewski et al., 2024). When it comes to nutrition FOP labels, An et al., (2021) conducted a systematic review of the effect of FOP nutrition labels on food purchases which showed mixed results. Another recent systematic review was conducted in 2023 by Schruff-Lim et al., (2023) on FOP nutrition labels plus complementary interventions. Also their findings stressed the need for more research to "give cause to act on nutrition labels". As suggested by Song et al., (2021), this results heterogeneity could be explained by the high variety in label formats which could lead to different psychological mechanisms. Several graphic formats, regulatory approaches (voluntary *vs.*

mandatory), and algorithms exist, which may have a different impact on consumers' behavior (Vandevijvere et al., 2020). In particular, the Nutri-Score (NS) has been one of the most investigated labels due to its wide adoption in several EU countries, which has led to a societal and political debate among several governments regarding its possible mandatory implementation (Stiletto et al., 2024). A more recent FOP label – the Eco-Score (ES) – with a similar graphic representation (color- and letter-coded) of the NS, has been recently introduced on the market to convey messages about the environmental impact of food products (Colruyt Group, 2024).

In this systematic review, we aim at investigating consumers' responses to a specific FOP format – i.e., a color- and letter-coded – which ranges from a dark green A (better nutritional value/lower environmental impact) to a red E (worse nutritional value/higher environmental impact). Therefore, the present work focuses on NS and ES FOP label design and synthesizes the available literature assessing its effect on consumer behavior. A systematic review was conducted to identify studies that tested the impact of these two labels – when used on their own or in combination – on consumers' understanding, purchasing behavior, and attitude. Policymakers could use results from this work to define their decisions on policy measures to encourage people toward healthier and sustainable food choices.

**Table 1.** FOP nutrition labeling schemes implemented/proposed/announced at the European Union (EU) level.

| *Taxonomies put forward in the literature* | | | | *Examples of FOP schemes* | | *Developer* | *EU Member State* |
|---|---|---|---|---|---|---|---|
| **Nutrient-specific labels** | **Numerical** | Non-directive | Reductive (non-interpretative) | *Reference Intakes label* |  | *Private* | *Across the EU* |
| | | | | *NutrInform Battery* |  | *Public* | *IT* |
| | **Colour-coded** | Semi-directive | Evaluative (interpretative) | *UK "traffic light" label* |  | *Public* | *UK* |
| | | | | *Other 'traffic light' labels* |  | *Private (retailers)* | *PT, ES* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Summary labels** | **Positive (endor-sement) logos** | Directive | Evaluative (interpretative) | *Keyhole* |  | *Public* | *SE, DK, LT* |
| | | | | *Heart/Health logos* |  | *NGO*<br>*Public* | *FI SI*<br>*HR* |
| | | | | *Healthy Choice* |  | *Private* | *CZ, PL*<br>*Phased out in NL* |
| | **Graded indicators** | | | *Nutri-Score* |  | *Public* | *FR, BE*<br>*ES, DE, NL, LU* |

Source: (European Commission, 2020b)
Note: BE= Belgium; CZ= Czechia; DE= Germany; DK= Denmark; FI= Finland; FR= France; ES= Spain; HR= Croatia; IT= Italy; LT= Lithuania; LU= Luxembourg; NL= Netherland; PL= Polonia; PT= Portugal; SE= Sweden; SI= Slovenia; UK= United Kingdom.

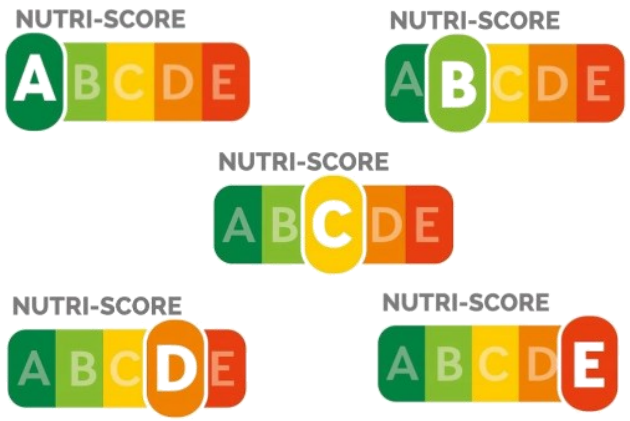
### *1.3.1.1 Nutri-Score*

Over the last decades, several nutrition FOP labels have been developed and tested worldwide (Mazzu et al., 2021; Vandevijvere et al., 2020). Given the increasing interest in this tool, countries – among which the European Union member states – are evaluating the endorsement of a mandatory FOP nutrition labeling scheme as a key source of information to allow informed choices (European Commission, 2020b). Among the proposals, the NS is a FOP nutrition label developed by an independent French research group – the Nutritional Epidemiology Research Team (EREN) – in 2014 (Santé Publique France, 2024). The NS displays a food product's overall nutritional quality using a 5-letter (A to E), 5-color (dark green to red) format. An image of the NS is reported in (Figure 5). Following the NS design, a food product displaying an A (dark green) letter identifies the healthiest choice, whereas an "E" (red) NS indicates the less healthy option. The computation of the nutritional score is given by an algorithm based on the nutrient profiling system of the British Food Standards Agency (Julia et al., 2017) and considers 100g of product. The NS was officially adopted in France in 2017 and its original algorithm was reviewed in 2023 to be implemented in 2024 (Santé Publique France, 2024). Although it has been adopted as the official FOP label by several European countries on a voluntary basis (e.g., Belgium, Germany, Luxembourg, Spain, the Netherlands, and Switzerland)

(De Marchi et al., 2023), other EU countries would like to prevent its adoption as the mandatory FOP nutrition label (Fialon, Salas-Salvadó, et al., 2021). Among the countries that challenge the adoption of the NS, Italian stakeholders argue that this label might be incompatible with some traditional products, which cannot be reformulated since they are part of the national heritage, as they receive "low scores" from this labeling system (Fialon, Nabec, et al., 2022; Stiletto et al., 2023). Nonetheless, previous research showed that the NS algorithm is generally in agreement with national dietary guidelines and its 2023 updated algorithm is strongly in agreement with the WHO Europe nutrient profile (Hafner & Pravst, 2024).

Given the current socio-politic context and debates on this FOP label, the present study assesses and examines the current literature by considering the comparison of the NS with other nutrition FOP labels, in terms of consumers' perception and understanding. The final objective is to contribute to the decision-making process to define the adoption of a mandatory nutrition FOP label.

**Figure 5.** The Nutri-Score.




*1.3.1.2 Eco-Score*

Given the increasing consumers' interest in knowing the environmental impact of their diets, a growing number of sustainable standards and labeling schemes have been developed and adopted all over the globe (Sonntag et al., 2023; Tiboni-Oschilewski et al., 2024). In this context, the Ecolabel

Index (https://www.ecolabelindex.com/ecolabels/) listed over 450 public and private environment labels across the world. However, a systematic and universally accepted approach to scientifically measure and communicate the environmental impact of activities related to food production is still missing (De Bauw et al., 2021).

In this context, one recently developed sustainable FOP label is the ES. This label was developed in France in 2021 to reduce information overload and facilitate informed choices (Jürkenbeck, 2023). The ES has a similar layout to the NS (an image is reported in Figure 6) as it is a 5-color, 5-letter label. In this case, dark green – which is associated with an "A" letter – represents a low environmental impact, while a red ES – associated with an "E" letter – indicates a high environmental impact. The algorithm behind its computation is based on the Life Cycle Assessment (LCA) from the Agribalyse database (Colruyt Group, 2024). The algorithm also considers bonuses and penalties to refine the final score of the product to take into the ingredients' origin, the presence of certifications, the packaging, and other aspects (De Bauw et al., 2021; Jürkenbeck et al., 2024). This label has recently been adopted by selected stores in France and Germany (Jürkenbeck et al., 2024).

Despite the ES being more recently developed than the NS – and, thus, the currently available literature on its effect is still limited – the present study includes the investigation of its potential impact on consumers' perceptions and choices, as well as its effect when both the ES and NS are displayed simultaneously on the same product.

**Figure 6.** The Eco-Score.


### 1.3.2 Materials and Methods

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021), we conducted a systematic review of which protocol was registered on the OpenSourceFramework – OSF (reference: https://osf.io/3vyts/).

#### *1.3.2.1 Search strategy*

In May 2023, a systematic search of the literature was conducted using two separate electronic databases: Scopus and Web of Science. The search strategy was structured to combine 3 dimensions: 1) the label dimension: the type of label under investigation (either the NS or the ES), 2) the "consumer" dimension, and 3) the decision-making dimension: terms to select the topics of interest (e.g., perception, understanding, choice). A representation of the terms used for each dimension is reported in Table 2. The final keyword search was set as follows: ("eco-score" OR ecoscore OR "nutri-score" OR nutriscore OR color-coded OR colour-coded) AND consumer* AND (perception* OR attitude* OR behavio* AND accept* OR preference* OR choice* OR decision* OR purchas*

OR willing* OR pay OR buy OR consum* OR trust OR understand*). In addition, papers were restricted to English-written and original published articles only.

**Table 2.** Dimensions considered in the search strategy.

| Label dimension | Consumer dimension | Decision-making dimension |
|---|---|---|
| *Eco-score* | *Consumer** | *Perception** |
| *Ecoscore* | | *Attitude** |
| *Ecolabel* | | *Behavio** |
| *Nutri-score* | | *Accept** |
| *Nutriscore* | | *Preference** |
| | | *Choice** |
| | | *Decision** |
| | | *Purchas** |
| | | *Willing** |
| | | *Pay* |
| | | *Buy* |
| | | *Consum** |
| | | *Trust* |
| | | *Understand** |

*1.3.2.2 Selection of studies and inclusion criteria*

Retrieved papers (n=289) were assessed using a 4-step strategy. First, duplicates were identified and removed using Covidence (www.covidence.org), an electronic platform defined as one of the most accurate for identifying duplicate references (McKeown & Mir, 2021). Successively, a title and abstract screening was used to determine the articles' eligibility. Each article had to be evaluated by two independent researchers and discrepancies were solved by a third evaluation. The inclusion criteria for this stage were: i) the presence of either the NS or ES and ii) the presence of the consumer dimension. Papers meeting the inclusion criteria were recorded for the full-text evaluation and data extraction. A total of 83 papers were included in the full-text evaluation and data extraction phase.

*1.3.2.3 Data extraction*

Four independent researchers conducted a full-text screening and data extraction to collect information on each study included in the review. The specific exclusion criteria used in the full-text screening were defined as follows:

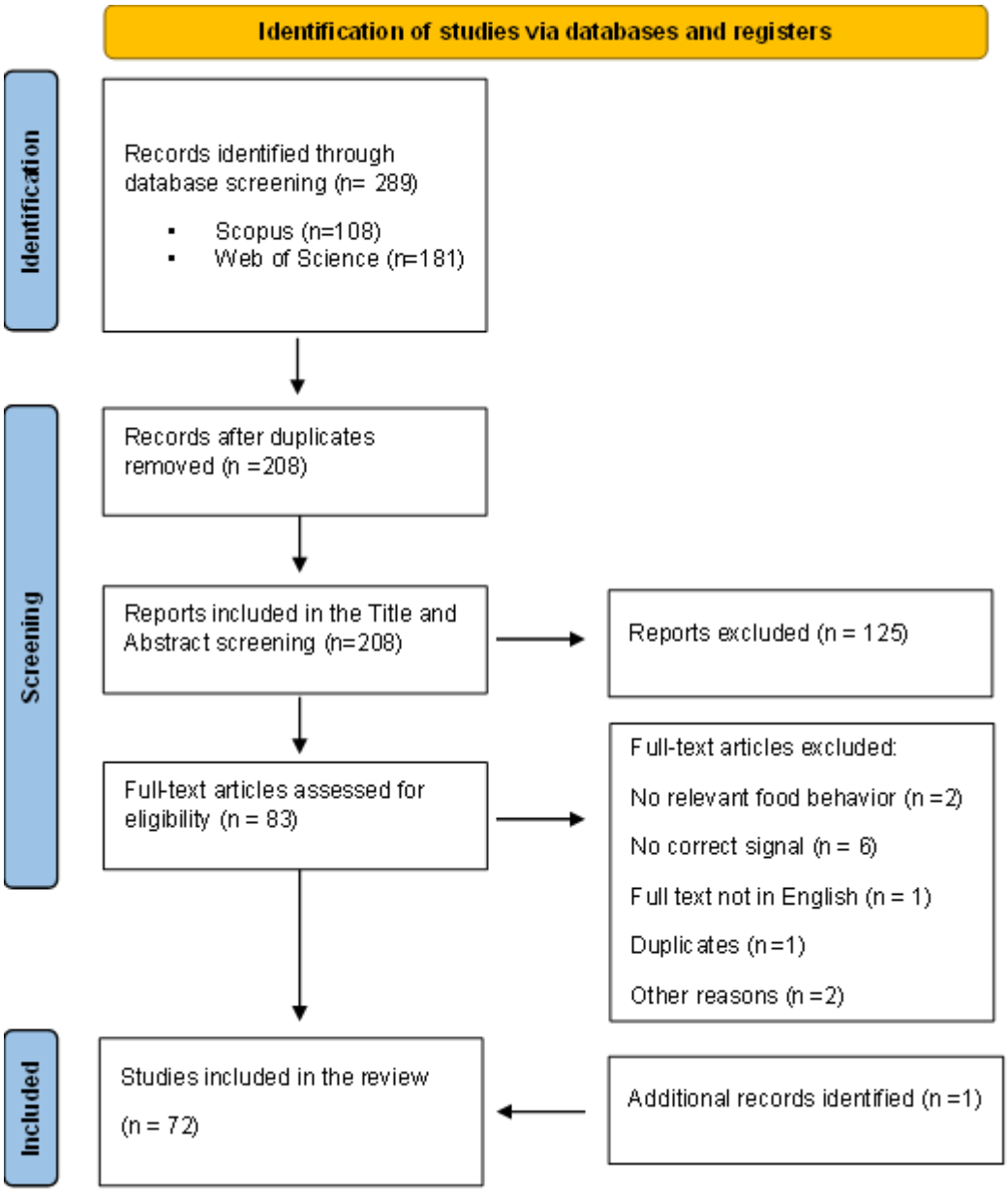
- No NS or ES as a signal: studies that did not include (at least) one of the two labels were excluded.
- No relevant food behavior: studies that did not focus on consumer behavior (e.g., food technology) or were not in line with the objectives (e.g., weight loss outcome, pills, dietary supplement, etc.) were excluded.
- Full paper not found: when the full paper was not retrieved, authors were contacted. If no article was received, the study was excluded.
- No research article: research articles only were included – e.g., reviews were excluded.
- Full text not in English: if the article was not available in English, it was excluded.
- Not consumers as the main actor: if other stakeholders (e.g., producers, health professionals) were the main actors of the study, this was excluded.

Out of the 83 remaining papers, 71 were included in the data extraction phase to retrieve methodological and outcome variables. In addition, a forward and backward reference search (i.e., a search of the references cited in the articles) was conducted based on the remaining 71 manuscripts, and one new article was identified that met the study selection criteria and, thus, was included in the data extraction. A table with the summary information (i.e., authors, publication year, sample size, country, food category, label under investigation) of the 72 included papers is reported in the Supplementary Material (Table A1).

To provide a comprehensive representation of the findings, articles were divided and analyzed based on the final outcome under investigation: consumer objective or subjective understanding, purchasing behaviors, consumer attention, and public support.

The study selection flow chart including all steps is reported in Figure 7.

**Figure 7.** Flow diagram of literature searching and screening phases.




*1.3.2.4 Quality assesment*

Each investigator independently assessed the study quality based on eight criteria, defined considering previous literature (An et al., 2021; Schruff-Lim et al., 2023):

1. Was (were) the research question* or study objective* clearly stated?
2. Were data provided on the sample sufficient to ensure reproducibility? (i.e., sufficient demographic data and details of the study participants.)
3. Was the sample representative of the target population?

4. Was Ethical Committee approval obtained OR was informed consent obtained from participants of the study?
5. Was sufficient detail given about the design/method? (e.g., the survey or the variables are provided in the manuscript, the information provided is sufficient to allow the study replication, pictures of the products are available etc.)
6. Was the study conducted in real settings? (e.g., real choice, actual behavior)
7. Was the information collected with sufficient detail and depth to provide insight into the meaning and perceptions of informants?
8. Was the conclusion justified given the conduct of the study?

For each criterion, each study received a score of 0 (indicating a "no" answer to the question) or 1 (indicating a "yes" answer). A final score (ranging from 0 to 8) was computed for each article by summing up individual scores.

### 1.3.3 Results

#### *1.3.3.1 Study characteristics*

Of the 72 eligible articles, the majority (92%, n=66) investigated the effects of FOP nutrition labels. Only 1 paper focused on the eco-label, and 5 explored the effects of both the NS and ES, with four of these five studies focusing on their combination, whereas one research investigated the impact of the two labels separately.

Descriptive statistics show that data were collected between 2015 and 2021, with studies including the ES starting in 2018 – presumably because it was developed after the NS.

The majority of the studies focused on European populations (81%, n=58). Two studies were conducted in Africa, two in Asia, two in South America, and one in Oceania. The rest of the articles (n=7) included studies across continents. Of the 76 articles, the six including the ES in their investigation were all conducted in European countries and used general consumers as the sample,

apart from one study that focused on young adults' behaviors. For papers investigating the NS only, out of 66 articles, 50 focused on general consumers. The remaining studies on nutrition labeling focused either on adolescents or young adults (n=7), fragile consumers (n=4), or parents (n=2). Finally, the remaining three articles considered store/supermarket purchases.

When considering studies exploring the effects of FOP labels on specific food categories, the most investigated ones were cereals and derivates – especially breakfast cereals, followed by pizza, cakes, and cookies. Additionally, yogurt was the second most investigated food category. Fewer studies focused on meat and only few papers considered fish products, legumes, oil, or beverages.

For the study quality assessment, the average global rating score was 5.6, with a range from 2 to 7 and a median value of 6. All included studies scored 1 in the first criterion, thus, all of them clearly stated the research question and/or study objective. Furthermore, more than 80% of the studies included an Ethical Committee approval or obtained informed consent from participants. However, the quality assessment highlights some limitations of the included articles. Specifically, around 80% of the studies did not use representative samples and the sample characteristics were not sufficient to ensure reproducibility in almost 25% of the papers. Moreover, nearly 10% of the analyzed articles did not provide sufficient evidence to run the conclusions. Ultimately, comparison across studies showed that most of the evaluated articles included online surveys/shopping tasks (86%) instead of in-person experiments. In addition, most of the studies were conducted in hypothetical scenarios and only 5 studies considered real purchases.

*1.3.3.2 Nutri-Score*

*1.3.3.2.1 Consumer understanding*

Objective understanding involves accurate interpretation of the nutritional quality of foods by using FOP labels. The goal is to define whether consumers correctly understand the meaning that the label aims to communicate. On the contrary, subjective understanding is the interpretation of consumers

based on the perceived information present on the label (i.e., whether consumers think the label is believable and understandable) (Andreeva et al., 2020; Baccelloni et al., 2021; Mazzu et al., 2021).

*Objective understanding*

In most of the studies, the objective understanding of the nutritional quality of food products is investigated as the ability of consumers to correctly rank products based on their nutritional value when displaying the target FOP label (Egnell et al., 2019). Most of these studies show images of label-free food packages (i.e., without any FOP label displayed on the front-of-pack) to participants and ask them to rank products based on nutritional quality (e.g., high, medium, low). The same task is repeated with the food packages displaying the FOP label. An example of this exercise is reported in Figure 8.

Overall, studies showed that the addition of FOP labels on product packaging improves participants' ability to correctly classify foods based on their nutritional value (Egnell, Ducrot, et al., 2018; Hutton & Gresse, 2022; Kontopoulou et al., 2022; Packer et al., 2022). In addition, most of the studies found that the presence of the NS, in particular, is associated with greater improvement in the objective understanding of the nutritional quality of the products compared to the absence of the FOP label or other labels – e.g., the Guideline Daily Amounts (GDA), Health Star Rating (HSR), Multiple Traffic Light (MTL), NutrInform (NI), Reference Intake (RI), and Warning Label (WL).

**Figure 8.** Example of a task used to explore consumers' objective understanding of nutrition FOP labels.


Source: (Andreeva et al., 2020)

For instance, Packer et al., (2022), in a study with British consumers, found that participants were more likely to correctly rank the healthiest product when a product was displayed along with an FOP label than compared to the control group (without FOP labels). Specifically, they showed that the NS performed better in ranking the healthiest product among all the six food categories (pizza, instant hot chocolate, cake, crisps, yogurt, and breakfast cereals), followed by the MTL and the WL; no significant differences were identified across food categories. Interestingly, the authors found that participants ranked the products significantly faster when using the NS rather than the MTL. In another study, the same authors found that the NS, followed by the MTL, resulted in a considerable improvement in participants' accuracy in classifying healthy products. Their results also highlighted differences across food categories; yogurt and breakfast cereals, for instance, had the highest increment in correctly ranking the healthiness of the product when the FOP label was present (Packer et al., 2021). Also Vandevijvere et al., (2020) observed that the greatest increase in the percentage of correct ranking was linked to the NS when compared to other FOP labels (HSR, MTL, GDA, and WL). Similarly, Hagmann and Siegrist (2020) found that, when considering salty snacks in a Swiss sample, the NS led to the most accurate evaluations regarding the identification of the healthiest product. Interestingly, the authors found that the NS becomes less effective when a different tool is used to classify products (i.e., the Health Canada Surveillance Tool system). In a study conducted in South Africa (Hutton and Gresse, 2022), researchers found that the RI was the only FOP label that did not considerably increase respondents' ability to correctly rank products based on their nutritional value. On the other hand, the NS led to the most accurate answers, followed by the HEL (Health Endorsement Logo), MTL, and WL. In a similar study with Greek consumers, all FOP labels (NS, MTL, GDA, warning label, HSR) helped consumers in the ranking tasks compared to the control (no-label) condition, with the NS showing the greatest improvement rate for the three food categories under investigation (pizza, cake, and breakfast cereals) (Kontopoulou et al., 2022). In Spain, Fialon et al., (2023) provided evidence to support the NS over the NI. Specifically, participants were asked to indicate the healthiest item across three food categories, namely added fats, breakfast cereals, and

breakfast products. In this study, conducted with a representative of over 1000 Spanish consumers, the NS showed a significantly stronger ability to support consumers in the identification task when compared with the NI.

Some differences across food categories were identified in a few studies (Andreeva et al., 2022; Fialon, Serafini, et al., 2022). Fialon, Serafini, et al., (2022), for instance, tested the effect of the NS compared to the NI label for several food categories, namely added fats, breakfast cereals, and breakfast products, on a sample of Italian participants. In terms of subjective understanding, the NS was considered more helpful than the NI for determining the nutritional quality of breakfast cereals; the authors found no significant differences for the remaining two food categories. On the other hand, in terms of objective understanding (i.e., selecting the product with the most favorable nutritional quality), the NS showed the strongest effect across all categories. Finally, their results also showed that the NS was easier to understand and less confusing – i.e., easier to use – than the NI. Other authors also tested the effects of several FOP labels, namely the NS, WL, MTL, RI, and HSR, on the objective understanding of consumers from different countries – both European and non-European ones (Argentina, Australia, Belgium, Bulgaria, Canada, Denmark, France, Germany, Italy, Mexico, Netherlands, Poland, Portugal, Singapore, Spain, Switzerland, the UK, and the USA) – for three food categories: pizza, cake, and breakfast cereals. Across all three categories and with similar trends in each country, the NS was the most effective label in improving participants' ability to correctly determine the healthiest product option. The NS also performed as the best label in the identification of the unhealthiest products. The label showing the weakest performance was the RI (Andreeva et al., 2020, 2022; Egnell et al., 2019; Egnell, Galan, et al., 2020; Egnell M. et al., 2019; Egnell, Talati, et al., 2018, 2020; Goiana-Da-silva et al., 2021; Pettigrew, Jongenelis, Jones, et al., 2023; Pettigrew, Jongenelis, Talati, et al., 2023; Talati et al., 2019a, 2019b; Vandevijvere & Berger, 2021).

In a slightly different study conducted by Bossuyt et al., (2021), the NS was compared to the mandatory Nutrition Facts Panel (NFP) to investigate the impact on healthfulness estimation accuracy. Results showed a positive effect of the NS; specifically, its impact was larger on difficult-to-judge

foods (e.g., mocha ice cream), whereas the effect of the NFP was significant only for products with a direct and simple NFP. Instead, Ares et al. (2018) tested the effects of three interpretive schemes – NS, WL, and HRS – on consumer healthfulness perception and found that interpretive FOP nutrition labels were able to change the perception of products that have intermediate perceived healthfulness. Thus, in their study, these schemes did not modify consumer perception of foods identified as healthy (e.g., beans) or unhealthy (e.g., potato chips). In another study, Santos et al. (2020) assessed the effect of four FOP nutrition labeling schemes – the GDA, HSR, MTL, and NS – on Portuguese consumers using a web-based questionnaire. The authors found that the most popular FOP nutrition labeling system among Portuguese adults was the TL label. When considering the effectiveness of FOP labels in helping consumers select the healthiest choices, all FOP nutrition labels outperformed the no-label condition, with no major differences across labels.

Contrary to the above-described findings, which show the distinct and positive effect of the NS label on consumers' objective understanding, two studies (Hoge et al., 2022; Mora-Plazas et al., 2022) suggested that the NS performed worse than other FOP labels. Specifically, Hoge et al. (2022) found, in their study with Belgian students, that the MTL label had the greatest increase in the correct ranking for breakfast cereals compared to the "no-label" condition. However, the NS had a positive impact in identifying the correct nutritional quality options for appetizers (crisps and peanuts), dairy products, and pizza. In particular, the authors showed that among the three FOP labels used in their study (NS, MTL, and RI), the NS achieved the highest performance with 15 times more likelihood of correctly ranking the products, followed by the MTL and RI respectively. In another study, a slightly different approach to investigating consumers' objective understanding was used by Mora-Plazas et al. (2022), who asked Colombian consumers to identify the less healthy products across several food categories. Results showed that WLs were more effective in helping participants when compared to the no-label, NS, and GDA.

To conclude, the majority of the studies confirmed the superiority of the NS over other FOP labels in ranking the healthiness of food products. This is true both for EU countries, such as Spain (Galan et

al., 2020), Poland (Andreeva et al., 2022), Portugal (Goiana-Da-silva et al., 2021), and France (Egnell, Ducrot, et al., 2018; Talati et al., 2019a), and extra-EU countries, such as Morocco (Aguenaou et al., 2021), South Africa (Hutton & Gresse, 2022), and Switzerland (Egnell, Galan, et al., 2020).

*Subjective understanding*

Along with consumer objective understanding, also subjective understanding and perception/liking of nutritional labels affect consumer evaluation and choices (Mazzu et al., 2021). Most of the studies retrieved in our research investigating subjective understanding included a series of questions about participants' perception toward FOP labels in terms of attractiveness (e.g., 'I like this label'), trust (e.g., 'I trust this label'), clarity (e.g., 'This label is confusing'), and easy to process information (e.g., 'This label provides quick information').

A positive perception is a critical requirement for the success of FOP labels (Julia et al., 2017). In a French study aimed to explore the perception of different FOP labels, the NS was considered quicker to process and easier to identify and understand than the SENS (a summary, graded and color-coded label, developed and promoted by retailers), the MTL, and the modified version of the RI (which was too complex to understand) (Julia et al., 2017). Interestingly, even if the study identified clustered preferences toward each of the different FOP formats, the NS was considered easy to identify and understand beyond the specific cluster. Moreover, the authors found that this label was positively perceived among subjects who did not strictly follow dietary guidelines. In a study conducted in Belgium, the NS was identified as the least confusing and the quickest-to-understand label by consumers (Vandevijvere et al., 2020).

Some studies also investigated the perception of specific letters of the label. For instance, when comparing the same product with different NS categories (e.g., A *vs.* B *vs.* C), De Temmerman et al. (2021) found that category C evoked lower product quality perceptions than category A or B. Also, the presence of an A or B category led consumers to perceive the products as healthier. On the other hand, the same authors did not find any effect of the NS on perceived tastiness. Jurkenbeck et al.,

(2022) investigated to what extent the NS, combined also with nutrition and taste-related claims, influences German consumers' healthiness perception of different products. For unhealthy products (i.e., instant cappuccino or chocolate muesli), both the "less sweet" and the "30% less sugar" claims led to a higher health evaluation of the products; however, the C and D NSs letters showed the ability to correct the health evaluation. With the product normally perceived as healthy (i.e., oat drink), the "without added sugar" nutrition claim did not impact consumers' health evaluation, whereas the A NS was able to improve its health assessment. In addition, in a pilot study conducted in Brazil, Italy, and the Netherlands, the authors found that, despite low NS scores (D or E) associated with ultra-processed foods (UPFs) being correctly identified as "processed" and "not healthy", high NS letters (A or B) had large variations in the healthiness evaluation. Therefore, when comparing UPFs and medium-processed foods with similar NSs, consumers considered UPFs as relatively less healthy, which suggests that consumers take into account the level of industrial processing when evaluating the healthiness of foods (Bolhuis et al., 2022). However, when considering the old NS algorithm (on which studies prior to 2023 were based), not all the letters could be assigned to some food categories, such as added fats (e.g., olive oil, butter, rapeseed oil, peanut oil, palm oil, and others). Thus, in the old NS classification, the letter C represented the best rank for a fat product (Fialon, Salas-Salvado, et al., 2021), which raised the question of whether this letter C could negatively impact oil perception and consumption (Julia et al., 2017; Visioli et al., 2021). Despite a 2021 study suggesting that the display of the NS on olive oil was widely understood by most respondents, who appeared to recognize that the C NS was the highest rank an added fat could have (Fialon, Salas-Salvado, et al., 2021). The more recent version of the NS algorithm took into consideration this aspect and revised the classification for this food category, with walnut, olive and rapeseed oils (rich in unsaturated fatty acids) now classified as B (Santé Publique France, 2024).

Despite these studies showing a positive subjective understanding of the NS, other studies found more heterogeneous outcomes. In a work comparing different FOP labels (i.e., NS, MTL, GDA, warning label, HSR), for instance, Greek consumer perception was favorable for all labeling schemes, with

the NS showing the highest rating; however, no significant differences were found across labels (Kontopoulou et al., 2022). Similarly, Egnell et al. (2019) showed that differences in labels' perceptions appeared very low in magnitude for Dutch consumers. A pilot study by Folkvord et al. (2021), also showed that the NS did not modify consumers' attitudes, taste perception, and purchase intention for snack bars, highlighting the complexity of consumption behaviors. In a between-group study in which participants were randomly assigned to one out of five conditions (i.e., the NFP, MTL, NS, NS on half of the products, and no nutrition LABEL/information condition), Hagmann and Siegrist (2020) found that participants perceived the NS as the least useful information. Nonetheless, participants who became familiar with the NS during the study evaluated the label's perceived usefulness significantly higher than the other respondents. Moreover, the participants exposed to the NS in the experiment exhibited significantly higher support in favor of the mandatory use of such a label, than the rest of the sample. Another study examined the impact of the NS on perceived healthfulness. Specifically, the research conducted by Hock et al., (2021) was a cross-country study (Australia, Canada, Chile, Mexico, the UK, and the US) and focused on sugar-sweetened beverages (SSBs) and young consumers (10-17 years old). Participants in the five conditions (HSR, WL, GDS, NS, and TL) perceived SSBs as significantly unhealthy when compared to the control (no-label) condition. The WL had the strongest impact on perceived healthfulness across all countries. For the NS, a higher probability of identifying the SSB as unhealthy was found in Australia and the UK.

In contrast, some studies showed that other nutrition FOP labels performed better than the NS in terms of subjective understanding (Baccelloni et al., 2021; Cui et al., 2022; Mazzu et al., 2021; Mazzù et al., 2021; Mazzu et al., 2022, 2023; Talati et al., 2019a). Specifically, in a study conducted in China with parents of primary and secondary school students, the authors found that participants perceived the MLT as the label that better and more quickly helped the selection of the healthiest food, followed by the WL, GDA, and Smart Choice (Cui et al. (2022). In other studies, conducted by Mazzù et al. (2021) and Baccelloni et al., (2021), the authors compared the subjective understanding and liking of the NS *vs.* the NI Battery among European consumers. Their results showed that, although

participants expressed a generally positive evaluation of both FOP labels, the NI Battery showed more positive results in terms of subjective understanding when compared with the NS, with some minor differences across countries (Baccelloni et al., 2021; Mazzù et al., 2021; Mazzu et al., 2021). In Sweden, a mix of the NI Battery and the Keyhole label was more effective than the NS and Keyhole label double-directive bundle in terms of comprehensibility, help to shop, complexity reduction, and overall liking. The authors suggested that adding complementary information could improve the performance of the provided information (Mazzu et al., 2023). In a similar study on Italian participants, the same authors found that attitude towards using the label, behavioral intention, perceived ease of use, usefulness, and trust towards the label were all significantly different between the NI and NS, favoring the NI (Mazzu et al., 2022). In another research investigating consumer perception of five FOP labels across 12 countries, Talati et al. (2019) found that participants were ambivalent about the NS, and the best-perceived label was the MTL.

Finally, when it comes to consumers' understanding of nutrition FOP labels, studies show that the NS often outperforms other labels for objective understanding; thus, consumers – also from different countries – usually correctly interpret this label. However, results are more heterogeneous for subjective understanding. Given that most research on the topic focuses on objective understanding, we suggest future research concentrates on subjective understanding to further explore how the NS is perceived by consumers.

*1.3.3.2.2 Consumers' food choices and purchasing behaviors*

Despite FOP nutrition labels being considered effective tools to encourage consumers to make healthy food choices, their effectiveness is context-dependent and can vary depending on the goal, cultural factors, individuals' health literacy level, socioeconomic status, and product category (Brownell & Koplan, 2011; Talati et al., 2019b).

Studies exploring the effects of the NS on food purchasing behaviors mostly compared results from different conditions (e.g., no label *vs.* FOP label) in hypothetical scenarios/situations. In these studies,

participants are usually asked to pick the product they would most likely buy/consume or to rate their purchasing intention. Among the analyzed articles, many studies focused on online shopping behaviors (Crosetto et al., 2020; Egnell, Boutron, et al., 2021; Egnell et al., 2022; Egnell, Galan, et al., 2021; Jansen et al., 2021; Kühne et al., 2022). Findings from these studies showed an overall positive performance of the NS. For instance, in a research activity focused on fragile population groups (i.e., students, low-income individuals, and consumers suffering from at least one nutrition-related cardiometabolic disease), participants were asked to simulate a shopping situation in an experimental online supermarket. Overall, individuals in the NS arm (rather than the RI or no-label condition) tended to purchase fewer food products in number, with a decrease in pre-packed products and food classified from 'C' to 'E' (Egnell, Boutron, et al., 2021; Egnell et al., 2022; Egnell, Galan, et al., 2021). In contrast, another study using a web-based shopping task showed that the NS led participants to select more products, although these were mostly healthy foods (Kühne et al., 2022). Another work conducted in a simulated online supermarket showed that the swap offer (i.e., the possibility to change the initial food choices with similar product alternatives) and the NS significantly improved the nutrient profile of consumers' choices compared to the control condition (Jansen et al., 2021). In another study, participants were asked to follow their usual shopping habits and shop for 2 days for their household using an e-shopping environment. Respondents had to shop twice, first by using a catalogue without any labels and then using a catalogue displaying the NS. Results showed that the nutritional quality of the second basket improved compared to the first basket (Crosetto et al., 2020).

Instead of investigating food purchasing behaviors in hypothetical online environments, other studies focused on the impact of FOP nutrition labels on dish serving sizes. For instance, in a study by Egnell, Kesse-Guyot, et al. (2018) French consumers were invited to complete a portion-size task, in which respondents were exposed to one out of 4 conditions (no label, the NS, MTL, or Evolved Nutrition Label – a modified version of the MTL). Each respondent was shown a total of 12 products (four products for three "less healthy" food categories: cheeses, sweet biscuits, and sweet spreads) and then

asked to select the serving size they would most likely consume. The results showed a significant interaction between labels and food categories, with the NS consistently lowering the portion size across all food categories compared to the no-label condition, followed by the MTL label. Similarly, in a lab-in-field experiment, van den Akker et al. (2022) investigated the effects of two labels (NS and MTL *vs.* no label condition) in fostering healthy choices among Dutch consumers through a choice task using breakfast cereals. Results showed that the NS promoted the healthiest choice and that neither of the two FOP labels altered the serving size selection of a product with a "good" FOP label. However, the authors highlighted that health-conscious shoppers were less impacted by the presence of the FOP labels as they were more likely to choose healthier products even without the FOP label. Different results were found by Abou Jaoudé et al., (2022), who carried out an online experiment including a menu composition task in which respondents had to compose the meal they would most likely consume if they were to eat at the university canteen. To do so, participants had to select both food items and quantities. Results showed that the NS had no effects on food choices, however, it altered consumers' meal composition strategies and induced changes when considering the final composed meals. Hence, the NS could create a complex relationship among the dishes in a meal.

To investigate consumers' food choices, other studies focused on individuals' purchase intentions for different food items or used a choice task. For instance, Ares et al. (2018) investigated Uruguayan consumers' purchase intention for several food products (i.e., canned green beans, breakfast cereals, bread, lentils, mayonnaise, orange juice, potato chips, and yogurt) using a 10-point scale. The authors used a between-subjects design to compare a no-label condition (control) and the three interpretive FOP schemes (the NS, HSR, and WL). Results showed that the three labels under investigation significantly reduced participants' purchase intention when compared to the control condition. The WL was able to lower consumers' purchasing intention for breakfast cereals, bread, mayonnaise, and yogurt, whereas the NS showed significant results for breakfast cereals and mayonnaise. Positive results were also obtained by Savov et al. (2022), who investigated the effects of the NS and the NI

on hypothetical Slovak consumers' food choices across three food categories (cereals, yogurt, and protein bars). Their findings showed that both FOP nutrition labels improved the respondents' choice, with the NS having a stronger effect. Similarly, a comparative experiment carried out across 12 countries (Argentina, Australia, Bulgaria, Canada, Denmark, France, Germany, Mexico, Singapore, Spain, the United Kingdom, and the United States) employed an online survey to explore to what extent consumers' food choices change in the presence of a FOP nutrition label. Overall, the majority of respondents' choices (82%) did not change between the no-label and the label condition. Across the 5 investigated labels (HSR, MTL, NS, RI, and WL), the NS and the MTL were the most effective in leading to healthier choices (Talati et al., 2019b). Using a different approach, Poquet et al. (2019) assessed the effect of the NS on snack choices in mother-child dyads (i.e., the person who shares an intimate biological, social, and psychological relationship with the child), as well as potential differences in the estimated budget and hedonic score. When comparing choices before and after labeling, both children's and mothers' choices were significantly more prone to healthier products. However, the authors observed a hedonic cost of changing choices: when the NS of the chosen snack increased, its liking score decreased.

Furthermore, a few studies investigated consumers' willingness to pay (WTP) for products displaying the NS scheme (Gassler et al., 2023; Stiletto & Trestini, 2022). One study employed a discrete choice experiment (DCE) to elicit Italian consumers' WTP for cheese in the presence/absence of the NS and the PDO (Protected Designation of Origin) label (Stiletto & Trestini, 2022). Results showed that consumers who were already familiar with the NS were willing to pay less for a product labeled with a low NS (D category). However, the simultaneous presence of the NS and the PDO labels reduced the negative effect of the NS. A second study using a DCE approach focused on German consumers and their WTP for yogurt. Results showed a positive effect of the NS on WTP for products considered "healthier" according to this system (A and B letters) and revealed that products displaying low NSs were stigmatized and less likely purchased (Gassler et al., 2023). A laboratory experiment conducted in a real setting in France to investigate the role of the color-coded NS in signaling the nutritional

quality of breakfast cereals (including national brands and private labels) showed a significant influence of both the NS and the use of additional explanations on consumers' WTP (Marette et al., 2019). Regarding the NS, the red color (letter E), associated with less healthy foods, had a higher impact than the green (letter A) and yellow (letter C) colors. Results showed an increased WTP for products A/green (ranging from +5% to +15%) and a higher decrement in WTP for E/red products (from -14% to -18%). The letter C, with the yellow color, showed a lower effect, with a significant negative effect on national brands (-8%) and no impact on private labels. In a different study, Sonntag et al. (2023) analyzed consumers' WTP for different multilevel sustainability labels (i.e., animal welfare label, climate label, and organic label) and a nutritional label (the NS) on chicken breast and whole milk. Nearly 1,000 German consumers participated in the online DCE: half of them evaluated the chicken breast and the other half the whole milk. For chicken breast, results showed that consumers were willing to pay the highest price premium for the B NS, followed by the climate label. Results from the interaction effects were mostly not significant, highlighting that displaying one sustainable label does not impact the marginal utility of a second sustainable label. However, the presence of either a high climate impact label or the organic label significantly decreased the marginal utility of the positive effect of the positive NS. For whole milk, respondents were willing to pay the highest price premium for the climate label, followed by the B NS. Similarly to the chicken breast, the estimates for interaction effects of the two labels were, in most cases, not significant on consumers' WTP. The authors argued that participants were able to manage two sustainability labels (also when potentially conflicting) and that multi-level labels could provide assistance in trade-off situations.

Despite the above-described studies mainly showing the positive effects of the NS in hypothetical scenarios, other studies found conflicting results related to the effectiveness of NS in influencing consumers' choices and WTP. For instance, Fialon et al. (2020) conducted an online survey to compare the effects of 5 FOP labels (HSR, MTL, NS, RI, and WL) on Italian consumers' understanding and food choices. Although authors showed that the NS could improve consumers' understanding (correctly ranking foods based on their nutritional quality), there was no significant

difference across FOP labels in changing consumers' food. In a similar study, Egnell et al. (2019) found congruous results among Dutch consumers. In a between-subject survey in which respondents had to rate their purchase intention towards snack bars in the presence or absence of the NS, the authors found no differences when comparing the control and treatment groups (Folkvord et al., 2021). Along with these studies in which no effect was found, an online survey conducted by Mora-Plazas et al. (2022) – which focused on a food choice task of "high-in" products – found that the nutrient WL led to a lower percentage of consumers who wanted to purchase the less-healthy fruit drinks when compared to the no-label, GDA, or NS condition. Godden et al. (2023), in a study conducted in Belgium on four products (potato chips, granola, yogurt, and orange juice), showed that consumers can have different food label preferences and identified consumer segments with different preferences for the NS label. The authors suggested that studies that do not segment consumers may fail to represent this heterogeneity.

Finally, some studies focused on actual purchasing behaviors. Specifically, the findings of a large-scale randomized controlled trial exploring real-life grocery shopping behaviors showed that the NS was the most effective nutrition label (compared to the SENS, the Nutri-Couleurs – similar to the MTL – and the Nutri-Repère – similar to the GDA) in improving the nutritional quality of the grocery basket (Dubois et al., 2021). In-store surveys suggested that this effect may be due to the NS's ability to capture consumers' attention and help them rank products by nutritional quality. However, the authors found that effect sizes were, on average, seventeen times smaller than the ones identified in comparable laboratory experiments and that the NS effect was stronger for healthier foods. In another study conducted in a real setting, Mora-García et al. (2019) explored the effects of the NS plus information provision in a university canteen in Colombia. The researchers randomly provided participants with information leaflets before entering the canteen, where products were labeled with the NS. Receipts were retrieved after consumers' purchases. The findings showed that participants who received information were more likely to purchase at least one product with the highest NS category (NS-A) and to have a higher total expenditure. However, the probabilities of buying products

in other NS categories were not significantly different between the control (NS without information leaflets) and the treatment group (NS plus information leaflets). Also a study conducted by Ahn and Lee (2022) took place in real food stores (a sport- and a non-sport-related facility). Results showed promising results for sales in the sport-related store, where purchases for healthy food were higher than for less healthy food compared to sales prior to displaying the NS label on food items (control condition). Similar results were not identified for sales in the non-sport-related facility store, in which mixed results were observed. Another study investigated actual purchasing behavior in an online environment (between-subject design with control *vs.* NS condition). In this case, displaying the NS on food products led to healthier food choices (e.g., 7.5% less saturated fat and 3.3% less sugar) (Fuchs et al., 2022). Vandevijvere and Berger (2021) conducted a natural experiment in Belgian supermarkets to evaluate the effect of electronic shelf labels (ESL) displaying the NS on consumer purchases; whereas the NS on the food packages has a 5-color layout, the NS is in black and white when displayed on the ESL. Results showed that the proportion of sales of B and C NS products was higher in the intervention than in the control stores, whereas displaying a D NS led to lower sales in the intervention when comparing the pre- and post-intervention moments. When considering different food categories, the authors found a positive effect (either an increment in healthier food sales and/or a decrement in the sales of less healthy products) for fruit and vegetables, dairy products, and sugar and confectionery. Negative effects (either a decrement in the sales of healthier foods and/or an increment in less healthy food sales) were mainly found for bread and bakery products.

Finally, several studies exploring consumers' food choices and purchasing behaviours (Savov et al., 2022; Talati et al., 2019b; van den Akker et al., 2022; Vandevijvere & Berger, 2021) indicated that the NS could positively impact consumers' choices and increase the nutritional quality of reported shopping carts/choices. This potential to equally impact the population across educational and sociodemographic backgrounds may be linked to the fact that the NS is easy to understand, without requiring previous nutrition knowledge on the consumer side. Nevertheless, studies show differences

in the NS outcomes across product categories and NS levels (Mora-García et al., 2019; Savov et al., 2022; Vandevijvere & Berger, 2021).

*1.3.3.2.3 Consumer attention*

Attention to FOP labels is an essential element to effectively guide consumers' food choices through labeling schemes. Consumers' attention can depend on the visual design of the label, which is especially relevant for individuals with limited ability to process information or who are under time constraints (Nohlen et al., 2022).

Only a couple of works used methodologies and techniques to measure consumer attention towards the NS, such as eye-tracking (Bossuyt et al., 2021; Gabor et al., 2020). Specifically, in a study conducted by Bossuyt et al. (2021), the authors investigated the role of visual attention (i.e., relative fixation duration) on healthfulness estimation accuracy under the presence of the NS, the mandatory NFP, and their combination. Results showed that respondents who paid more visual attention to the NS had a lower average mistake in the estimation task. Concerning the NFP, it had no effects on consumers' evaluation when presented alone, while it led to information overload when presented along with the NS. Another study using eye-tracking focused on analyzing consumers' visual attention to food packaging when exposed to three different FOP labels (NS, MTL, and GDA) (Gabor et al., 2020). Despite the most accurate healthfulness estimates coming from the GDA condition, the NS required the least time to process the information. However, faster visual attention (i.e., lower values of total fixation time, number of fixations, and average fixation) was not associated with a better performance in the evaluation of food products (Gabor et al., 2020).

Overall, results from studies using eye-tracking confirm that less complex labels require less attention to be processed (Nohlen et al., 2022). As time constrains affect actual label use and given the low time needed to process the NS, this label could support consumers in time-pressure situations, as found by Packer et al. (2022).

*1.3.3.2.4 Public support*

Few studies (Fialon, Salas-Salvado, et al., 2021; Talati et al., 2019a) investigated whether individuals would support the use of the NS on food packaging. Specifically, in a study by Talati et al. (2019a), the NS received the lowest score when asking "It should be compulsory for this label to be shown on packaged food products". Another study on Swiss consumers showed higher public support for the MTL rather than the NS when considering the overall sample; however, participants who became familiar with the NS throughout the experiment showed higher support than those who did not, showing that the acceptance of health policy measures is strictly linked to the familiarity level of consumers with the measure itself (Hagmann & Siegrist, 2020). On the opposite way, in a study conducted in Spain, most participants declared that they would support labeling olive oils with the NS (Fialon, Salas-Salvado, et al., 2021). Similarly, an online survey conducted in France after the adoption of the NS showed that 90% of participants strongly supported this measure and 87.2% encouraged the idea of a mandatory NS scheme (Sarda et al., 2020).

*1.3.3.3 Eco-score*

Out of the 72 studies under investigation, only two papers considered the effect of the ES on consumers' understanding and preferences – excluding those focusing on the combined effect of the NS and ES.

Hallez et al. (2021) investigated to what extent the presence of the ES or the NS can influence the environmental impact of consumers' choices. Given that the two labels were never displayed simultaneously, this paper was not classified as dual labeling. In their articles, the authors present two choice tasks in a hypothetical, online shop setting, in which participants had to shop for a one-person meal by selecting the food items and their quantities. In the first experiment, participants were allocated to one of three conditions: no label, NS, or ES. The second experiment used a between-subject design with a 2 (nutrition *vs.* sustainable label) × 2 (interpretative *vs*. reductive label) approach, plus 1 control condition (no label). In this case, the reductive sustainable label presented four

sustainability elements (the carbon footprint, the land use, the nitrogen per 100 grams of a food product, and the water used,), whereas the reductive nutrition label considered four nutritional elements (the energy content, and the amount of salt, saturated fats, and sugar in grams per 100 grams of product). Findings of the first experiment, performed with a convenience sample of undergraduate students, showed no evidence that the ES changed young adults' choices compared to the no-label or NS condition. In the second experiment (also performed with a convenience sample of young adults), the results revealed that consumers exposed to the ES label selected less meat and composed a meal with a lower carbon and water footprint than the NS group.

A second article focusing on the ES used a DCE to explore the trade-off between different coexisting environment-related labels considering preferences for seasonality, localness, organic production, and the ES (De Bauw, Franssens, et al., 2022). The results revealed that consumers preferred local and organic, as well as more positive ES values/letters. The relative attribute importance showed that the ES was the second most important attribute, after price. Interaction effects showed a significant and negative interaction between the ES and the "local" claim, indicating that, for bundles with local vegetables, consumers' preferences for positive ESs were less strong than for imported vegetables. In other words, for vegetables displaying negative ESs (letters E or D), consumers had a higher tendency to prefer local over imported options than for bundles with positive ESs (letters A or B).

*1.3.3.4 Dual-labeling*

Only a few studies considered the impact of a dual-labeling scheme, i.e., the combination of displaying the NS and ES simultaneously (De Bauw, De La Revilla, et al., 2022; De Bauw et al., 2021; Marette, 2022; Potter et al., 2023). For instance, in a between-groups experimental design, De Bauw et al., (2021) tested whether a combined NS and ES labeling scheme affects the nutritional quality, measured by the nutritional quality index (NQI), and the environmental impact, assessed with the environmental impact index (EII), of Belgian consumers' food choice (2021). The results demonstrated that simultaneously displaying the NS and ES in an online grocery environment

increased the NQI of participants' food choices, but not their EII. In another paper (De Bauw, De La Revilla, et al., 2022), the authors used a similar approach to investigate food choices in a mock-up online supermarket to explore the effects of displaying the NS and ES simultaneously, plus the use of digital functionalities. In this study, respondents could review their basket and adjust it by removing items and/or modifying quantities after their initial food selection. During this basket overview, digital functionalities were tested (i.e., basket scores, product scores, recommendation agents, and social norms). Finally, the NQI and EII of the basket were calculated. Similar to the previous study, results showed that the combination of the NS and ES improved the NQI but did not affect the EII of the food choice. However, an improvement in the EII was observed when the choice was facilitated by recommendation agents (defined by Bo & Benbasat (2007) as "software agents that elicit the interests or preferences of individual users for products, either explicitly or implicitly, and make recommendations accordingly"). Hence, the authors suggest that a dual-labeling system could potentially support consumers, however, recommendation agents should be considered to enhance the effect of such a system in lowering the environmental impact of food decisions.

Different results – although still positive – were found by Potter et al. (2023). In their study, the authors used a similar approach (i.e., experimental online supermarket) and randomized participants across four conditions: no label (control) displayed, ES alone, NS displayed alone, or their combination. Compared to the control condition, significant reductions in the environmental impact of consumers' food choices were identified in the presence of the environmental label, with no differences in effectiveness when displayed alone or in combination with the NS. For the NS, no significant differences were found either for the environmental impact or the nutritional quality, both when displayed alone or in combination.

In a slightly different study conducted with a representative sample of the French population, Marette (2022) investigated consumers' purchasing intention for pizza. In this web-based questionnaire, participants were asked for their purchase intention for one pizza (using a yes/no question) before and after seeing the NS, ES, and a Global Score (GS), synthesizing both nutritional and sustainable

dimensions in a single label. Results showed that the presence of FOP labels significantly affected the purchase intent for pizza. Specifically, for all three labels, the main effect was the reduction in participants' purchase intent in the presence of the red color. Nevertheless, green and yellow colors also affected the purchasing behavior, but to a lower extent. In addition, despite the NS showing a stronger effect than the ES or GS, the author found that the effect of the red color of one label was not stronger than the positive effect of the green color of the second one.

Finally, these studies provide some initial evidence of the use of a dual NS-ES scheme; however, despite the overall positive results, the topic needs further investigation to strongly support such a system as a strategy to promote a transition towards healthier and more sustainable diets.

### 1.3.4 Discussion and Implications

Consumers are constantly exposed to more and more sustainable and nutrition labels displayed on food products, which could potentially allow them to make informed dietary choices (De Temmerman et al., 2021; Sonntag et al., 2023). With the objective of supporting the decision-making process to define the adoption of mandatory labeling systems, our systematic review aims at assessing and examining the available literature on the effects of the NS, ES, and their combination in terms of consumers' understanding, perception, and purchasing behaviors.

For the NS, the majority of the included articles showed the superiority of this label – compared to other nutrition FOP labels – in supporting consumers to correctly identify the products' healthiness. Specifically, the presence of the NS contributes to assessing the healthiness of foods more easily (Andreeva et al., 2022; De Temmerman et al., 2021) and faster (Packer et al., 2022) than other FOP labels. This positive performance of the NS in terms of objective understanding could be linked to its format (graded summarized information through a single indicator) which limits potential confusion on nutrition terms (Aguenaou et al., 2021; Egnell, Ducrot, et al., 2018). In addition, the incorporation of both text and green-yellow-red colors (corresponding to the well-recognized "go" and "stop" signals) makes this label format easy-to-read and comprehend (Egnell, Talati, et al., 2018). This

translates into a higher purchase intention for products with positive NSs (i.e., A and B letters) than for food items with negative scores (i.e., D and E letters) (De Temmerman et al., 2021). Although the NS had generally a positive effect on consumers' purchasing behaviors (Ares et al., 2018; Crosetto et al., 2020; Savov et al., 2022) – both in hypothetical and real settings – it is worth noting that the effect size when considering actual behavior was smaller than of comparable laboratory experiments (Dubois et al., 2021). Despite the overall positive impact of the NS on consumers' objective understanding and purchasing behaviors, more heterogeneous results were identified for subjective understanding, advocating for further research investigating this aspect.

Regarding the ES, our systematic review found only six studies investigating the effects of this sustainable FOP label on consumers. Of these, two studies used the ES on its own (De Bauw, Franssens, et al., 2022; Hallez et al., 2021) and found that this label was able to trigger pro-environmental food choices, whereas the remaining four papers (De Bauw, De La Revilla, et al., 2022; De Bauw et al., 2021; Marette, 2022; Potter et al., 2023) tested dual-labeling and showed positive, but still mixed results. Therefore, to draw more concrete implications, future studies should be conducted on these topics to explore differences between the ES and other sustainable labels and the potential effect of a dual NS-ES scheme in comparison to the presence of a single NS and/or ES.

At the European level, the EU's Farm to Fork Strategy advocates for the mandatory implementation of a nutritional FOP label to improve citizens' diets by including healthier foods (European Commission, 2020a). Thus, the scientific evaluation of the potential implementation of the NS as such a (quasi-)mandatory label (for instance due to government legislation or pressure from food stores with significant purchasing power) is necessary to support the policymaking process. However, it is worth noting that understanding and knowledge about FOP labels increase with familiarity, as suggested by Packer et al. (2021). As a matter of fact, in their study with British consumers, differences between the NS and MTL appeared to be small, probably because the MTL was introduced in the UK in 2013 and, thus, participants were already familiar with this label. As a result, we expect that raising awareness of the NS and ES systems will increase the demand for FOP-labeled

products. At the same time, a rating system logo would not exclude operators but instead encourage them to focus on improving the nutrition and environmental quality of their products, for example by reformulating or introducing new healthy and sustainable products (Schruff-Lim et al., 2023). In addition, the NS guideline defines “D” and “E” products as foods that should be limited for public health reasons (Santé Publique France, 2024), which does not imply a total exclusion of these foods from the diet. The same reasoning could be applied to the ES. Thus, as proposed by Stiletto et al. (2023), these labels could be considered an “indication of use” rather than an evaluation of the product quality. To avoid misleading interpretations, tailored education and communication campaigns will be required to explain the label format and raise public understanding of the related health and environmental challenges (De Marchi et al., 2023; Julia et al., 2017; Meijer et al., 2021; Tiboni-Oschilewski et al., 2024).

With potential mandatory labeling schemes being adopted in the future, it might become more common for consumers to find products with conflicting rating labels (i.e., positive nutritional quality and negative environmental impact, or vice versa). Therefore, more studies on dual-labeling schemes are needed to evaluate whether the food's perceived environmental impact (e.g., expressed by the ES) and its perceived healthiness (e.g., represented by the NS) influence each other during consumers’ choices. In addition, as suggested by Stiletto et al. (2023), another research line of increasing interest in the area is the effect that the simultaneous presence of the NS and Geographical Indications labels (PDO and PGI) can have on consumers, which has been little investigated so far (Stiletto et al., 2024; Stiletto & Trestini, 2022). Research on these aspects is necessary to address the current political debate behind the NS and traditional food products and, thus, support policymakers in their decisions. Overall, our research strengthens the importance of investigating the effects of new labels on consumer perceptions, especially when these are introduced on the market. However, one potential limitation of our review, which may limit the generalizability of the results, is related to the heterogeneity in the methodologies and measures applied in the included articles as these may capture different mechanisms behind consumer behavior. As a matter of fact, most studies did not share the

same outcome and measures, which advocates for the need to standardize study protocols to facilitate comparison. In addition, the majority of the articles did not use representative samples and/or reported a power analysis to justify the sample size, which may limit the identification of proper sample segmentation and potential differences between consumer groups. In this context, Godden et al. (2023) suggested conducting proper sample segmentations to capture consumers' heterogeneity since FOP labels can have different effects based on individuals' characteristics and may even have adverse effects for some. Moreover, the quality assessment carried out for each article highlights the need to conduct more "real world" studies and, possibly, include longer timeframes (e.g., by investigating whether changes in food choices are consistent over time) to provide more robust results. An additional suggestion for future studies would be to include new product categories, as certain categories have not been investigated so far, including animal products *vs*. their plant-based counterparts. Such studies could include the use of approaches that have been less adopted – such as eye-tracking data, to gather new and valuable information on consumers' attention – or that have not been used up to now – such as sensory research, to test whether the NS, ES, or their combination affect sensory acceptability.

To conclude, the results reported in this review could support policymakers in their decisions on policy measures to encourage healthier and more sustainable food consumption behaviors. Communicating products' attributes, in terms of either nutrition or sustainability, in an accurate and trustworthy manner – for instance through FOP labeling schemes that are clearly understood (also through the support of tailored education campaigns) – could provide consumers with the necessary tools to make more informed food choices.

## Glossary

| | |
|---|---|
| EII | Environmental Impact Index |
| ES | Eco-Score |
| FOP | Front-of-pack |
| GDA | Guideline Daily Amounts |
| HSR | Health Star Rating |
| MTL | Multiple Traffic Light |
| NFP | Nutrition Facts Panel |
| NI | NutrInform Battery |
| NQI | Nutritional Quality Index |
| NS | Nutri-Score |
| PDO | Protected Designation of Origin |
| PGI | Protected Geographical Indication |
| RI | Reference Intake |
| SSBs | Sugar-Sweetened Beverages |
| WL | Warning Label |

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**Disclosure statement**

The authors report there are no competing interests to declare.

3037 **Appendix**

3038 **Table A1.** Summary information of the 72 included papers.

| ID | Authors | Publication Year | Sample size | Country | Food category | Label |
|---|---|---|---|---|---|---|
| 1 | Julia, C., et al. | 2017 | 21702 | France | n.a. | NS |
| 2 | Egnell, M., et al. | 2018 | 3751 | France | Breakfast cereals; Prepared meals; Sandwiches; Canned fish; Cookies | NS |
| 3 | Egnell, M., et al. | 2018 | 11812 | Argentina; Australia; Bulgaria; Canada; Denmark; France; Germany; Mexico; Singapore; Spain; UK; USA | Cakes; Pizza; Breakfast cereals | NS |
| 4 | Egnell, M., et al. | 2018 | 25772 | France | Mixed food categories | NS |
| 5 | Ares, G., et al. | 2018 | 502 | Uruguay | Yogurt; Bread; Chips; Mayonnaise; Juice; Breakfast cereals; Pulses | NS |
| 6 | Talati, Z., et al. | 2019 | 11812 | Argentina; Australia; Bulgaria; Canada; Denmark; France; Germany; Mexico; Singapore; Spain; UK; USA | Cakes; Pizza; Breakfast cereals | NS |
| 7 | Egnell, M., et al. | 2019 | 1032 | Netherlands | Cakes; Pizza; Breakfast cereals | NS |
| 8 | Talati, Z., et al. | 2019 | 11100 | Argentina; Australia; Bulgaria; Canada; Denmark; France; Germany; Mexico; Singapore; Spain; UK; USA | Cakes; Pizza; Breakfast cereals | NS |
| 9 | Mora-García, C.A., et al. | 2019 | 484 | Colombia | Mixed food categories | NS |
| 10 | Marette, S., et al. | 2019 | 86 | France | Breakfast cereals | NS |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | Poquet, D., et al. | 2019 | 95 | France | Snacks | NS |
| 12 | Gabor, A.M., et al. | 2020 | 76 | Croatia | Chocolate bars | NS |
| 13 | Sarda, B., et al. | 2020 | 4006 | France | n.a. | NS |
| 14 | Galan, P., et al. | 2020 | 1000 | Spain | Cakes; Pizza; Breakfast cereals | NS |
| 15 | Santos, O., et al. | 2020 | 357 | Portugal | Yogurt; Cereals; Canned tuna; Lasagna; Cookies | NS |
| 16 | Fialon, M., et al. | 2020 | 1032 | Italy | Cakes; Pizza; Breakfast cereals | NS |
| 17 | Egnell, M., et al. | 2020 | 1088 | Switzerland | Cakes; Pizza; Breakfast cereals | NS |
| 18 | Egnell, M., et al. | 2020 | 12391 | Belgium; Bulgaria; Denmark; France; Germany; Italy; Netherlands; Poland; Portugal; Spain; Switzerland; United Kingdom | Cakes; Pizza; Breakfast cereals | NS |
| 19 | Vandevijvere, S., et al. | 2020 | 1007 | Belgium | Cakes; Pizza; Breakfast cereals | NS |
| 20 | Hagmann, D., et al. | 2020 | 1561 | Switzerland | Snacks | NS |
| 21 | Andreeva, V.A., et al. | 2020 | 1013 | Bulgaria | Cakes; Pizza; Breakfast cereals | NS |
| 22 | Crosetto, P., et al. | 2020 | 691 | France | Mixed food categories | NS |
| 23 | Bossuyt, S., et al. | 2021 | 398 | Belgium | Beverages; Ice cream; Prepared meals; Dairy products | NS |
| 24 | Egnell, M., et al. | 2021 | 1127 | France | Mixed food categories | NS |
| 25 | De Temmerman, J., et al. | 2021 | 354 | Belgium | Mixed food categories | NS |
| 26 | Folkvord, F., et al. | 2021 | 192 | Netherlands | Snack bars | NS |
| 27 | Packer, J., et al. | 2021 | 4530 | Great Britain | Pizza; Drinks; Cakes; Crisps; Yogurt; Breakfast cereals | NS |
| 28 | Vandevijvere, S., et al. | 2021 | Food stores | Belgium | Mixed food categories | NS |
| 29 | Goiana-Da-silva, F., et al. | 2021 | 1059 | Portugal | Cakes; Pizza; Breakfast cereals | NS |
| 30 | Egnell, M., et al. | 2021 | 336 | France | Mixed food categories | NS |
| 31 | Aguenaou, H., et al. | 2021 | 814 | Morocco | Yogurt; Cookies; Cold cuts | NS |
| 32 | Mazzù, M.F., et al. | 2021 | 2776 | France; Germany; Greece; Italy; Portugal; Romania; Spain | Yogurt; Sauces; Cookies; Saltines | NS |
| 33 | Jansen, L., et al. | 2021 | 550 | Netherlands | Breakfast cereals; Muesli bars; Crackers; Pizza | NS |

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| 34 | Mazzù, M.F., et al. | 2021 | 200 | Italy | Sauces; Yogurt; Cookies; Crackers; Processed meat | NS |
| 35 | De Bauw, M, et al. | 2021 | 766 | Belgium | Meat; Vegetables; Pasta; Cheese | Dual |
| 36 | Fialon, M, et al. | 2021 | 486 | Spain | Olive oil; Rapeseed oil; Soybean; Sunflower; Corn oil; Peanut; Palm oil; Butter | NS |
| 37 | Baccelloni, A, et al. | 2021 | ND | Slovenia; The Netherlands | n.a. | NS |
| 38 | Dubois, P., et al. | 2021 | Food stores | France | Mixed food categories | NS |
| 39 | Hock, K, et al. | 2021 | 10762 | Australia; Canada; Chile; Mexico; the UK; the US | Sugar-sweetened beverages | NS |
| 40 | Hallez, L., et al. | 2021 | 196 | Belgium | Mixed food categories | ES; NS |
| 41 | Marette S. | 2021 | 1200 | France | Pizza | Dual |
| 42 | Stiletto, A., et al. | 2022 | 300 | Italy | Cheese | NS |
| 43 | Kontopoulou, L., et al. | 2022 | 1278 | Greece | Cakes; Pizza; Breakfast cereals | NS |
| 44 | Gassler, B., et al. | 2022 | 445 | Germany | Yogurt | NS |
| 45 | Kühne, S.J., et al. | 2022 | 354 | Switzerland | Beverages; Bread; Meat; Dairy products; Eggs; Vegetables; Fruit; Pasta; Snacks; Sweets; Frozen food | NS |
| 46 | Mora-Plazas, M., et al. | 2022 | 8091 | Colombia | Fruit drinks; Breakfast cereals; Yogurt; Bread; Cookies | NS |
| 47 | Packer, J., et al. | 2022 | 4530 | Great Britain | Pizza; Drinks; Cakes; Chips; Yogurt; Breakfast cereals | NS |
| 48 | Fialon, M., et al. | 2022 | 1064 | Italy | Breakfast products; Breakfast cereals; Added fats products | NS |
| 49 | Hoge, A., et al. | 2022 | 2260 | Belgium | Pizza; Dairy products; Breakfast cereals; Appetizers | NS |
| 50 | Ahn, C., et al. | 2022 | Food stores | South Korea | n.a. | NS |
| 51 | Fuchs, K.L., et al. | 2022 | 126 | Switzerland; Germany | Mixed food categories | NS |
| 52 | Cui, J., et al. | 2022 | 2407 | China | Mixed food categories | NS |
| 53 | Ducrot, P., et al. | 2022 | 1201 | France | n.a. | NS |
| 54 | Savov, R., et al. | 2022 | 1000 | Slovak republic | Cereals; Yogurt; Protein bars | NS |
| 55 | Andreeva, V.A., et al. | 2022 | 1159 | Poland | Cakes; Pizza; Breakfast cereals | NS |
| 56 | Jurkenbeck, K., et al. | 2022 | 1103 | Germany | Instant cappuccino; Oat drink; Chocolate crunchy | NS |
| 57 | De Bauw, M., et al. | 2022 | 994 | Belgium | Mixed food categories | Dual |
| 58 | Mazzù, M.F., et al. | 2022 | 202 | Italy | n.a. | NS |

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| 59 | Egnell, M., et al. | 2022 | 1180 | France | Mixed food categories | NS |
| 60 | Bolhuis, D., et al. | 2022 | 662 | Netherlands; Italy; Brazil | Mixed food categories | NS |
| 61 | Abou Jaoudé, L., et al. | 2022 | 371 | France | Mixed food categories | NS |
| 62 | van den Akker, K., et al. | 2022 | 299 | The Netherlands | Breakfast cereals | NS |
| 63 | Kontopoulou, L., et al. | 2022 | 510 | Greece | n.a. | NS |
| 64 | De Bauw, M, et al. | 2022 | 300 | Belgium | Vegetables | ES |
| 65 | Hutton, TR, et al. | 2022 | 359 | South Africa | Chicken; Ready-to-eat meals; Breakfast cereals; Dairy products; Snacks | NS |
| 66 | Fialon, M., et al. | 2023 | 1026 | Spain | Breakfast products; Breakfast cereals; Added fats products | NS |
| 67 | Mazzù, M.F., et al. | 2023 | 327 | Sweden | Breakfast cereals | NS |
| 68 | Pettigrew, S., et al. | 2023 | 1000 | Australia | Cakes; Pizza; Breakfast cereals | NS |
| 69 | Potter, C., et al. | 2023 | 2730 | UK | Mixed food categories | Dual |
| 70 | Pettigrew, S, et al. | 2023 | 18393 | Argentina; Australia; Belgium; Bulgaria; Canada; Denmark; France; Germany; Italy; Mexico; Netherlands; Poland; Portugal; Singapore; Spain; Switzerland; the UK; and the USA | Cakes; Pizza; Breakfast cereals | NS |
| 71 | Godden, E, et al. | 2023 | 1156 | Belgium | Chips; Granola; Yogurt; Orange juice | NS |
| 72 | Sonntag, WI, et al. | 2023 | 493 | Germany | Chicken; Milk | NS |

Note: NS= Nutri-Score; ES= Eco-Score

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# Chapter 2:
# Experimental Research

## 2.1 Study 4

# Understanding Italian Consumers' Motivations for Purchasing Plant-Based Burgers: Insights from The Means-End Chain Theory

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**Abstract**

By applying the means-end chains (MEC) theory, the purpose of this paper is to provide new insights related to the motivations behind consumer purchase intention of plant-based burgers (PBBs). We provided 62 Italian burger consumers with six pictures of PBBs showing the front and back of the product packages and asked them to rank their preferred product of purchase. This stage was followed by a soft laddering interviewing technique ("Why is this element important for you?") to elicit the most important attributes, consequences, and values associated with the selected product. Socio-demographic and attitudinal variables were asked to segment the sample into sub-groups. Our findings showed heterogeneity in the drivers leading consumers to purchase PBBs. Specifically, differences based on individual traits (gender and meat attachment level) and product characteristics (meat-like burgers *vs.* non-meat-like burgers) were identified. In addition, some similarities across consumer segments emerged, which confirm that both non-sensory attributes (e.g., nutritional information) and expected sensory characteristics (e.g., product appearance) are important elements to the market success of plant-based meat alternatives. Interestingly, environmental motives emerged only for specific consumer groups. Finally, to ensure the market success of PBBs, marketing strategies should consider different consumer segments based on demographic and attitudinal variables to meet consumers' specific needs. This study contributes to the literature on consumer motivation to include plant-based products by directly asking consumers to elicit the most important product attributes, consequences, and values linked to such products. Implications for business and policymakers are provided.

**Keywords:** meat alternatives; health; sustainability; food choices; motives.

### 2.1.1 Introduction

With the global food demand expected to increase over the next decade, the consumption of animal-based products is expected to rise accordingly (OECD, 2022). Livestock farming is responsible for feed crops occupying one-third of all arable land (La Barbera et al., 2023) and the meat sector is assumed to produce 9% more greenhouse gas emissions by 2031 (OECD, 2022). Therefore, due to the environmental impact, along with health-related risks (e.g., Non-Communicable Diseases) and ethical reasons (e.g., increasing public attention towards animal welfare) (Nezlek and Forestell, 2022), many stakeholders – among which the scientific community, policy-makers, and consumers – support a reduction in the production and consumption of animal-based products (Demartini et al., 2024).

Among the possible strategies, individuals can abstain from consuming food that comes from animals, reduce their intake or substitute animal-based products (e.g., meat) with plant-based proteins (Onwezen and Dagevos, 2024). As a result, we are experiencing a rise in the popularity of plant-based diets, which leads to market growth of the so-called plant-based meat alternatives or analogues (PBMAs) (Andreani et al., 2023; Ghaffari et al., 2022). These PBMAs are designed to resemble processed meat, such as burgers, patties, sausages, or nuggets, in terms of nutrition (Cutroneo et al., 2023) as well as sensory properties – e.g., texture, flavor, and appearance (Andreani et al., 2024). Currently, burgers are the plant-based food category with the largest share of the market of PBMAs (Andreani et al., 2023). The reason is due to their composition, availability in the market, ease of preparation, and relatively low costs.

However, even if considered to have high nutritional value (e.g., high protein content), some of these PBMAs that aim at mimicking meat are highly processed and may not have the same nutritional benefits as the foods from which they are derived, such as legumes (Nezlek and Forestell, 2022). Currently, these products can be categorized into two main groups: those that try to mimic the sensory profile of conventional meat products (e.g., made with extruded proteins from soy or pea) and those that do not mimic conventional meat and instead use whole ingredients (e.g., quinoa or whole

legumes) as the primary protein ingredient (Giezenaar et al., 2024). Given this difference, there is a need to explore the impact that the information of concrete product attributes reported on the packaging (via text or images) of these two different PBMA categories could have on consumers' expectations and emotional responses, which is one research question of this study. Moreover, the presence of ingredient lists on PBMAs' packaging that are longer than the ones on animal meat products (Cutroneo et al., 2022) could create skepticism among consumers. Thus, several attributes could potentially be considered important for consumers when choosing PB products. Understanding the connection between attributes (e.g., labels, ingredients, price) and purchasing motivations (e.g., health and environmental benefits) of plant-based products is vital for designing more consumer-oriented food products.

The application of the Means-End Chain (MEC) Theory is recognized as a valuable approach to exploring this link (Gutman, 1982; Reynolds and Olson, 2001). The main assumption of the MEC Theory is that individuals organize their product knowledge hierarchically: specific attributes are associated with broader consequences, that is, the delivery of key benefits. The premise is that consumers select products that possess attributes (A) crucial for attaining their desired consequences (C), which are ultimately linked to more abstract elements, defined as personal values (V) (Reynolds and Gutman, 2001). It has been observed that consumers have diverse personal values and prioritize different products accordingly.

In our study, we used a laddering technique to identify how different product characteristics can generate preferences within a specific product category. In the last decades, laddering has been employed in the food area to understand consumer cognitive structures surrounding a variety of products. For example, studies including both traditional and ethnic foods (Arsil et al., 2022; Cerjak et al., 2014; Tey et al., 2018) as well as products that have not yet gained widespread acceptance in society, such as novel foods and technologies (Barrena et al., 2017; Crofton and Scannell, 2020; Sonne et al., 2012).

To our knowledge, few studies have used the laddering technique to investigate the drivers of choice for novel alternative proteins, including PBMAs (e.g., McCarthy et al., 2017). Thus, the aim of this study is to understand consumer product motivations to purchase plant-based burgers (PBBs), using the MEC theory. By asking the reasons for choosing such products, we gain insight into the drivers, including personal values, that influence the demand for PB products in the Italian market.

This study contributes to the literature on consumer motivation to include PB products by directly asking consumers to elicit the most important product attributes, consequences, and values linked to such products. The final output of the laddering techniques (i.e., hierarchical value map) provides indications about the attributes and benefits of the product that influence consumers' adoption. As a result, this is the starting point to formulate specific marketing and/or communication strategies and position the product in the market, based on the values orientations elicited by consumers (Reynolds and Gutman, 2001; Reynolds and Phillips, 2009; Zanoli and Naspetti, 2002). Finally, we propose implications for policy and practitioners to address groups (segments of the populations) that have common characteristics (e.g., demographic or attitudinal variables) and thus could react similarly to marketing campaigns.

### 2.1.2 Theoretical framework

Establishing a psychological connection between customers and a product or service is one of the main goals of marketing (Walker and Olson, 1991). Therefore, understanding the link between product features and purchasing motivations is necessary for designing consumer-focused food items. To achieve this objective, it is important to explore consumer perception and knowledge, especially in the early stages of new product development, as it could significantly increase consumers' acceptance (van Kleef et al., 2005).

One marketing approach to studying consumer behavior is to investigate the cognitive process behind individuals' elaboration of preferences. The objective is to investigate what consumers know about

products, how they perceive them, and the needs they wish to satisfy (Zanoli and Naspetti, 2002). In this context, it is crucial to develop models to study and explain consumers' perceptions of products in relation to themselves (Walker and Olson, 1991), and, in the past decades, much research on consumer behavior attempted to do this.

In 1973, the research by Rokeach (1973) showed that personal values, which represent fundamental and desirable beliefs, play a significant role in shaping individuals' behavior across various aspects of life. Later, in 1982, Gutman (1982) extended this concept to the field consumer studies and marketing. Gutman showed how, when making choices, individuals prefer the product attributes that are instrumental to achieving the desired consequences (benefits) and that lead them to higher-order personal values. Therefore, personal values guide consumers to seek products that fulfill their needs and wants (Gutman, 1982; Reynolds and Olson, 2001). However, most of the time, consumers cannot verbalize their needs and wants and are unaware of the process behind their decisions, thus, simply asking directly "Why do you prefer this product?" may not be sufficient to reveal their true motivations (Crofton and Scannell, 2020; Zanoli and Naspetti, 2002). By using the MEC analysis, marketers can have a useful method to effectively understand consumers' behavior (e.g., personal reasons for purchasing a product).

The MEC theory assumes that individuals do not purchase goods just for their own sake, but for the benefits they will achieve from using the product (Sonne et al., 2012). By developing a hierarchical cognitive structure, this theory shows the links between consumers' understanding of product attributes (the means), the correlated consequences, and their relationship with personal values (the ends) (Figure 1). The rationale of this theory is that consumer knowledge is organized into a hierarchical structure based on different levels of abstraction inside the consumer's mind: attributes, consequences, and values (Gutman, 1982).

First, at lower levels, the MEC theory considers the product attributes (A) that may be categorized as tangible/concrete – i.e., directly perceivable properties or characteristics of a product (concrete knowledge), such as color, size, or price – or *intangible/abstract* – i.e., not directly perceivable

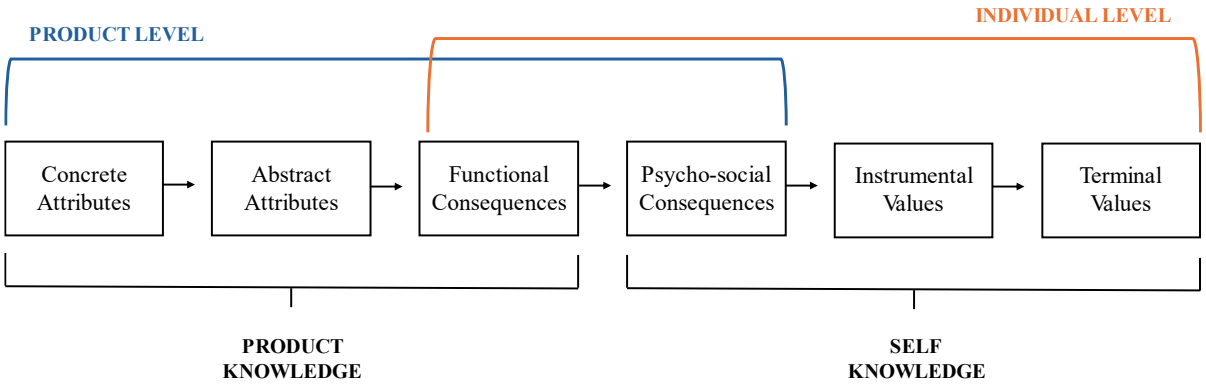
characteristics, which derived from internal or external cues, such as the level of convenience or nutritional benefits (Vanden Abeele et al., 2012; Barrena et al., 2015).

Second, consequences (C) related to the product use are usually categorized based on their outcomes: *functional*, which are situated at the usage level and represent the tangible benefits obtained from the product attributes (such as, "that [product attribute] makes me healthier"), or *psychological and social*, which are associated with more abstract knowledge (such as, "that [product attribute] makes me feel better about myself") (Vanden Abeele et al., 2012; Gutman, 1982). Moreover, consequences can be classified as positive or negative – i.e., a consumer seeks or avoids a product.

Finally, at the value (V) level, consumers do not talk about the product anymore but mention their personal values, suggesting a highly abstract driving motivation for usage behavior (abstract self-knowledge). Values are categorized into *instrumental* and *terminal*, with instrumental values (e.g., "it is important to save the planet") serving as cognitive pathways to achieve terminal values, which represent individuals' ultimate life goals (e.g., "happiness" or "peace-of-mind") (Reynolds and Olson, 2001).

To sum up, consumer's product knowledge (the means) is formed by the three lower levels (concrete characteristics, abstract attributes, and functional consequences), whereas their self-knowledge (the ends) is represented by the three upper levels (psycho-social consequences, instrumental values, and terminal values) (Barrena et al., 2015; Walker and Olson, 1991).

**Figure 1**. Means-End Chain Theory




Source: own elaboration.

One particular method used in research using the MEC theory is the laddering method (Vanden Abeele et al., 2012). This specific interviewing methodology is a qualitative research technique and focuses on revealing the means-end chains by asking repetitive 'Why-probing' questions: why is this important for you? (Reynolds and Phillips, 2009). Initially, interviewees are prompted to list significant attributes that hold importance to them (elicitation of product attributes). Then, by using this why-probing technique, consumers naturally reveal their personal reasons by developing their own attribute-consequence-value sequences (Reynolds and Gutman, 2001). Individual MECs can report all or some of the hierarchical levels and the number of links on the ladder (which typically ranges from four to six) can vary (Reynolds and Phillips, 2009).

There are two types of laddering techniques: soft and hard laddering (Grunert and Grunert, 1995). The soft approach involves conducting in-person interviews using directed probe questions in which the natural flow of speech is limited. It includes a relatively small sample size (e.g., typically < 50-60 people). On the other hand, the hard laddering method does not require in-person interviews but uses online or paper-and-pencil self-administered surveys, which include a structured questionnaire. In the hard laddering, the respondent is required to create ladders one at a time and to arrange their responses so that the answers reflect progressively higher levels of abstraction. Whereas in soft laddering, the ladders are built afterwards and it requires a trained interviewer since individuals may move back and forth between the levels of abstraction or deviate from providing semantic knowledge (Grunert and Grunert, 1995).

As a result, this cognitive network (means-end chain) of sequential connections between product attributes, personal consequences, and values allows researchers to gain a deeper understanding of motivation by highlighting traits that consumers value more when making preference decisions about a specific product (Zanoli and Naspetti, 2002). For this reason, the MEC analysis is a consumer research technique that is frequently utilized to successfully develop products (Reynolds and Phillips, 2009), especially in the early phases of new product development (NPD) (Krystallis, 2007).

Understanding how individuals perceive PBMAs and the primary cognitive processes that influence their purchasing behavior is crucial to successfully develop such products, in terms of ingredient composition, taste, and other important packaging attributes (Andreani *et al.*, 2023).

### 2.1.3 Methods

#### 2.1.3.1 Sample

Interviewees were recruited through snowballing sampling via email among the student population of the University of Parma, Italy. The data collection took place from Winter 2022 to Spring 2023. To participate in our study, consumers had to be 18 years old and the primary food-purchasing person in their households. The survey for the recruitment included questions related to the consumption frequency of regular and/or plant-based burgers (at least once in the last three months).

A total of 62 consumers (64% females, aged 18–32 years) were interviewed. This sample size is consistent with previous studies that used the MEC method (Barrena et al., 2017; Cerjak et al., 2014; Crofton and Scannell, 2020; Giovane da Silva et al., 2023; Zanoli and Naspetti, 2002). Most participants were students (74%), 50% held a bachelor's degree and resided in northern Italian regions (70%). From a dietary regimen, most considered themselves to be omnivores (82%), followed by flexitarians (11%); a notable 85% had consumed plant-based burgers at least once in the past. Table 1 shows the sample characteristics.

This study was reviewed and approved by the Research Ethics Board of the University of Parma (Protocol number 0123745, 2022).

**Table 1**. Sample's characteristics (n= 62).

| Sample characteristic | Responses | Results (%) |
|---|---|---|
| **Gender** | Female | 64% |
| **Age (years)** | average±SD | 24.4±2.8 |
| **Education Status** | High School Diploma | 19% |
| | Bachelor | 50% |
| | Postgraduate program | 31% |
| **Employment Status** | Student | 74% |
| | Worker | 26% |

| | | |
|---|---|---|
| **Place of residence (Italy)** | North-East | 44% |
| | North-West | 26% |
| | Center | 6% |
| | South | 24% |
| **Diet** | Omnivore | 82% |
| | Flexitarian | 11% |
| | Veg*n | 5% |
| | Others | 2% |
| **Plant-based burger consumption** | Yes | 85% |

### 2.1.3.2 Procedure

Before starting the interview, the focus of the study, i.e., the purchase intent of plant-based burgers, was made clear to the participant.

The interview process consisted mainly of three parts. In the first part, the participants were administered a short survey including questions related to their socio-demographic characteristics, such as age, gender, education and employment status, and region of residence. They were also asked about their diet regimen, PBB consumption (previous experience), and their relationship with meat by using the Meat Attachment Questionnaire – MAQ (Graça et al., 2015). Specifically, the MAQ included 16 questions, with answers ranging from "strongly disagree (1) to "strongly agree" (5), which investigate different dimensions (i.e., hedonism, affinity, entitlement, and dependence) of consumers' bond towards meat consumption.

In the second part, as done in previous studies (e.g., Cerjak et al., 2014; Ghaffari et al., 2022), the interview process contained a projective technique (word association test). The participants were presented with the word of interest, "plant-based burger", and asked to mention the first meaning that came to their mind. This technique is useful for investigating consumer perception of food since the associations that initially occur may be the most relevant for consumers' purchasing decisions (Mesías and Escribano, 2018).

In the third part, the laddering procedure took place, including two stages: 1) elicitation of differences among products and 2) in-depth interviews using the so-called soft laddering, a semi-structured face-

to-face interview. In the first stage of the laddering interview, respondents are usually asked to identify the salient characteristics of a specific product. We elicited distinctions between products using the method of *Preference-Consumption Differences* (Reynolds and Gutman, 2001), which involves asking respondents to rank products according to their preference and provide justification for their choices. This method has been adopted in other food consumer studies (Crofton and Scannell, 2020; Sonne et al., 2012). Specifically, participants were provided with a set of printed pictures showing the front and back of the product package and the price of six PBBs. Then, interviewees were asked to rank the products in order of preference, from the one they would most likely buy to the one they would least likely buy. The six pictures (Figure A1) included a range of commercially available products representative of the PBB market available in Parma (Italy) at the time of the data collection. Out of the six products, we selected three PBBs that represented the "first generation" of plant-based burgers, which were mostly developed for vegetarians and vegans without the aim of mimicking meat attributes (Andreani et al., 2023), and three "new generation" PBBs, designed to be more similar to beef patties. In all pictures, the brand was blurred in order to eliminate the potential association with the brand's particular effect on the respondent.

*Laddering procedure*

Instead of using *hard laddering* (a written questionnaire), we preferred using *soft laddering*, which is suggested when there is a high or low involvement and experience with the product (Grunert and Grunert, 1995).

Considering that this was a hypothetical task (i.e., not an actual purchase), we first asked respondents to pretend they were at a supermarket and wanted to buy a PBB. This approach aimed at improving the effectiveness of eliciting cognitive structures by creating their associations while thinking of a realistic situation. After this initial attribute elicitation stage, participants were asked to justify why they chose that specific burger as the one they would most likely purchase: "You mentioned that you would buy this burger instead of the others. What is it, specifically, that makes it more desirable

compared to the others?". In this way, the laddering interviewing technique uses a product-driven stimulus as an information source to elicit consumer needs (van Kleef et al., 2005). Thus, the immediate responses that emerged from their choices were regarded as elements (concrete attributes) and used as the initial focus for the laddering interview. If a respondent started mentioning abstract attributes or consequences, a reverse laddering technique was applied to connect these to specific concrete product attributes, present on the packaging (Crofton and Scannell, 2020).

Successfully, in the second stage, the standard laddering question was posed: "Why is this element important for you?". This question was repeated repetitively until the entire sequence of attribute-consequence-value (A-C-V) was completed or until the respondent could no longer provide additional responses, as shown in Table 2. This questioning line was repeated for all motivations elicited for the most preferred.

The in-depth interviews were conducted by two interviewers trained by a team of researchers with practical experience in MEC concepts and laddering techniques. Each interview lasted between 30 and 45 minutes.

**Table 2.** Example of an excerpt of a laddering interview.

| Laddering questions and answers | Category | Code |
|---|---|---|
| **I:** You said that the presence of the spinach is important to you. Why is that? | A | Ingredient |
| **R:** Because it's a healthy ingredient. | A | Healthy |
| **I:** Why is it important to you to buy healthy products? | | |
| **R:** Because I care about my physical well-being. | C | I feel a sense of well-being |
| **I:** Why is your physical well-being important to you? | | |
| **R:** Because, when I'm well, I enjoy my life more. | V | Enhances my quality of life and security |
| **I:** Why is it important to you to enjoy your life? | | |
| **R:** Because it allows me to live a better life. | V | Achievement |
| **I:** Why is it important to you to live a better life? | | |
| **R:** Because. | | |

Note: I= interviewer; R= respondent. For the category: A= attribute, C= consequence, and V= value.

### 2.1.4 Data Analysis

The main steps for data analysis included the content analysis of the raw interview data into ladders, the generation of the score and implication matrixes, and the construction of the hierarchical value map (HVM).

First, all the interviews were tape-recorded and transcribed to facilitate the initial content analysis procedure (Crofton and Scannell, 2020; Polizer Rocha et al., 2019).

Second, a comprehensive analysis of every transcript was conducted to obtain a broad understanding of the various interviews. The individual verbatims of each respondent were broken down into 'chunks' of responses (distinguishable utterances). Next, during the content analysis, meaningful categories were identified in the interview responses and classified into laddering data, i.e., attributes, consequences, or values. The final aim was to have a list of 'content codes' (single words or phrases). To summarize the respondents' responses, similar content codes were combined under a single content code label. The goal was to classify, based on common sense, comparable answers, and to identify commonalities between statements that were elicited and use the same content code to express them (Miles and Rowe, 2003). To limit interpretation bias, two researchers reviewed and confirmed each content code identified in the initial coding analysis; when disagreement occurred, it was resolved through discussion.

Each ladder provided a hierarchy order of the elements classified into concrete and abstract attributes, functional and psycho-social consequences, and instrumental and terminal values (Reynolds and Gutman, 2001). The ladders were inserted into the online software LadderUX (LadderUX, n.d.), a tool that aids the quantitative analysis of laddering by creating the score and the implication matrix, and by developing the hierarchical value map. First, the ladder coding was condensed into a scoring matrix that compiles all ladders elicited from participants, i.e., rows connecting single categories of attributes, consequences, and values for each respondent.

As done by previous authors (e.g., Giovane da Silva et al., 2023), the chains were interpreted by classifying the final values with the terminal values outlined in Schwartz's theory (2017). First, each

participant can have multiple ladders (rows) (Miles and Rowe, 2003). Second, from this score matrix, the implication matrix, which is the basis for developing the HVM, was generated. This table, in which the content codes are represented both in the rows and in the columns, illustrates the connection frequency (i.e., the number of times two codes were linked to one another) among all the elements (A-C-V) for all individuals (aggregated level) (Zanoli and Naspetti, 2002). The links included both direct and indirect relationships. A direct relationship connects one content code directly to another (i.e., when these are adjacent); whereas an indirect link is referred to when one content code leads to another with one or more other content codes in between (Miles and Rowe, 2003).

As for the final step of the data analysis, implication matrices were computed to generate an HVM. This map provides a visual summary of the most important A-C-V content codes and the most frequently associated links between them (Crofton and Scannell, 2020). When generating an HVM, the selection of the cut-off level is one of the most important factors to consider (Barrena *et al.*, 2015). The cut-off level represents the minimum number of links (threshold) required between two elements to be considered in the HVM. Direct and indirect links between pairs of elements that exceed the cut-off are retained, while marginal links (links below the cut-off) are disregarded. Therefore, to reduce the complexity of the map, different cut-off levels were tested to find the optimal threshold, which is the one that retains the most information while being easy to interpret (Barrena et al., 2015; Reynolds and Olson, 2001). Usually, to have a representative and clear HVM it is recommended to keep two-thirds of the total connections among the categories (Reynolds and Gutman, 2001). Moreover, in soft laddering techniques, there are usually more links observed at lower levels of abstraction (i.e., attributes) compared to higher levels (i.e., values) as it is more difficult for the participants to suggest responses as the level of abstraction increases (Leppard et al., 2004). As a result, using the same cut-off point across all levels of abstraction might not be the best option. Therefore, as done in previous studies (Barrena and Sánchez, 2013; Cerjak et al., 2014), we used different cut-offs for each level of abstraction and respondents' group. As suggested in previous studies (Arsil et al., 2022; Reynolds

and Olson, 2001), a cut-off level of between 3 and 5 can be considered suitable for our sample size, representing approximately 60–70% of the active links.

In our study, the laddering process resulted in a total of 45 elements, generating 1463 links (625 direct links and 838 indirect links). However, to deeply explore consumers' motivations, implication matrixes and HVMs were created after segmentation analysis. Respondents were thus divided into several sub-groups and the above-described steps needed to develop an HVM were conducted for each sample segment. First, we split the overall sample based on respondent results (median level) for the four hedonistic items of the MAQ ("To eat meat is one of the good pleasures in life", "I love meals with meat", "I'm a big fan of meat", and "A good steak is without comparison"). Considering that we provided pictures of burgers resembling meat and other non-meat-like, we decided to use the hedonism dimension because it refers to pleasure gained from consuming meat. In such a manner, we obtained a group comprised of consumers showing a higher meat attachment level (n= 32) – i.e., those with a score equal to or higher than the median value – and another group (n= 30) with a lower meat attachment – i.e., those with a score lower than the median value. Consumers were also divided by gender (F=40; M= 22) and by the PBB they selected as the one they would most likely buy. Specifically, out of the 6 pictures shown to participants, 3 burgers resembled a meat burger patty (i.e., resembling the brownish beef mice color), whereas the remaining 3 were non-meat-like products, meaning burgers that do not remind beef mice (i.e., the burger patty was either orangish or greenish). Of 62 participants, 26 consumers chose a meat-like burger and 36 chose a non-meat-like product. All these segmentations were possible as a minimum of 20 respondents should be included in any single subgroup. The implication matrixes of the sample subgroups are reported in the Supplementary materials.

For every attribute, consequence, or value, centrality and abstractness indexes were computed to better understand the role of each element within the HVM structure (Barrena et al., 2015). First, we define the terms "out-degree" and "in-degree" which are important terms in the construction of these two indexes. The term "out-degree" describes the number of times an element (attribute, consequence,

or value) is the source of a link with other elements in the ladders; the out-degree of an item is equal to its row total in the implication matrix. Conversely, the term "in-degree" describes how many times a certain element (attribute, consequence, or value) is the end or received from other elements gathered in the ladders and corresponds to the column total of an element in the implication matrix (Miles and Rowe, 2003).

The centrality index (CI) is calculated as the ratio of in-degrees plus out-degrees of a specific item over the total number of active cells in the implication matrix. The CI serves as an indicator of the relative importance of a certain element within the structure; the higher the value, the more frequently the item is connected to other elements, which makes it one of the most central elements in the structure. The CI ranges from 0 (indicating that the A-C-V is not connected to any other A-C-V) to 1 (meaning that all connections within the HVM involve the A-C-V in question).

The abstractness ratio (AR) represents the degree to which concepts are primarily means (at the beginning of ladders) or ends (at the end of ladders) in the participants' mind and it is calculated as the in-degree over the sum of in-degree and out-degree. The AR ranges from 0, indicating a low abstractness ratio (i.e., a relatively concrete element) to 1, indicating a high abstractness ratio (i.e., a relatively abstract element). Table 3 presents the level of abstraction and descriptions of the 45 elements identified in this study, comprised of X attributes, X consequences, and x values.

**Table 3.** Attributes, consequences, and values associated with plant-based burgers.

| Level of abstraction | Code | Description |
|---|---|---|
| *Concrete attributes* | | |
| | Ingredient list | Presence of one or more specific ingredients (e.g., soy, spinach) |
| | Nutrition claim | Presence of a nutrition claim (e.g., "source of protein/fibers") |
| | Packaging | Packaging layout/design |
| | Vegan logo | Presence of the vegan logo |
| | Product appearance | Apparent color/shape/texture of the burger |
| | Sustainable claim | Presence of a sustainable claim (e.g., "100% CO2 compensation") |
| | Price | Price |
| | Packaging color | Packaging color (e.g., green) |
| | Transparent packaging | Transparent packaging (i.e., with a transparent film on top), which allows the consumer to see the actual product |

| | | |
|---|---|---|
| | Visible vegetables | The burger design shows there are one or more vegetables in it. |
| *Abstract attributes* | | |
| | Nutritional value | Good protein, fiber, or fat content |
| | Sensory attributes | It provides the idea of good sensory attributes (e.g., taste, texture) |
| | Captivating | Attractive product |
| | Healthy | It provides the idea of a healthy product |
| *Functional consequences* | | |
| | Appetizing and enjoyable to eat | It seems a tasty product |
| | It makes my purchases easier | Some aspects lead to easier and safer purchasing |
| | It supports me in consuming a complete meal | It comprises all the necessary micro- and macro-nutrients that are part of a complete meal |
| | It allows easy identification | It stands out because of its visual elements |
| | It reminds me of meat | There are one or more elements that recall a meat burger |
| | It saves me money | It provides the option to spend money on different things |
| | It allows me to see the product | It allows me to see the actual product inside the packaging |
| *Psycho-social consequences* | | |
| | It provides me with happiness and satisfaction | It allows me to realize my personal objectives |
| | I feel confident about what I eat | It provides me with confidence in the food I am consuming |
| | I feel I am eating sustainable food | The product is sustainable and respects the environment |
| | I am consuming a simple product | The product contains simple and natural ingredients |
| | I feel a sense of well-being | It allows me to practice sports and have a healthy body |
| *Instrumental values* | | |
| | I value a healthy planet | It supports environmental health, including both humanity and the ecosystem, which is critical to me |
| | Provides fun, pleasure, and enjoyment | It provides hedonic satisfaction |
| | Enhances my quality of life and security | It provides a sense of personal well-being |
| *Terminal values* | | |
| | Nature universalism | Preservation of the natural environment |
| | Hedonism | Pleasure and sensuous gratification |
| | Achievement | Personal success, living a life with no worries |
| | Personal security | Safety in one's immediate environment |

Note: Terminal values are adopted from Schwartz et al. (2012)

### 2.1.5 Results

#### 2.1.5.1 Word associations results

In the word association question, participants were asked the following: “When thinking of a plant-based burger, what is the first thing that comes into your mind?”. The free association revealed 110 elicited words. Out of 62 respondents, 2 provided four associations, 10 gave three associations, and

22 named two associations; the rest of the respondents (45%, n=28) could name only one association. Overall, meanings related to plant-based burgers were both positive and negative; however, among the associations mentioned by at least three participants, mostly positive concepts were identified– e.g., "health" and "healthy planet" – and only one negative concept (i.e., "less tasty") was found. The results of the word association question are reported in Table 4.

**Table 4**. Top 10 most cited words in the word association task.

| Associations | Number of answers |
|---|---|
| Vegetables | 17 |
| Health | 9 |
| Meat reduction | 8 |
| Sustainability | 5 |
| Meat substitution | 5 |
| Familiarity | 5 |
| Green | 5 |
| Something new | 3 |
| Less tasty | 3 |
| Healthy planet | 3 |

#### 2.1.5.2 Laddering results

The word association task allowed not only an introduction to the topic of the interview but also a preliminary investigation of consumers' perception of plant-based burgers. However, a more structured and cognitive approach was used during the laddering interviews. The results of this phase are represented through HVMs. Several maps were created for different groups: female vs. male, consumers with high vs. low meat attachment levels, and respondents who opted for a meat-like vs. a non-meat-like burger.

*Females vs. Males*

The A-C-V and the respective abstractness ratio (AR) and centrality index (CI) of females (n=40) and males (n=22) are represented in Table 5 and Table 6, respectively, while their HVMs are reported in Figur A2 and Figure A3, respectively. Both the females' and males' maps were developed by using the following cut-off levels: 4 for concrete and abstract attributes and functional and psycho-social

consequences, and 3 for instrumental and terminal values. These cut-off levels ensured clear and representative HVMs for both groups.

Using these cut-offs, the female HVM accounts for 23 content codes (10 A, 8 C, and 5 V), which represented 78.3% of all links (1463). For males, the map includes 19 content codes (7 A, 7 C, 5 V), representing 71.12% of all links. Thus, the HVM for females is more attribute-rich, with 3 more attributes than the males' map, these being "visible vegetables", "nutrition claim", and "packaging color". The remaining attributes are similar in both maps: "ingredients list", "packaging", "price", "product appearance", "nutritional value", "sensory attributes", and "healthy". In both groups, the most important concrete attribute was the "ingredient list" (Female, CI = 0.05 | Male, CI = 0.03); however, "sensory attributes" is the most relevant abstract attribute for females (CI = 0.06), whereas being "healthy" is the key one for males (CI = 0.06). Also, the females' map has a higher number of consequences than the males'.

In addition, along with 6 consequences that are similar in both groups ("appetizing and enjoyable to eat", "it allows an easy identification", "I feel a sense of well-being", "it saves me money, "it reminds me of meat", and "it provides me with happiness and satisfaction"), "it makes my purchases easier" is present in the males' map only, whereas "I feel confident about what I eat" and "it supports me in consuming a complete meal" can be found in the females' HVM only. In line with the key attribute ("sensory attributes" for females and being "healthy" for males), "appetizing and enjoyable to eat" is the most important consequence for females (CI = 0.07), whereas males' key consequence is "I feel a sense of well-being" (CI = 0.06).

Finally, the same values, with similar centrality indexes, are identified between groups, with the most relevant terminal value being "hedonism" (Female, CI = 0.06 | Male, CI = 0.07) for both groups. Finally, an additional difference between the two groups is the presence of a stand-alone pathway in the males' map, which links the "price" attribute to "saving money", which "provides happiness and satisfaction", and finally leads to living a life with no worries ("achievement"). On the contrary, for

females, the “achievement” value can be reached also starting from different consequences and/or attributes.

**Table 5.** Attributes, consequences, and values of female consumers (n= 40).

| Codes | AR | CI |
|---|---|---|
| *Attributes* | | |
| Ingredients list | 0 | 0.05 |
| Nutrition claim | 0 | 0.01 |
| Packaging | 0 | 0.02 |
| Price | 0 | 0.01 |
| Product appearance | 0 | 0.03 |
| Nutritional value | 0 | 0.01 |
| Sensory attributes | 0.25 | 0.06 |
| Packaging color | 0.25 | 0.01 |
| Healthy | 0.26 | 0.05 |
| Visible vegetables | 0.27 | 0.02 |
| *Consequences* | | |
| It supports me in consuming a complete meal | 0.29 | 0.01 |
| It saves me money | 0.33 | 0.02 |
| It allows easy identification | 0.40 | 0.05 |
| It reminds me of meat | 0.40 | 0.02 |
| I feel a sense of well-being | 0.47 | 0.05 |
| Appetizing and enjoyable to eat | 0.48 | 0.07 |
| I feel confident about what I eat | 0.55 | 0.03 |
| It provides me with happiness and satisfaction | 0.67 | 0.02 |
| *Values* | | |
| It enhances my quality of life and security | 0.72 | 0.11 |
| It provides fun, pleasure, and enjoyment | 0.73 | 0.12 |
| Achievement | 1 | 0.02 |
| Hedonism | 1 | 0.06 |
| Personal security | 1 | 0.05 |

Note: CI= Centrality Index; AR= Abstractness Ratio.

**Table 6.** Attributes, consequences, and values of male consumers (n= 22).

| Codes | AR | CI |
|---|---|---|
| *Attributes* | | |
| Ingredients list | 0 | 0.03 |
| Packaging | 0 | 0.03 |
| Price | 0 | 0.01 |
| Product appearance | 0 | 0.03 |
| Nutritional value | 0 | 0.01 |
| Sensory attributes | 0.24 | 0.03 |
| Healthy | 0.25 | 0.06 |
| *Consequences* | | |
| It saves me money | 0.33 | 0.02 |
| It makes my purchases easier | 0.38 | 0.04 |
| It allows easy identification | 0.40 | 0.03 |
| It reminds me of meat | 0.42 | 0.05 |
| Appetizing and enjoyable to eat | 0.42 | 0.05 |
| I feel a sense of well-being | 0.50 | 0.06 |
| It provides me with happiness and satisfaction | 0.67 | 0.02 |
| *Values* | | |
| It provides fun, pleasure, and enjoyment | 0.72 | 0.13 |
| It enhances my quality of life and security | 0.75 | 0.10 |
| Achievement | 1 | 0.01 |
| Hedonism | 1 | 0.07 |
| Personal security | 1 | 0.05 |

Note: CI= Centrality Index; AR= Abstractness Ratio.

*Consumers with high vs. low meat attachment levels*

Figure A4 and Figure A5 represent the HVMs for respondents who showed a high meat attachment (HMA, n= 32) and a low meat attachment (LMA, n= 30) level, respectively. Specifically, HMA consumers were comprised of half females (n= 16) and half males (n= 16), whereas LMA consumers were mostly (80%) females (Female= 24, Male= 6).

In order to keep two-thirds of the total connections, thus ensuring clear, but representative HVMs, the following cut-off levels were adopted: for HMA consumers, a 5-cut-off level was used for concrete and abstract attributes, 4 for functional and psycho-social consequences, and 3 for instrumental and terminal values; for LMA participants, a 4-cut-off level was used attributes and

consequences, and a 3-cut-off level was used for values. These cut-offs for HMA consumers led to 22 content codes (9 A, 8 C, 5 V) and captured 79.71% of all links (1463). On the contrary, the HVM of LMA respondents included 10 A, 11 C, and 6 V, for a total of 25 content codes, and represents 74.15% of all links.

When examining the dominant contents codes for both groups, the top-5 most important attributes are similar between HMA and LMA consumers, namely "sensory attributes" (HMA, CI = 0.05 | LMA, CI =0.05), "healthy" (HMA, CI = 0.05 | LMA, CI =0.05), "ingredients list" (HMA, CI = 0.04 | LMA, CI =0.04), "product appearance" (HMA, CI = 0.03 | LMA, CI =0.03), and "packaging" (HMA, CI = 0.03 | LMA, CI =0.02). Similarly, "price" (HMA, CI = 0.01 | LMA, CI =0.01) and "nutritional value" (HMA, CI = 0.01 | LMA, CI =0.01) are the less important ones in both groups. However, 2 attributes can be identified in the HMA maps only – "packaging color" and "nutrition claim" – and 3 attributes can be found in the LMA map only – "captivating", visible vegetables", and the "vegan label".

For consequences, the LMA map has three more elements than the HMA one: "it supports me in consuming a complete meal", "I feel I am eating sustainable food", and "I am consuming a simple product". The remaining consequences, with slightly different CI, are present in both maps: "appetizing and enjoyable to eat" (HMA, CI = 0.06 | LMA, CI =0.06), "I feel a sense of well-being" (HMA, CI = 0.06 | LMA, CI =0.05), "it allows an easy identification" (HMA, CI = 0.05 | LMA, CI =0.03), "it reminds me of meat" (HMA, CI = 0.04 | LMA, CI =0.02), "it saves me money" (HMA, CI = 0.03 | LMA, CI =0.02), "it provides me with happiness and satisfaction" (HMA, CI = 0.03 | LMA, CI =0.02), "it makes my purchases easier" (HMA, CI = 0.02 | LMA, CI =0.03), and "I feel confident about what I eat" (HMA, CI = 0.02 | LMA, CI =0.03). Finally, the main difference in terms of values is the concept of the preservation of the natural environment ("Nature universalism"), which is present in the LMA map only. Because of the selected cut-off level, the map does not show the starting point attribute of this pathway. However, examining the chains of the participants mentioning this value, it was possible to retrieve the starting points (concrete attributes), which were: the presence of the "vegan logo", a "sustainable claim", or the "packaging".

Another difference that can be highlighted from the HVMs of the two groups under investigation is the presence – in the HMA consumers' map only – of the same stand-alone pathway present in the males' map ("price" (A) → "saving money" (C) → "provides happiness and satisfaction" (C) → "achievement" (V)). In the LMA consumers' map, "achievement" can be reached also through different means. Part of this difference – which follows the same pattern highlighted in the genders-based HVMs – could be explained by the fact that the HMA sample was comprised of half females and half males, whereas the LMA sample was mostly represented by females (80%, n= 24), who did not show this dominant pathway in their HVM.

Tables including the CI and AR for both HMA and LMA consumers are reported in Table 7 and Table 8, respectively.

**Table 7.** Attributes, consequences, and values of HMA consumers (n= 32).

| Codes | AR | CI |
|---|---|---|
| *Attributes* | | |
| Ingredients list | 0 | 0.04 |
| Nutrition claim | 0 | 0.0.1 |
| Packaging | 0 | 0.03 |
| Price | 0 | 0.01 |
| Product appearance | 0 | 0.03 |
| Nutritional value | 0 | 0.01 |
| Packaging color | 0.19 | 0.02 |
| Sensory attributes | 0.25 | 0.05 |
| Healthy | 0.25 | 0.05 |
| *Consequences* | | |
| It saves me money | 0.33 | 0.03 |
| It allows easy identification | 0.5 | 0.05 |
| It makes my purchases easier | 0.41 | 0.02 |
| It reminds me of meat | 0.4 | 0.04 |
| Appetizing and enjoyable to eat | 0.46 | 0.06 |
| I feel a sense of well-being | 0.48 | 0.06 |
| I feel confident about what I eat | 0.54 | 0.02 |
| It provides me with happiness and satisfaction | 0.67 | 0.03 |
| *Values* | | |
| It enhances my quality of life and security | 0.73 | 0.1 |
| It provides fun, pleasure, and enjoyment | 0.73 | 0.14 |
| Achievement | 1 | 0.02 |
| Hedonism | 1 | 0.07 |

| | | |
|---|---|---|
| Personal security | 1 | 0.05 |

Note: CI= Centrality Index; AR= Abstractness Ratio.

**Table 8.** Attributes, consequences, and values of LMA consumers (n= 30).

| Codes | AR | CI |
|---|---|---|
| *Attributes* | | |
| Ingredients list | 0 | 0.04 |
| Packaging | 0 | 0.02 |
| Price | 0 | 0.01 |
| Product appearance | 0 | 0.03 |
| Vegan label | 0 | 0.01 |
| Nutritional value | 0 | 0.01 |
| Captivating | 0.25 | 0.02 |
| Sensory attributes | 0.25 | 0.05 |
| Healthy | 0.27 | 0.05 |
| Visible vegetables | 0.28 | 0.02 |
| *Consequences* | | |
| It supports me in consuming a complete meal | 0.29 | 0.02 |
| It saves me money | 0.33 | 0.02 |
| It allows easy identification | 0.38 | 0.03 |
| I feel I am eating sustainable food | 0.38 | 0.01 |
| It makes my purchases easier | 0.42 | 0.03 |
| It reminds me of meat | 0.44 | 0.02 |
| Appetizing and enjoyable to eat | 0.47 | 0.06 |
| I feel a sense of well-being | 0.48 | 0.05 |
| I am consuming a simple product | 0.5 | 0.01 |
| I feel confident about what I eat | 0.57 | 0.03 |
| It provides me with happiness and satisfaction | 0.67 | 0.02 |
| *Values* | | |
| It enhances my quality of life and security | 0.73 | 0.12 |
| It provides fun, pleasure, and enjoyment | 0.73 | 0.11 |
| Achievement | 1 | 0.02 |
| Hedonism | 1 | 0.06 |
| Nature universalism | 1 | 0.01 |
| Personal security | 1 | 0.06 |

Note: CI= Centrality Index; AR= Abstractness Ratio.

*Meat-like vs. non-meat-like products*

The sample was also divided based on the product respondents chose as the one they would most likely buy. Twenty-six participants chose a product that resembled a meat burger patty (i.e.,

resembling the brownish beef mice color) and thirty-six chose a non-meat-like product, meaning burgers that do not remind beef mice (i.e., the burger patty was either orangish or greenish). This first group included a fair distribution in gender (Female= 12, Male= 14), whereas participants who chose a non-meat-like product were mainly (78%) females (Female= 28, Male= 8).

To develop the HVMs of these two groups different cut-off levels were needed to keep two-thirds of the total connections and ensure clear, representative HVMs. Specifically, for consumers who chose a more meat-like burger, the following cut-off values were established: 4 for concrete attributes and 3 for all remaining elements (abstract attributes, functional and psycho-social consequences, and instrumental and terminal values). The HVM developed from these cut-offs (Figure A6) represents 71.12% of all links (1463), with 24 content codes (8 A, 10 C, 6 V). For consumers who chose a non-meat-like burger, the following cut-offs were used: 5 for concrete and abstract attributes, 4 for functional and psycho-social consequences, and 3 for instrumental and terminal values. Using these cut-offs, the HVM (Figure A7) includes 20 content codes (9 A, 6 C, 5 V) and represents 78.09% of all links.

Table 9 and Table 10 show the CI and AR of the different elements (A-C-V) per group. Specifically, for people who chose a meat-like burger, the most important concrete attribute is the "product appearance" (CI = 0.05), whereas for the other group is the "ingredient list" (CI = 0.05), which does not appear in the meat-like group's map. In addition, the key abstract attributes for consumers who opted for a non-meat-like product are "sensory attributes" (CI = 0.07) and "healthy" (CI = 0.07), which are less relevant to participants who chose a burger that resembled meat (CI = 0.02). In terms of consequences, the latter group shows four consequences – two being the most relevant one – that are not considered by consumers who chose the non-meat-like burger, these being "it reminds me of meat" (CI = 0.08), "it makes my purchases easier" (CI = 0.05), "I feel I am eating sustainable food" (CI = 0.02), and "it allows me to see the product" (CI = 0.01). Fewer differences are highlighted for values, as both instrumental and terminal values are similar between the groups, with slightly different values for AR and CI. The only difference is the presence of the instrumental value "I value a healthy

planet" and the terminal value "nature universalism", which are part of the HVM of consumers who chose a meat-like burger only.

In addition, while the HVM of the interviewees who chose a non-meat-like burger is more interconnected, the HVM of the other group presents two stand-alone pathways. The first one connects "price" with the idea of "saving money", which "provides happiness and satisfaction" and leads to a sense of success and living a life with no worries ("achievement"). The second stand-alone pathway links the idea of "feeling I am eating sustainable food" to "I value a healthy planet", to the concept of the preservation of the natural environment. However, the cut-off used does not allow for retracing the concrete attributes that led to this link, which were the presence of the "vegan logo", a "sustainable claim", or the "packaging color". In addition, the defined cut-off level does not show the concrete attribute associated with the "it allows me to see the product" consequence, which leads to "feeling confident about what I eat" and "it enhances my quality of life", and, finally, to the "personal security" value. From the participants' chains, it was possible to identify the "transparent packaging" attribute as the starting point of this pathway of the HVM.

**Table 9.** Attributes, consequences, and values of consumers who chose a meat-like burger (n= 26).

| Codes | AR | CI |
|---|---|---|
| *Attributes* | | |
| Packaging | 0 | 0.04 |
| Price | 0 | 0.02 |
| Product appearance | 0 | 0.05 |
| Nutritional value | 0 | 0.01 |
| Captivating | 0.25 | 0.01 |
| Sensory attributes | 0.25 | 0.02 |
| Healthy | 0.25 | 0.02 |
| Packaging color | 0.25 | 0.03 |
| *Consequences* | | |
| It saves me money | 0.33 | 0.04 |
| It makes my purchases easier | 0.37 | 0.05 |
| Appetizing and enjoyable to eat | 0.38 | 0.04 |
| It allows easy identification | 0.41 | 0.04 |
| It reminds me of meat | 0.41 | 0.08 |
| It allows me to see the product | 0.43 | 0.01 |
| I feel I am eating sustainable food | 0.47 | 0.02 |

| | | |
|---|---|---|
| I feel a sense of well-being | 0.48 | 0.03 |
| I feel confident about what I eat | 0.62 | 0.02 |
| It provides me with happiness and satisfaction | 0.67 | 0.04 |
| | | |
| *Values* | | |
| It provides fun, pleasure, and enjoyment | 0.71 | 0.15 |
| It enhances my quality of life and security | 0.74 | 0.08 |
| I value a healthy planet | 0.78 | 0.01 |
| Achievement | 1 | 0.03 |
| Hedonism | 1 | 0.07 |
| Nature universalism | 1 | 0.01 |
| Personal security | 1 | 0.04 |

Note: CI= Centrality Index; AR= Abstractness Ratio.

**Table 10.** Attributes, consequences, and values of consumers who chose a non-meat-like burger (n= 36).

| Codes | AR | CI |
|---|---|---|
| *Attributes* | | |
| Ingredients list | 0 | 0.05 |
| Packaging | 0 | 0.02 |
| Nutritional claim | 0 | 0.01 |
| Price | 0 | 0.01 |
| Product appearance | 0 | 0.02 |
| Nutritional value | 0 | 0.01 |
| Sensory attributes | 0.25 | 0.07 |
| Healthy | 0.26 | 0.07 |
| Visible vegetables | 0.28 | 0.02 |
| | | |
| *Consequences* | | |
| It saves me money | 0.33 | 0.01 |
| It allows easy identification | 0.39 | 0.04 |
| I feel a sense of well-being | 0.48 | 0.07 |
| Appetizing and enjoyable to eat | 0.49 | 0.07 |
| I feel confident about what I eat | 0.52 | 0.03 |
| It provides me with happiness and satisfaction | 0.67 | 0.02 |
| | | |
| *Values* | | |
| It provides fun, pleasure, and enjoyment | 0.73 | 0.12 |
| It enhances my quality of life and security | 0.73 | 0.12 |
| Achievement | 1 | 0.02 |
| Hedonism | 1 | 0.06 |
| Personal security | 1 | 0.06 |

Note: CI= Centrality Index; AR= Abstractness Ratio.

### 2.1.6 Discussion

By applying the means-end chains, our research contributes to new insights to better understand the factors influencing the acceptance of PBMAs by revealing the basis for consumers' motivations to purchase PBBs. First, we define the most important relationships between product attributes, their benefits, and the corresponding consumer values that drive their choices. Second, this study considers individual traits (gender and attachment to meat consumption) and product choice (meat-like burgers vs. non-meat-like burgers) as variables for market segmentation. Although we noticed similarities in attributes, consequences, and values among the different groups, important differences emerged in their respective chains (i.e., how the ladders were formed) and their strength.

When comparing HVMs for females and males, we noticed both similarities and differences. In the females' map, we found attributes such as "visible vegetables", "nutrition claim", and "packaging color", which were not present in the males' map. Additionally, when focusing on the consequences, the female group prioritized unique elements, such as confidence in eating and meal completeness. In the male group, the link between "it reminds of meat" and "it provides fun, pleasure, and enjoyment" is stronger than in the female group. Nonetheless, common values emerged in both groups, namely hedonism, personal security, and achievement. In the literature (Giacalone et al., 2022), gender association towards plant-based is still debatable and it could vary based on the extent to which such products are developed to mimic meat.

When comparing the HVM results of the respondents with high and low levels of the meat attachment subscale related to the hedonism dimension (i.e., when meat is represented as a source of pleasure) (Graça et al., 2015), the main drivers for choosing PBMAs showed distinct patterns. This confirms that the level of meat attachment is strongly linked with the intention to try plant-based alternatives (Chen, 2023; Circus and Robison, 2019). First, even if both HMA and LMA consumer groups prioritized sensory qualities, healthiness, and product appearance, only the LMA group (made mostly by females) included the presence of visible vegetables and the vegan label as concrete attributes.

Second, this latter group is the only one to have "Nature universalism" as a final value. Past literature (Giacalone et al., 2022; Saini et al., 2024) found that environmental sustainability is a frequently cited driver for adopting PBMAs. More specifically, our findings suggest that individuals with a lower attachment to meat might be more environmentally conscious than consumers with a positive bond towards meat consumption.

When it comes to product appearance, and as previous research suggested (Giezenaar et al., 2024; Michel et al., 2021), differences exist between PBMAs that are perceived to be 'somewhat similar to meat' and those that do not aim to imitate conventional meat. Also in our study, different attributes, consequences, and values elicitation emerged based on whether the burger represented the so-called "first" or "new" generation (Andreani et al., 2024). Not surprisingly, participants who preferred the meat-like burgers (mostly males) during the ranking task reported the product appearance as the main attribute, which was related to "being appetizing and enjoyable" and, consequently, to the idea of meat. This result is in line with previous research (e.g., Giezenaar et al. 2024) showing that meat-like samples were associated with positive emotions such as "happy" and "pleasant". Conversely, our results found that consumers who preferred non-meat-like products (i.e., made with whole ingredients as the main protein source, such as legumes and spinach) valued the product's appearance since it allowed them to see the vegetables in the burgers, making them feel confident about the ingredients. Despite different consequences, the final values for both groups were the same: the products were linked to hedonism and personal security. However, interestingly, the value "Nature Universalism" was only present in the HVM of the group who preferred the meat-like burgers, suggesting that consumers may associate the consumption of PBBs recalling the traditional meat product to a sense of achievement in reducing the environmental impact of their meat intake (Saini et al., 2024).

Along with the above-discussed differences, some similarities emerged across HVMs. Specifically, in each of the six HVMs, the price attribute was always present as a choice motivator, even though €/kg amount slightly varied across products. This could indicate that the price range in which these products are currently sold is attractive and is not considered a barrier. This is in line with previous

research (Michel et al., 2021) that suggested that if the price of meat alternatives is competitive with their animal counterparts, there is a greater chance of successful adoption of these products.

Finally, this research deepened the understanding of how consumers perceive PBBs and the main motivators to choose a product. In turn, our results confirmed that both non-sensory attributes (e.g., nutritional information) and expected sensory characteristics (e.g., product appearance) are important to the market success of PBMAs (Andreani et al., 2024). Interestingly, while some values such as personal security (health) and hedonism (product liking) are always cited as reasons for purchasing a plant-based burger, environmental motives emerged only for specific consumer categories (i.e., for those less attached to meat and for consumers who chose a meat-like burger).

### 2.1.7 Policy and Business Implications

Based on our study on consumer preferences for PBBs, several managerial insights for marketers and policy implications are proposed to increase the adoption of plant-based diets. Our findings highlight the need for tailor-made communication campaigns due to the diversification of consumer segments based on gender, attachment to meat, and similarity to conventional products.

First, our results suggest that businesses should consider gender-specific preferences. Female consumers give more importance to visible vegetables and nutritional claims, so packaging should display such information accordingly. On the other hand, male consumers prefer packaging that supports the purchasing process, especially by emphasizing the qualities of the product that resemble meat (e.g., appearance). However, for both groups, marketing actions should highlight the health benefits of PBMAs as the reasons for consuming such products are closely associated with well-being and quality of life, in light of the growing trends in health concerns (Saini et al., 2024).

Second, from a business perspective, for consumers with high meat attachment levels, it is critical to emphasize attributes such as meat-like appearance by showing images of the products or using transparent packaging. These aspects will connect consumers with a familiar meat product and

reassure them about the characteristics of the burger, which are linked to high liking expectations (Giacalone et al., 2022). Conversely, for those with low meat attachment levels, marketing strategies should pay particular attention to the packaging by including the communication of sustainability and health benefits, as well as the displaying of the vegan label, as these were identified as the main drivers of choice for this consumer segment.

Third, product development strategies for consumers who are not looking for meat-like burgers should include visible vegetables and information on the main vegetables used. On the other hand, for consumers with a high meat attachment level, resembling the appearance of a beef burger is likely to reinforce the personal value of hedonism. Thus, for this target group marketers may provide sensory sampling to showcase that their products taste similar to regular meat (Saini et al., 2024).

As a result, despite the health and environmental benefits associated with PBMAs – which could be conveyed also through proper labeling systems (e.g., claims) – some individuals may not accept these new products because they are still seeking the unique look, taste, and texture that come with animal-based products (Andreani et al., 2024; Sogari et al., 2024). In line with this, a study by Giezenanar et al. (2024) showed that negative emotions were associated with sensory attributes such as “green color”, “green vegetables”, and “visible grains and herbs/vegetables”. Therefore, the appearance of the burger, already visible at the packaging level, is an important factor of choice as it creates expectations. In turn, at the attribute level, one strategy could be to develop PBMAs using ingredients that provide similar sensory properties as their animal counterparts; whereas, at a more abstract level (consequences and values) communication strategies should emphasize hedonic pleasure by explicitly referencing meat (Andreani et al., 2024; Giezenaar et al., 2024). Creating positive expectations at the packaging level when purchasing the product could increase the willingness to try PBMAs.

Nevertheless, our results showed that some consumers are looking for PB products that do not mimic meat. Therefore, companies should also consider this target group by focusing on the list of ingredients, as this attribute is considered important during the choice.

From a policy standpoint, our research findings may help legislators develop policies that encourage plant-based diets to reduce meat consumption. First, given that product choice is primarily linked with health values, policymakers should ensure clear and proper communication on the nutrition profile (e.g., nutrition claims). Regarding this aspect, the packaging should also provide clear information on the ingredients list (e.g., through the use of claims or a clean label) to reassure consumers of the use of familiar ingredients. In addition to promoting nutrition aspects and health benefits, sustainability about the positive impact of reducing meat consumption could be emphasized. This information – for instance, through communication and education campaigns – should be addressed not only to consumers with low meat attachment levels but also to those who are currently more meat lovers and perhaps do not associate animal farming with environmental consequences. Finally, by studying consumer preferences for PBMAs currently available on the market, practitioners and policymakers can gain a better understanding of which consumers' values are in line with the product attributes, and as a result, increase the adoption of plant-based dietary lifestyles.

### 2.1.8 Strengths, limitations, and future research

Compared to previous works investigating consumer acceptance of general meat alternatives (without specifying the type of food, e.g., burgers, sausages, mince, cutlet), one of the strengths of our study is the focus on a specific PBMA category (plant-based burgers) and the uncovering of consumer preferences for real product packaging available on the market. Another strength of our research is the use of a means-end chain approach, which links concrete product attributes to the final values driving food choices. The means-end chain approach was chosen as the main method as, when consumers are at the point of purchase, their preferences are primarily driven by the information they read or observe on the packaging.

In addition, our results confirm the use of the MAQ (Circus and Robison, 2019; Graça et al., 2015) to be an effective tool for predicting different behaviors toward PBMAs among consumers. Thus, it is recommended to use such a tool in studies focusing on meat consumption and meat reduction.

Even though our study provides novel findings, some limitations occur and create opportunities for further investigation. First, given the type of the study (individual interviews), social desirability biases, that is the propensity to respond in a way that conforms to cultural norms, could have arisen. Second, the hypothetical nature of this study is a limitation as it investigates respondents' self-reported intention to buy plant-based burgers rather than their actual purchasing behavior. Future studies should consider measuring purchases in a supermarket or restaurant, and provide sample products to measure whether sensory expectations are truly met. Product satisfaction after trying PBMAs once is crucial to repurchase the product and thus for the overall market success (Giezenaar et al., 2024). Finally, we used a convenience sample and, thus, it was predominantly composed of young Italian consumers, with a high education level, and mostly omnivores. All these elements limit the generalizability of the results. Next studies should consider more balanced samples to explore potential differences among socio-demographics, including the impact of diets (e.g., veg*ns vs meat eaters), and cultural settings.

### 2.1.9 Conclusions

The increasing availability of PBMAs in the retail market, the investments made in recent years, and the efforts to improve the overall product quality are all elements that suggest that this market will likely continue to grow. To support this vibrant industry, the results of this study showed potential implications for manufacturers and policy-makers advocating for a reduction in meat consumption.

By using the MEC theory and laddering technique, we were able to investigate what consumers consider when choosing PBMAs and, consequently, the main relevant factors during the purchasing process. Specifically, we found similarities across consumer segments, which confirm the critical role

of both non-sensory attributes (e.g., nutritional information) and expected sensory characteristics (e.g., product appearance). Nevertheless, our findings also showed some heterogeneity in the drivers that lead consumers to purchase plant-based products. Thus, successful marketing strategies for PBBs should be developed considering different target groups based on demographic and attitudinal variables in order to meet their specific motivations.

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## Appendix

**Figure A1.** The 6 burgers used in the study.

a) Non-meat-like burger


Prezzo per confezione: 2.69€
Prezzo al kg: 15.5 €

Source: own elaboration.

b) Non-meat-like burger


Prezzo per confezione: 2.84€
Prezzo al kg: 15.7 €

Source: own elaboration.

c) Non-meat-like burger


Prezzo per confezione: 2.93€
Prezzo al kg: 18.3 €

Source: own elaboration.

d) Meat-like burger


Prezzo per confezione: 1.99€
Prezzo al kg: 13.2 €

Source: own elaboration.

e) Meat-like burger


Prezzo per confezione: 1.99€
Prezzo al kg: 13.2 €

Source: own elaboration.

f) Meat-like burger

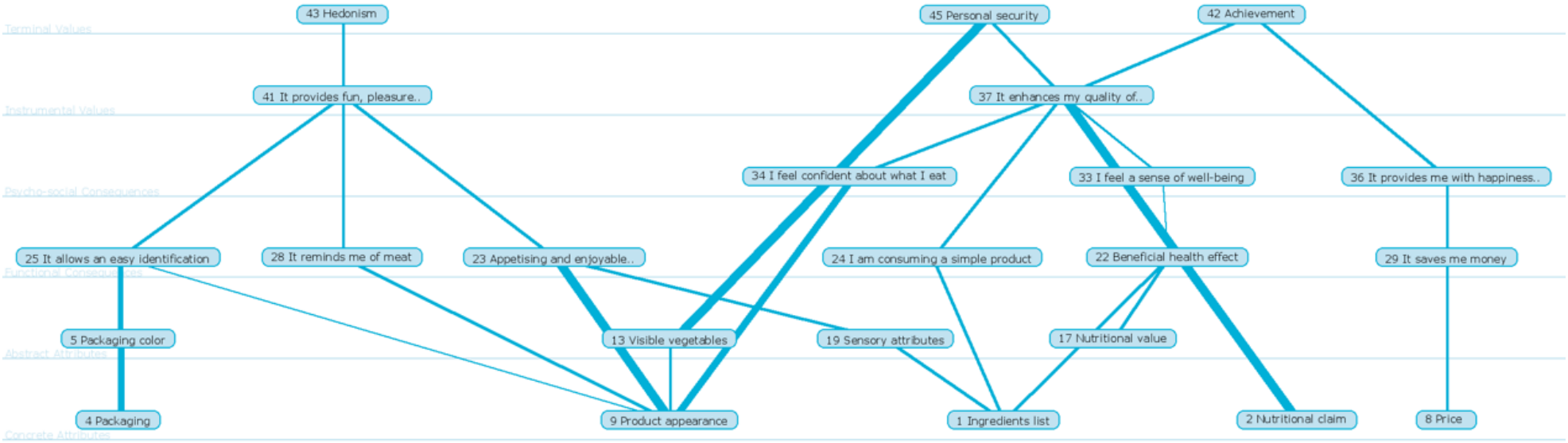




Prezzo per confezione: 3.59€
Prezzo al kg: 17.95€

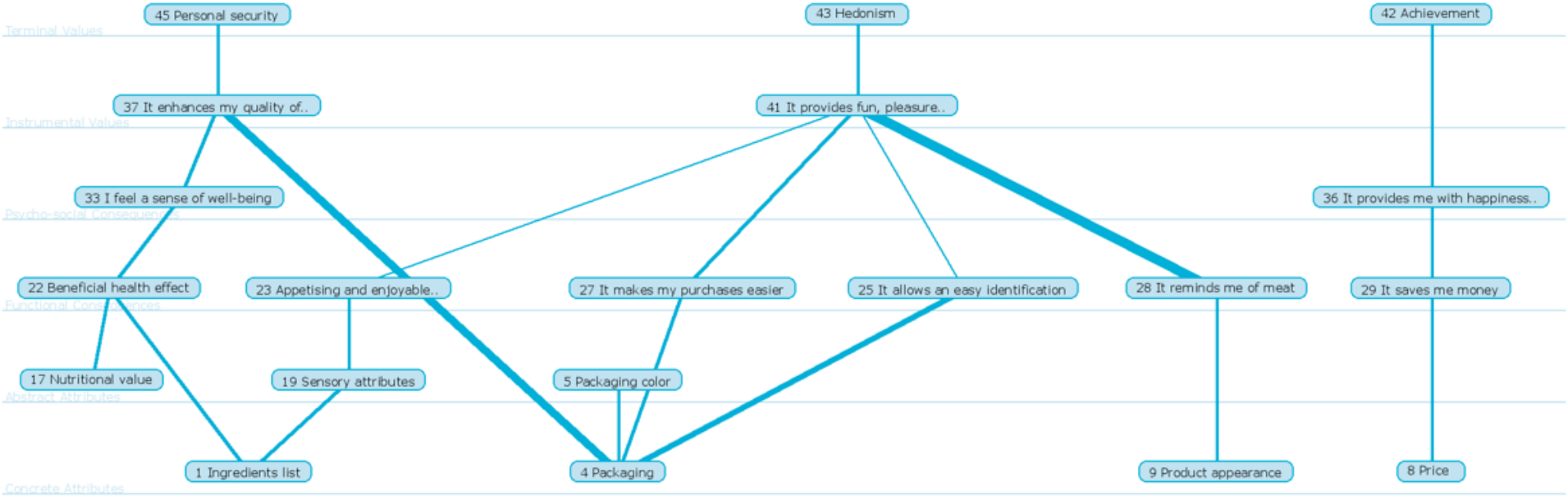
Source: own elaboration.

**Figure A2.** Hierarchical Value Map of female consumers (n= 40).



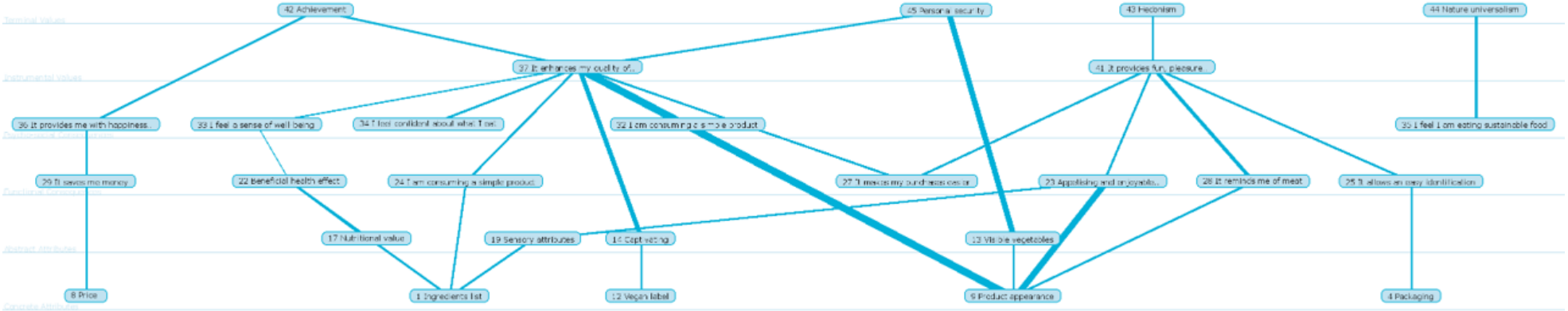

Note: The HMV was developed using Ladderux (https://ladderux.org/)
The thicker the line between two elements in the means-end chain, the higher the link strength.
Source: ladderux.org

**Figure A3.** Hierarchical Value Map of male consumers (n= 22).



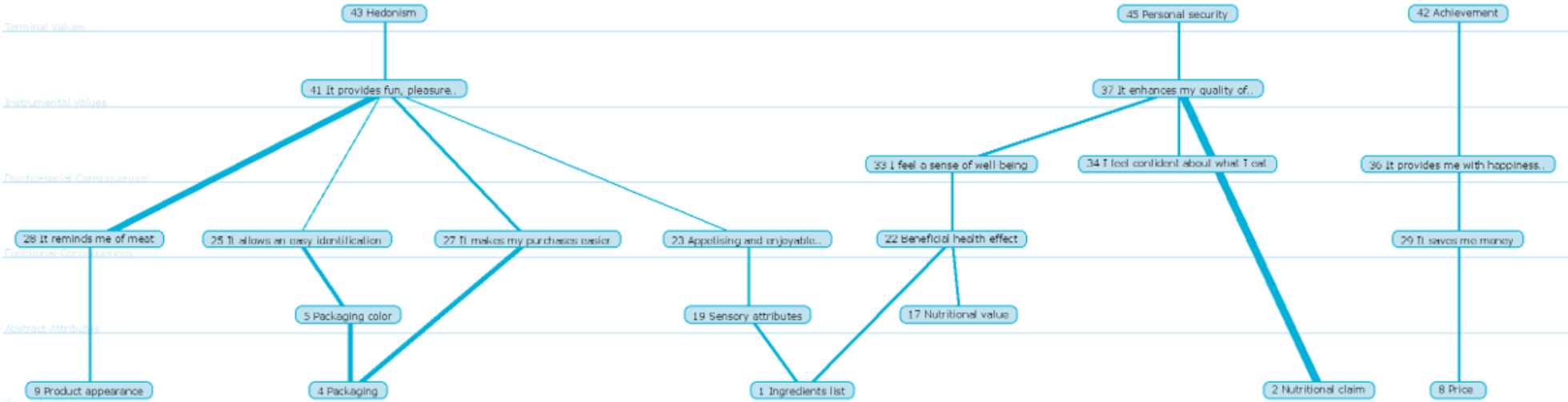

Note: The HMV was developed using Ladderux (https://ladderux.org/)
The thicker the line between two elements in the means-end chain, the higher the link strength.
Source: ladderux.org

**Figure A4.** Hierarchical Value Map of high meat attachment consumers (n= 32).



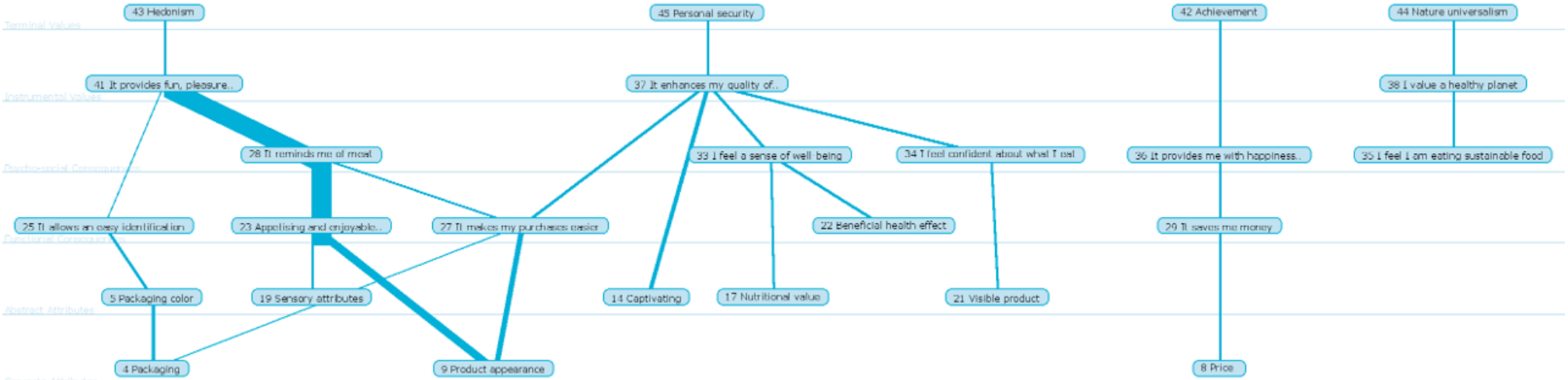

Note: The HMV was developed using Ladderux (https://ladderux.org/)
The thicker the line between two elements in the means-end chain, the higher the link strength.
Source: ladderux.org

**Figure A5.** Hierarchical Value Map of low meat attachment consumers (n= 30).



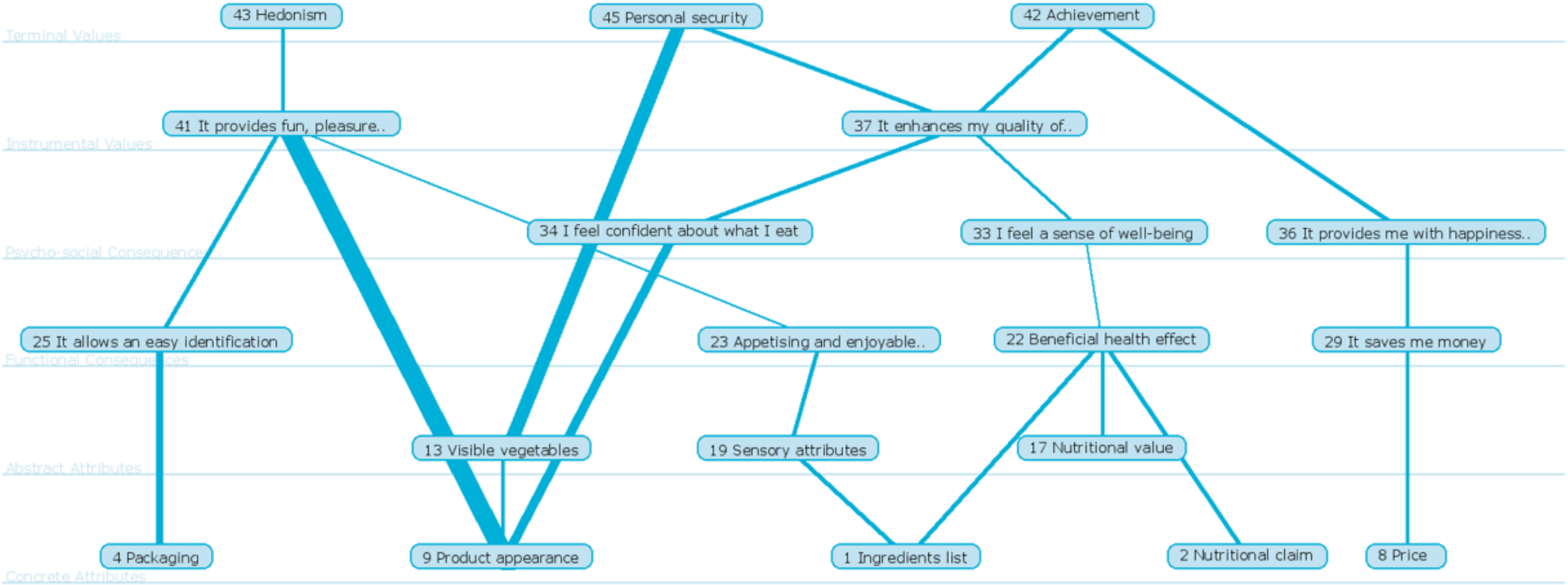

Note: The HMV was developed using Ladderux (https://ladderux.org/)
The thicker the line between two elements in the means-end chain, the higher the link strength.
Source: ladderux.org

**Figure A6.** Hierarchical Value Map of consumers consumers who chose a meat-like burger (n= 26).




Note: The HMV was developed using Ladderux (https://ladderux.org/)
The thicker the line between two elements in the means-end chain, the higher the link strength.
Source: ladderux.org

**Figure A7.** Hierarchical Value Map of consumers who chose a non-meat-like burger (n= 36).




Note: The HMV was developed using Ladderux (https://ladderux.org/)
The thicker the line between two elements in the means-end chain, the higher the link strength.
Source: ladderux.org

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## 2.2 Study 5

# Filling the Sensory Gap: A Sensory Evaluation of a Plant-Based vs. a Pork Hot Dog

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**Abstract**

Plant-based meat alternatives (PBMAs) are gaining increasing attention due to their potential role as substitutes for traditional meat products. Therefore, investigating and understanding consumer acceptance of less-explored PBMAs remains crucial. In this context, this research explored sensory expectations and actual experiences of a plant-based hot dog compared to a pork hot dog in a US sample. Using a within-subject design, participants (n= 88) evaluated both products before and after tasting, assessing overall liking, willingness to buy (WTB), and key sensory attributes. Furthermore, Check-All-That-Apply (CATA) batteries were used to explore product descriptors and situational appropriateness, while open-ended questions were employed to deeply examine what consumers liked and disliked the most about the products.

Results revealed no significant differences in the expected liking between the two products; however, after tasting, the pork hot dog received higher scores for both overall liking and WTB. Despite the plant-based product being associated with situations related to health and sustainability, it did not lead to the same appealing hedonic experience as the animal product. In addition, both penalty-lift analysis and text mining of the open-ended responses confirmed that consumers seek meaty characteristics in both animal- and plant-based hot dogs.

Finally, this research provides valuable implications for policymakers and the food industry, contributing to strategies aimed at reducing red meat consumption and promoting healthier and more sustainable dietary choices.

**Keywords:** plant-based diet; meat alternatives; liking; consumers; natural language processing.

### 2.2.1 Introduction

The growing concerns over environmental sustainability and public health are driving a global shift toward healthier and more sustainable diets, with particular emphasis on the reduction of meat consumption (WHO, 2023). This shift is prompted by the significant impact of livestock farming, especially for red meat, on climate change as it contributes to more greenhouse gas emissions than most other food sources while also negatively impacting land and water usage (FAO, 2017; Godfray et al., 2018). Simultaneously, excessive red meat consumption has been associated with various health issues, such as cardiovascular diseases, cancer, and obesity (Godfray et al., 2018; WHO, 2023). Therefore, there is a current need to support the promotion of a dietary shift toward healthier, more sustainable eating choices. Moreover, there is a current global inequitable distribution of meat consumption across regions, with the US being one of the leading countries and reaching over 100 kg per capita per year (FAO, 2024).

To address the reduction in meat consumption, a potential strategy that has been proposed is the adoption of plant-based meat alternatives (PBMAs) (FAO, 2022). The objective of PBMAs is to provide consumers with a substitute for meat while still delivering the sensory experience of meat consumption. Thus, these alternatives often mimic the taste, texture, and appearance of traditional meat products to support more environmentally and health-conscious decisions while maintaining a familiar food product experience (Andreani et al., 2023; Caputo et al., 2024). However, despite their increased availability in the global market (Andreani et al., 2024), meat consumption has not significantly decreased; rather, its shares are expected to grow in the coming years (OECD-FAO, 2021; WHO, 2023). This paradox indicates that while PBMAs are growing in popularity (Andreani et al., 2023), they are still not sufficiently modifying meat consumption patterns and, thus, further understanding of the factors driving consumer acceptance is required (Giacalone, Clausen, et al., 2022).

While much of the sensory and consumer research on PBMAs has focused on beef alternatives, such as PBMA burgers and their counterparts (Grasso et al., 2022; Sogari et al., 2024), fewer studies (e.g., Martin et al., 2021) have examined plant-based counterparts to pork. This gap in the literature is particularly important considering that pork consumption is expected to increase in several countries (Font-i-Furnols, 2023), as well as in its processed forms, such as sausages and hot dogs (Statista, 2020). Given the prominence of hot dogs in the US market, they provide a valuable context for investigating consumer acceptance of PBMAs to pork and understand what elements could mostly influence consumer perceptions of plant-based substitutes designed to replicate their animal counterpart.

Understanding consumer acceptance of plant-based pork alternatives is crucial for fostering the adoption of these products (Aschemann-Witzel et al., 2019; Boukid, 2021). Thus, we focused our research on investigating the sensory expectations and actual experiences of eating a plant-based hot dog compared to its animal-based counterpart in a US sample. The research also explored consumers' purchasing intention before and after tasting, as well as additional measures that can help predict future consumption behavior (Giacalone, Llobell, et al., 2022). Specifically, product descriptors and situational appropriateness – defined as the perceived suitability of a product for specific usage contexts (Giacalone, Llobell, et al., 2022) – were explored both pre- and post-tasting. By focusing on pork, our research aims at contributing to a more comprehensive understanding of what consumers expect and consider when consuming PBMAs with respect to meat products, ultimately supporting strategies that may encourage a reduction in red meat consumption.

### 2.1.2 Methodology

*Participants*

A total of 88 adults participated in the experiment. Participants were recruited via emails and flyers and had to i) be more than 18 years old, ii) have purchased sausages/hot dogs at least once over the

six months prior to the study, and iii) have no allergies/restrictions to soy or pork. The study was conducted in the fall of 2023 at Cornell University, Ithaca (NY, the US). The study was granted ethical approval by Cornell's Institutional Review Board for Human Participant Research (Protocol n°: IRB0147823) and participants signed informed consent before taking part in the study.

*Study Design*

Using a within-subject design, each participant evaluated a plant-based and a pork hot dog under two conditions (expected and actual) and the presentation order of the two products was randomized. In the expected condition (with information and without tasting), consumers were presented with the information on whether the product was plant-based or a pork hot dog (i.e., "Plant-based hot dog" or "Pork hot dog"). It is important to highlight that – as already done in previous studies (Grasso et al., 2022; Savov et al., 2022) – no additional information (e.g., brand or nutrition facts) was provided to minimize potential biases or associations. Using this information only, participants were asked to rate their expected overall liking –from 1 (Dislike extremely) to 9 (Like extremely) (Peryam & Pilgrim, 1957) – and their willingness to buy (WTB) – from 1 (Definitely would not buy) to 7 (Definitely would buy) – of the product (Grasso et al., 2022). Additionally, based on frequently mentioned attributes in the literature, Check-All-That-Apply (CATA) batteries were used to investigate the products' descriptors (dry, juicy, weak meat flavor, strong meat flavor, yucky, good taste, cheap, expensive, processed, unprocessed, classic product, unusual product, strong vegetable flavor, and weak vegetable flavor, non of the above) (Rodrigues et al., 2022; Sogari et al., 2023), and the product's situational appropriateness ("When I want something I like", "When I feel like trying something new", "To move my diet in a more sustainable direction", "When I want something healthy", "As part of the meals that I post on social media", "To set a good example for those around me", "As a regular part of my diet", "As part of easy and convenient meals", and "None of the above") (Cardello et al., 2022).

After responding to the questions under the expected condition, consumers were presented with the actual product and asked to taste the hot dog they had just evaluated in a hypothetical way. In this phase (actual condition), consumers tasted the hot dog and answered the same questions provided in the expected condition. Furthermore, appearance, flavor, and texture were evaluated on a 9-point scale from 1 (Dislike extremely) to 9 (Like extremely) and two open-ended questions were added to further explore what consumers liked and disliked the most about the product ("What, if anything, do you LIKE about this hot dog?"/ "What, if anything, do you DISLIKE about this hot dog?").

The same procedure was carried out for both the pork and plant-based hot dogs using a balanced presentation order to avoid order effects (Williams, 1949).

Finally, the survey included sociodemographic questions (i.e., gender, age, education level, and employment status), of which results are reported in Table 1.

**Table 1**. Descriptive characteristics of the sample (n=88).

| Variable | N | % |
|---|---|---|
| *Gender* | | |
| Female | 60 | 0.68 |
| Male | 26 | 0.30 |
| Other | 2 | 0.02 |
| *Age mean (±SD)* | 32.3 (±13.2) | |
| *Education level* | | |
| High school | 10 | 0.11 |
| Bachelor's degree | 38 | 0.43 |
| Post-graduate (e.g., Master, PhD) | 40 | 0.45 |
| *Employment status* | | |
| Student | 46 | 0.52 |
| Full-time | 31 | 0.35 |
| Part-time | 7 | 0.08 |
| Retired | 2 | 0.02 |
| Other | 2 | 0.02 |

*Products and cooking procedure*

In this study, we employed two products, a plant-based and a pork hot dog. Both products were commercially available in US grocery stores at the time of the study and were purchased from local

supermarkets (Ithaca, NY, the US). The ingredient list is available in the Appendix (Table A1). After purchasing, the hot dogs were refrigerated until the sensory experiment. Both products were cooked in a crockpot following the instructions provided by the manufacturer and served hot to participants. The sample consisted of 5 hot dog slices served on a single-use plate and a fork, and no dressing or topping was added. Between samples, participants were encouraged to drink still water to clean their palate.

### 2.1.3 Analysis

Statistical analysis was performed using R statistics, version 4.2.3 (R Core Team, 2023). The packages used for the analysis were readxl (Wickham & Bryan, 2023), tidyr (Wickham, Vaughan D, et al., 2023), ggpubr (Kassambara, 2023a), lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017), emmeans (Lenth, 2023), dplyr (Wickham, François, et al., 2023), performance (Lüdecke et al., 2021), sjPlot (Lüdecke, 2023), rstatix (Kassambara, 2023b), openxlsx (Schauberger & Walker, 2023), kableExtra (Zhu, 2024), corrplot (Wei & Simko, 2021), FactoMineR (Lê et al., 2008), tidyverse (Wickham et al., 2019), factoextra (Kassambara & Mundt, 2020), ggplot2 (Wickham, 2016), cata (Castura, 2024), purr (Wickha & Henry, 2023).

Paired t-tests were carried out to investigate differences in consumers' WTB and overall liking between products and within conditions. Similarly, paired t-tests were used to explore differences in the products' appearance, texture, and flavor.

For CATA batteries, frequency counts and percentages were calculated and Cochran's Q tests (with Sheskin as a post hoc test) were performed to determine the presence of significant differences ($p < 0.05$) in the frequency of the terms selected by respondents. In addition, for both CATA batteries, correspondence analysis (chi-square distances) was conducted to explore the relationship between the samples and the descriptors/situational appropriateness selected by participants. Successively, penalty-lift analysis was conducted to assess the average influence of each product descriptor on

consumer liking (Giacalone, 2018). This method considers the difference between the average hedonic score when a CATA attribute is selected versus when it is not selected. This difference estimates how much the hedonic response increases (or decreases) when the attribute is used to describe the product being evaluated. In addition, paired t-tests were performed to compare the average liking score of participants who checked a specific descriptor versus those who did not to identify significant differences.

Regarding the open-ended questions posed after tasting each product ("What, if anything, do you LIKE about this hot dog?"/ "What, if anything, do you DISLIKE about this hot dog?"), Natural Language Processing (NLP) and text mining were performed to investigate structures and common patterns from the unstructured text format (Netsiri & Lhotáková, 2023; Tao et al., 2020). The respondents' comments were systematically organized through tokenization, which involves breaking the text into meaningful tokens for further analysis, and stemming, where base words are identified (e.g., "tasty", "taste", and "tastiness"' are all reduced to the root "tast"). Subsequently, we examined the stemmed tokens in terms of word frequency and presented the results graphically to enhance visualization and interpretation of consumer sentiments.

### 2.1.4 Results

*Expected and actual conditions*

In the expected condition, no significant differences were observed for the overall liking between the pork and plant-based products, with both products showing positive scores. However, significant differences emerged after tasting, with the pork hot dog receiving a higher actual liking than the plant-based one. When exploring differences within products before and after tasting, results showed a significantly lower actual liking for the plant-based product compared to the expected condition (despite still receiving a positive score) and a significantly higher actual liking for the pork hot dog compared to its expected liking. Results are reported in Table 2.

**Table 2.** Overall liking of the two hot dogs in the expected and actual condition.

| Sample | Expected | Actual |
|---|---|---|
| Plant-based hot dog | $5.69 \pm 1.50^{aA}$ | $5.03 \pm 1.83^{bA}$ |
| Pork hot dog | $5.27 \pm 2.09^{aA}$ | $6.53 \pm 1.41^{bB}$ |

Note: Data expressed as mean values ± standard deviations, calculated on a 9-point hedonic scale (from 1 = dislike extremely to 9 = like extremely). Different lowercase letters, within a row, indicate significant differences ($p < 0.01$ - t-test) between the two conditions (expected *vs*. actual) within the same product sample. Different capital letters, within a column, indicate significant differences ($p < 0.05$ - t-test) between the two products (plant-based vs. pork) within the same condition.

In addition to liking, participants' WTB also changed after tasting. Before tasting, consumers showed a higher willingness to purchase the plant-based product compared to the animal-based one, with the pork hot dog receiving a negative WTB score and the plant-based product obtaining a positive score. However, after tasting, the WTB for the plant-based hot dog significantly decreased, reaching a negative value. On the contrary, the willingness to purchase the pork hot dog significantly increased and shifted to a slightly positive value. Table 3 shows the results for the WTB.

**Table 3.** Willingness to buy (WTB) of the two hot dogs in the expected and actual condition.

| Sample | Expected | Actual |
|---|---|---|
| Plant-based hot dog | $4.47 \pm 1.46^{aA}$ | $3.19 \pm 1.79^{bA}$ |
| Pork hot dog | $2.91 \pm 1.64^{aB}$ | $3.66 \pm 1.62^{bA}$ |

Note: Data expressed as mean values ± standard deviations, calculated on a 7-point hedonic scale (from 1 = Definitely would not buy to 7 = Definitely would buy). Different lowercase letters, within a row, indicate significant differences ($p < 0.001$ - t-test) between the two conditions (expected vs. actual) within the same product sample. Different capital letters, within a column, indicate significant differences ($p < 0.001$ - t-test) between the two products (plant-based vs. pork) within the same condition.

Regarding more specific sensory attributes (evaluated on a 9-point scale), no differences were identified between products in terms of appearance (PB = 5.63±1.71 | AB = 5.33±1.87). Nonetheless, the pork hot dog scored significantly higher in both flavor ($p<0.001$; PB = 5.13±2.07 | AB = 6.81±1.45) and texture ($p<0.001$; PB = 4.71±2.05 | AB = 6.00±1.89).

*Check-all-that-apply*

CATA questions were used to gather information about the sensory descriptors and situational appropriateness consumers associated with the products under investigation.

Table 4 represents the contingency table summarizing the frequency of use for each CATA descriptor by participants. Before tasting (thus, within the expected condition), few descriptors did not discriminate between products, specifically “yucky” and “weak vegetable flavor”. All the remaining descriptors significantly differentiated in their selection frequency. The plant-based hot dog was more frequently associated with the expectation of being “expensive”, “unusual”, and having a “weak meat flavor”. Opposite terms – i.e., “cheap”, “classic”, and “strong meat flavor” – were more frequently associated with the pork hot dog, along with being a “processed” product. After tasting, the only attributes not discriminating between products were “processed” and “unprocessed”, as both hot dogs were considered processed foods. Apart from this, tasting the plant-based product led more participants to associate it with being “dry”, “yucky”, and “good taste”, and fewer respondents associated it with being “expensive”. However, it is worth noting that, despite more consumers defining the plant-based product as having a “good taste”, this attribute was significantly more associated with the pork hot dog after tasting. For the animal product, the tasting experience led more consumers to define it as “juicy” and having a “good taste”.

**Table 4.** Proportions of CATA terms selected by respondents for the descriptors of the plant-based (PB) and animal-based (AB) hot dog and by condition.

| Attributes | Expected | | Actual | |
|---|---|---|---|---|
| | PB | AB | PB | AB |
| *Dry* | 0.284 [a] | 0.045 [b] | 0.477 [c] | 0.045 [b] |
| *Juicy* | 0.102 [a] | 0.284 [b] | 0.045 [a] | 0.534 [c] |
| *Weak meat flavor* | 0.466 [a] | 0.091 [b] | 0.432 [a] | 0.080 [b] |
| *Strong meat flavor* | 0.057 [a] | 0.511 [b] | 0.125 [a] | 0.557 [b] |
| *Yucky* | 0.045 [a] | 0.068 [a] | 0.159 [b] | 0.034 [a] |
| *Good taste* | 0.148 [a] | 0.239 [b] | 0.273 [b] | 0.602 [c] |
| *Cheap* | 0.057 [a] | 0.670 [b] | 0.148 [c] | 0.455 [d] |
| *Expensive* | 0.443 [a] | 0.011 [b] | 0.080 [c] | 0 [b] |
| *Processed* | 0.545 [a] | 0.773 [b] | 0.659 [b] | 0.761 [b] |
| *Unprocessed* | 0.057 [a] | 0 [b] | 0 [b] | 0 [b] |
| *Classic product* | 0.057 [a] | 0.625 [b] | 0.068 [a] | 0.614 [b] |
| *Unusual product* | 0.455 [a] | 0 [b] | 0.432 [a] | 0.045 [b] |
| *Strong vegetable flavor* | 0.216 [a] | 0 [b] | 0.216 [a] | 0.011 [b] |

| | | | | |
|---|---|---|---|---|
| *Weak vegetable flavor* | 0.182 [a] | 0.136 [a] | 0.227 [a] | 0.045 [b] |

Note: Data expressed as percentages calculated on frequency counts. Different superscript letters indicate a significant difference ($p \leq 0.05$, Cochran's Q test).

Finally, CATA terms were also used to discriminate between the situational appropriateness associated with the two products (Table 5). In the expected condition, "when I want something I like" was more frequently related to the pork hot dog, whereas the plant-based one scored higher for "when I feel like trying something new", "to move my diet in a more sustainable direction", "when I want something healthy", and "to set a good example for those around me". Results remained similar for most statements after tasting, with a slight decrement for the "when I feel like trying something new", "when I want something healthy" and "to set a good example for those around me" statements for the plant-based product. Finally, despite some minor differences, both hot dogs were not considered "as a regular part of my diet" or "as part of the meals that I post on social media" but were frequently related to "as part of easy and convenient meals".

**Table 5.** Proportions of CATA terms selected by respondents for the situational use associated with the plant-based (PB) and animal-based (AB) hot dog and by condition.

| Situational Use | Expected | | Actual | |
|---|---|---|---|---|
| | **PB** | **AB** | **PB** | **AB** |
| *When I want something I like* | 0.125 [a] | 0.318 [b] | 0.091 [a] | 0.364 [b] |
| *When I feel like trying something new* | 0.750 [a] | 0.023 [b] | 0.500 [c] | 0.080 [b] |
| *To move my diet in a more sustainable direction* | 0.682 [a] | 0.023 [b] | 0.625 [a] | 0 [b] |
| *When I want something healthy* | 0.534 [a] | 0.011 [b] | 0.375 [c] | 0 [b] |
| *As part of the meals that I post on social media* | 0.057 [a] | 0.011 [a] | 0.011 [a] | 0.023 [a] |
| *To set a good example for those around me* | 0.250 [a] | 0.011 [b] | 0.125 [c] | 0 [b] |
| *As a regular part of my diet* | 0.091 [a] | 0.011 [b] | 0.023 [b] | 0.045 [b] |
| *As part of easy and convenient meals* | 0.545 [ab] | 0.670 [b] | 0.466 [a] | 0.795 [c] |

Note: Data expressed as percentages calculated on frequency counts. Different superscript letters indicate a significant difference ($p \leq 0.05$, Cochran's Q test).

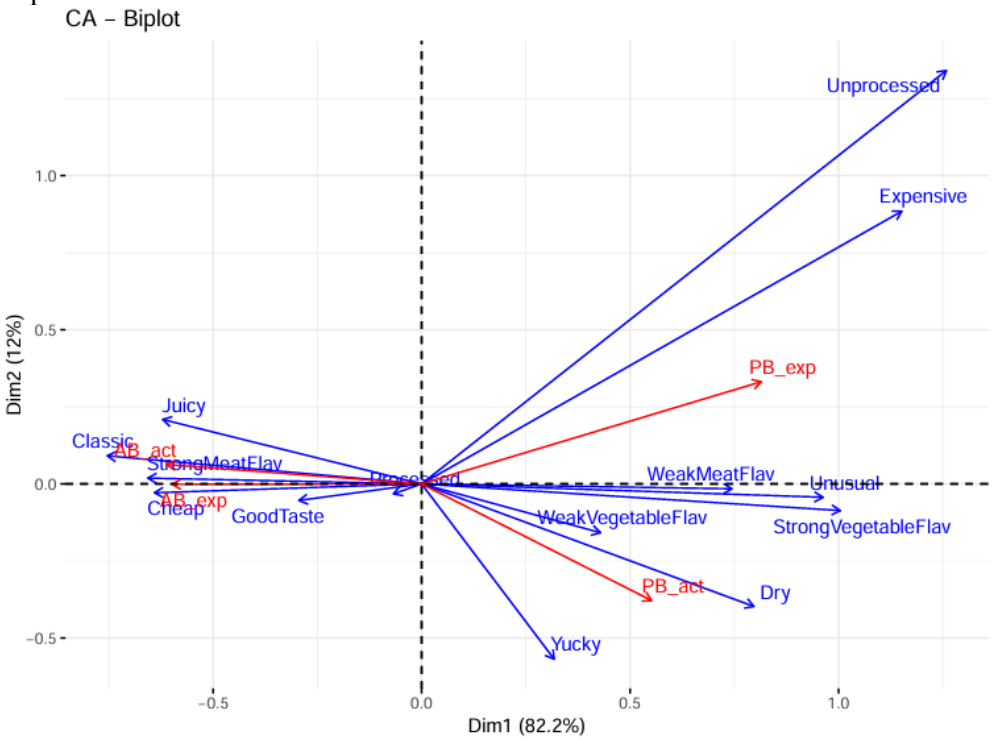
*Correspondence analysis*

Figure 1 represents the results of the correspondence analysis and represents the products and CATA terms used as product descriptors in both conditions. Dimensions one and two together explain 94.22%

of the variance, with dimension one explaining 82.24% and dimension two explaining 11.98%. More specifically, dimension one was positively correlated with “unprocessed”, “expensive”, “unusual” and “strong vegetable flavor”, and negatively correlated with “classic”, “strong meat flavor”, “cheap”, and “juicy”. Instead, the second dimension was positively correlated with “unprocessed” and “expensive”, and negatively correlated with “yucky” and “dry”.

The plot of the correspondence analysis shows that products are arranged in different areas according to the CATA descriptors. However, when comparing the two conditions, results show no major impact of the taste experience as products did not change their location between conditions, with a slight move for the plant-based product in dimension two after tasting. More specifically, the pork hot dog was associated with “cheap”, “strong meat flavor”, “classic product”, and “juicy” in both conditions. Oppositely, the plant-based hot dog was mostly associated with being “expensive” in the expected condition, and with being “dry” and having a “weak meat flavor” after the taste experience.

**Figure 1.** Correspondence analysis performed using the CATA terms used to describe the products under expected and actual condition.

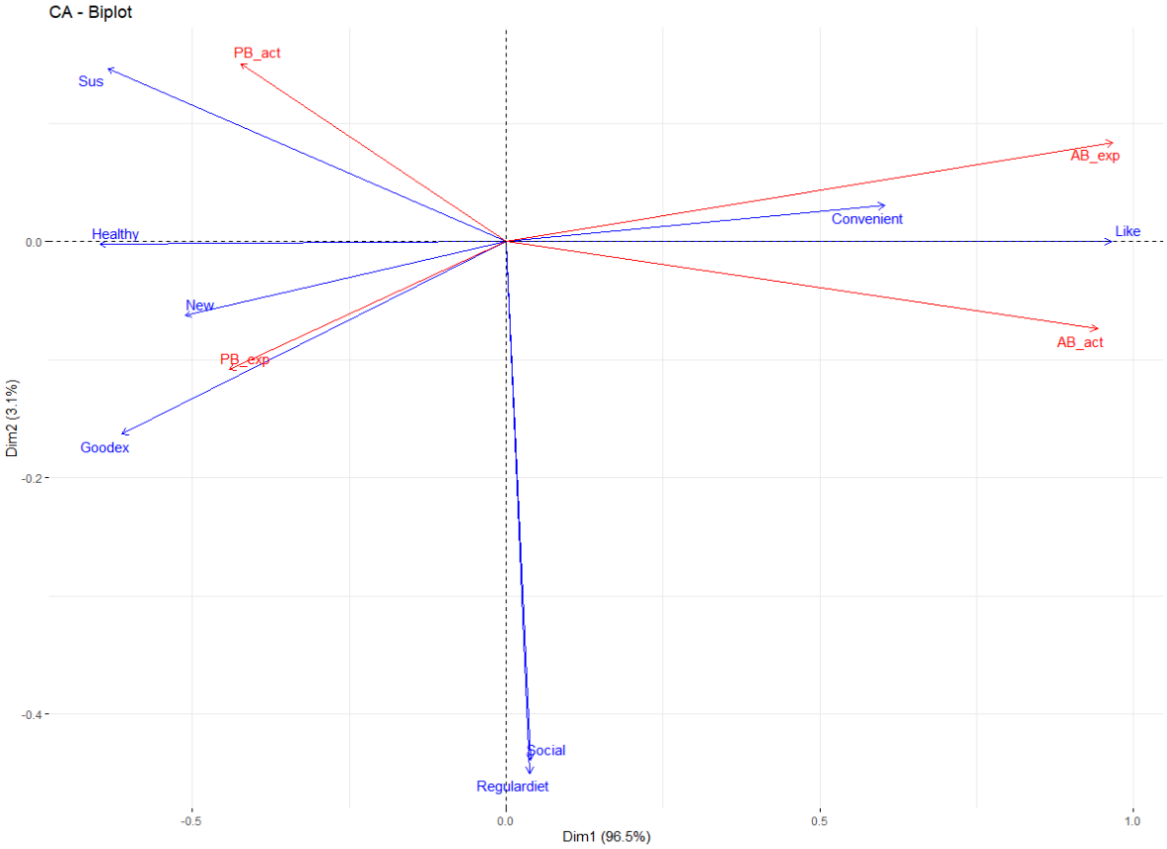



Note: Blue terms are CATA descriptors used to describe the two products under expected and actual conditions. Red terms indicate the products: PB_exp = plant-based product in the expected condition; AB_exp = animal product in the expected condition: PB_act = plant-based product in the actual condition; AB_act = animal product in the actual condition.

Figure 2 shows the results of the correspondence analysis when using the CATA terms for situational appropriateness. Dimensions one and two together explain 99.54% of the variance, with dimension one explaining 96.46% and dimension two explaining 3.08%. More specifically, dimension one was positively correlated with “When I want something I like” and “As part of easy and convenient meals”, and negatively correlated with “When I feel like trying something new”, “To move my diet in a more sustainable direction”, “When I want something healthy”, and “To set a good example for those around me”. Instead, the second dimension was positively correlated with “To move my diet in a more sustainable direction”, and negatively correlated with “As part of the meals that I post on social media”, “To set a good example for those around me”, and “As a regular part of my diet”.

The correspondence analysis for the situational appropriateness aligns with the one computed for the CATA descriptors, as also here results show no major impact of the taste experience. Especially for dimension one, in fact, the products maintained their positions between conditions. More specifically, before tasting, consumers primarily associated the plant-based product with “To set a good example for those around me” and with “When I feel like trying something new”. After tasting, the plant-based product was mostly associated with “To move my diet in a more sustainable direction”. On the contrary, the pork hot dog was linked to “As part of easy and convenient meals” in the expected condition, whereas, in both conditions, respondents associated it with “When I want something I like”.

**Figure 2.** Correspondence analysis performed using the CATA terms for the situational use of the products under expected and actual condition.




Note: Blue terms are CATA situational use selected by participants for the two products under expected and actual conditions: Like: "When I want something I like"; New: "When I feel like trying something new"; Sus: "To move my diet in a more sustainable direction"; Healthy: "When I want something healthy"; Social: "As part of the meals that I post on social media"; Goodex: "To set a good example for those around me"; Regulardiet: "As a regular part of my diet"; Convenient: "As part of easy and convenient meals". Red terms indicate the products: PB_exp = plant-based product in the expected condition; AB_exp = animal product in the expected condition: PB_act = plant-based product in the actual condition; AB_act = animal product in the actual condition.

*Penalty-lift analysis*

Figures 3 and 4 represent the results of the penalty-lift analysis. Specifically, Figure 3 shows how much selected attributes contributed (positively or negatively) to consumer liking for the plant-based products under both conditions, whereas Figure 4 shows the results for the pork hot dog.

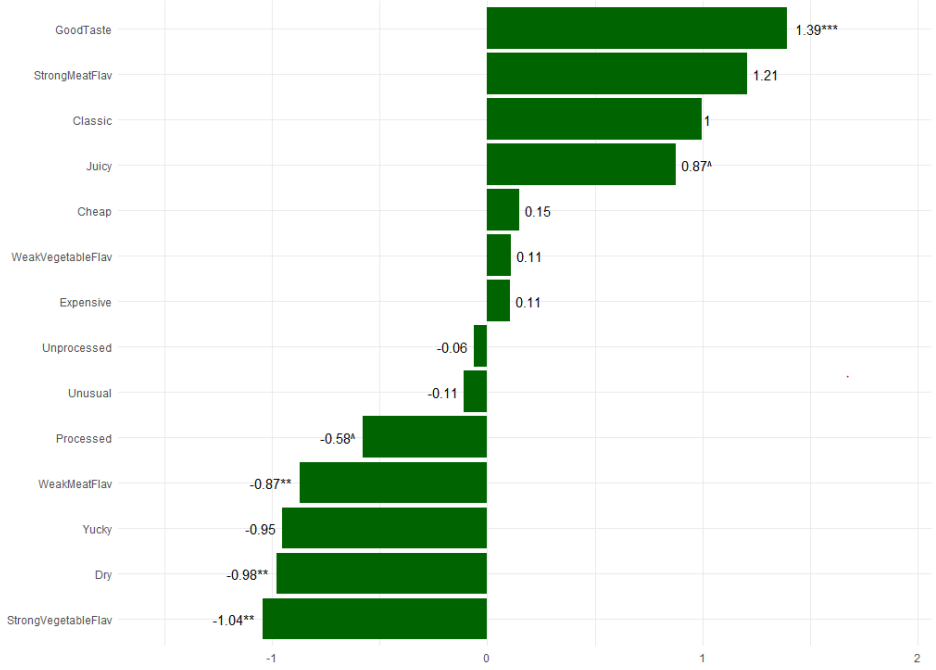
For the plant-based hot dog, the primary drivers of consumer liking slightly changed before and after tasting, with having "good taste", a "strong meat flavor", and being "juicy" and a "classic product" being the top 4 drivers in both conditions. For the attributes leading to disliking the plant-based product, "dry" and "yucky" remained major drivers between conditions, with the last becoming a more pronounced negative driver after tasting. In addition, while having a "strong vegetable flavor"

was a key factor for dislike before tasting, its impact diminished in the actual condition, where the perception of the product being “cheap” emerged as a significant element negatively contributing to the liking.

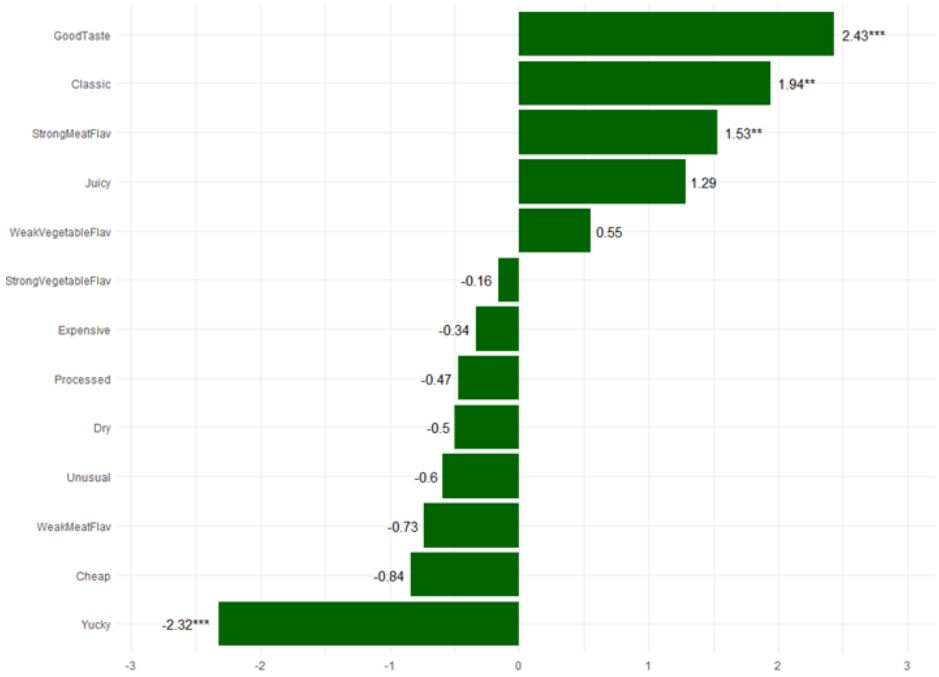
As for the plant-based hot dog, having “good taste” and a “strong meat flavor”, and being “juicy” and a “classic product” all positively contributed to the liking of the animal product in both conditions. Moreover, in the expected condition only, the “expensive” attribute was recognized as another positive driver for liking. Regarding the drivers negatively impacting the liking of the animal hot dog, results showed that “dry”, “cheap”, “weak meat flavor”, the presence of “vegetable flavor”, and “processed” were all identified as negative attributes for liking. In addition, while “yucky” was present in the expected condition only, after tasting the product, the attribute “unusual” appeared and the presence of “vegetable flavor” assumed a stronger impact for disliking the pork hot dog.

**Figure 3**. Penalty-lift analysis for the plant-based hot dog under the expected (a) and actual (b) condition.

a)

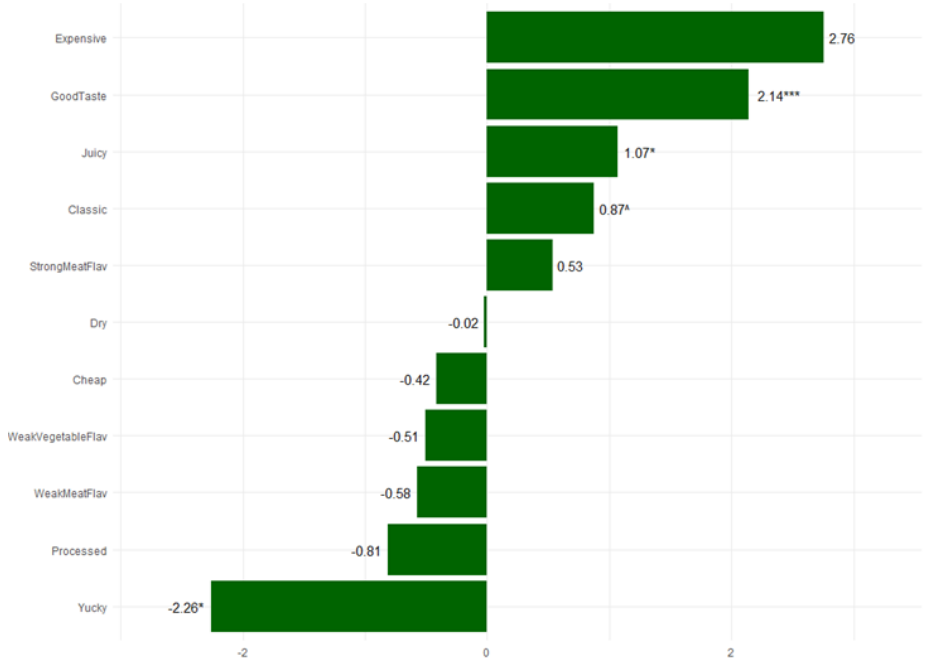



b)

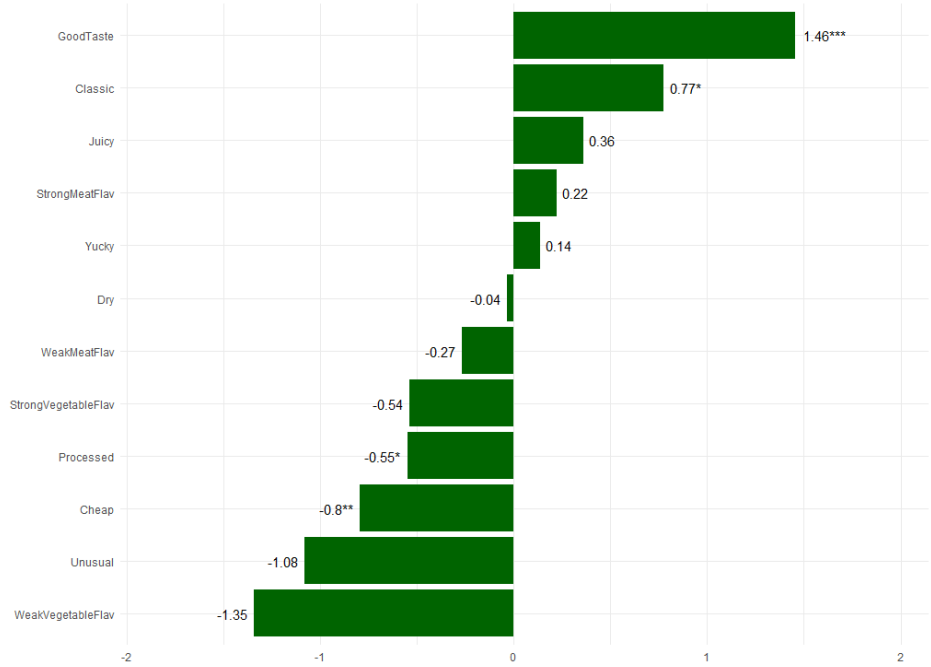



Note: The values indicate a change in the liking when an attribute (y-axis) was selected in the CATA task compared to when it was not selected. *** p<0.001; ** p<0.01; * p<0.05; ^ p<0.1.

a)




b)



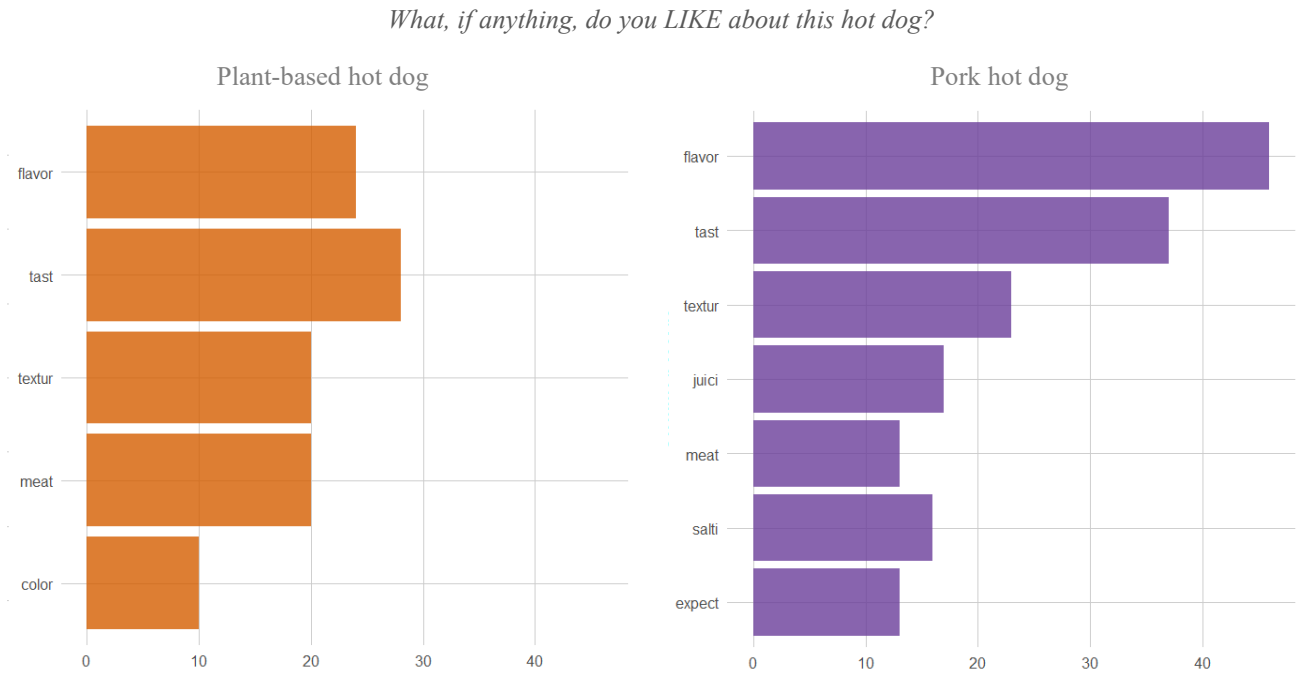

Note: The values indicate a change in the liking when an attribute (y-axis) was selected in the CATA task compared to when it was not selected. *** p<0.001; ** p<0.01; * p<0.05; ^ p<0.1.

*Text mining*

Results from the NLP and text mining analyses reveal the key characteristics that influenced consumers' preferences for (or against) the two products from the open-ended questions asked after tasting. Figure 5 shows the results for the "What, if anything, do you LIKE about this hot dog?"

question. Specifically, while flavor, tastiness, and texture were valued in both products, a higher number of respondents cited these attributes in relation to the pork hot dog, particularly emphasizing its flavor. In addition, the pork hot dog was also appreciated for its juiciness, meat-like characteristics (e.g., "it has a meaty flavor", "meaty texture", "a real taste of meat"), saltiness, and for well-aligning with consumers' expectations (e.g., "It tastes like what I would expect from a regular hot dog", "The texture, shape and smell resembles what I would normally expect in a hot dog"). Regarding the plant-based product, along with its flavor, tastiness, and texture, respondents also highlighted its meaty attributes (e.g., "similar to a real meat hotdog", "a real feel of meat"), as well as its appealing color.

**Figure 5.** Text mining results for the characteristics that consumers liked about the two products.

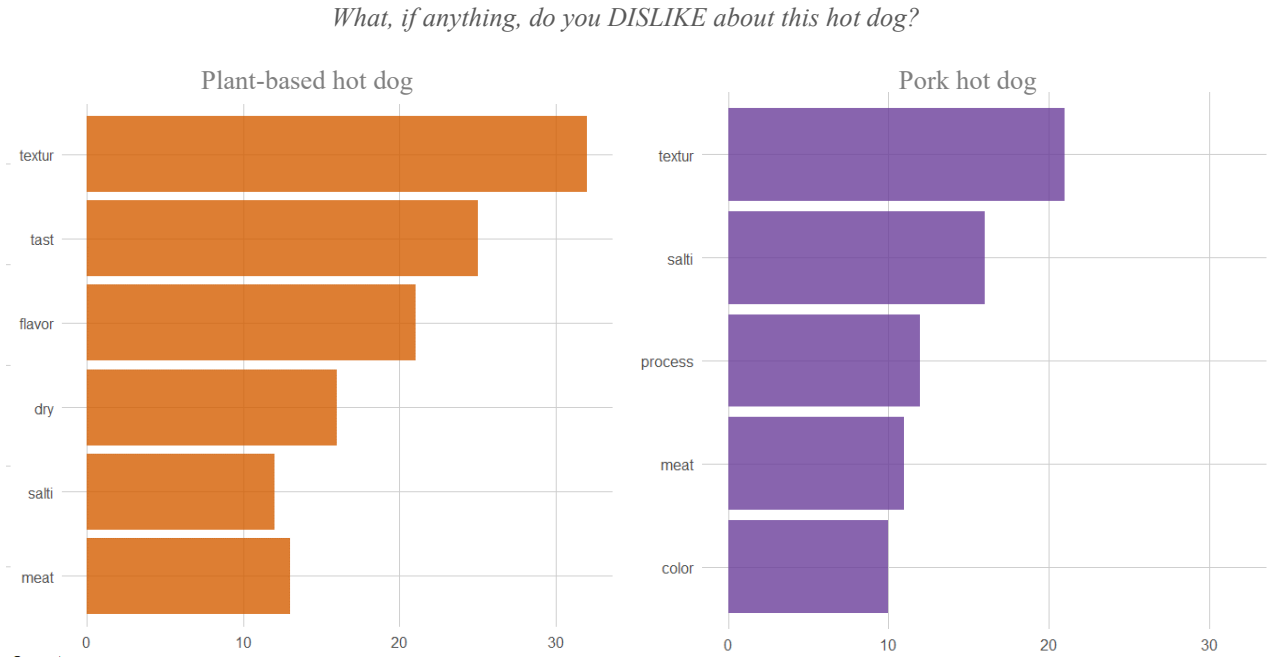



Note: The y-axis represents the stemmed tokens, while the x-axis shows the number of respondents who mentioned that word in their comments. Orange: plant-based hot dog; Purple: pork hot dog.

While a greater number of attributes were identified for the animal product in relation to positive comments investigating elements of liking, more characteristics were identified for the plant-based hot dog when exploring what consumers disliked about the product (Figure 6). Specifically, although some respondents liked the texture of the plant-based product, more consumers expressed dissatisfaction with comments like "The texture is not my favorite" or "I don't like the texture".

Similarly, despite some respondents appreciating the taste or the flavor, others commented “I don’t like the taste”, “a bit of a weird aftertaste”, “kind of a plastic taste”, “mild flavor”, “lack of meat flavor”, “no meat flavor”, or “no much of a hot dog flavor”. Finally, some respondents found the product too dry and too salty and with a lack of meat-like characteristics (e.g., “it does not seem a meat product” or “lack of a meat flavor”). In contrast, for the animal product, some consumers stressed some texture issues by describing it as “rubbery” or expressing dissatisfaction with the skin's texture. Additionally, some participants found the pork hot dog overly salty and highly processed, did not like the color, and did not perceive it as meaty as they would have expected (e.g., “I don’t like how light the meat is” or “would like a more meat flavor”).

**Figure 6**. Text mining results for the characteristics consumers disliked about the two products.




Note: The y-axis represents the stemmed tokens, while the x-axis shows the number of respondents who mentioned that word in their comments. Orange: plant-based hot dog; Purple: pork hot dog.

### 2.1.5 Discussion and Implications

Despite technological advancements, a key challenge in the development of PBMAs lies in meeting consumers' sensory expectations (Appiani et al., 2023; Giacalone, Clausen, et al., 2022). Therefore, sensory and consumer science play an essential role in understanding consumer perceptions and the factors that influence acceptance of these products. In this context, our research aimed at furthering the scientific literature on the topic by assessing consumers' sensory expectations and actual evaluation of a less explored PBMA, specifically a plant-based hot dog and its animal counterpart.

Our results revealed no significant differences in consumers' sensory expectations between the animal and the plant-based product, with both hot dogs showing positive scores in terms of expected liking. This finding is in contrast with previous studies on PBMAs, which found a higher liking expectation for the animal product (Grasso et al., 2022; Michel et al., 2021; Schouteten et al., 2016). Furthermore, our results showed that, before tasting, consumers had a higher purchase intention for the plant-based hot dog than the animal one. This, along with the lack of difference in the sensory expectations between the two products, might suggest that consumers are becoming more familiar with plant-based alternatives. Therefore, since familiarity is often linked to higher product acceptance (Andreani et al., 2024; Giacalone, Clausen, et al., 2022), the growing availability of PBMAs in the global market may be fostering greater consumer familiarity, which, in turn, could lead to a higher acceptance of PBMAs as comparable to traditional meat options.

Despite a similar sensory expectation between the two hot dogs and a higher WTB for the plant-based product before tasting, opposite results were found after tasting. Specifically, the liking for the animal hot dog significantly increased, while the one of the plant-based product significantly decreased. In addition, the tasting led consumers to a negative WTB for the latter product and a higher WTB for the pork hot dog. These findings confirm the critical role that sensory appeal has in the acceptance of PBMAs. As a matter of fact, despite the positive perception before tasting, the sensory experience did change both consumers' liking and purchasing intention. This is in line with previous studies

showing that tasting leads to a higher sensory appeal for traditional animal products than PBMAs (Grasso et al., 2022; Martin et al., 2021; Schouteten et al., 2016). Additionally, our study showed that appearance was not the main factor distinguishing the two products; instead, flavor and texture were rated more favorably for the animal-based product, highlighting these attributes as key differentiators. Similarly, when focusing on the CATA tasks, more positive descriptors were associated with the animal product (e.g., "juicy"), whereas consumers linked the plant-based hot dog to less favorable descriptors, such as "unusual" and "dry". Nevertheless, when investigating the situational appropriateness, the plant-based hot dog was more strongly associated with the concepts of sustainability and health ("to move my diet in a more sustainable direction" and "when I want something healthy"), as well as with the "when I feel like trying something new" situational use. In contrast, respondents associated the animal product mostly with "When I want something I like". Given the positive association of plant-based products with health and sustainable concepts – also confirmed by previous studies (e.g., Grasso et al., 2022; Michel et al., 2021) – it is worth considering that policymakers and industries may emphasize such aspects to steer consumer acceptance of PBMAs. As an example, interpretative front-of-pack labels that clearly communicate the health and environmental benefits could serve as an effective strategy to encourage their adoption. However, these results also support the idea that reduced sensory quality remains a major barrier to the broader adoption of most PBMAs, particularly when compared to traditional animal-based products. Therefore, while communication strategies highlighting the health and sustainability of PBMAs are essential, these must be complemented and supported by sensory and consumer research, as well as product development, to enhance sensory appeal and drive greater consumer acceptance. Moreover, it should be noted that more participants associated the plant-based hot dog with both "yucky" and "good taste" after tasting, reflecting two opposite directions. This suggests the presence of two consumer segments, those who liked and those who disliked the plant-based product. However, this aspect could not be explored due to the sample size not allowing further sample clustering; thus,

future research could investigate such aspects to gain more precise insights into the factors driving preferences for plant-based alternatives based on different consumer groups.

Additionally, this study explored the key drivers of product liking to offer more targeted insights for product developers. This was achieved through both penalty-lift analysis and open-ended questions, which can allow a more detailed investigation of the drivers for liking and disliking the products by using consumers' own language (Grasso et al., 2022; Sogari et al., 2023). Findings from both the penalty-lift analysis and text mining revealed that consumers predominantly sought meaty attributes – in terms of flavor, texture, and color – in both animal and plant-based products. Similarly, a weak meat flavor was a major element leading to product dislike for both products. Along with this, the plant-based hot dog was criticized for its texture and for being too dry. These findings are in line with previous work showing that PBMAs still do not meet consumers' sensory needs, especially when compared to meat products (Martin et al., 2021; Michel et al., 2021; Schouteten et al., 2016). In this context, most studies have confirmed that one critical aspect is the lack of meat-like sensory characteristics (Grasso et al., 2022; Sogari et al., 2023). Thus, our research supports the idea that – particularly for plant-based alternatives designed to replace traditional hot dogs – the food industry should prioritize replicating the sensory characteristics of the animal product to deliver a meaty experience.

Finally, this study is among the few focusing on pork alternatives while incorporating both hedonic responses and "beyond liking" measures. By examining consumers' degree of liking, WTB, and product descriptors and situational appropriateness, this research offers valuable insights for policymakers and food developers aiming at promoting PBMAs. However, certain limitations need to be drawn. First, the study population is not representative of US consumers, and, in addition, the sample size used in this research, despite being in line with previous sensory studies (Cordelle et al., 2022; Grasso et al., 2022), does not allow for a representative subsampling of the population. However, segmenting consumers is crucial for understanding diverse preferences and identifying key drivers of acceptance or rejection within specific groups. Therefore, future research with larger and

more diverse samples is suggested to confirm our results and enable a deeper exploration of consumers' behaviors. In addition, we conducted our study in a laboratory context, which may limit the generalizability of our results (Stelick & Dando, 2018); thus, similar research could be conducted in real-world settings to determine whether comparable results are observed in environments where the products are typically consumed. Furthermore, we did not provide information on the products' brand or nutritional value, which could potentially influence consumers' perceptions; however, this is commonly done in consumer studies to minimize potential biases or associations (Grasso et al., 2022; Savov et al., 2022). Ultimately, the preparation procedure of the products may have impacted the sensory perception. To mitigate this limitation, a consistent preparation method was employed throughout the experiment.

### 2.1.6 Conclusions

This study highlights the critical role of sensory attributes in consumer acceptance of PBMAs, specifically in the context of plant-based hot dogs. However, along with traditional sensory evaluations (i.e., hedonic responses), it is crucial to examine other factors, such as product descriptors and situational appropriateness, to gain a more nuanced understanding of consumer acceptance and better predict consumers' consumption behaviors (Giacalone, Llobell, et al., 2022). By combining measures that go beyond hedonic responses, our findings showed that, despite positive scores for liking and WTB in the expected condition, plant-based hot dogs still do not meet consumers' sensory expectations in the actual experience. Specifically, results indicated that while the plant-based hot dog was perceived as a healthy and sustainable option, its sensory characteristics pose significant barriers to acceptance. In this context, consumers primarily seek meaty characteristics, such as flavor, texture, and color, in both animal and plant-based products.

Therefore, to enhance consumer acceptance and drive the adoption of PBMAs, the food industry must prioritize replicating the sensory qualities that consumers associate with traditional meat. Finally,

4759 future sensory and consumer studies on the topic are advised to ensure the successful integration of
4760 PBMAs into the mainstream market, ultimately contributing to healthier and more sustainable dietary
4761 choices.
4762

## Appendix

Table A1. Ingredient list of the products used in the study.

| | |
|---|---|
| Pork hot dog | pork, water, beef, veal, and less than 2% of the following: salt, dextrose, corn syrup, flavorings, citrus fiber, paprika, sodium phosphate, sodium acetate, sodium diacetate, sodium erythorbate, sodium nitrite. |
| Plant-based hot dog | water, soy protein isolate, soybean oil, raw cane sugar, salt, contains 2% or less of: pea protein, tapioca starch, yeast extract, natural flavor, garlic juice concentrate, sunflower oil, glutamic acid, xanthan gum, carrageenan, garlic powder, guar gum, hardwood smoked sugar, red rice flour (color), canola oil, oleoresin paprika (color). |

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## 2.3 Study 6

# The Role of the Nutri-Score and Eco-Score in Shaping Consumers' Sensory Expectations and Purchase Intention: An Eye-Tracking Study on Animal- and Plant-Based Foods

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**Abstract**

Front-of-pack (FOP) labeling schemes could be adopted to provide consumers with timely and credible information and promote healthy and sustainable food consumption. In addition, when defining healthy and sustainable food behaviors, international authorities agree that reducing meat consumption could benefit both human health and the planet. Given the increasing interest in meat replacements (e.g., plant-based meat alternatives, PBMAs) and FOP labels, this study investigates the effects of interpretative FOP labeling schemes – the Nutri-score (NS) and Eco-score (ES) – on consumers' sensory expectations and purchase intention of a meat product and its plant-based counterpart. To do so, we used eye-tracking data to analyze whether and to what extent the attention to the proposed labels affects participants' behaviors (n=76). In addition, to provide further implications based on consumer segments, we divided our sample based on the Meat Attachment Questionnaire (MAQ). Results showed that attention to the NS or ES did not impact participants with higher MAQ scores (i.e., with a more positive bond toward meat consumption); however, the sensory expectation of both the meat and plant-based product was influenced by consumer visual attention for participants with a lower meat attachment level (lower MAQ scores). More specifically, a positive relationship was identified between the attention paid to the positive ES of the plant-based product and its expected liking, and a positive interaction was found between the attention paid to the negative NS of the animal product and its expected liking. Finally, results are discussed to provide insights for future research and implications are defined for both food industries and policymakers.

**Keywords:** hot dogs; meat analogs; meat attachment; front-of-pack labels.

### 2.3.1 Introduction

Nowadays, many governmental and international institutions are looking for effective strategies that could steer consumers' food decisions toward more sustainable and healthier choices (EESC, 2022; FAO and WHO, 2019). Reducing GHG emissions while preserving individuals' health has become a top priority over the last few years and providing consumers with the right tools to make informed and timely choices is a recognized strategy to mitigate the impact of the food system on both our health and the planet (WHO, 2019).

Many countries already have mandatory nutrition information on the back of food packages (Reg. (EU) No 1169/2011, 2011); however, the World Health Organization (WHO) also recommends mandatory front-of-pack (FOP) labeling schemes to promote healthy and sustainable diets and stress the importance of visible information on the nutritional value of food products, as well as information on their environmental impact (WHO, 2013, 2017). Although previous studies support the adoption of mandatory FOP policies to steer consumers' choices and to encourage the food industry to reformulate its products, few countries have adopted labeling systems, either on a mandatory or voluntary basis (Cámara et al., 2022; Song et al., 2021). Thus, research on this topic remains critical to guide policymakers in choosing the optimal FOP to adopt (WHO, 2019). Following this line, the European Commission also proposed a harmonized mandatory FOP labeling scheme to be adopted in the European Union (European Commission, 2020a, 2020b).

Several classifications of FOP labels exist (De Marchi et al., 2023). Among these, a common method to classify FOP labels is to divide them into interpretative and non-interpretative (Song et al., 2021). The first category includes symbols and figures that "advise" consumers by providing them with the overall healthfulness/sustainability of the product. On the other hand, non-interpretative FOP labels provide a summary of specific nutrition or environmental aspects (Mhurchu et al., 2017; Song et al., 2021). Previous research agrees that interpretative FOP labels can be an effective tool to assist consumers in their daily decisions by avoiding information overload (Cecchini & Warin, 2016; Song

et al., 2021; Weber, 2021; WHO, 2017). In addition, to ensure that both health- and sustainability-related aspects are conveyed on the front-of-food packages, the concept of an interpretative dual labeling scheme – where both nutrition and sustainable labels are present – has been proposed (De Bauw et al., 2021). Although the literature on the topic is still scarce (de Bauw et al., 2021; Marette, 2022; Osman & Thornton, 2019), combining interpretative FOP labels on nutrition and sustainable aspects has shown promising results in prompting consumers' food choices (de Bauw et al., 2021; Osman & Thornton, 2019).

One recently developed interpretative FOP scheme is the Nutri-Score (NS) label, a nutrition label that displays the food product' overall nutritional quality by using a rating system that conveys the "indication of use" of a product (De Marchi et al., 2023; Santé Publique France, 2024). Specifically, the NS ranges from A ("the healthiest option") to E ("the less healthy option") and associates colors ranging from green to red. The calculation of the final score is based on an algorithm derived from the UK Food Standards Agency nutrient profiling system (FSA score) (IARC, 2021; Julia et al., 2017). The NS was first implemented in France in 2017 as a response to the French Ministry of Health's willingness to create a FOP nutrition labeling system to facilitate consumers' food choices (Santé Publique France, 2024). Since then, other European countries have adopted this system on a voluntary basis (e.g., Belgium, Spain, and Germany), while others are challenging its adoption (Fialon et al., 2022; Merz et al., 2024).

More recently, an interpretative FOP system – the Eco-score (ES) – recalling the NS format has been developed also for the sustainable dimension of food products (Colruyt Group, 2024). Similar to the NS, the ES is a food label that ranges from A ("the most sustainable option") to E ("the least sustainable option") and from green to red. The ES gives an overall evaluation of a food product's environmental impact, and, in its algorithm, it incorporates the Life Cycle Assessment (LCA) from the Agribalyse database with additional environmental-related factors, such as production and transportation, packaging, country of origin of ingredients, and the seasonality of the finished product (Colruyt Group, 2024). This environmental FOP label is already in use in France and on a limited

number of private-label products in Germany (Jürkenbeck, 2023). An image of the NS and ES is reported in Figure .

**Figure 1.** a) the Nutri-Score, and b) the Eco-Score.

a)


b)


In this context, the present study aims at expanding the scientific literature on the topic of FOP labeling schemes and testing the impact of a dual labeling scheme (i.e., when both the NS and ES are displayed on the front of the food package) on consumers' sensory expectation and purchasing behaviors. To do so, this study moves beyond consumers' self-reported measures by merging these data with participants' visual attention. Specifically, eye-tracking data were employed to evaluate consumers' attention to the FOP labels and explore the relationship that this has on individuals' behavioral intentions and expectations.

In addition, given that the main objective of an FOP system is to provide consumers – especially those who do not have in-depth knowledge of nutrition and sustainability aspects – with an intuitive and easily accessible tool to make informed food purchases, we tested the dual labeling scheme on a population who is not familiar with the proposed labels. Thus, because the investigated labeling schemes were developed in France and are currently adopted in some European countries only, we focus our research on North American consumers. This approach could allow a deeper understanding of the impact that interpretative, but unfamiliar labeling schemes have on general consumers.

*Background and hypotheses*

While research on eye-tracking and FOP labels is increasing, to the best of our knowledge, literature measuring consumer attention to the NS or ES using eye-tracking is still scarce. Only few authors investigated visual attention to the NS (Bossuyt et al., 2021; Gabor et al., 2020) and no study used eye-tracking to explore visual attention on the ES or a dual NS-ES scheme or evaluated its relationship with consumers' behaviors. Bossuyt et al., (2021), for instance, investigated the effect of visual attention on the accuracy of healthfulness evaluation when displaying the NS, the Nutrition Facts Panel, or both. The authors found a lower average mistake in the estimation task for participants who paid more visual attention to the NS. In another study, Gabor et al., (2020) used eye-tracking to analyze consumers' visual attention to food packaging with different FOP nutrition labels. The most accurate healthfulness estimates were linked to the Guideline Daily Amounts label; however, the NS required the least time to process the information. Thus, a lack of studies on the relationship between attention to interpretative FOP labels and consumer behavioral intention currently exists.

In addition, to evaluate the adoption of FOP labels, it is necessary to assess their effects on consumers' choices when displayed on critical food categories, among which red meat. Specifically, red meat is associated with a higher risk of non-communicable diseases, such as cardiovascular diseases and cancer. Additionally, red meat production hinders environmental sustainability due to increased greenhouse gas emissions (González et al., 2020; WHO, 2023). The risks associated with red meat consumption have led to the development and production of plant-based meat alternatives (PBMAs) – i.e., foods that recall meat products (e.g., burgers or sausages) but are made with plant-based ingredients (e.g., soy, wheat, pulses, etc.) (FAO, 2022). Indeed, promoting PBMAs could potentially improve consumers' health and increase the sustainability of their food choices by leading to red meat consumption reduction (Onwezen et al., 2021). In terms of nutritional differences, studies showed that PBMAs mostly have lower energy and total and saturated fat content. Concerning sustainable aspects – despite methodological limitations in the assessment process – the few resources required

per product unit of PBMAs represent a promising opportunity to decrease the environmental impact of meat consumption (Andreani et al., 2023). In this context, we developed 2 hypotheses to explore the impact of a dual NS-ES scheme on consumers' purchasing intention and sensory expectation of a PBMA and its animal counterpart. Given the low number of studies on pork meat substitutes (Andreani et al., 2024) and the projection of an increasing frankfurter consumption pattern in the US (Statista, 2024), we focused our research on traditional pork hot dogs and their plant-based version. The hypotheses follow the direction of research evaluating the role of color-coded FOP labels, which shows that – in line with the scope of these labels – the red color negatively affects consumers' purchase intention, while the green color is associated with more positive purchasing behaviors (Ahn & Lee, 2022; Marette, 2022; Taillie et al., 2024). The following hypotheses are thus drawn:

- H1: A higher visual attention to the positive NS and ES of a PBMA results in a higher willingness to buy and expected liking for the product.
- H2: A higher visual attention to the negative NS and ES of a traditional meat product results in a lower willingness to buy and expected liking for the product.

To test these hypotheses, we combined eye-tracking data with self-reported measures to investigate how much time consumers spent on each label and to define whether attention affected their purchasing intention and sensory expectation. Additionally, FOP labels can have different effects based on individuals' characteristics (Godden et al., 2023). Because we tested the role that interpretative labels can have when prompting consumers to reduce meat consumption and since past research showed an interaction between consumers' positive or negative bond towards meat consumption and how meat alternatives are perceived (Circus & Robison, 2019), we segmented our sample based on participants' meat attachment level. Finally, results from this research could be of help to policymakers and industries involved in food labeling and PBMA production to develop and implement effective tools to foster healthy and sustainable food choices among consumers.

### 2.3.2 Methodology

Consumers were recruited from the city of Ithaca (NY, the US) via emails and flyers and a total of 76 adults took part in the study. To participate, consumers had to: i) be more than 18 years old, ii) be non-vegans/vegetarians, iii) have purchased wieners/frankfurters/sausages/hot dogs at least once over the six months prior to the study; iv) have normal or corrected-to-normal eye vision; and v) have no allergies/restrictions to soy and pork. Data collection was conducted between October and November 2023 at the Eye Tracking Laboratory of the Dyson School of Applied Economics and Management, Cornell University. The study was granted ethical approval by Cornell's Institutional Review Board for Human Participant Research (Protocol number: IRB0147823).

*Study procedure*

The experiment was performed individually, and each participant signed informed consent before the study. Upon their arrival, participants were introduced to the study and were asked to read the definitions of the following terms: front-of-pack label, Nutri-Score, Eco-Score, and plant-based food. The same definitions were presented to each participant and can be found in the Appendix (Table A1). After reading these descriptions, the experiment began with an individual calibration for the eye-tracking, which was performed by the investigator using a 9-point calibration method. The eye-tracking employed in this study was the Eye-link Plus 1000® (https://www.sr-research.com/eyelink-1000-plus/). After the calibration, participants were randomly shown the image of either a plant-based or a pork hot dog packaging (no minimum or maximum time was given to participants to observe the image). The packaging information included the hot dog composition (i.e., "Plant-based hot dog" or "Pork hot dog"), and the NS and ES labels of the product. The NS and ES values were assigned considering their average values for plant-based ("A" for the NS and a "B" for the ES) and pork hot dogs ("E" for the NS and "D" for the ES). The images used in the study are displayed in the Appendix (Figure A1).

After observing the first image (either a plant-based or a pork hot dog), consumers were asked to rate their willingness to buy (WTB) for the product from 1 (Definitely would not buy) to 7 (Definitely would buy) and their expected liking on a 9-point scale (from 1=dislike extremely to 9=like extremely). After the assessment of the first product, participants were shown the second image (if the plant-based hot dog was displayed first, they were shown the pork hot dog, and vice versa) and asked the same questions to investigate their WTB and expected liking.

Additional questions included in the study were socio-demographic questions (i.e., age, gender, education level, employment status, familiarity with the FOP labels ("Before participating in this study, had you ever seen this front-of-pack nutrition/sustainable label?"), and meat consumption frequency) and attitudinal questions with the Meat Attachment Questionnaire (MAQ). The MAQ was developed and validated by Graça et al. (2015) to measure a positive bond toward meat consumption. It comprises 16 items divided into 4 dimensions (hedonism, affinity, entitlement, and dependence), with responses ranging from 1 (strongly disagree) to 5 (strongly agree). In our study, we included the 8 items that define hedonism – in which higher scores indicate meat is a source of pleasure – and affinity – in which higher scores define the affinity level toward meat consumption. Finally, three subdimensions of consumers' subjective understanding were investigated using multi-item Likert scales derived from previous literature (Mazzù et al., 2021; Mazzu et al., 2023): i) comprehensibility (I feel well informed by this label; This label is believable and trustworthy; This label is easy to interpret); ii) help to shop (This label helps me to understand the product comparison; This label helps me to understand different nutritional (sustainable) values; This label makes it easier to choose food); iii) complexity reduction (This front-of-pack food label is rather extensive; Using this front-of-pack food label to choose food is better than just relying on my own knowledge about what is in them). Responses ranged from 1 (strongly disagree) to 5 (strongly agree).

*Eye-tracking*

Eye-tracking was used to support the investigation of whether consumers visually pay attention to certain elements and how these impact their behaviors (Fisher, 2021; Van Loo et al., 2018). For both images shown to participants, specific areas of interest (AOIs) were defined. AOIs are important areas of the image, and, in our study, these corresponded to the two labels under investigation: the NS and the ES. For the two AOIs of both images, total visit durations were calculated, which can be considered a proxy for visual attention (Van Loo et al., 2021). The total visit duration for an AOI can be defined as the sum of the single visit durations of that AOI, where a visit duration is the time passed between the first and the last fixation, with no fixation outside that AOI – in other words, this is the sum of all fixations falling withing an AOI (Orquin & Holmqvist, 2018; Van Loo et al., 2021). Fixation counts are often used in consumer studies since information acquisition occurs during fixations (Khachatryan & Rihn, 2014).

### 2.3.3 Analysis

Analyses were performed using R statistics, version 4.2.3 (R Core Team, 2023), with readxl (Wickham & Bryan, 2023), writexl (Ooms, 2023), tidyr (Wickham, Vaughan D, et al., 2023), dplyr (Wickham, François, et al., 2023), eyelinkReader (Pastukhov, 2023), ggplot2 (Wickham, 2016), psych (Revelle, 2023), GPArotation (Bernaards & Jennrich, 2005), lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017), emmeans (Lenth, 2023), performance (Lüdecke et al., 2021), sjPlot (Lüdecke, 2023), and lavaan (Rosseel, 2012) package. Descriptive statistics were used to analyze the sample characteristics and explore eye-tracking data. To identify consumer segments based on the MAQ, an exploratory factor analysis with varimax rotation was conducted to reduce the 8 items of the MAQ to a smaller set of factors. Then, a two-step cluster analysis was performed by using the eigenvalues for the hierarchical Ward's method and the obtained centroids were used for a nonhierarchical K-means clustering. Differences across groups were tested using Chi-squares for

gender, education, employment status, and familiarity with the FOP labels, Mann-Whitney for consumption frequency, and a t-test for age. In addition, t-tests were conducted to investigate differences in the subjective understanding of each label; whereas, and two-way ANOVAs were used to explore differences in the visual attention each cluster paid to each AOI by image. Finally, a series of mixed-effect models were performed to explore whether the visual attention to the labels had an impact on the dependent variables, i.e., participants' expected liking and WTB for both hot dogs. To control for interpersonal differences, visual attention was considered as the average relative fixation duration for both AOIs, i.e., the share of total time spent in each AOI (the NS or ES) out of the total time spent looking at each image. In addition, an interaction effect between the product (plant-based *vs.* pork hot dog) and the independent variable (the average relative fixation duration) was considered in the models, which were conducted separately by product and by cluster.

### 2.3.4 Results

Two clusters were identified based on the respondents' meat attachment level (MAQ Cronbach alpha=0.8). Specifically, respondents in cluster 1 (consumers with a Higher Meat Attachment – HMA, n=44) showed higher scores for both MAQ dimensions (hedonism: 4.01±0.58; affinity: 4.25±0.53), whereas cluster 2 (consumers with a Lower Meat Attachment – LMA, n=32) had lower scores, especially for the hedonistic dimension (hedonism: 2.76±0.65; affinity: 3.48±0.54). When investigating differences between groups, no differences were highlighted in terms of gender, age, education level, employment status, familiarity with the proposed labels, and meat consumption frequency. The main socio-demographic information by cluster is reported in Table 1.

**Table 1**. Descriptive characteristics of the sample divided by cluster.

| | | HMA N= 44 | LMA N= 32 | *p-value* |
|---|---|---|---|---|
| *Gender*[1] | | | | |
| | Female | 27 | 25 | |
| | Male | 15 | 7 | 0.298 |
| | Other | 2 | 0 | |
| *Age mean (±SD)*[2] | | 31.9 (±13.1) | 33.3 (±14.4) | 0.661 |
| *Education level*[1] | | | | |
| | High school | 3 | 5 | |
| | Bachelor's degree | 17 | 15 | 0.274 |
| | Post-graduate (e.g., Master, PhD) | 24 | 12 | |
| *Employment status*[1] | | | | |
| | Full-time employment | 15 | 11 | |
| | Part-time employment | 4 | 2 | |
| | Unemployed | 1 | 0 | 0.939 |
| | Retired | 1 | 1 | |
| | Student | 23 | 17 | |
| | Other | 0 | 1 | |
| *Meat consumption frequency*[3] | | | | |
| | Never | 0 | 0 | |
| | Rarely (up to one time a month) | 16 | 16 | |
| | Occasionally (once-twice a month) | 22 | 14 | 0.174 |
| | Sometimes (about once a week) | 5 | 2 | |
| | Often (two-three times a week) | 1 | 0 | |
| *Familiarity with the NS* [1] | | | | |
| | Yes | 3 | 6 | 0.180 |
| | No | 41 | 26 | |
| *Familiarity with the ES* [1] | | | | |
| | Yes | 2 | 2 | 1 |
| | No | 42 | 30 | |

Note: HMA= consumers with a higher meat attachment level; LMA= consumers with a lower meat attachment level.
[1] Pearson Chi-square; [2] t-test; [3] Mann-Whitney test.

Moreover, cluster differences in visual attention were investigated by comparing the average relative fixation duration of each AOI, per image. For the plant-based hot dog image, the two clusters differed in the total visit duration of the ES ($p < 0.001$), with LMA consumers reporting a higher visit duration for this label than the HMA group. Moreover, within HMA consumers, significant differences were found in the time allocated to the two AOIs, with the ES being attended the most. Concerning the pork hot dog image, no major differences were found either between or within clusters. Results from visit durations are reported in Table 2.

**Table 2.** Visit duration per image and AOI, divided by cluster.

| AOI | Average relative fixation duration | | | |
|---|---|---|---|---|
| | Plant-based hot dog | | Pork hot dog | |
| | HMA | LMA | HMA | LMA |
| NS | 28.1 (9.0) [a, X] | 29.5 (8.9) [a, X] | 31.0 (7.8) [a, X] | 30.6 (9.6) [a, X] |
| ES | 28.5 (9.1) [a, X] | 36.1 (10.6) [b, Y] | 30.8 (8.6) [a, X] | 31.8 (11.9) [a, X] |

Note: HMA= consumers with a higher meat attachment level; LMA= consumers with a lower meat attachment level. Standard deviation is reported in parentheses. Different lowercase letters within a row denote visit durations with significant differences ($p < 0.001$) between clusters, within each image. Different uppercase letters within a column denote visit durations with significant differences ($p < 0.01$) within the cluster, within each image.

*Mixed-effect models*

Table 3 represents the estimated marginal trend of the mixed models. To answer the hypotheses, we used mixed models with an interaction effect between the plant-based (H1) or the pork (H2) hot dog and the average relative fixation duration of the ES and NS. Results show no impact of visual attention on participants with a HMA level – i.e., consumers who had higher MAQ scores and, thus who had a more positive bond towards meat consumption. Nonetheless, the estimate directions of the models are aligned with the hypotheses for the ES only. When focusing on the visual attention to the NS, the model shows a positive estimate direction for consumers' expected liking and WTB for the pork hot dog, despite its negative NS. In addition, a negative estimate value is identified for participants' WTB when considering the time spent looking at the NS of the plant-based product.

For LMA consumers (i.e., participants who had lower MAQ scores and, thus who had a more negative bond towards meat consumption, especially for the hedonistic aspects), the estimate directions follow the hypotheses, with a tendency of the visual attention to the ES of the plant-based hot dog positively influencing its expected liking. However, one result contrasts H2; specifically, higher visual attention to the negative NS of the pork hot dog had a significant positive effect on consumers' expected liking for the product.

**Table 3.** Estimated marginal trends of the mixed-effect models.

| | HMA | | | LMA | | |
|---|---|---|---|---|---|---|
| | Estimate | SE | Marginal R2 | Estimate | SE | Marginal R2 |
| Exp_liking_NS_pork | 0.014 | 0.037 | 0.004 | **0.076**** | 0.033 | 0.148 |
| Exp_liking_NS_plant | 0.006 | 0.033 | | 0.045 | 0.036 | |
| Exp_liking_ES_pork | -0.009 | 0.033 | 0.013 | -0.033 | 0.027 | 0.122 |
| Exp_liking_ES_plant | 0.030 | 0.032 | | **0.057*** | 0.03 | |
| WTB_NS_pork | 0.028 | 0.032 | 0.079 | -0.017 | 0.029 | 0.385 |
| WTB_NS_plant | -0.008 | 0.028 | | 0.044 | 0.031 | |
| WTB_ES_pork | 0.000 | 0.029 | 0.071 | -0.038 | 0.023 | 0.414 |
| WTB_ES_plant | 0.010 | 0.027 | | 0.040 | 0.025 | |

Note: HMA= consumers with a higher meat attachment level; LMA= consumers with a lower meat attachment level. Exp_liking_NS_"product": expected liking as the dependent variable and interaction between the product and the visual attention paid to the NS as the independent variable; Exp_liking_ES_"product": expected liking as the dependent variable and interaction between the product and the visual attention paid to the ES as the independent variable; WTB_NS_"product": willingness to buy as the dependent variable and interaction between the product and the visual attention paid to the NS as the independent variable; WTB_ES_"product": willingness to buy as the dependent variable and interaction between the product and the visual attention paid to the ES as the independent variable; ** and * denote that the parameters differ from zero at the 5% and 10% significance level, respectively.

*Subjective understanding of the labels*

To analyze consumers' subjective understanding of the NS and ES, three subdimensions were investigated: comprehension, help to shop, and complexity reduction.

The ANOVA showed no significant difference between clusters in any of the three subdimensions. More specifically, the three items on comprehensibility, which measured the ability to easily interpret the label, were positive for the NS and ES, with the "This label is easy to interpret" item receiving the most positive score for both labels. In terms of help to shop, the item obtaining the lowest score was "This label helps me to understand the product composition" in both cases; whereas "This label helps me to understand different sustainable values" received the highest score for the ES and "This label makes it easier to choose food" received the highest value for the NS. For the two items investigating complexity reduction, both labels received lower scores for the "This front-of-pack food label is rather extensive" item – which is also in line with the idea of interpretative labels, which describe the product's features and aspects without providing many details.

Finally, results on consumers' subjective understanding showed an overall positive evaluation of the two labels, with minor discrepancies in the support provided in understanding the product

composition and the labels being extensive. Means values of the three subdimensions are reported in Table 4.

**Table 4.** Subjective understanding of the NS and ES by cluster.

| | NS | | ES | |
|---|---|---|---|---|
| | HMA | LMA | HMA | LMA |
| *Comprehensibility* | | | | |
| I feel well-informed by the food label | 3.5 (1.0) | 3.4 (0.9) | 3.5 (0.9) | 3.5 (1.0) |
| This label is believable and trustworthy | 3.5 (0.9) | 3.3 (0.8) | 3.6 (0.9) | 3.2 (0.9) |
| This label is easy to interpret | 4.3 (0.7) | 4.4 (0.7) | 4.3 (0.9) | 4.3 (0.6) |
| *Help to shop* | | | | |
| This label helps me to understand the product composition | 2.7 (1.1) | 2.9 (1.2) | 2.4 (1.1) | 2.5 (1.2) |
| This label helps me to understand different nutritional (sustainable) values | 3.7 (1.1) | 3.5 (1.3) | 4.1 (0.9) | 4.0 (1.0) |
| This label makes it easier to choose food | 3.8 (0.8) | 3.8 (1.0) | 3.6 (0.9) | 3.8 (0.8) |
| *Complexity reduction* | | | | |
| This front-of-pack food label is rather extensive | 2.4 (0.9) | 2.3 (0.9) | 2.4 (1.1) | 2.1 (0.8) |
| Using this front-of-pack food label to choose foods is better than just relying on my own knowledge about what is in them | 3.5 (1.2) | 3.6 (1.0) | 3.7 (1.0) | 3.6 (1.0) |

Note: HMA = consumers with a higher meat attachment level; LMA consumers with a lower meat attachment level. Data expressed as mean values and calculated on a 5-point scale (from 1 = Completely disagree to 5 = Completely agree). Standard deviations are reported in parentheses.

### 2.3.5 Discussion

The present work aimed at analyzing the effects of visual attention to interpretative FOP labels (i.e., the NS and ES) on consumers' expected liking and purchasing intention. The few previous studies investigating whether the NS impacts consumers' taste perception of food products found no major influence of this labeling system (De Temmerman et al., 2021; Folkvord et al., 2021); however, none of these studies focused on meat and PBMAs. Therefore, our research investigated the impact of consumers' visual attention to the NS and ES on their behavior toward a plant-based and a pork hot

dog. To do so, we combined self-reported measures with eye-tracking data to capture participants' attention to the two labels under investigation. Since FOP labels can have different effects based on individual characteristics, as suggested by Godden et al., (2023), and because we focused our study on animal products and their plant-based counterparts, we segmented our sample based on participants' meat attachment level (MAQ by Graça et al. (2015)), as previously done in other studies (Circus & Robison, 2019; Williams et al., 2023).

Results showed interesting patterns in terms of visual attention for participants with a LMA level. Specifically, no difference was found in the average relative time of fixation for the pork hot dog, either by product or cluster; however, for the plant-based one, LMA consumers paid significantly more attention to the ES than the NS and when compared to HMA participants. This difference in visual attention could elicit a different engagement level for the sustainability aspects of LMA consumers (Albert & Tullis, 2023; Tullis & Albert, 2013). However, future studies are needed to further explore potential consumer differences in such topics.

Overall, findings of the mixed models showed that visual attention to the NS and ES did not impact the expected liking and WTB of participants who had a more positive bond toward meat consumption (HMA consumers). However, interesting trends were identified for this cluster when considering the estimate directions of the mixed models used to explore the relationship between attention to FOP labels and self-reported expectations and behaviors. Specifically, attention paid to the negative NS of the pork hot dog was linked to a positive direction of the reported expected liking and WTB for the product. Despite this, HMA participants did not show a negative attitude toward either the NS or the ES in terms of label comprehensibility, help to shop, and complexity reduction. These findings are in line with a previous study by Williams et al. (2023), who found that the higher the consumer meat attachment level, the less consumers' purchase intention for meat products is influenced by negative eco-labels; similarly to our findings, the authors also found no impact of the meat attachment level on label perception. Since previous work showed that consumers with high meat attachment levels have a lower desire to reduce meat consumption (Dowsett et al., 2018; Williams et al., 2023), it is

necessary to investigate multi-strategy approaches to support meat reduction in this consumer group. For instance, targeted communication campaigns on the use of FOP labels should be developed and tested on different consumer segments before an intervention with such labels. In addition, it is worth noting that studies focusing on meat products and the effects of health/sustainable messaging on consumers' responses often consider positive labels/claims rather than negative ones (Hoek et al., 2017; Van Loo et al., 2014; Van Wezemael et al., 2014). Thus, future research on the topic could test the effects that negative labels have on consumer purchasing behaviors of meat products (especially of those showing high meat attachment levels) in order to obtain a more robust research body to support both policymakers and manufacturers in their decisions. In addition, future research could carry out a similar study involving eye-tracking and positive interpretative FOP labels for PBMAs in association with sensory tasting to explore the potential, combined effect of FOP labels and actual sensory experience to promote PBMAs as meat replacements.

When considering the results of LMA consumers (participants with lower MAQ scores – i.e., with a less positive bond toward meat consumption), attention paid to the NSs and ESs did not affect consumers' purchase intention of either product. Nonetheless, the estimate directions of the mixed models were in line with the hypotheses, thus, with a positive direction for the plant-based hot dog and a negative one for the pork hot dog. However, participants' visual attention did have an impact on the expected liking of both products. Specifically, for LMA consumers, paying more attention to the positive ES of the plant-based hot dog was associated with a higher expected liking for the product. Despite the significance level of this finding showing only weak evidence of this relation – which might be explained by the small sample size not allowing the identification of a stronger significant interaction – this result confirms that labeling highlighting positive sustainable aspects has a positive influence on the sensory perception of food products, as already found in previous research ( e.g., Banovic et al., 2022; Fernqvist & Ekelund, 2014; Lee et al., 2013; Silva et al., 2017). Results for LMA participants also showed that paying more attention to the negative NS of the pork hot dog led to a significantly higher expected liking for the product. This finding follows the estimate direction

of HMA participants, showing that, regardless of the meat attachment level, attention to a negative NS on a meat product leads consumers to higher sensory expectations. A possible explanation for these results – which are in contrast with H1 – could be linked to American consumers' tendency to implicitly associate unhealthy food with tastiness (Raghunathan et al., 2006). However, previous research showed that such an association could be based on intercultural differences (Werle et al., 2013); thus, future studies could investigate whether similar results are confirmed also when focusing on non-American consumers. Despite participants' attention to the negative NS of the meat product having a positive effect on sensory expectations for both clusters, this did not imply an increased purchasing intention for consumers with a lower meat attachment level. As a matter of fact, attention to the label showed a positive estimate direction for LMA consumers only.

When it comes to consumer understanding of the proposed labels, results showed an overall positive evaluation, with no differences between clusters and mean values in line with previous studies (Mazzù et al., 2021; Mazzu et al., 2023). However, it should be noted that understanding and knowledge increase with familiarity (Hagmann & Siegrist, 2020; Packer et al., 2021). Similarly, previous work showed that the higher the familiarity with the label, the higher consumers' public support and engagement level is (Hagmann & Siegrist, 2020). As a result, we anticipate that communication campaigns on these labeling systems will positively impact the perception of such labels – in terms of comprehensibility, help to shop, and complexity reduction – and provide even more positive results in terms of consumer understanding.

Finally, to the best of our knowledge, this work is the first study employing eye-tracking in the case of a dual labeling scheme and exploring the effects of visual attention on sensory expectations and purchasing behaviors toward meat and PBMAs. However, this study is not without limitations, which suggest potential opportunities for future research. First, despite the sample size of the study being in line with previous studies employing eye-tracking (Bialkova et al., 2020; Brazil & Caulfield, 2017; Rramani et al., 2020), it may not allow to detect small differences between groups. Second, the products used in this study were hypothetical instead of real products. While this is common practice

in consumer studies to eliminate the potential association with the brand's effect (Savov et al., 2022), future works could investigate whether labels displayed on real products evoke a different level of attention. Third, this study considers laboratory settings, and it would be of interest to verify whether similar outcomes are met also in real contexts. Additionally, future studies could use a similar approach on consumers who are already familiar with the proposed labels to explore potential differences in consumer behavior based on different familiarity levels.

### 2.3.6 Conclusions

This research investigated consumer attention to interpretative nutrition and sustainable labels (the NS and ES) and how this related to their sensory expectation and purchasing intention for pork and plant-based hot dogs. Results showed that while attention to the proposed FOP labels does not impact consumers with a high meat attachment level, the sensory expectation of both products was related to visual attention for consumers with LMA levels. Specifically, a positive and significant interaction was identified between the attention paid to the negative NS of the animal product and its expected liking, and between the attention paid to the positive ES of the plant-based product and its expected liking.

With regard to potential implications, our findings confirm the positive effect of favorable sustainable labels on consumers' sensory expectations for PBMAs. Thus, reformulating products to guarantee positive sustainable labels on the front of food packages could encourage consumers' engagement while promoting sustainability in the food sector. In addition, for companies concerned about the potential negative effects that labeling systems such as the NS could have on animal products, our study showed that attention to such a label would not hinder consumers' purchasing intention or expected liking; on the contrary, some consumer segments might link this negative score to a tastier sensory experience. Finally, knowing how much attention consumers pay to specific FOP labels on meat and PBMAs and how this impacts individuals' behavior could assist policymakers when

defining tools for tackling meat reduction. Policymakers could also benefit from the results on the subjective understanding as the overall positive findings for both the NS and ES (especially on a population who is not familiar which such labels) may support the decision-making process related to the implementation of labeling schemes needed to guarantee informed food choices

5340 **Appendix**

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5342 **Table A1.** Information provided to participants before starting the experiment.

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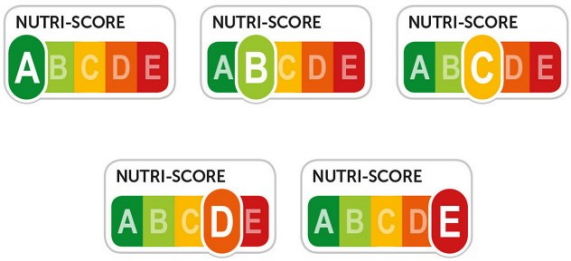
| Information 1: Front-of-pack food labels[1]<br><br>**Front-of-package (FOP)** food labels are symbols, schemes, or systems designed to communicate concise and useful information (e.g., nutrition- or environment-related) to consumers to facilitate their food choices. Among the proposed FOP schemes developed, here we described two labels: the NutriScore and the EcoScore. |
| Information 2: NutriScore[2]<br><br>The **NutriScore** is a five-color nutrition label that displays food products' overall nutritional value. It ranks products from A ("healthiest") to E ("the least healthy") and associates colors ranging from green to red. The calculation is based on an algorithm that takes into account both problematic components, such as fat, saturated fat, salt, sugar, and caloric levels, as well as beneficial elements, such as fiber and protein contents.<br><br>An image of the NutriScore is displayed on this page.<br><br>  |
| Information 3: EcoScore[3]<br><br>The **EcoScore**, similar to the NutriScore, is a food label with five categories, ranging from A (green, the most sustainable option) to E (red, the least sustainable option). While the NutriScore provides an overall assessment of a product's nutritional aspect, this label gives an overall evaluation of a food product's environmental impact to promote more responsible and sustainable consumption. In its algorithm, the EcoScore incorporates various environmental factors, from production to transportation, packaging, country of origin of ingredients, and seasonality of the finished product. |

[1] Adapted from:
WHO. (2019). Guiding principles and framework manual for front-of-pack labelling for promoting healthy diet.
De Marchi, E., Cavaliere, A., Pucillo, F., Banterle, A., & Nayga, R. M. (2023). Dynamics of demand-side and supply-side responses to front-of-pack nutrition labels: a narrative review. European Review of Agricultural Economics, 50(2), 201–231. https://doi.org/10.1093/erae/jbac031

[2] Adapted from:
M., D. L., Van Eijsden, M., Van Roost, M. H., De Graaf, K., & Roodenburg, A. J. (2022). The Nutri-Score algorithm: Evaluation of its validation process. Frontiers in Nutrition, 9, 974003. https://doi.org/10.3389/fnut.2022.974003 & Pomeranz, J. L., Wilde, P., Santé Publique France. (2024). Nutri-Score. https://www.santepubliquefrance.fr/en/nutri-score

[3] Adapted from:
Marette, S. (2022). Ecological and/or Nutritional Scores for Food Traffic-Lights: Results of an Online Survey Conducted on Pizza in France. Sustainability, 14(1), 247. https://doi.org/10.3390/su14010247
Colruyt Group. (2024). How do we calculate the Eco-score? https://www.colruytgroup.com/en/conscious-consuming/eco-score/calculate-the-eco-score

An image of the EcoScore is displayed on this page.


Information 4: Plant-based alternatives[4]

**Plant-based alternatives** are food products designed to mimic the animal counterpart in terms of sensory experience and nutritional content by using animal-free ingredients (e.g., soy, pulses, wheat). Examples are plant-based burgers, plant-based hot dogs, plant-based milk, plant-based eggs, and plant-based tuna.

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[4] Adapted from:
Van Vliet, S., Kronberg, S. L., & Provenza, F. D. (2020). Plant-Based Meats, Human Health, and Climate Change. Frontiers in Sustainable Food Systems, 4, 555088. https://doi.org/10.3389/fsufs.2020.00128
Ketelings, L., Havermans, R. C., Kremers, S. P., & De Boer, A. (2023). How Different Dimensions Shape the Definition of Meat Alternative Products: A Scoping Review of Evidence between 2000 and 2021. Current Developments in Nutrition, 7(7), 101960. https://doi.org/10.1016/j.cdnut.2023.101960
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**Figure A1.** Images showed to participants during the experiment: a) plant-based hot dog, and b) pork hot dog.

a)


b)

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# Conclusions

## Overall Conclusion

By focusing on plant-based alternatives and front-of-pack labeling schemes, this work highlights two promising areas where consumer empowerment is key. On one side, alternative protein sources, such as plant-based substitutes to animal food, have the potential to promote meat consumption reduction and, thus, investigating consumers' acceptance of these foods is critical to ensure their widespread adoption. On the other hand, front-of-pack labels have been recognized as a promising tool for supporting consumers in their daily food choices. Ultimately, the research presented in this manuscript underscores the potential for individual food choices to collectively drive meaningful environmental, health, and social changes. The combination of literature reviews and empirical studies offers actionable insights to support policymakers, industry stakeholders, and researchers interested in guiding consumers toward healthier and more sustainable food consumption.

## Synthesis of Key Findings

The findings of this dissertation underscore how plant-based alternatives and interpretative front-of-pack labels can guide consumers toward healthy and sustainable food choices. However, to allow such a potential, consumers' expectations and motivations need to be considered and carefully evaluated.

The literature reviews presented in the first chapter of this manuscript highlight the growing interest in plant-based alternatives, both from a consumer and a producer perspective. Overall, findings show that, while these foods offer a compelling alternative to traditional animal products, challenges remain to ensure their successful integration into the mainstream market. Specifically, increasing familiarity with and interest in these products is key to steering consumers' preferences. In addition, the lack of sensory appeal limits consumer acceptance of plant-based substitutes, mostly due to scarce animal-like sensory features. Given these limitations, research on the topic is needed to further understand

the most suitable way to produce and communicate such products, with a focus on plant-based categories that have been less investigated.

The first chapter also includes a systematic review of front-of-pack labeling systems, specifically the Nutri-Score and Eco-Score, and their effectiveness in guiding consumer food choices. The analysis highlights the potential of these tools to enhance consumer understanding and influence purchasing behaviors, with stronger evidence for the Nutri-Score due to the larger body of literature. However, variability in consumer perception of these labels suggests that further studies are needed to deeply assess their potential, especially to better comprehend their effectiveness among consumers with differing levels of familiarity.

After a thorough evaluation of the available literature on the topics of interest, the second chapter shifts to empirical studies conducted to address research gaps that need to be addressed to maximize the effectiveness of these tools. Through three original studies, this dissertation examines consumer motivations, sensory expectations, and the role of visual attention in shaping consumer perceptions and purchasing intentions. More specifically regarding plant-based meat alternatives, the findings reported in the second chapter show that consumers often seek meaty sensory characteristics, such as meaty aspect, flavor, and/or texture. However, this could change based on the specific product the alternative is trying to replace – for instance, burgers or hot dogs – as well as on the consumer segment. As a matter of fact, different individuals prioritize distinct values in their food choices, which underscores the importance of incorporating different attitudinal elements to define targeted product development and communication strategies that can encourage the adoption of plant-based options. Despite individual differences, consumers generally associate plant-based meat alternatives with health and sustainability aspects. Therefore, implementing clear and proper communication strategies on the nutrition profile and sustainability impact of plant-based alternatives, as well as on the effect that meat reduction would have on humans and the planet's health, is key to fostering consumer acceptance of these products.

Finally, the last empirical study of the second chapter combines plant-based meat alternatives and front-of-pack labels by exploring consumer visual attention to interpretative front-of-pack labels and its effect on their sensory expectations and purchase intentions of a traditional meat product and its plant-based counterpart. Findings further confirm differences among consumer segments, with label effectiveness varying based on consumers' attachment to meat. Specifically, consumers with a lower meat attachment level were more influenced by the visual attention paid to the front-of-pack labels, suggesting the need for further research assessing the impact of such labels on diverse consumer groups.

**Implications for Policymakers and Industry Stakeholders**

The dissertation findings highlight the importance of a coordinated approach among policymakers, industry stakeholders, and researchers. For plant-based meat alternatives to support the transition toward healthy and sustainable diets, industry stakeholders must focus on improving sensory qualities while maintaining transparency about the ingredient lists. In addition, policymakers could further this transition by encouraging regulations that incentivize cleaner ingredient profiles and by fostering public awareness campaigns that promote plant-based diets and communicate their positive impact on human health and the environment.

Regarding front-of-pack labeling, the results advocate for the adoption of well-researched, interpretative labels, which can effectively guide consumers toward healthy and sustainable choices. Policymakers are advised to consider mandatory front-of-pack labeling schemes for both nutritional and sustainability aspects to support well-rounded, informed food choices. However, when defining such labels, attention should be paid to the heterogeneity in consumer responses Finally, for front-of-pack labels to drive meaningful behavior change, they should be part of a broader and widely adopted framework that includes educational initiatives targeting diverse consumer groups.

## Directions for Future Research

Building on these findings, future research should continue to explore the effectiveness of plant-based alternatives and front-of-pack labels across diverse consumer populations and regions. Studies examining plant-based analogs should aim at addressing consumer concerns regarding ingredient complexity and optimizing sensory attributes to match traditional meat products and meet consumers' needs. Additionally, further work is needed to understand how socio-demographic– such as age, dietary preferences, and cultural influences – and attitudinal factors interact with motivations for choosing plant-based products across different categories.

In terms of front-of-pack labels, research should further investigate how combining both nutritional and sustainable labels influences consumer decisions. Employing advanced methodologies, such as eye-tracking and neuromarketing tools, could further unravel the cognitive processes underlying their effectiveness and provide valuable insights for policymakers to define such tools.

## Conclusion

In summary, this dissertation advances the understanding of consumer behavior toward plant-based meat alternatives and front-of-pack labels and offers actionable insights for fostering a healthy and sustainable transition within the food system. By enhancing our knowledge of consumers' perceptions and understanding, this research supports the design of informed strategies that align consumer behavior with public health and environmental goals. The findings call for continued interdisciplinary collaboration and policy development to strengthen the role of plant-based meat alternatives and front-of-pack labels as key elements for dietary changes.