INSIGHTS IN CONSUMER AWARENESS AND PERCEPTION OF NEW FOODS AND FOOD RELATED TECHNOLOGIES

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Insight in consumer awareness and perception of new foods and food related technologies

Doctoral Dissertation

Vpogled v ozaveščenost potrošnikov in dojemanje novih živil in živilskih tehnologij

Doktorska disertacija

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To the readers of this dissertation,

"Consumption is the sole end and purpose of all production; and the interest of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer." — *Adam Smith*

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Abstract

As the global population is predicted to reach billions in the coming decades, the challenge of providing sustainable and efficient protein sources is becoming increasingly urgent. Simultaneously, the need to mitigate climate change and prevent further depletion of natural resources continues to place immense pressure on existing food systems. In response, new foods and food related technologies (also referred to as food technologies), such as alternative protein sources, have emerged as potential solutions. Despite their nutritional, environmental and ethical benefits, consumer acceptance remains limited.

Studies show that while many consumers express concern about environmental issues, their purchasing behaviours do not always align with their beliefs. Literature suggests that consumer motivations, perceived barriers, and differing understandings of sustainability contribute to this complex web of influences. Barriers such as neophobia, accessibility, scepticism, cost, and past failures in communication during food safety crises often hinder the adoption of such foods and food technologies.

Addressing these challenges requires an interconnected and comprehensive approach towards sustainable consumption that promotes environmentally friendly and ethically produced products while aligning with consumer preferences. To bridge these gaps, this dissertation employed a mixed-methods approach, combining quantitative tools such as questionnaires with qualitative insights from interviews and focus groups. The research was structured in two parts: first, to understand the drivers and barriers in consumption and second, to assess the effectiveness of communication for complex scientific topics.

Findings revealed that while health and sustainability motivated many consumers, several barriers impeded such as unfamiliarity with new foods and food technologies, limited information on origin and processing, accessibility, and cost hindered adoption. Concerns about additives were prominent for processed plant-based alternatives, while sensory appeal and food safety were key issues for edible insects. Cell-culture-derived meat raised concerns related to safety and artificiality due to stark differences in global regulatory frameworks.

In the second phase, results indicated that clear, engaging scientific content improved public interest in science communication. Digital communication tools have shown promise in making scientific topics more accessible and increasing understanding. Digital tools, such as podcasts, proved effective in raising awareness of advanced analytical techniques like mass spectrometry, which is critical in environmental monitoring and food safety.

Adoption strategies developed with consumers highlight the need for addressing consumer concerns. Educational campaigns, transparent labelling, and clear explanations of ingredients, sources, and processing methods were key in reducing scepticism. As consumer preferences evolve, future research should track responses to shifting regulations, cultural influences, and technological advancements.

This research has wide-reaching implications. For policymakers and researchers, it underscores the need for transparency and accessible information to build trust and drive sustainable adoption. For the food industry, it identifies key factors to help manufacturers develop products that align with consumer priorities while promoting sustainability.

Povzetek

Ker naj bi svetovno prebivalstvo v prihodnjih desetletjih doseglo več milijard, postaja izziv zagotavljanja trajnostnih in učinkovitih virov beljakovin vse bolj nujen. Hkrati je potreba po blaženju podnebnih sprememb in preprečevanju nadaljnjega izčrpavanja naravnih virov vse večji pritisk na obstoječe prehranske sisteme. Kot odgovor na to so se pojavile nove prehranske tehnologije, kot so alternativni viri beljakovin, ki predstavljajo potencialne rešitve. Kljub prehranskim, okoljskim in etičnim koristim ostaja sprejemanje med potrošniki omejeno.

Študije kažejo, da čeprav mnogi potrošniki izražajo skrb za okoljske težave, njihovo nakupno vedenje pogosto ne odraža njihovih prepričanj. Literatura nakazuje, da na to zapleteno mrežo vplivov vplivajo motivacije potrošnikov, zaznane ovire in različna razumevanja trajnosti. Med ovirami so pogosto prisotni neofobija, dostopnost, skepticizem, stroški ter pretekli neuspehi v komuniciranju med krizami na področju varnosti hrane.

Reševanje teh izzivov zahteva celovit pristop k trajnostni potrošnji, ki spodbuja okolju prijazne in etično proizvedene izdelke ter se prilagaja potrošniškim preferencam. Za zapolnitev vrzeli je bila uporabljena metoda mešanih pristopov, ki združuje kvantitativna orodja, kot so vprašalniki, in kvalitativne vpoglede iz intervjujev ter fokusnih skupin. Raziskava je bila strukturirana v dveh delih: prvi se je osredotočal na dejavnike in ovire pri potrošnji, drugi pa na učinkovitost komuniciranja kompleksnih znanstvenih tem.

Rezultati so pokazali, da sta zdravje in trajnostnost motivirala številne potrošnike, vendar so različne ovire, kot so nepoznavanje novih živil in prehranskih tehnologij, omejene informacije o izvoru in predelavi, dostopnost ter stroški, ovirale sprejemanje. Pri predelanih rastlinskih alternativah so bili izraženi pomisleki glede aditivov, pri užitnih insektih pa senzorična privlačnost in varnost hrane. Pri mesu iz celične kulture so bile glavne skrbi varnost in umetnost postopka, predvsem zaradi velikih razlik v regulativnih okvirih.

Drugi del raziskave je pokazal, da jasno in privlačno znanstveno komuniciranje povečuje zanimanje javnosti za znanost. Digitalna orodja so učinkovita pri izboljšanju dostopnosti znanstvenih tem in razumevanja. Zlasti podkasti so bili uspešni pri ozaveščanju o analitskih tehnikah, kot je masna spektrometrija, ki je ključna pri nadzoru okolja in varnosti hrane.

Strategije sprejemanja, razvite s potrošniki, poudarjajo potrebo po naslovitvi njihovih pomislekov. Izobraževalne kampanje, transparentno označevanje in jasne razlage sestavin, izvora ter predelovalnih metod so ključne pri zmanjševanju skepticizma. Ker se potrošniške preference razvijajo, bi morale prihodnje raziskave spremljati odzive na spreminjajoče se regulative, kulturne vplive in tehnološke napredke.

Raziskava ima široke implikacije. Za oblikovalce politik in raziskovalce poudarja potrebo po transparentnosti in dostopnih informacijah za krepitev zaupanja in spodbujanje trajnostnih praks. Za prehransko industrijo pa opredeljuje ključne dejavnike, ki lahko pomagajo proizvajalcem razviti izdelke, ki ustrezajo potrošniškim prioritetam in podpirajo trajnostnost.

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Abbreviations

CCDM ... Cell-Culture-Derived Meat
CFP ... Carbon Footprint
EC ... European Commission
EFSA ... European Food Safety Authority
EU ... European Union
FAO ... Food and Agriculture Organization
FCR ... Feed Conversion Ratio
FDA ... U.S. Food and Drug Administration
FSA ... Food Standards Agency
GMO ... Genetically Modified Organism
SDG ... Sustainable Development Goals
USDA ... U.S. Department of Agriculture

Glossary

Alternative Proteins	Protein sources derived from non-traditional methods, such as plant-based ingredients, cell-culture-derived meat, insects, or fermentation.
Cell-Culture-Derived Meat	Meat grown from animal cells in a controlled environment, eliminating the need to raise or slaughter animals, offering a sustainable, ethical alternative to traditional meat.
Circular Economy	An economic system aimed at eliminating waste and promoting the continual use of resources by reusing, repairing, recycling, and regenerating products and materials.
Consumer Acceptance	Willingness of consumers to try, adopt, and regularly consume a product, influenced by factors like taste, price, and perceived benefits.
Consumer Attitudes	A consumer's feelings, beliefs, and behavioural intentions towards a product, service, or brand, shaped by personal experiences, cultural influences, and marketing efforts.
Consumer Behaviour	The decision-making processes of individuals or groups as they search for, purchase, use, evaluate, and dispose of products or services.
Consumer Perception	The process by which consumers interpret and make sense of information about products, services, or brands based on their experiences, expectations, and sensory input.
Food Innovation	The development and implementation of new food products, processes, or technologies designed to improve quality, sustainability, and appeal.
Food Related Technologies	The application of scientific knowledge, engineering, and technological innovations to the production, processing, preservation, packaging, and distribution of food (also referred to as "food technologies").
Insect-Based Foods	Edible products derived from insects, either whole or as ingredients (e.g., insect flour), promoted as a sustainable and nutrient-rich alternative to traditional protein sources.
Listener Engagement	The degree to which podcast listeners interact with, respond to, or are influenced by the content, often measured through feedback, surveys, or behavioural patterns.
Mass Spectrometry	An analytical technique used to identify and quantify chemical compounds by measuring the mass-to-charge ratio of ions.
New Foods	Food products introduced to the market for the first time, often involving novel ingredients, production methods, or formats to meet emerging consumer demands.
Plant-Based Foods	Foods made from plants, including fruits, vegetables, grains, legumes, and nuts, often formulated as alternatives to animal-derived products.
Podcast	A digital audio or video series distributed online, often used as a tool for storytelling, education, and engagement with specific audiences.
Sustainable Consumption	The practice of consuming goods and services without compromising the ability of future generations to meet their own.

Chapter 1

Introduction

The global food industry stands at a pivotal moment, shaped by shifting consumer priorities, evolving regulatory frameworks, and rapid technological advancements. Consumers, once passive recipients of food products, have emerged as active participants who shape trends by demanding greater transparency, ethical practices, and sustainability. These shifts have driven significant changes in food production, marketing, and product development, compelling industries to align with values such as health, environmental stewardship, and ethical consumption.

Among the most transformative innovations are alternative proteins. These novel solutions address pressing concerns tied to traditional livestock farming, including greenhouse gas emissions, resource inefficiencies, and animal welfare. Despite their potential to revolutionise food systems, the adoption of alternative proteins hinges on consumer perception, awareness, and acceptance. Motivations rooted in environmental and ethical considerations generate interest, yet challenges like sensory appeal, cost, and scepticism surrounding processing remain substantial barriers.

Communication and engagement play a critical role in bridging the gap between innovation and acceptance. Effective strategies, ranging from transparent labelling to educational campaigns, are vital for building trust and helping consumers make informed decisions. This chapter explores these themes in three parts: the evolving influence of consumers on food trends and regulations, consumer perceptions of new foods and food technologies (referred to more broadly as food related technologies, used here for simplicity), particularly alternative proteins, and the critical role of communication in enabling broader acceptance of specialised sciences involved in the field of food research.

1.1 Consumer Influence on Food Trends and Market Dynamics

The evolution of food consumption patterns clearly reflects how societies transform across different historical periods (Kearney, 2010; Johnson & Earle, 2016). During the 20th century, convenience foods emerged as a sign of rapid urbanisation, accompanied by changing priorities in traditional or typical family structures (Scholliers, 2015). This shift also marked a growing consumer focus on time efficiency while maintaining food quality (Harris & Shiptsova, 2007; Zhong & DeVoe, 2010). Gradually, food consumption patterns further transitioned to reflect increased expectations regarding food quality and innovation (Grunert, 2005).

As these expectations evolved, understanding consumer behaviour became increasingly important for adapting to these changes and achieving market acceptance (Albertsen et

al., 2020). To meet these shifting demands, modern consumer research typically relies on systematic methods like qualitative and quantitative approaches, depending on the objectives at hand. Quantitative research, for instance, focuses on measurable data that can be analysed across larger populations (Payne & Wansink, 2011). Surveys are commonly used to identify trends and preferences, allowing researchers to assess patterns such as the willingness to pay or the popularity of certain brands and products. While these methods provide statistically robust results, they may overlook factors impacting consumer psychology such as impact of emotions and personal reasoning (Fischer & Guzel, 2023).

Qualitative methods, on the other hand, are useful for exploring the motivations and attitudes underlying consumer behaviour (Spiggle, 1994). Techniques like focus groups and interviews provide rich, detailed information about perceptions and preferences, particularly those influenced by emotional and cultural factors. However, their smaller sample sizes make generalising findings more challenging (Vicsek, 2010).

To fully understand the complexity of the research questions and their intersection with consumer psychology, many studies integrate both qualitative and quantitative methods to formulate a mixed-methods approach (Malina et al., 2011). Such approaches are beneficial in identifying general trends and patterns and subsequently diving deeper into the motivations and attitudes behind these behaviours (Kleih et al., 2022).

Currently, consumers expect their foods to prioritise health and nutrition (McCluskey, 2015; Duarte & Teixeira, 2021). There is also a strong emphasis on factors that drive ethical and sustainable practices (Kuokkanen, H., & Sun, 2020) in the food processing industry. This change in demand is particularly advocated by the overall increase in awareness of global challenges and their impact on food systems such as climate change, resource management and processing practices (Lusk & McCluskey, 2018; Lusk, 2019; Fang et al., 2023; Peiró-Signes et al., 2022).

At the core of this paradigm lies the concept of sustainability in consumption patterns, which gained significant traction at the 1992 UN Earth Summit in Rio and the subsequent adoption of Agenda 21. At that time, the framework highlighted the critical balance between meeting fundamental human needs while preserving environmental integrity. This was when various sectors were evaluated for their environmental impact, with production and consumption systems standing out prominently due to their contributions to greenhouse gas emissions, water quality degradation, and biodiversity reduction (Grubb et al., 1993; Reisch et al., 2013).

Despite recognising it as a challenge to sustainable consumption, progress towards integrating sustainability into the development of sectors like food systems has been slow and inconsistent, necessitating a more robust action plan from key players, including governments and various stakeholders (Mensah, 2019).

Perhaps the biggest reason for this is the difficulty surrounding the complex definition of what constitutes sustainable consumption parameters and the varying levels of consumer engagement with it (Glavič & Lukman, 2007; Sedlacko et al., 2013). Therefore, it is difficult to overlook the significant impact consumers have on the products that the food industry can potentially manufacture, place on market shelves, and ensure their success (Linnemann et al., 2006; Boström & Klintman, 2019).

A growing point of consideration in measuring this impact is the shift observed in how the majority of companies have transitioned from supply-driven models to demand-driven ones, with consumer feedback being considered on multiple stages of the food supply chain (Saitone & Sexton, 2017). This shift has also given rise to the need for transparency and accountability, resulting in the emergence of the "farm to fork" concept (Donaldson, 2022). At present, this is achieved through the implementation of procedures and practices to ensure traceability in the food supply chain (Aung & Chang, 2014).

The benefits of introducing traceability in the supply chain have been considerable, not just for gaining consumer trust but also for establishing food safety. Traditionally demonstrated by the use of barcodes and enhancements in barcode features, this system of traceability has now progressed to the use of blockchain technologies in the food industry (Fan et al., 2019; Chun-Ting, 2020).

These technological advancements have revolutionised the ability to trace products through multiple operations in the supply chain. Specifically, they address key areas such as tracking goods during transportation, ensuring transparency in information sharing, and managing both in-house and outsourced production processes. They also play a critical role in meeting food safety and quality requirements (Ringsberg, 2014).

In addition to improving operational efficiency, these technologies enable real-time verification of production standards and provide clear insights into the local or regional origins of food products. This level of traceability helps companies validate their claims about ethical and sustainable practices, such as fair-trade certifications (Sun & Wang, 2019).

Such innovations further contribute to building consumer trust, provided that the information is made available to consumers in an accessible manner. This enables consumers to make informed decisions about the products they purchase (Zhang et al., 2020; Lam et al., 2024). Table 1.1 provides a brief overview of the factors that currently contribute to consumer trust in food systems, including transparency, source credibility, perceived benefits and risks, and cultural and personal beliefs.

Table 1.1: Factors impacting consumer perception and trust on food-related matters.

Factor	**Importance**	**Implementation**
Transparency	Consumers value clear, honest communication about ingredients, production processes, and safety measures.	Provide detailed information on websites, packaging, and marketing materials.
Source Credibility	Information from trusted sources is more likely to be accepted by consumers.	Collaboration of researchers, businesses and policy-makers to present information authentically.
Perceived Benefits and Risks	Consumers weigh the perceived benefits and risks of food products.	Communicate scientific evidence supporting safety and benefits, highlighting evidence and cases.
Ease of Understanding	Simplifying complex information helps consumers make informed decisions.	Use visual aids, bullet points, and simple terms; employ interactive media and tools.
Cultural and Personal Beliefs	Personal values and cultural beliefs significantly impact consumer choices.	Tailor messages to align with the values and beliefs of different consumer segments.
Past Experiences	Previous experiences with similar products or technologies can shape current perceptions.	Outline past issues and improvements transparently; take quick action to address concerns.

This increase in awareness has also had a significant impact on the dietary choices of consumers over time. Currently, diets relying heavily on plant-based options, such as vegetarian and vegan diets, have become popular among consumers for their ethical and environmental benefits (Hassoun et al., 2022). Emerging Climatarian dietary patterns focus on foods with minimal carbon footprints, reflecting the growing consumer interest in

reducing environmental impact through dietary choices (Dixon et al., 2023; Tilman & Clark, 2014). Other dietary trends like flexitarian diets, which are still being refined and clarified in terms of their definitions and what they constitute, have also gained popularity as they avoid relying solely on red meat for protein content (Dagevos, 2021; Derbyshire, 2017).

Dietary lifestyles that do not depend solely on the consumption of traditional meat sources for protein are often linked to better health and nutrition (Derbyshire, 2017; Fresán & Sabaté, 2019). They not only address ethical and environmental concerns but also offer several health benefits, which have been extensively documented in the literature. This link was established primarily due to the issues and diseases associated with red meat consumption, such as cardiovascular disease, diabetes, and, in certain cases, an increased risk of mortality (Shi et al., 2023; Lippi et al., 2015; Pan et al., 2012; McAfee, 2010). However, diets that completely omit animal proteins must be carefully balanced to meet human nutritional needs, including adequate protein, vitamin B12, and omega-3 fatty acid intake (Dagevos, 2021; Vogtschmidt et al., 2021; Craig, 2009; Derbyshire, 2017).

As a result, balanced dietary frameworks like the Mediterranean and Nordic diets have gained popularity, reflecting the connection consumers make between their traditions and health, particularly in Europe (Biggi et al., 2024; Micheelsen et al., 2013). Being more similar in design than different, these dietary frameworks also contribute to the goal of promoting sustainable consumption (Krznarić et al., 2021).

The Mediterranean dietary pattern, often called the MedDiet, was first introduced by Ancel Keys in the 1960s. Simple traditional practices and the use of fresh ingredients contribute to its nutritional effectiveness since it focuses on foods such as fruits, vegetables, whole grains, nuts, olive oil, and moderate amounts of fish, with an emphasis on healthy unsaturated fats. Over time, this diet has been linked to significant health benefits, including lower risks of cardiovascular disease, cancer, and other chronic illnesses. The MedDiet has also been shown to improve cholesterol levels, support better vascular health, and reduce inflammation (Davis et al., 2015; Dernini & Berry, 2015; Estruch et al., 2018; Becerra-Tomás et al., 2020; Guasch-Ferré & Willett, 2021; et al., 2013; Martínez-González et al., 2015).

However, defining the MedDiet is not always straightforward. For instance, recommendations for the amount of olive oil or vegetables to include can vary, making it difficult to establish a standard version. Another challenge is making the MedDiet accessible outside its native regions. Key ingredients, such as fresh produce and olive oil, can be expensive or difficult to source, which can limit its adoption in different regions (Biggi et al., 2024; Tsofliou et al., 2022).

The Nordic dietary framework, particularly the New Nordic Diet (NND), shares a similar focus on sustainability and health. This diet emphasises whole grains, fatty fish, root vegetables, and seasonal produce, with a focus on locally sourced, resource-efficient foods. Inspired by the New Nordic Cuisine movement, the NND integrates health, gastronomy, and sustainability into a cohesive lifestyle. Literature highlights the significant health benefits of the NND, including improved cardiovascular health, reduced obesity, and lower risks of chronic diseases such as type 2 diabetes. Initiatives like the OPUS project have further supported the NND, promoting its high nutrient content and low environmental impact (Adamsson et al., 2012; Mithril et al., 2012; Mithril et al., 2013; Adamsson et al., 2014; Kanerva et al., 2014).

The diet also aligns with sustainability goals by advocating for locally grown and organic foods (Meltzer et al., 2019). However, despite being a valuable dietary model, there are challenges to its widespread adoption. Economic constraints and the limited availability of key ingredients, particularly outside the Nordic region, remain significant barriers.

Additionally, the reliance on region-specific foods, such as wild herbs or fish, raises questions about its practicality in non-Nordic regions (Micheelsen et al., 2013; Leer, 2016).

Accompanying these dietary trends is a growing consumer preference for so-called minimally processed and "clean label" products. The core concept behind these products is the removal of artificial colours, flavours, preservatives, genetically modified organisms (GMOs), and any other chemical additives to promote health-conscious and environmentally sustainable consumption. Clean-label products cater to individuals prioritising natural ingredients in their diets, focusing on quality and regional produce and further include transparency, ethical sourcing, and environmental considerations to meet the demands of modern consumers (Maruyama et al., 2021; Cao & Miao, 2023; Hsu et al., 2023).

Modern dietary patterns have also evolved to include specialised certifications in product labelling to reflect consumers' growing demand for transparency and ethical sourcing. A report by FMI and NIQ (2023) highlights that 76% of shoppers affirm the significance of transparency from brands and manufacturers in 2023, reflecting a steady rise from 72% in 2021 and 69% in 2018.

Certifications such as organic, non-GMO, and fair trade have become essential for food industries aiming to demonstrate that their products are responsibly sourced and meet ethical and environmental standards. For instance, fair trade certification, which indicates that the product is responsibly sourced, farmed, and processed, also has a positive impact on its perceived healthiness among consumers. In the case of organic certification, the organic food label, indicating that the food is grown without synthetic pesticides or fertilisers, is perceived by consumers as healthier and more nutritious (Drexler et al., 2018; Janssen & Hamm, 2012; Annunziata et al., 2011).

One prominent certification scheme is the European quality schemes. These labelling schemes, as shown in Figure 1.1, include some of the most important labels, such as Protected Designation of Origin (PDO), Protected Geographical Indication (PGI), and Traditional Speciality Guaranteed (TSG). These labels are globally associated with quality products in Europe. Their aim plays a critical role in advancing these principles by safeguarding authenticity, regional identity, and traditional practices (Becker, 2009; Albuquerque et al., 2018; Glogoveţan et al., 2022; Dias & Mendes, 2018).



Figure 1.1: EU Quality Schemes Labels (European Commission, 2020).

PDO certification is the most stringent category in the EU quality schemes because it requires every stage of production, processing, and preparation to occur within a specific geographic area (European Commission, 2020). For example, Parmigiano Reggiano, the iconic Italian cheese, is PDO-certified, meaning it can only be produced in designated provinces of Emilia-Romagna and Lombardy. This certification mandates that the cheese be produced in accordance with traditional methods and use locally sourced ingredients (Arfini et al., 2019). PGI certification is slightly less restrictive and states that at least one phase of production, processing, or preparation must occur within a specific geographic

area associated with its claim (European Commission, 2020). A well-known example is Scottish Farmed Salmon, which carries the PGI label to signify its sourcing in the UK, even if it is packed in other regions (UK Government, n.d.).

Literature has extensively covered the impact of PDO and PGI certification on consumer willingness to purchase certified products. These certifications are often preferred due to their perceived authenticity and strong connection to regional heritage. However, competitive pricing and effective product presentation are two significant factors influencing their purchasing decisions (Dafni & Likudis, 2024).

TSG certification, in contrast, focuses on protecting traditional recipes or production methods regardless of geographic origin. For instance, Neapolitan pizza is a TSG-certified dish which means that it would be made using traditional techniques like hand-stretching the dough and baking it in a wood-fired oven, even if it is produced outside Naples (Stazio, 2021). Similarly, Belgian Gueuze Beer is a TSG-certified lambic-style beer known for its unique brewing process of spontaneous fermentation (Avermaete & Vandermosten, 2016).

These certifications play an integral role in contributing to sustainable consumption along with food authentication. PDO and PGI promote local production, reducing transportation-related emissions and supporting regional economies. They also help preserve biodiversity by encouraging traditional farming practices, such as the use of native plant varieties or livestock breeds, which are often more resilient to local environmental conditions (Becker, 2009; Albuquerque et al., 2018; Glogoveţan et al., 2022; Dias & Mendes, 2018; European Commission, 2020).

Innovation, however, does not stop at packaging or labelling; it extends deeply into the products themselves. As consumers increasingly seek food options that align with their health, ethical, and environmental values, companies are rethinking the very foundations of food development. A prominent example is the evolution of alternative proteins and plant-based foods, which exemplify how brands are innovating not just in presentation but also in addressing fundamental consumer demands (Aschemann-Witzel et al., 2021; Wild et al., 2014).

The plant-based food revolution began with the dairy industry to meet the rising demand for non-dairy alternatives (ProVeg International, n.d.). Brands like Oatly are at the forefront of this shift by positioning itself as a case study for how brand-driven activism can challenge traditional consumption, production, and policies while driving systemic change. Oatly offers oat-based milk alternatives that cater to health-conscious consumers and those seeking plant-based dietary options. It also promotes its products as having a smaller carbon footprint compared to traditional dairy, positioning itself as environmentally and socially responsible (Koch, 2020).

Leading the meat alternatives category are companies like Beyond Meat, Quorn, and Impossible Foods, which offer plant-based burgers, sausages, and ground meat alternatives designed to replicate the sensory experience of traditional meat (Business Wire, 2023). These products aim to appeal not only to vegans but also to flexitarians and meat lovers. For instance, Quorn products are made from a naturally occurring fungus called *Fusarium venenatum*, while Impossible Foods has introduced groundbreaking techniques using heme, an iron-containing molecule that mimics the flavour of meat (Quorn, n.d.; Impossible Foods, n.d.).

As demand for plant-based options grows, major fast-food chains have also recognised the need to adapt their menus. Companies like Burger King and McDonald's have partnered with Beyond Meat and Impossible Foods to integrate plant-based offerings into their product lines. Burger King, for example, collaborated with Impossible Foods to launch the Impossible Whopper, a plant-based version of its signature Whopper. Similarly, McDonald's introduced the McPlant burger in partnership with Beyond Meat to cater to consumers seeking plant-based options (The Guardian, 2019; Mcdonald's, n.d.).

1.2 New Foods and Food Technologies

The evolution of food technologies reflects shifting priorities in addressing the increasingly complex challenges of food security and sustainable consumption. In this context, food security refers to the ability of every individual to access sufficient, safe, and nutritious food. This goes hand in hand with the concept of sustainable consumption which ensures that production, distribution and consumption of food meet needs of consumers without compromising resources for future generations (Mc Carthy et al., 2018; Berry et al., 2015; Premanandh, 2011).

This has become particularly challenging as the global population is projected to reach approximately 10 billion by 2050. Global agricultural systems are already constrained by the depletion of land and water resources. The effects of climate change have added further stress to this equation. The pressure brought by this population growth highlights the need to increase resilience across the entire food supply chain. It should be noted that this is not just about increasing production volumes, but also about meeting dietary needs, addressing nutritional deficiencies, and creating a food system that can adapt to changing global demands (FAO, 2017; Fitton et al., 2019; Rockström et al., 2017; Fischer et al., 2002; Pretty, 2018; Mrabet, 2023; Gillespie & van den Bold, 2017).

Historically, the development of food technologies has mirrored the evolving priorities of societies. In the 19th and 20th centuries, innovations directed towards food preservation, such as canning, freeze-drying, and food irradiation, emerged to meet the demands of rapidly urbanising populations. These preservation methods extended food shelf life, reduced waste, and improved accessibility, enabling urban centres to rely on safe and durable food supplies. For example, irradiation extends shelf-life by eliminating pathogens in food items that cannot be refrigerated or quickly transported due to any infrastructure and logistical limitations (Rahman, 2020; Owusu-Apenten & Vieira, 2023; Shukla, 2011; Farkas & Mohácsi-Farkas, 2011; Josephson, 1983).

In the 1980s and 1990s, advancements in biotechnology and genetic engineering shifted the focus towards enhancing crop productivity and resilience. Genetically modified organisms (GMOs) allowed precise modifications to crops and improved their resistance to pests, diseases, and environmental stressors (Ronald, 2011; Chassy, 2007; Glass-O'Shea, 2021). Monsanto's glyphosate-resistant crops, for instance, enabled farmers to manage weeds more efficiently, reduce chemical inputs, and ensure stable yields while mitigating environmental impacts (Green, 2009).

In addition to improving crop conditions, food technologies have played a vital role in addressing health and nutrition. Moving beyond basic sustenance, biofortification technologies have targeted dietary deficiencies, particularly in vulnerable populations. Innovations such as iron-rich beans and zinc-enriched wheat demonstrate the potential of food technologies to combat micronutrient deficiencies. A notable example is Golden Rice, which is enriched with vitamin A and has been instrumental in preventing malnutrition-related diseases like childhood blindness in developing countries (Bouis et al., 2003; Bouis & Saltzman, 2017; Kumar et al., 2019; Shahzad et al., 2014).

The historical trajectory of food technologies underscores the importance of scientific advancement and innovation in addressing global food-related priorities (Tian et al., 2016). As the challenges facing the global food system become increasingly complex, the need to prioritise the development of innovative food technologies has become more crucial to meeting the needs of present and future generations.

Literature indicates that the food sector contributes approximately one-third of global greenhouse gas emissions. Traditional livestock farming, for instance, is a leading cause of deforestation, methane emissions, and water overuse. In the development of food

technologies, this necessitates accounting for environmental impacts and ensuring they are designed to address these issues (Gilbert, 2012; Clune et al., 2017; Garnett, 2009).

One approach to tackling this has been finding alternative sources of protein to reduce dependence on traditional livestock farming. Thus, the concept of alternative protein sources emerged to minimise this sector's environmental footprint without compromising food security. Furthermore, the shift towards plant-based and cellular agriculture is a direct response to the environmental pressures associated with traditional livestock farming (Poore & Nemecek, 2018; He et al., 2020; Nyika et al., 2021).

Plant-based meat alternatives have gained significant interest as a promising substitute for traditional meat, with many variants focusing on replicating the taste and texture that appeal to consumers (Jang & Lee, 2024; Michel et al., 2021). Building on innovation in this category, cellular agriculture takes a step further by cultivating animal proteins directly from cells in controlled environments to produce cultured meat (Stephens et al., 2018).

The environmental advantages of these technologies extend beyond providing new sources of protein to meet the global demand of nutrition. However, they need to be evaluated carefully and comprehensively for their potential to address the ethical and environmental concerns tied to traditional sources of meat (Van der Weele et al., 2019; Shanmugam et al., 2023; Sinke et al., 2023).

Precision agriculture is another example of how digital tools can optimise use of resources to aid sustainable consumption. Technologies based on Internet of Things (IoT)-based automation such as GPS, drones, and data analytics can be used by producers and farmers to monitor soil health, detect disease outbreaks early, and apply water and fertilisers with precision. This not only improves productivity but also reduces resource waste and mitigates pollution caused by agricultural runoff into water bodies (Shafi et al., 2019; Gebbers & Adamchuk, 2010).

A key consideration in the development of any new food technology is its compliance with public health safety standards (Henson & Heasman, 1998). This compliance is regulated by robust frameworks that oversee the development and adoption of novel foods and food technologies. Table 1.2 outlines countries and regions with prominent regulatory bodies and their regulations for evaluating such food commodities (Good Food Institute, 2023; Good Food Institute APAC, n.d.; European Food Safety Authority, 2018; Food and Drug Administration, 2022; Food and Drug Administration, n.d.; Food Standards Agency, 2024; Food Standards Agency, 2022; Good Food Institute Europe, 2024; Singapore Food Agency, 2024; Keller and Heckman LLP, 2024; National People's Congress of the People's Republic of China, 2011; Zmuni, 2022; Vegconomist, 2023; Food Safety Commission of Japan, n.d.; Ministry of Food and Drug Safety, 2022; Health Canada, 2006; Food Standards Australia New Zealand, 2022; Saudi Food and Drug Authority, 2021).

Table 1.2: Novel food regulations adopted by different countries/ regions.

Regulatory Body	**Country/ Region**	**Regulation**	**Year**
European Food Safety Authority (EFSA)	European Union	Regulation (EU) 2015/2283	Last reviewed on 3rd December 2024.
Food and Drug Administration (FDA)	United States	No specific regulation for novel foods. Alternatives regulated under Federal Food, Drug, and Cosmetic Act (FD&C Act)	Case-by-case evaluation. Draft guidance on plant-based alternatives on 6th January 2025.

Food Standards Agency (FSA)	United Kingdom	Regulation (EC) 2017/2469	Adopted in 2018. Plans to modernise guidelines for meat alternatives.
Singapore Food Agency (SFA)	Singapore	Novel Food Regulatory Framework	Published in 2019. Food Safety and Security Bill (FSSB) defines alternative proteins.
National Centre for Food Safety Assessment (CFSA)	China	Food Safety Law of the People's Republic of China	Adopted in 2009. Last amendment in April 2021. China's General Principles for Plant-Based Food published in August 2021.
Food Safety Commission of Japan (FSCJ), Ministry of Agriculture, Forestry and Fisheries (MAFF)	Japan	No fixed regulations in place	Reviewed on case-by-case basis. MAFF Food Tech Study Group Interim Report (2020) for meat alternatives.
Ministry of Food and Drug Safety (MFDS)	South Korea	Korean Food Code	Draft Amendment in August 2023. Enforced since 1st January 2024.
Health Canada (HC)	Canada	Guidelines for the Safety Assessment of Novel Foods	Published in June 2006, last updated on July 2022.
Food Standards Australia New Zealand (FSANZ)	Australia and New Zealand	Australia New Zealand Food Standards Code (Standards 1.1.1 and 1.5.1)	Guidelines published in June 2022. Last updated in 2024.
Saudi Food and Drug Authority (SFDA)	Saudi Arabia	SFDA FD 5031:2020	Draft published in December 2019.

Regulatory bodies, such as the EFSA and FSA, have established guidelines to assess novel food products and food technologies. For example, EFSA operates under Regulation (EU) 2015/2283, which defines novel foods as those not significantly consumed within the EU prior to May 15, 1997. The FSA in the UK follows a similar process post-Brexit for novel foods. With such regulation, there is a pre-market authorisation process for a thorough risk assessment to evaluate the nutritional, toxicological, and allergenic properties of each product being introduced to the market. Alternative proteins, including plant-based products, edible insects, and cultured meat, fall under this framework (EFSA, 2018; FSA, 2024).

In the U.S., the FDA does not implement a strict guideline and evaluates alternative proteins through a pre-market consultation process followed by a detailed scrutiny of the product. Companies must provide comprehensive data on production methods, safety

protocols, and the product's equivalence to conventional counterparts. For cell-culture-derived meat (CCDM), however, the FDA requires more complete details and transparency on the production phase, while the U.S. Department of Agriculture (USDA) manages labelling (FDA, 2022).

It is important to note that many countries, including China, Singapore, and South Korea, follow similar guidelines as FDA (Good Food Institute, 2023; Good Food Institute APAC, n.d.). However, the presence of varying regulatory frameworks across nations often adds complexity to the international trade in the food sector. Despite these differences, the overarching goal of all regulatory bodies remains the same: to safeguard the health and well-being of their citizens.

Having regulations and policies also influence the pace of innovation through research funding, tax incentives, and public-private partnerships. Programmes like the European Commission's Horizon 2020 initiative and the UK's Advanced Food Manufacturing Innovation Fund have provided critical support for developing plant-based and cell-based proteins, demonstrating how government investment can catalyse technological breakthroughs (European Commission, 2020; UK Government, 2023).

Overly stringent regulations can also stifle innovation, while insufficient oversight risks breaking public trust. Adaptive frameworks, such as regulatory sandboxes that allow for controlled testing of novel technologies, offer a promising approach to addressing these challenges (European Commission, 2020).

There is also a possibility of guidelines that could lead to global harmonisation of standards, similar to the Codex Alimentarius by the Codex Alimentarius Commission. Such guidelines could navigate the complexities of international trade and global food supply chains (Codex Alimentarius, 2020).

1.2.1 Alternative Proteins

High levels of meat consumption in certain regions emphasises the need for sustainable dietary alternatives (Font-i-Furnols, 2023; Van der Weele et al., 2019). Across over 20 EU countries, EFSA reports that adults consume a median of 35 grams of meat daily, with significant variation—ranging from 20 grams per day in Sweden to 237 grams in Austria (Turesky, 2018; Lyon, 2014).

This widespread reliance on meat has raised substantial health and environmental concerns. Regular red meat consumption is closely linked to chronic conditions such as type 2 diabetes, cardiovascular disease, and certain cancers (Pan et al., 2012; Willett et al., 2019; Ekmekcioglu et al., 2017).

As awareness of these risks grows, alternative proteins have emerged as a viable and health-conscious solution. These alternatives typically contain lower levels of saturated fats and cholesterol, making them a compelling choice for individuals looking to reduce their red meat intake (Satija & Hu, 2018).

The urgency of finding sustainable food solutions is further underscored by global population projections. By 2050, the planet is expected to host nearly 10 billion people, necessitating a 70% increase in food production to meet growing demand. Protein, a cornerstone of human nutrition, poses a particular challenge given the environmental toll of traditional livestock farming. Livestock production has been linked to an increase in greenhouse gas emissions, deforestation, land and water scarcity. These factors prompted the search for alternatives that balance nutritional needs with ecological sustainability. In this context, alternative protein sources such as plant-based proteins, CCDM, edible insects are gaining momentum as innovative solutions that address food security, reduce ecological impact, and align with ethical concerns regarding animal welfare (FAO, 2009; Boland et al., 2013; Tilman & Clark, 2014; Henchion et al., 2017).

Plant-based proteins, derived from sources such as soya, pea, and chickpea, are among the most accessible alternatives to animal-derived proteins. These plant-based options offer a rich nutritional profile, providing a good amount of essential amino acids, vitamins, and minerals, while containing significantly lower levels of saturated fats than traditional meat (Qin et al., 2022; Poore & Nemecek, 2018). The appeal of plant-based proteins has been further bolstered by advancements in food technology allowing them to closely mimic the sensory experience of meat. Improved extraction and texturisation techniques have enhanced the taste and texture of plant-based products, thereby contributing increasing consumer acceptance (Michel et al., 2021; Aschemann-Witzel et al., 2021; Onwezen et al., 2021).

Beyond their nutritional benefits, plant-based proteins stand out for their environmental efficiency. For instance, producing 100 grams of protein from peas requires just 1.2 to 6.4 square metres of land, compared to 42 to 369 square metres for beef (Poore & Nemecek, 2018). This stark difference illustrates the potential of plant-based alternatives to alleviate deforestation, soil degradation, and water scarcity which are considered as key challenges associated with traditional livestock farming (He et al., 2020; Gilbert, 2012; Clune et al., 2017; Garnett, 2009).

Innovative products made from non-meat components that replicate the taste and texture of meat align closely with the growing demand for animal-free, vegan, and vegetarian alternatives. One notable example is mycoprotein, a single-cell protein rich in protein and fibre while being low in fat. Fermentation-based proteins, including mycoprotein and dairy substitutes, are produced by cultivating specific microbes to create protein-rich foods. These fermentation processes are resource-efficient, requiring minimal land, water, and energy compared to traditional animal farming (Ritala et al., 2017).

CCDM often referred to as lab-grown meat, represents a groundbreaking innovation in sustainable food production. Through cultivating animal cells in a controlled laboratory environment, CCDM produces real meat without the need for raising or slaughtering animals. This process involves isolating animal cells and growing them in nutrient-rich media, enabling the development of muscle tissue that is structurally identical to conventional meat (Post, 2012; Tuomisto & Teixeira de Mattos, 2011; Rodríguez Escobar et al., 2021).

The production of CCDM can be directly linked to ethical implications in terms of animal welfare. It eliminates the need for industrial-scale animal farming which has been a considerable topic of discussion and concern about animals being used for food (Treich, 2021).

While the technology is currently energy-intensive, ongoing research focuses on integrating renewable energy sources and optimising cell growth conditions. A complete life-cycle assessment is helpful in understanding all the challenges and opportunities associated with CCDM (Sinke et al., 2023; Chriki et al., 2022).

With advancements in production methods, CCDM has the potential to substantially lower greenhouse gas emissions and land use compared to traditional red meat farming. It can also be beneficial in overcoming challenges related to antibiotic resistance and frequent cases of disease in livestock. For instance, the incorporation of sustainable feedstocks, such as blue-green algae, could further enhance its environmental profile (Aiking, 2014; Sinke et al., 2023; Aiking & de Boer, 2020; Hocquette et al., 2022).

Edible insects such as crickets, mealworms, and black soldier flies are another alternative with potential to become excellent traditional protein sources. Insects are rich in protein, vitamins, and minerals which makes them a good source of nutrients required for the human body. Their environmental impact is remarkably low, requiring minimal land and water compared to livestock. For example, insect farming uses just 0.36 to 3.6 square metres of land per kilogram of biomass, compared to 23.1 square metres for beef.

Furthermore, the carbon footprint of insect farming is as low as 0.3 kilograms of CO_2 per kilogram of biomass (van Huis, 2013; Raheem et al., 2018).

Insects also excel in feed conversion efficiency. The black soldier fly, for instance, has a feed conversion ratio (FCR) of 1.4 to 2.6. This value is substantially better than that of cows, which have an FCR of 8.8 (Oonincx et al., 2019). Additionally, insect farming generates minimal waste; by-products such as frass serve as effective organic fertilisers, promoting sustainable agricultural practices (Hénault-Ethier et al., 2023).

Although consumer acceptance is a considerable barrier for insects, particularly in Western markets where factors such as associated disgust and neophobia limit their acceptance, However, the ecological and nutritional benefits of insect-based proteins make them one of most viable alternatives to be incorporated in sustainable food systems (Deroy et al., 2015; Onwezen et al., 2021; Verbeke, 2015; Smetana, 2023; Aiking, 2014; Heath et al., 2024; Anusha Siddiqui et al., 2022).

Existing literature on alternative proteins offers valuable insights into how consumers perceive CCDM, plant-based proteins, and edible insects (Hartmann & Siegrist, 2017; Onwezen et al., 2021; de Oliveira Padilha et al., 2022). To build a comprehensive understanding for this dissertation, a targeted search was conducted using the Scopus database, with an emphasis on acceptance, preferences, and perceptions. The search query included broad behavioural terms such as acceptance, preferences, willingness to buy, and perceptions. It also covered specific alternative protein sources: cultured meat (e.g., "cultured meat," "in vitro meat," "synthetic meat"), plant-based proteins (e.g., pulses, legumes, chickpeas, lentils, and beans), and edible insects. Table 1.3 presents a concise overview of the motivations and barriers based on these findings.

Table 1.3: Overview of consumer perceptions towards alternative proteins.

Alternative Protein Source	**Aspect (Motivation/Barrier)**	**Subcategory**	**Overview of findings**
Plant-Based Proteins	Motivation	Health & nutrition	High in protein and fibre, low in cholesterol, appealing to fitness enthusiasts, vegans, and vegetarians globally.
		Sustainability	Considered eco-friendly, gaining traction among environmental advocates in Europe and Asia.
		Convenience	Ready-to-eat and easy-to-prepare options resonate with busy professionals and families in urban markets worldwide.
	Barrier	Sensory perceptions	Perceived as bland by traditional eaters and children, with acceptance varying based on regional culinary habits.
		Cultural resistance	Viewed as non-traditional in meat-centric cultures.
		Allergies and processing	Use of chemicals in form of additives. Concerns about overprocessing and allergens

			(e.g., soy) among health-conscious consumers globally.
Edible Insects	Motivation	Nutrition & sustainability	High in protein and nutrients, seen as sustainable, with acceptance growing among adventurous and eco-conscious consumers in Southeast Asia and Africa.
		Novelty	Offers unique culinary experiences, attracting younger, open-minded individuals, with increasing interest in Europe and the United States.
	Barrier	Sensory factors	Unfamiliar textures and flavours lead to aversion, especially among older demographics in Western cultures.
		Cultural resistance	Considered inappropriate for consumption in Western societies, contrasting with normalised consumption in Southeast Asia and Africa.
		Accessibility & scaling	Limited availability in mainstream markets and scalability challenges hinder wider adoption, with acceptance varying by region.
CCDM	Motivation	Health & safety	Seen as free from antibiotics and diseases associated with livestock, appealing to health-conscious consumers, particularly younger demographics in Europe and Asia.
		Environmental impact	Recognised for reducing greenhouse gas emissions and efficient resource use, attracting environmental advocates, especially in Europe and Australia.
		Ethical concerns	Aligns with the values of vegans, vegetarians, and animal welfare proponents globally, avoiding animal slaughter.
		Novelty	Valued for its innovative concept, sparking curiosity among tech-savvy and

		experimental eaters in urban areas worldwide.
Barrier	Natural and unnatural concerns	Perceived as overly artificial with unknown long-term health effects, creating scepticism among older and traditional meat-eaters, particularly in North America and parts of Europe.
	Cultural resistance	Facing cultural pushback from conventional meat-eaters in the United States, the Middle East, and traditional societies.
	Economic accessibility	High production costs and limited market availability deter price-sensitive consumers, particularly in developing regions.

These advantages of alternative proteins have appealed to a wide range of consumers depending on what motivates them. For example, health-conscious consumers would be drawn to the lower levels of cholesterol and saturated fats offered by alternative proteins (Tso et al., 2020). Individuals who adopt sustainable practices would appreciate the reduced resource use and environmental impact associated with these products (Hartmann & Siegrist, 2017).

The ethical dimension of alternative proteins resonates strongly with consumers seeking cruelty-free and humane options (Van der Weele et al., 2019; de Boer & Aiking, 2022). Findings from Rehman et al. (2024) reinforced these motivations, as shown in Figure 1.2.

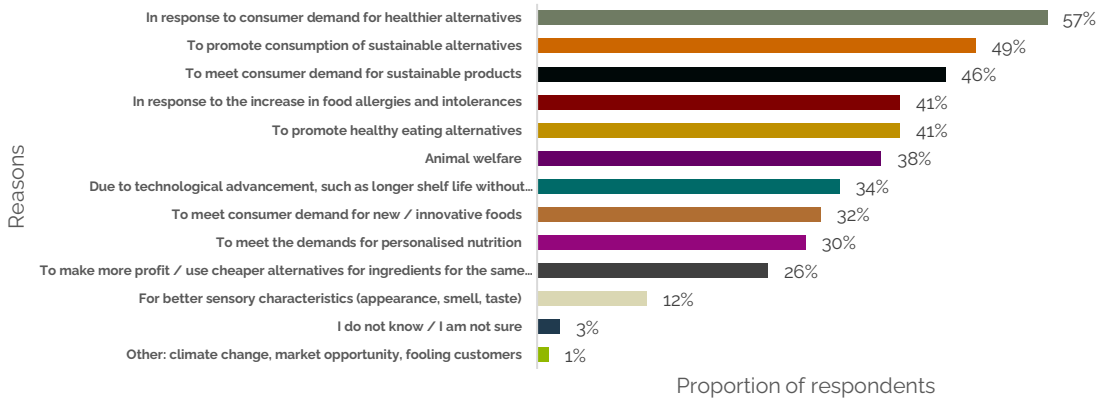


Figure 1.2: Consumer perception of new alternative foods.

The results indicated that 57% of consumers believed health benefits drove the rise of alternative proteins, while 49% attributed the trend to sustainability concerns. A notable 41% of consumers linked these foods to the promotion of healthier options and addressing rising food allergies and intolerances. The results also showed that 30% of respondents viewed personalised nutrition as a significant factor, reflecting the variety of dietary preferences among consumers. Concerns about animal welfare were shared by 38% of

participants, while 34% attributed the trend to technological advancements. Curiosity about food innovation (32%) also played a role, as some consumers viewed alternative proteins as an exciting opportunity to engage with modern food technologies (de Koning et al., 2020; Circus & Robison, 2018; Hwang et al., 2020).

All of these factors highlighted how health, ethical values, and sustainability are shaping food preferences today. Some consumers attributed the trend to profit motives through cheaper ingredients (26%) and sensory characteristics (12%). A small percentage of respondents were uncertain (3%) or linked the trend to climate change and marketing strategies (1%). These findings underscored the growing consumer awareness of well-being, environmental impact, and ethical issues.

Despite these compelling motivations, several barriers hinder the widespread adoption of alternative proteins. While these products offer health and environmental benefits, consumer preferences for taste, texture, and appearance present challenges. Many find that plant-based proteins and lab-grown meat (i.e., CCDM) do not replicate the flavour and mouthfeel of traditional meat, limiting their appeal (Chriki & Hocquette, 2020; Hartmann & Siegrist, 2017; Michel et al., 2021). Economic accessibility is another issue, as the high production costs associated with new technologies mean alternative proteins are often more expensive than conventional meats, making them less accessible to a broader market (Onwezen et al., 2020; Van Loo et al., 2020).

Cultural and social factors further influence consumer acceptance. CCDM, for example, is particularly scrutinised due to its novel production methods. While some consumers are drawn to the ethical and environmental benefits of lab-grown meat (i.e., CCDM), others perceive it as artificial or unnatural, which conflicts with their preference for “clean” and “natural” foods (Siegrist et al., 2018; Ribeiro et al., 2022).

Insect-based proteins similarly encounter cultural resistance, especially in Western markets, where insects are not traditionally seen as food and may evoke aversion (Tan et al., 2015; Wendin & Nyberg, 2021; Gere et al., 2017). These cultural factors are especially challenging, as food habits and preferences are deeply rooted in cultural practices and social norms, impacting acceptance and consumption choices significantly (Piha et al., 2018).

The regulatory landscape surrounding meat alternatives adds complexity to existing barriers. In the European Union, CCDM and edible insects are classified as "novel foods". This category is subjected to rigorous safety assessments and regulatory controls. For example, only four insect species are currently approved under the EU’s Regulation (EU) 2015/2283, which allows companies in the EU to produce and market insect-based foods (EFSA, 2018; Delgado Calvo-Flores et al., 2022; Heath et al., 2024).

Although the edible insect market is projected to reach 260,000 tonnes in the EU by 2030 (IPIFF, 2022), stringent regulatory frameworks could result in fewer insect-based options being available, potentially causing distrust among consumers regarding their safety (Science, Research and Evidence Directorate, 2022).

CCDM is another example of an alternative that has been constantly subjected to changing regulations in the EU. For instance, while CCDM is banned in Italy, it is scheduled for consumer trials in the Netherlands (Bambridge-Sutton, 2024; Southey, 2024). This situation is not limited to the EU alone; the UK is another example of confusing regulatory guidelines. Post-Brexit, the UK re-evaluated its regulations regarding novel foods, resulting in additional hindrances for companies working on CCDM. These diverse legal landscapes shape consumer perceptions, access, and familiarity with alternative proteins.

Additionally, plant-based alternatives, while less controversial in production, face labelling restrictions in the EU. Regulations such as (EU) 1169/2011 prohibit terms like “sausage” or “burger” for plant-based products in some countries like France. It adds a

layer of confusion and potentially reinforces negative perceptions that these products are lesser or highly processed substitutes (Regulation (EU) 1169/2011; Southey, 2024).

Beyond cultural and regulatory issues, rapid market expansion has led to some consumer scepticism. While a significant portion of the population supports alternative proteins for health and sustainability reasons, others are wary of what they perceive as a marketing trend primarily driven by corporate profit motives. Concerns about greenwashing and exaggerated claims of health or environmental benefits contribute to a gap between consumer awareness and acceptance (Devitt, 2024; Bryant, 2019; Ghvanidze et al., 2016). This general scepticism is compounded by worries over unknown health risks and food safety, particularly for CCDM and insects (Orsi et al., 2019).

Overcoming these challenges requires targeted strategies that emphasise transparency, trust-building, and education. Clear communication about the health and environmental benefits of alternative proteins is essential, particularly when addressing consumer doubts about new technologies. Educational campaigns could help clarify the science, safety, and benefits of these products, bridging the gap between awareness and understanding (Grasso et al., 2019; Piha et al., 2018).

Digital tools like interactive infographics and videos can make the information about production processes and sustainability accessible, especially for consumers interested in knowing more about the origins and impact of their food (de Koning et al., 2020).

But an important question remains: How can these strategies be implemented effectively across regions with distinct social, cultural, and economic landscapes? The challenge lies in crafting adaptable approaches that genuinely address diverse consumer needs and preferences, balancing innovation with insight into traditional food practices. As policymakers and the food industry work towards a more sustainable and inclusive food system, the journey to full acceptance of alternative proteins will require creative solutions that resonate deeply with consumers' expectations and values, wherever they may be.

1.3 Role of Communication in Consumer Engagement

In today’s world, effective engagement is essential for maintaining impact and relevance; therefore, communicating with consumers has become a cornerstone for businesses, governments, and research organisations. Modern communication is no longer a one-sided process; it usually involves a dynamic exchange where organisations actively listen to feedback and adapt their approaches accordingly.

Adopting a two-way dialogue strategy strengthens connections with audiences to allow businesses to influence purchasing decisions and foster brand loyalty. Similarly, governments address public concerns and build support for policies while research organisations use engagement to effectively share their findings and ensure their work resonates with society. Crafting effective engagement strategies, however, requires careful consideration of how information is presented, the clarity of key messages, and the accessibility of feedback channels.

1.3.1 Effective Communication Strategies

The landscape of scientific communication serves as a vital bridge between communicating complex technical information and the public's understanding of science. Effectively translating scientific concepts into accessible and relatable language helps to build awareness and trust in the information being shared. When the information communicated resonates with the public, it not only enhances their understanding but also influences their

decision-making and prompts actions that contribute to scientific progression and positive outcomes for society in general (Durant et al., 1989; Ziman, 1991; Bonney et al., 2016).

In practice, effective scientific communication is challenging to achieve. Poorly designed communication strategies can often lead to mistrust in scientific information. As shown in Figure 1.3, this mistrust arises from various factors, including flaws in how information is shared. Informational campaigns that rely on one-way communication methods often overlook the audience's perspectives, specific information needs, and concerns. These approaches, coupled with inaccessible channels at times, contribute to significant knowledge gaps in the public's understanding of science, leaving room for alternative narratives to take hold and spread misleading information. This information, often misinformation or excess information, is damaging to the credibility of actual scientific sources (Fischhoff & Scheufele, 2013; West & Bergstrom, 2021).

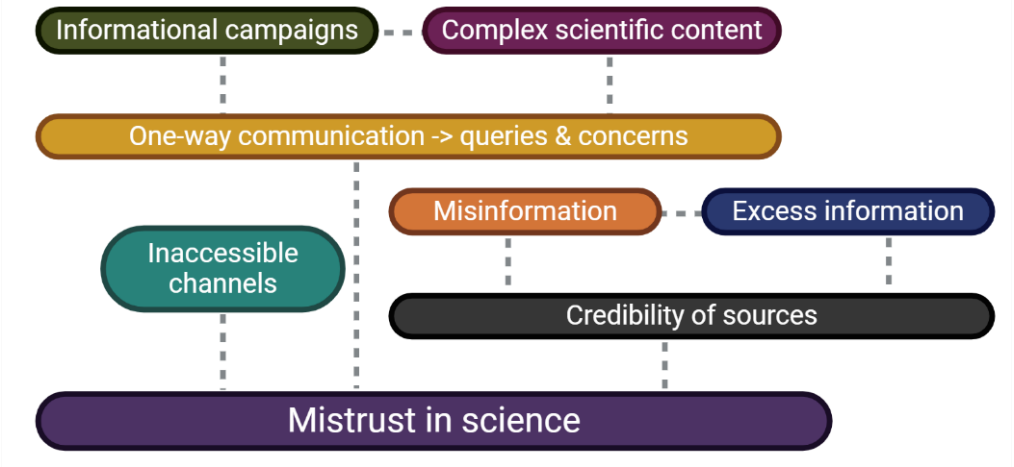


Figure 1.3: Factors contributing to mistrust in scientific communication (Own Illustration).

Misinformation, or in certain cases, excess information, has emerged as a formidable challenge in today's world. However, it is not possible to evaluate its source or its impact without considering the rising use of digital platforms and their connection with the spread of fake news, public understanding of science and trust in its content, information ecosystems, and their outreach (Scheufele & Krause, 2019; Allgaier, 2016).

Topics such as GMOs causing cancer (Jiang & Fang, 2019) and climate change (Treen et al., 2020) have been negatively influenced in public opinion through the use of adverse campaigns amplified by social channels. The COVID-19 pandemic is a recent example of the overwhelming consequences of unchecked information spread (Caceres et al., 2022). The World Health Organisation revealed shocking impacts of misinformation, including the hospitalisation of approximately 6,000 people and 800 deaths linked to false information about treatments (World Health Organization, 2020).

The biggest and most ongoing impact, however, is on the concept of vaccination, which has resulted in global health issues due to misinformation (AROUND & ARE, 2018). It was estimated that more than 20% of adults demonstrated vaccine hesitancy during the COVID-19 pandemic in the US and UK, often driven by social media misinformation (Loomba et al., 2021). The BBC News reported instances of fear-mongering posts falsely linking vaccines to infertility, significantly undermining public health efforts (BBC News, 2021).

Over time, researchers have raised concerns about the growing influence of social media on science news, questioning whether the lack of online quality control poses a threat to public trust in science (Weingart and Guenther, 2016; Weingart, 2023). Addressing these

issues requires a sophisticated approach centred on transparency and proactive information dissemination.

Successful communication strategies prioritise clarity, timeliness, and the acknowledgment of scientific uncertainties. By being transparent and open, the public perceives greater honesty and develops trust in the guidelines provided, as exemplified during the COVID-19 pandemic (Lee & Li, 2021). The World Health Organisation's periodic guidelines, as part of their communication strategy during the pandemic, demonstrated how effective communication can help curb a global crisis, considering its impact and lethality (World Health Organization, 2020). Public health institutions such as the US Centers for Disease Control and Prevention and the UK's National Health Service now provide detailed guidelines for the public regarding COVID-19 and vaccination to counter the spread of misinformation (Centers for Disease Control and Prevention, 2024; National Health Service, n.d.).

Multi-channel communication to address inaccessibility represents another critical approach in contemporary scientific discourse (Moore et al., 1996). By disseminating information across diverse platforms, organisations can reach broader audiences and create multiple touchpoints for engagement (Bode & Vraga, 2017). Media literacy, understanding misinformation, and recognising its elements are some examples of strategies that can help control the spread of false information (Dame Adjin-Tettey, 2022).

The evolving nature of scientific communication continues to challenge and inspire communicators, requiring them to adapt, empathise, and embrace innovative approaches to sharing knowledge. Drawing inspiration from Bandura's social learning theory, which suggests that people learn by observing (Bandura, 1969; Bandura, 1977), one such approach is the use of narratives and personal experiences via storytelling.

Extensively discussed in the literature, storytelling is recognised as a powerful tool that engages audiences on a psychological level, moving beyond traditional methods of information delivery. It fosters familiarity and ensures that the content is both memorable and impactful. In a scientific context, storytelling transforms complex concepts into accessible and engaging narratives, resonating with a broader audience (Dahlstrom, 2014; Avraamidou & Osborne, 2009; Picardi & Regina, 2008; Riesch, 2014).

The positive impact of narratives in building trust and promoting informed choices can be seen in the pandemic communication strategies surrounding virus variants, particularly in tackling misinformation and vaccine hesitancy (Elizabeth et al., 2023; Borah et al., 2022). For example, the Tough Talks app, originally designed to support HIV disclosure, was adapted to help young Black adults make informed decisions about COVID-19 vaccination. Through interactive storytelling, the app received a positive response to its key messages regarding safety, autonomy, and social pressures (Stoner et al., 2022).

Another effective strategy in scientific communication is audience segmentation. Research shows that different demographic groups have unique information needs and preferences. For example, younger audiences are more likely to engage with visually appealing content on platforms like Instagram and TikTok, while older populations often prefer detailed and traditional formats. Tailoring communication methods to match these preferences can increase the impact of scientific messages and encourage meaningful engagement with scientific content (Auxier & Anderson, 2021; Taneja et al., 2012).

1.3.2 Digital Tools for Consumer Engagement

Science communication has undergone a significant transformation with the rise of digital technologies. Literature highlights how these digital channels have created new opportunities for scientific discussions on a global scale. As shown in Table 1.4, these platforms are not just simple communication tools but dynamic ecosystems that facilitate

detailed and interactive exchanges of scientific information. Over time, they have proven invaluable in the dissemination and outreach of scientific knowledge, serving both scientists and researchers as well as the public (Osterrieder, 2013; Collins et al., 2016; Jensen & Gerber, 2020; Kouper, 2010; Davies & Hara, 2017; Drew, 2017; Chan-Olmsted & Wang, 2020; Berry, 2016; Barrios-O'Neill, 2018; Handley & Chapman, 2012; García-Marín, 2020; Boulos et al., 2006).

Table 1.4: Science communication tools and applications.

Tool	**Description**	**Use in science communication**
Social Media Platforms	Broad audience reach with real-time engagement and interaction	Share infographics and short videos; engage through comments, Q&As, and live discussions.
Websites and Blogs	Comprehensive resources with in-depth articles and expert insights	Publish detailed updates on breakthroughs, research, and summaries of complex topics.
Webinars and Live Streams	Direct interaction with experts via Q&As and live demonstrations	Host interactive presentations on climate change, health science, or emerging research areas.
Podcasts	Accessible audio format for discussions, interviews, and storytelling	Share research insights, explain methodologies, and discuss societal impacts through narratives.
Interactive Infographics and Data Visualisation	Visual tools to simplify and engage with complex data	Present climate data, biodiversity trends, or health issues in visually engaging formats.
Online Surveys and Polls	Collect public feedback and foster two-way engagement	Assess public perceptions of scientific issues and gather feedback on environmental or health topics.
Mobile Applications	Personalised, interactive tools for learning and engagement	Share science-based tips, support citizen science efforts, and provide environmental or health updates.

Social media platforms represent a pivotal innovation in scientific communication strategies. Platforms like Twitter (Su et al., 2017), Youtube (Yang et al., 2022) offer more than traditional broadcast mechanisms by creating sophisticated interactive spaces where complex scientific concepts can be distilled into visually engaging, immediately accessible content. Researchers can now share intricate infographics, short explanatory videos, and live discussions that make scientific understanding more accessible, breaking down traditional barriers between academic knowledge and public perception (Collins et al., 2016; Osterrieder, 2013).

Websites and blogs have emerged as comprehensive knowledge repositories, providing depth and context that traditional communication methods cannot achieve. Unlike static academic publications, these digital platforms offer dynamic, continuously updated resources that explain scientific breakthroughs in accessible language. They serve critical functions of providing detailed articles, frequently asked questions, and expert perspectives on complex topics, allowing readers to engage with scientific content at their own pace and level of comprehension (Kouper, 2010; Davies & Hara, 2017).

Podcasting has revolutionised scientific communication by introducing narrative-driven approaches to knowledge transmission. These audio platforms transcend traditional

informational delivery by creating immersive storytelling experiences that humanise scientific discourse. Shows like *Science Vs* and *Radiolab* demonstrate how complex scientific concepts can be transformed into compelling, relatable narratives that engage diverse audiences. The conversational format allows listeners to feel part of an intimate discussion, making scientific information more approachable and memorable (MacKenzie, 2019; McClung & Johnson, 2010; Berry, 2016; Drew, 2017).

The effectiveness of podcasts lies in their unique ability to create emotional connections with scientific content. By employing storytelling techniques, these platforms tap into cognitive and emotional pathways that enhance information retention. Listeners experience scientific discussions as personal journeys rather than abstract lectures, fostering deeper engagement and understanding. The informal tone and narrative structure make complex topics more accessible, breaking down intellectual barriers that often intimidate non-specialist audiences (McHugh, 2010; Rehman et al., 2024).

Digital communication tools play a vital role in building institutional trust, which is essential for effective science communication. Platforms like social media offer unparalleled transparency, enabling scientific organisations to share not only their successes but also their challenges and uncertainties. This approach presents science as a dynamic, evolving process rather than a fixed set of facts. During the height of the pandemic, digital platforms became indispensable for sharing real-time updates. Although instances of misinformation occurred, these platforms were crucial for explaining evolving recommendations and maintaining public confidence through open and transparent communication (Cinelli et al., 2020; Goel & Gupta, 2020; Hantrais et al., 2021).

Interactive digital forums and online communities play a significant role in democratising scientific communication. Platforms that allow anonymous posting provide spaces where experts can engage directly with the public, answering questions and addressing misconceptions in real time. These interactions are invaluable for uncovering concerns that might otherwise go unnoticed, while offering unfiltered scientific reasoning. Reddit, in particular, has gained credibility due to its large following and its commitment to privacy. Due to its value, it has also become a popular dataset for social media research to understand digital communication trends (Baumgartner et al., 2020; Fiske & Dupree, 2014).

The rise of mobile applications has introduced personalised, accessible scientific communication strategies. These tools offer tailored scientific information, encourage citizen science participation, and provide interactive learning experiences. By making scientific content adaptable to individual user preferences and learning styles, mobile applications represent the next frontier in inclusive scientific communication (Boulos et al., 2006).

Leveraging the strengths of social media, websites, blogs, podcasts, interactive forums, and mobile applications, scientific communication has become more inclusive, transparent, and engaging. These platforms have simplified complex topics, reached diverse audiences, and fostered active participation in scientific discourse.

While advancements in communication have successfully made widely applicable topics like health issues and climate change more accessible (García-Marín, 2020), a significant gap remains in effectively addressing specialised sciences that may not have immediate relevance to the public's daily lives (Weingart et al., 2021). Bridging this gap requires a deeper understanding of the audience, as well as the selection of the right digital tools for this purpose.

Chapter 2

Aims and Hypothesis

As the global population approaches 10 billion by 2050, the demand for sustainable and efficient protein sources has become a critical challenge. Meeting this demand requires urgent action on multiple fronts to ensure adequate nutrition while simultaneously combating climate change and preventing further depletion of natural resources (FAO, 2017; Rockström et al., 2017).

Sustainable consumption has emerged as a powerful concept to tackle these issues, emphasising the need to find better sources of nutrition while reducing the burden on existing systems. This shift has brought traditional livestock farming under scrutiny for its significant environmental impact. Practices in this sector contribute extensively to greenhouse gas emissions, deforestation, and the overuse of land and water resources (Poore & Nemecek, 2018).

In response, the food industry has begun reimagining protein sources, leading to the development of plant-based proteins, CCDM, and insect-based dishes. These alternatives have the potential to mitigate ecological damage, fulfil nutritional needs, and address ethical concerns regarding the use of animals for food and feed (Henchion et al., 2017; Qin et al., 2022; Raheem et al., 2018).

Despite their potential, alternative proteins face considerable barriers that hinder widespread adoption. Issues such as sensory limitations, higher costs, and cultural resistance remain significant challenges (Hartmann & Siegrist, 2017; Onwezen et al., 2021). Overcoming these barriers requires more than technological solutions; it necessitates the acceptance of these innovations by consumers, who play a pivotal role in the success of any product placed on the market.

Modern consumers are becoming increasingly aware of health, sustainability, and ethical practices, shaping their expectations of food systems. However, this growing awareness has not always translated into consistent purchasing decisions, as observed in the case of alternative proteins (Orsi et al., 2019; Ghvanidze et al., 2016; Gere et al., 2017; Cicatiello et al., 2016).

A major reason for this gap lies in consumer distrust, which has roots in past failures in communication. For instance, food safety crises like the BSE outbreak eroded public confidence by highlighting how limited transparency and the lack of independent research resources can undermine trust (Rollin et al., 2011; Frewer & Salter, 2002).

This scepticism is further compounded when new foods and technologies are introduced. History has shown that such innovations are often met with rejection, as seen in the case of genetically modified (GM) foods, which faced significant backlash and economic losses before achieving partial acceptance in certain markets (Lusk et al., 2014; Lusk & McCluskey, 2018).

Literature highlights that these behaviours are influenced by a multitude of factors, including differences in age groups, socio-economic backgrounds, and how various demographics perceive sustainability. These variations result in differing levels of interest in sustainable foods and technologies (Grunert, 2005; Albertsen et al., 2020).

This gap in acceptance necessitates the development of targeted communication strategies that build consumer trust and promote acceptance. Researchers have identified several approaches that can be beneficial for this purpose, such as transparency in labelling and initiating educational campaigns (Grasso et al., 2019; Piha et al., 2018).

However, communicating complex information on safety, quality, traceability, and security and design complexities of food technologies in an accessible and relatable way remains a significant challenge. Without clear and effective communication, many consumers distrust the scientific information provided, even when it benefits them (Rollin et al., 2011).

To address these issues, stakeholders in food production, including regulatory bodies and companies, must adopt consumer-centred approaches (Linnemann et al., 2006; Boström & Klintman, 2019). This involves aligning every aspect of production and research with consumer expectations while ensuring these alignments reflect values such as sustainability, health, and ethical practices (Lusk, 2019; Lusk & McCluskey, 2018). These efforts could also help overcome the scepticism surrounding complex information and technologies involved in food research (Bonney et al., 2016; Dahlstrom, 2014).

Communication tools must be accessible and engage individuals across all levels of the food sector, ensuring authentic, clear, and transparent information-sharing practices (Rollin et al., 2011; Sun & Wang, 2019). These tools will allow researchers to connect directly with the public, share their opinions, and address consumer concerns. They will also enable consumers to express their interests, clarify doubts, and understand the broader implications of food production processes.

Additionally, the integration of digital media tools will open up opportunities for companies to communicate more effectively with consumers, enabling them to gather feedback and improve their products and services (Hung-Baesecke et al., 2016). Initiatives that focus on sustainability and ethical consumption can further bridge the gap between scientific advancements and public acceptance (Onwezen et al., 2021).

This dissertation aims to address these overarching challenges through a two-step plan. The first step is to understand the diverse factors that influence consumer perceptions and acceptance of new foods and food technologies. It seeks to uncover the motivations and barriers shaping consumer behaviour, particularly with regard to alternative protein sources, and to identify actionable strategies for building trust and fostering acceptance (Hartmann & Siegrist, 2017; Van der Weele et al., 2019).

The second step is to evaluate the effectiveness of digital media tools, which have gained prominence for their ability to engage consumers. Social media platforms, for instance, offer opportunities to enhance scientific communication and connect with diverse audiences (Collins et al., 2016; Osterrieder, 2013). Traditional methods such as email and phone calls remain relevant but may be complemented by innovative tools like infographics, interactive media, and storytelling to effectively convey complex information (Dahlstrom, 2014; Bonney et al., 2016).

To achieve these objectives and ensure both depth and breadth in its findings, this dissertation employed a comprehensive mixed-methods approach, integrating qualitative and quantitative research methods (Palinkas et al., 2015; Malina et al., 2011). Quantitative approaches, like surveys and questionnaires, were used to identify trends and preferences, while qualitative approaches, such as interviews and focus groups, were designed to explore underlying motivations and barriers. The outcomes from these discussions were

instrumental in developing suggestions for improving consumer engagement with food innovations (Spiggle, 1994; Fischer & Guzel, 2023).

The findings from this research have practical and strategic implications. They provide guidance to various stakeholders in the field of food business and research to develop effective communication strategies that address consumer demands and align with global sustainability goals like the SDGs (Grubb et al., 1993; Reisch et al., 2013). These efforts could eventually drive market uptake, create economic growth opportunities, and contribute to the broader adoption of sustainable practices in the food sector (Kuokkanen & Sun, 2020; Henchion et al., 2017).

Within this dissertation, the following hypotheses, formulated by identifying gaps in the literature, were tested:

1. **The influence of consumer awareness and understanding on the acceptance of new foods and technologies.**
   Hypothesis: Increased awareness and understanding among consumers correlate with a 20-30% higher acceptance rate of new foods and technologies.
2. **The role of environmental considerations in shaping consumer acceptance of new foods and technologies.**
   Hypothesis: Integrating sustainability-related benefits with other motivators can increase consumer acceptance rates by at least 25%.
3. **The impact of communication and engagement on increasing acceptance of new foods and technologies.**
   Hypothesis: Active consumer engagement through digital communication tools, by identifying barriers and developing strategies to address them, can enhance acceptance rates by 10-20%.

2.1 Structure of the Scientific Part of the Thesis

This thesis is organised into two interrelated parts, as shown in Figure 2.1. Each part addresses distinct yet complementary research questions. The first half focuses on understanding consumer behaviour towards novel food technologies like alternative proteins, edible insects, and sustainable diets. The second half shifts attention to the role of digital communication tools, specifically podcasts, in enhancing public engagement with complex scientific topics such as mass spectrometry. Both parts employ insights from existing literature and a mixed-methods approach for primary research activities.

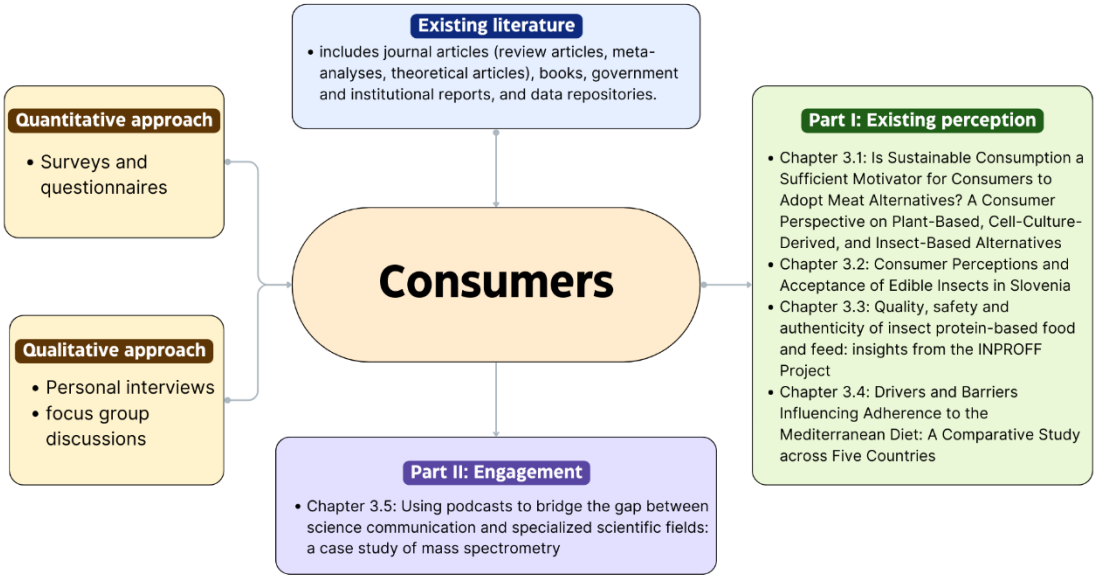


Figure 2.1: Schematic overview of the thesis structure.

In Part I, the focus is on understanding how various factors, such as health, sustainability, and price, influence consumer acceptance of alternative proteins, edible insects, and sustainable food choices. The research uses a mixed-methods approach, combining quantitative surveys and qualitative focus groups to gain deeper insights into the factors shaping consumer attitudes and behaviours.

A key study examines adherence to the Mediterranean diet (Biggi et al., 2024), revealing that health and sustainability concerns are strong motivators. However, barriers such as convenience and cost are more pronounced, particularly among younger populations. Another study on consumer attitudes towards edible insects in Slovenia (Rehman & Ogrinc, 2024) uncovers barriers to insect consumption, despite insects being identified as an excellent alternative protein source that could contribute to achieving SDG goals (Heath et al., 2024).

A third study on alternative proteins across Europe (Rehman et al., 2024) highlights that while sustainability remains important, health, sensory appeal, and price are more significant drivers of consumer behaviour. Collectively, these studies underscore the complexity of consumer decision-making and provide valuable insights into the motivations and obstacles to the adoption of new food technologies.

The data collection process for this section involved developing an online questionnaire inspired by the *Alternative Proteins: Consumer Survey* (Jarchlo & King, 2022), which was distributed via social media platforms to ensure broad reach while adhering to strict privacy and data protection standards. Additionally, focus groups were conducted following Breen's (2006) guidelines, using quota sampling to ensure a representative demographic. These virtual sessions, held via Zoom, facilitated in-depth discussions, offering valuable qualitative insights into consumer perceptions of novel food technologies.

Data analysis of the questionnaire responses was performed using descriptive statistics in MS Excel and Power BI, with advanced parametric and non-parametric tests applied using R to explore relationships in the data (Eftimov et al., 2017). The focus group discussions were analysed using template analysis with MaxQDA software, as recommended by Braun & Clarke (2006), to identify recurring themes and patterns in consumer attitudes.

In Part II, the thesis explores the role of digital communication tools, particularly podcasts, in enhancing public engagement with science, specifically mass spectrometry. Highly specialised fields such as mass spectrometry often struggle to communicate their complex concepts to the general public. Mass spectrometry plays a vital role in food safety, environmental monitoring, and pharmaceutical analysis (Ogrinc et al., 2005; Schönleben et al., 2024; Kaufmann, 2011; Kovačič et al., 2023; Swales et al., 2019) but its technical nature can make it difficult for non-specialists to grasp (Daughton, 2001).

Podcasts offer a unique opportunity to make such complex subjects more accessible and engaging (Berry, 2016; Chan-Olmsted and Wang, 2020). This research involved creating a series of four podcasts designed to explain the applications of mass spectrometry in various fields. Each episode featured expert interviews and focused on real-world examples, breaking down the technical aspects of mass spectrometry and demonstrating its relevance to everyday life, particularly in food safety and environmental monitoring.

The podcasts were crafted to be conversational and informative, ensuring that the content was not only scientifically accurate but also accessible to a broad audience. Data collection for this part involved distributing a second questionnaire via LinkedIn, Twitter, and other platforms to measure listeners' engagement and understanding of the scientific content before and after listening to the podcasts. Additionally, semi-structured interviews were conducted with selected listeners, providing deeper insights into their experiences and perceptions of the podcasts.

The survey data were analysed using descriptive statistics in MS Excel to assess listener preferences, engagement, and comprehension. The interview data were analysed through thematic analysis (Braun & Clarke, 2006; Maguire & Delahunt, 2017), which helped identify key themes, including listener preferences, understanding of the science, and suggestions for improvement.

The findings suggest that the podcasts were successful in improving public understanding of mass spectrometry, as discussed in Rehman et al. (2024). Many listeners noted that the content was more engaging and easier to comprehend compared to traditional scientific communication methods. This provides evidence that digital tools such as podcasts can effectively engage the public with complex scientific topics.

Ethical Considerations

Ensuring confidentiality and informed consent was central to the ethical integrity of this research. Throughout both parts of the study, strict adherence to ethical standards and privacy protocols was maintained. All participants were informed of their rights prior to completing questionnaires or participating in interviews and focus groups. Data were securely handled in compliance with the guidelines outlined by the European Commission (2013) and the Social Research Association (2021).

Chapter 3

Publications

3.1 Scientific Paper: "Is Sustainable Consumption a Sufficient Motivator for Consumers to Adopt Meat Alternatives? A Consumer Perspective on Plant-Based, Cell-Culture-Derived, and Insect-Based Alternatives"

The paper entitled "Is Sustainable Consumption a Sufficient Motivator for Consumers to Adopt Meat Alternatives? A Consumer Perspective on Plant-Based, Cell-Culture-Derived, and Insect-Based Alternatives" by Nayyer Rehman, Victoria Edkins, and Nives Ogrinc is presented in this chapter. I was responsible for designing the research framework, conducting data collection through surveys and focus groups, performing statistical analysis, interpreting consumer behaviour patterns, drafting the manuscript, and preparing it for publication.

This article was published in *Foods* in 2024 and explores European consumer perspectives on alternative protein sources such as plant-based, CCDM, and insect-based proteins as potential substitutes for conventional meat. The study's objective was to assess whether sustainability concerns alone are sufficient to drive consumer adoption of these alternatives, or if other factors, such as health benefits, sensory appeal, or price, play a more significant role in influencing acceptance.

To capture comprehensive insights into consumer attitudes, a mixed-methods approach was utilised as shown in Figure 3.1. The study began with a detailed questionnaire distributed in the UK and Slovenia, selected for their contrasting regulatory environments and high survey response rates. This was followed by focus group discussions conducted in both countries, which allowed for a deeper understanding of the motivations and barriers affecting consumer willingness to adopt alternative proteins. For the quantitative component, 237 survey responses were collected, and data were analysed using descriptive statistics and various inferential tests, including the Friedman test and post hoc comparisons, to determine statistically significant differences in consumer motivations across demographic variables. For the qualitative analysis, template analysis was applied to focus group transcripts, providing a framework for identifying key themes related to consumer preferences and barriers.

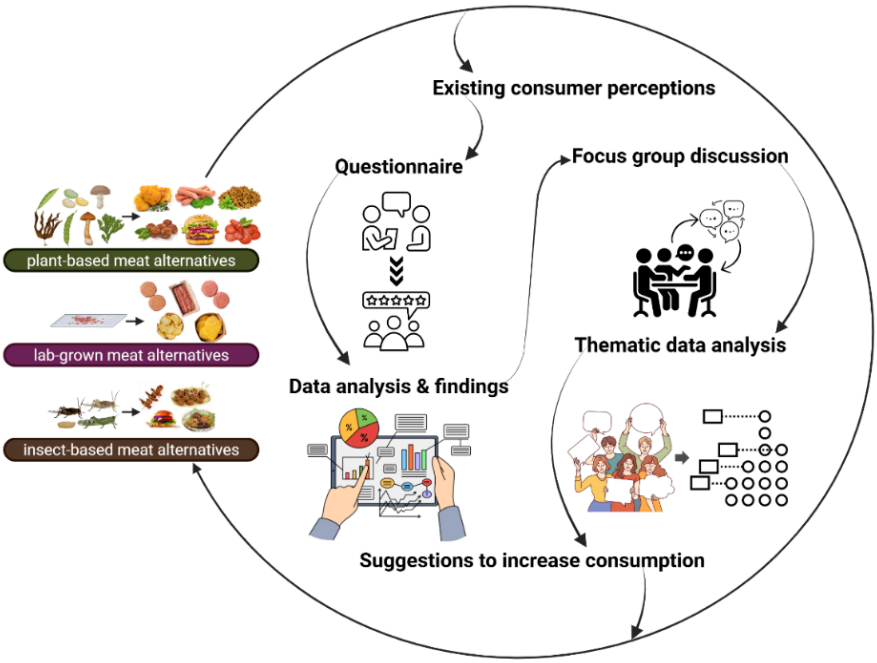


Figure 3.1: Graphical abstract for alternative protein foods study (Own Illustration).

The study found that plant-based proteins were the most familiar and accepted alternative, largely due to their availability and alignment with health-conscious consumers. In contrast, cell-culture-derived and insect-based proteins faced notable barriers, including perceptions of unnaturalness and lack of familiarity.

Although sustainability was a recognised motivator, health and nutrition were identified as primary factors driving consumer decisions. Other influencing factors included price, sensory characteristics, and a preference for minimally processed products. Based on these insights, the study proposed actionable strategies to enhance consumer acceptance, such as tailored educational campaigns, transparent labelling, and product positioning that aligns with consumer values.

The work has been presented in various academic settings, including an oral presentation at the 2024 IUFoST Conference. Additionally, preliminary findings were shared as a poster at the 2nd ISO-FOOD Symposium: ISO-FOOD from Food Sources to Health, held in Portorož, Slovenia, in 2023. This research contributes to the growing literature on consumer studies in alternative proteins to offer critical insights for policymakers and food industry stakeholders aiming to improve the acceptance of sustainable protein options across diverse European markets.

foods

MDPI

Article

Is Sustainable Consumption a Sufficient Motivator for Consumers to Adopt Meat Alternatives? A Consumer Perspective on Plant-Based, Cell-Culture-Derived, and Insect-Based Alternatives

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Abstract: This study investigates consumer preference and acceptance of three meat alternatives—plant-based, lab-grown, and insect-based—as sustainable choices to meet the demands of a growing population and evolving food systems. Insights were gathered from European consumers regarding their perceptions and consumption patterns using a mixed-methods approach. The approach employed a questionnaire followed by focus group discussions conducted in Slovenia and the UK to understand the motivations and barriers behind their responses. The UK and Slovenia were chosen as they provided the highest response rates to the questionnaire and they have differing legislation. The results show that plant-based alternatives are the most familiar and accepted option, while lab-grown meat and insect-based products are less familiar and have lower acceptance rates. Moreover, they show that although sustainability factors are important to consumers, they are not their only concern; health and nutrition are the primary motivators for choosing meat alternatives. These are followed closely by sensory appeal, pricing, and a preference for natural, minimally processed options. Based on insights from the focus groups, strategies to overcome the barriers to the acceptance of meat alternatives should include targeted product categorisation and placement, educational campaigns, effective use of media, and greater transparency in product information.

Keywords: consumer perception; consumer acceptance; alternative proteins; cell-culture-derived meat; edible insects; plant-based meat

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1. Introduction

With the projected global population set to reach 10 billion by 2050, it is crucial to increase food production by 70% to meet the growing demand, particularly for protein [1,2]. A solution to this challenge has emerged in the form of protein sources derived from plants, microorganisms, insects, or cultivated in laboratories. These food sources, often referred to as 'alternative protein sources to meat', 'alternative proteins', or 'meat alternatives', have gained attention as a promising solution to address the challenges posed by the rapidly expanding global population [3–5].

Alternative protein sources, such as insects, are recognised as sustainable solutions to the environmental issues associated with high meat consumption [6–8]. Insect production has been found to require significantly less land, using only 0.36 to 3.6 m^2 per kg of biomass compared to 23.1 m^2 for beef, 4.64 m^2 for chicken, and 1.48 m^2 for standard feed. Additionally, it has a lower carbon footprint, with emissions averaging just 0.3 to 3.0 kg of CO_2 equivalents per kg of biomass [9].

Insects also show more efficient feed conversion ratios (FCRs) than traditional livestock, meaning they can convert feed into edible meat more effectively, using fewer resources for

the same amount of protein. For instance, the FCRs of the black soldier fly (1.4 to 2.6) and the yellow mealworm (3.8 to 6.1) are much more efficient than for cows (8.8) [10].

Frass, the primary by-product of insect farming, is an effective organic fertiliser that can enhance soil fertility. Using frass could reduce reliance on chemical fertilisers, which are linked to water pollution and soil acidification, and contribute to a minimal waste and emissions profile of insect farming [11]. These benefits make insects a viable and sustainable alternative to conventional meat production, requiring less land and water and exhibiting rapid growth rates, making them an appealing option for sustainable agriculture [12,13].

The environmentally friendly aspect of cell-cultured-derived meat (herein referred to as CCDM) has been a topic of debate due to its production process. CCDM is developed in a laboratory by harvesting animal cells and cultivating them in a controlled environment [14], which requires significant energy. However, a proper life cycle assessment of CCDM has not yet been conducted due to the lack of information about the processes and materials involved, complicating the understanding of its environmental impacts. Despite the current limitations, CCDM is suggested to have the potential to be more environmentally friendly than conventional meat products, especially if sustainable energy sources are employed [15]. For instance, using renewable energy during production could lower the impact of greenhouse gas emissions compared to beef production. Currently, these emissions are expected to be similar to those of conventional poultry farms and, in some cases, higher than those of efficient poultry systems [16].

The land use for producing CCDM varies based on the feedstock sources that provide nutrients to the cells. Using efficient systems, such as those involving blue-green algae, can make CCDM require less land than beef and chicken [17]. However, the benefits are less predictable when traditional feeds such as soya and maize are used [18]. The biggest reason for CCDM gaining traction is as a humane alternative to slaughtering whole animals, thereby promoting animal welfare and establishing ethical alternatives for consuming traditional meat products [19].

Plant-based alternatives can also positively impact the environment and animal welfare. For instance, Poore and Namecek [20] found that peas are a more efficient protein source to grow, requiring less land (1.2–6.4 m^2 per 100 g of protein) in comparison to beef (42–369 m^2 per 100 g of protein) and poultry (3.8–9.2 m^2 per 100 g of protein) production.

The European Food Safety Authority (EFSA) concluded that the median mean meat consumption for adults in over 20 EU member states was 35 g/day. At the 95th percentile, meat consumption varied from 20 g/day (21% of Swedish consumers) to 237 g/day (88% of Austrian consumers) [21]. This widespread consumption raises concerns for individuals who regularly consume red meat as it has been associated with chronic health conditions such as type 2 diabetes, cardiovascular disease, colorectal cancer, and other forms of cancer, which in some cases may lead to mortality. Conversely, alternative proteins have been found to provide improved nutritional quality and lower levels of saturated fats and cholesterol, thus offering significant health benefits [22,23]. According to a 2019 global survey, 40% of consumers are trying to reduce their intake of animal proteins, and 10% avoid red meat altogether. With an increasing number of people looking to cut down on meat and embrace vegetarian or vegan lifestyles, meat alternatives offer a practical solution to cater to different dietary preferences [24].

Although existing research on the acceptance of alternative proteins yields substantial data on consumer perspectives, willingness to adopt these products, and the influencing factors such as taste, texture, price, health benefits, environmental sustainability, and the impact of social and cultural influences on consumption habits [3,25–34], the market share of meat substitutes remain low [35,36]. To better understand this reluctance to adopt alternative proteins, it requires a deeper understanding of consumer perceptions and attitudes, and how these factor into their evaluation of the benefits or potential risks of switching to alternative proteins or reducing their traditional meat consumption, and thus their role in their decision to include these products in the diet [37–39].

Siegrist et al. [40] suggest engaging directly with consumers and actively seeking their input to design campaigns and develop strategies based on consumer preferences and concerns, to address the challenge of consumer acceptance. This approach not only assists in identifying specific consumer groups and developing tailored strategies for them [41,42] but it also raises the intriguing question of how people's opinions might differ in regions with similar geographical locations but differing legal frameworks.

In the European Union (EU), four insect species (yellow mealworm, migratory locust, house cricket, and lesser mealworm) are currently classified as novel foods under Regulation (EU) 2015/2283 [43,44]. As a result of this classification, insect-based foods have become increasingly common in many EU countries, resulting in sales of around 500 tonnes in 2019, and are expected to reach approximately 260,000 tonnes by 2030 [45]. However, the situation differs in the UK, where regulations for novel foods have had to be re-evaluated in the post-Brexit era, leading to adverse effects on manufacturers of insect-based products [46]. These regulatory adjustments have impacted the availability of such foods in supermarkets, potentially rendering them unfamiliar to consumers in this country.

On the other hand, CCDM has also been the subject of debate regarding its production process and has had varying official statements in the UK and different regulations within the EU. For example, while it has been entirely banned in Italy [47], CCDM burgers are already scheduled for government-approved consumer tasting trials in the Netherlands [48].

In contrast, plant-based alternatives have encountered minimal production and safety concerns in Europe, where the plant-based food market is expected to grow at a CAGR of 10.1% from 2022 to 2029 [49]. Their primary challenge lies in labelling restrictions, such as the guidelines laid out in Regulation (EU) 1169/2011 regarding accurate labelling of ingredients and whether the product is of animal or plant origin [50]. As a result, plant-based manufacturers in France, for example, have been prohibited from using terms like "sausage" and "steak" for their products [51].

Despite numerous studies that examined consumer perceptions of alternative proteins and provided valuable insights for intervention strategies [39], consumers continue to reject these options, a sentiment reflected in their purchasing behaviour [52–56]. In addition, the existing literature provides limited insight into the factors that influence the acceptance of different alternative protein sources when compared to one another. This study addresses precisely that by placing consumers at the centre of the discussion of these barriers to consumption, engaging them to develop strategies that will yield results that prioritise consumer inputs, and assessing key differences in how consumers view acceptance of different meat alternatives.

The aim of this study is threefold: to assess current consumer perceptions and motivations towards alternative protein sources to meat and, subsequently, to evaluate whether sustainability-related factors alone motivate consumers to switch to these meat alternatives; then, finally, to understand how the source of alternative proteins can affect consumer perceptions, motivations, and barriers. With those purposes, this study selected three different types of alternative proteins, each originating from a different source: plant-based foods, edible insects and insect-based foods, and CCDM.

Additionally, this study examines the barriers preventing consumers from choosing alternative protein sources, and provides practical recommendations to address these barriers based on direct consumer insights. It must be considered that the availability of products and, by extension, consumer perception of these products in a country are highly dependent on its regulations [57]. For a meaningful comparison, two European countries with the highest response rates and differing regulatory environments were selected to understand the differences in opinions that can arise due to geographical location: Slovenia, falling under the EU jurisdiction, and the UK, which does not.

By employing both qualitative and quantitative approaches, we aim to enhance our understanding and corroborate our findings on consumer perceptions, motivations, and barriers, which will assist food companies, retailers, and policymakers in identifying

specific population segments more inclined to try alternative meat products and those who are not, enabling them to tailor communication and marketing efforts and bridge the gap between consumer awareness and acceptance of alternative protein sources to meat.

2. Materials and Methods

This study employed a two-stage, mixed-methods approach to address the identified research gaps, including a questionnaire and focus groups. Participants were provided with clear guidelines regarding data processing and confidentiality in accordance with the GDPR guidelines [58]. Since this study required voluntary participation, participants were requested to consent before attempting the questionnaire or participating in the focus group discussions. No personal information was collected, and all ethical practices were rigorously followed to ensure anonymity. This study also strictly adhered to the principles outlined in the European Commission's Ethics for Researchers [59] and the Social Research Association (SRA)'s Ethical Guidelines for Social Research [60].

2.1. Questionnaire Design and Data Collection and Analysis

The questionnaire (Supplementary Materials), designed to identify factors influencing consumer perception and purchasing behaviour of alternative protein sources to meat in Europe, was created on the Typeform survey platform. The questionnaire began by communicating privacy and data protection guidelines to participants, followed by questions on demographic information, including age, country of residence, sex, and education level.

The questionnaire's core components were derived from the 'Alternative Proteins: Consumer Survey' report [61] and adapted to meet this study's requirements, incorporating insights from experts within the institute specialising in this field. The questionnaire was structured in four sections. The first section focused on identifying the key factors influencing grocery purchasing decisions, aiming to gather insights into the drivers behind consumers' choices. In the second section, respondents were asked why they believed alternative protein sources had been introduced to the market, assessing their existing perceptions of these foods, while section three aimed to measure respondent awareness of various alternative protein options available in the market. The final section consisted of eight questions exploring safety perceptions and consumption habits for plant-based alternatives, edible insects, and CCDM. It is important to note that CCDM is still in the experimental development phase in European countries; thus, it is not yet available to supermarket consumers. The questions for this category were adapted accordingly.

Before the virtual distribution of the questionnaire, two test sessions were conducted with colleagues to ensure the questionnaire's accessibility for collecting online responses. After that, the questionnaire was distributed through official social media profiles on LinkedIn and Twitter.

The questionnaire did not include specific screening criteria. From August to October 2022, two hundred and forty responses (N = 240) were received. Three responses were omitted due to incomplete information; therefore, two hundred and thirty-seven (N = 237) were used for the analysis. Using MS Excel and Power BI, descriptive statistics were applied to analyse the responses obtained from the questionnaire's categorical variables, following the guidelines provided by Spriestersbach et al. [62]. Graphical representations were used to facilitate the interpretation of findings, identify patterns, and gain insights from the collected data.

The collected data were analysed using the R statistical package (version 4.1.2). The objective was to see if there were statistical differences between the responses collected for factors impacting consumer purchases and consumer perceptions of why new alternative protein sources are introduced to the market across different age groups, educational attainment levels, and countries of residence (UK, Slovenia, and Others). The required conditions for the safe use of the parametric test were first checked to select the appropriate statistical test for each dataset (i.e., normality of each data sample involved in the comparison, independence, and the homoscedasticity of the variance) using the guidelines set by

Eftimov et al. [63]. In this case, the questions were unrelated and were independent. The normality condition was checked using the Shapiro–Wilk test, while the homoscedasticity of the variance was checked by Levene's test. A non-parametric test was selected if either condition was not satisfied. It is also important to note that all the cases dealt with paired samples.

The results of selected statistical tests for each dataset are shown separately, together with the obtained *p*-values. A *p*-value below 0.05 indicated a statistically significant difference. In cases when the Friedman test revealed a statistically significant difference, the groups responsible for that difference were determined using an all vs. all post hoc procedure (Nemenyi test). The results of this test were then used to plot the Critical Difference (CD) diagrams. In each CD diagram, groups where $p < 0.05$, i.e., no statistical difference, are connected by a bold line.

Pearson correlation coefficients were calculated to assess the linear relationship between variables in multiple-choice questions, ranging from −1 (indicating a strong negative correlation) to +1 (indicating a strong positive correlation). *P*-values have been omitted due to space constraints, as the coefficients offer substantial insight into the strength and direction of the correlations.

The CHAID (Chi-squared Automatic Interaction Detection) method was employed to analyse data on the frequency of consumption of meat alternatives across demographic segments [64,65]. The analysis was structured into multiple decision nodes, each validated by significant Chi-square values. Demographic variables such as educational attainment, gender, and age group served as independent variables in relation to the dependent variable—the frequency of consuming these alternatives. Following the validation of prerequisites for Chi-square analysis, it was determined that the method could effectively evaluate the consumption patterns of plant-based alternatives. Due to insufficient responses, insect-based alternatives failed to meet the necessary conditions for CHAID analysis, specifically for the 'often' and 'very often' categories.

2.2. *Focus Group Design, Conduct, and Analysis*

Focus groups were conducted using Breen's [66] guidelines, with the moderator introducing the topic and setting the ground rules to ensure a respectful exchange and decorum amongst participants.

For each focus group conducted in the UK and Slovenia, purposive sampling was employed to recruit a diverse group of six individuals ($N = 12$) to gather the opinions of different age groups and educational backgrounds [67,68]. An equal distribution of male and female participants was maintained within each group for a standardised composition. These virtual discussions were conducted over Zoom from March to April 2023, lasting approximately 90 min each. Throughout each session, participants were actively encouraged to express their thoughts and perceptions in response to the prompts and questions shown in Table 1.

The focus group discussions were transcribed and analysed using MaxQDA, and template analysis was applied to identify, organise, and interpret key themes, patterns, and concepts from the data [69–71].

Table 1. Focus group discussion segments and prompts.

Segments	Prompts
Introduction	Self-introduction and dietary habits Usual protein sources in the diet Understanding of alternative proteins
Motivation	Experience with meat substitutes Reasons for interest Positive experiences Understanding the benefits of alternative protein sources to meat Personal preferences

Table 1. *Cont.*

Segments	Prompts
Barriers	Negative experiences Concerns about physiochemical properties such as taste and texture Concerns about plant alternatives Concerns about insects Concerns about cell-culture-derived meat Other concerns related to availability and affordability Personal preferences
Suggestions	Opinion on existing strategies/campaigns Suggestions for industry and government Suggestions that would work for other consumers Impact of addressing barriers
Wrap-up	Final thoughts from participants Questions regarding alternative protein sources to meat

3. Results

3.1. Demographic Characteristics

Table 2 presents the demographic characteristics of the questionnaire respondents. The data shows a greater proportion of respondents in the two younger age groups (16–25 and 26–35) who had higher education degrees and identified as female. Regarding countries, responses from the UK and Slovenia are displayed, as these countries had higher response rates than other European countries. Responses from other European countries have been aggregated under the 'Others' category to facilitate interpretation when comparing responses with those from the UK and Slovenia. These responses were collected from Germany (14%), Belgium (6%), Sweden (5%), Italy (3%), the Netherlands (2%), less than 2% each from Spain, Greece, France, and Switzerland, and less than 0.5% from Austria and Norway.

Table 2. Demographic characteristics of questionnaire respondents (%; $N = 237$).

Demographics	% of Sample
Sex	
Female	67%
Male	33%
Age group (in years)	
16–25	24%
26–35	41%
36–45	13%
46–55	14%
56–65	5%
66–75	3%
Educational attainment	
Doctoral degree	15%
Master's degree	34%
Bachelor's degree	19%
College/University/Level 3 (UK) diploma	13%
Vocational training/Apprenticeship	7%
Secondary school/High school diploma	12%
Country of residence	
UK	33%
Slovenia	32%
Others	35%

After the questionnaire, two focus groups were conducted, each with six participants ($N = 6$). In the UK focus group, participants were evenly distributed across age groups: one from the 16–25, 26–35, 46–55, and 56–65 groups and two from the 36–45 group. Similarly, the Slovenian focus group included one participant each from the 16–25, 36–45, 46–55, and 56–65 groups and two from the 26–35 group. Both focus groups maintained an equitable male–female ratio, with three males and three females in each group.

3.2. Factors Affecting Consumer Food Purchases

Figure 1 shows the factors that influence food purchases. Respondents had the opportunity to select multiple answers relevant to their decision. The results show that 'healthy and nutritious' (76%) was cited as the most important factor, followed by 'sensory appeal' (63%), which includes appearance, taste, and smell. The third and fourth factors, 'priced better than others' (59%) and 'natural or minimally processed' (57%), were similarly selected.

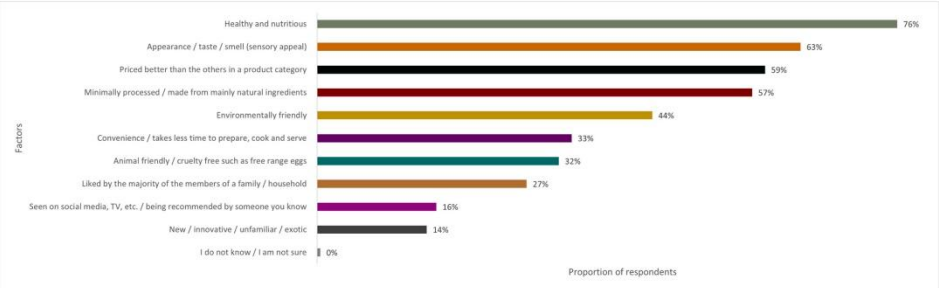


Figure 1. Bar graph showing factors affecting consumer purchase decisions for food items (%; $N = 237$).

'Environmentally friendly' (44%) ranked fifth, followed by 'convenience' (33%), 'animal welfare' (32%), and 'liked by the majority of family members', which was selected by 27% of the respondents. Factors indicating the influence of media and demand for new or innovative products received lower percentages at 16% and 14%, respectively, and less than 0.5% of respondents selected 'I do not know' or 'I am not sure'.

Table 3 shows the analysis of these variables in relation to demographic variables. Age ($p < 0.001$; $p < 0.05$) and educational attainment levels ($p < 0.001$; $p < 0.05$) have a higher level of statistical significance, while the country of residence ($p = 0.02$; $p < 0.05$) exhibits a lower level of statistical significance. In comparison, the assessment of factors with respect to sexes ($p = 0.06$; $p > 0.05$) indicates no statistical significance.

Table 3. Summary of statistical analysis results on factors affecting consumer food purchases.

Variables	Methods	*p*-Values
Age	Friedman	<0.001 (9.61×10^{-8})
Country of residence	Friedman	0.02
Education	Friedman	<0.001 (2.73×10^{-5})
Gender	Wilcoxon Signed-Rank	0.06

Statistical significance is determined at $\alpha = 0.05$ level.

Figure 2a presents the Critical Difference (CD) diagram of the Friedman/Nemenyi test for factors impacting food purchases across different age groups. Significant differences were found between 26–35 years and 36–45, 56–65, and 66–75 years, as well as between

16–25 years and 56–65 and 66–75 years. These differences indicate a generational divide, with younger groups (16–35 years) prioritising pricing and marketing, while older groups (56–75 years) emphasise appearance and a preference for natural or minimally processed options. The analysis revealed no statistical difference in preferences between the following age groups: 26–35 years and both 16–25 and 46–55 years; 16–25 years and both 36–45 and 46–55 years; and 46–55 years and 66–75 years. These similarities suggest shared behaviours and preferences within these age groups.

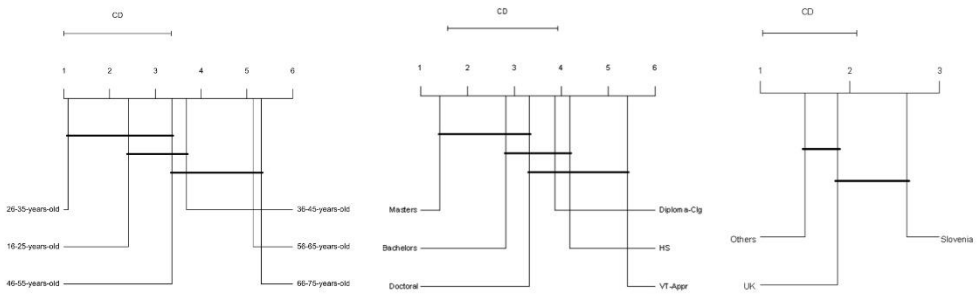


Figure 2. (**a**) CD diagram of the Friedman/Nemenyi test for factors affecting food purchases across different age groups. (**b**) CD diagram of the Friedman/Nemenyi test for factors affecting food purchases across different educational attainment groups. (**c**) CD diagram of the Friedman/Nemenyi test for factors affecting food purchases across the UK, Slovenia, and countries under the 'Others' category. (**a**–**c**) Groups are ranked from left to right based on the level of their influence on factors affecting consumer food purchases (higher rank means higher influence). Bold lines indicate no significant difference between connected groups ($p < 0.05$). The CD line at the top shows the threshold for statistical significance; differences exceeding this line are significant.

Figure 2b presents a Critical Difference (CD) diagram of the Friedman/Nemenyi test for factors impacting food purchases across different educational attainment groups. These groups are denoted as HS (Secondary school/High school diploma), VT-Appr (Vocational training/Apprenticeship), Diploma-Clg (College/University/Level 3 (UK) diploma), Bachelors (bachelor's degree), Masters (master's degree), and Doctoral (Doctoral degree). Significant differences were identified between Masters and Diploma-Clg, Masters and HS, Masters and VT-Appr, and Bachelors and VT-Appr. These findings suggest that higher educational attainment is associated with a stronger preference for 'healthy and nutritious', 'natural or minimally processed', and 'environmentally friendly' foods. No statistical difference in preferences was observed between other groups. The lack of significant differences between other groups could be due to overlapping socio-economic factors that influence behaviour and preferences similarly across different educational levels.

Figure 2c presents a Critical Difference (CD) diagram of the Friedman/Nemenyi test for factors impacting food purchases across different countries. A significant difference was found between Slovenia and Others, with Slovenian respondents placing more emphasis on pricing, sensory characteristics, and the quality of food they consume. The analysis showed no statistical difference in preferences between the UK and both Slovenia and Others. This lack of difference between the UK and the other groups might be attributed to shared market access and global consumer trends.

3.3. Perception of New Alternative Protein Sources to Meat

Figure 3 depicts the factors consumers consider important when asked why they think alternative protein sources to meat are being introduced to the market. Amongst the

factors given, healthier alternatives in response to consumer demand (57%) had the highest percentage, followed by sustainability, which 49% saw as a means to promote sustainable alternatives, while 46% saw it as a response to consumer demand and 41% of consumers believed it was a means to promote healthier alternatives.

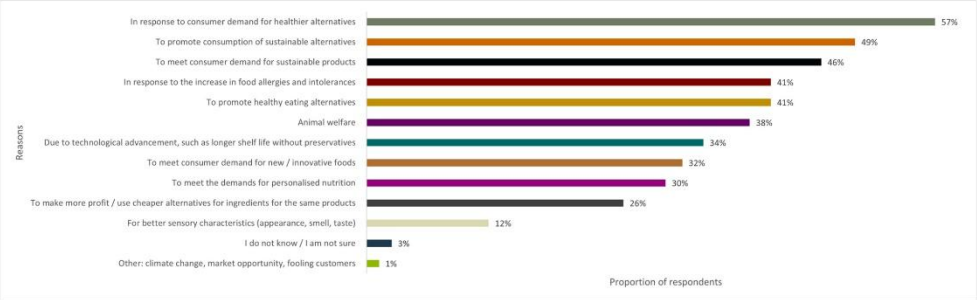


Figure 3. Bar chart illustrating reasons behind introducing new alternative protein sources to meat according to consumers (%; $N = 237$).

Another 41% of consumers attributed the demand to the increasing occurrence of food allergies and intolerances, and 30% chose the factor 'personalised nutrition'. While the percentage for personalised nutrition is lower than that for allergies, it still signifies that consumers like those who responded to this questionnaire have seen products that offer diverse options to serve a wider range of dietary preferences.

The well-being of animals (38%) also emerged as a salient concern, and 34% of respondents believed this was due to technological advancement. A further 32% believed it was a response to consumer demand for new or innovative food products, and 26% believed that producers could make more profit using cheaper ingredients. Only 12% of consumers opted for sensory characteristics, while a small percentage of respondents expressed uncertainty (3%) or provided reasons such as climate change and marketing strategies (1%). Nevertheless, consumer awareness of food choices is gradually evolving, particularly regarding overarching concerns about general well-being, environmental impact and ethical considerations.

Table 4 shows the analysis of these factors in relation to demographic variables. Age ($p < 0.001$; $p < 0.05$) and educational attainment levels ($p < 0.001$; $p < 0.05$) were found to have a higher level of statistical significance. In comparison, the country of residence ($p = 0.02$; $p < 0.05$) and sex ($p = 0.04$; $p < 0.05$) had a lower level of statistical significance.

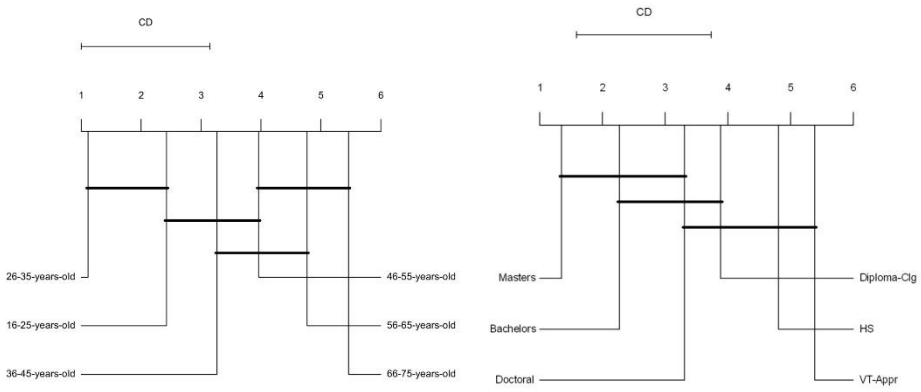
Table 4. Summary of statistical analysis results on the perception of new alternative protein sources to meat.

Variables	Methods	*p*-Values
Age	Friedman	<0.001 (6.56×10^{-9})
Country of residence	Repeated-Measures ANOVA	0.02
Education	Friedman	<0.001 (3.55×10^{-8})
Gender	Wilcoxon Signed-Rank	0.04

Statistical significance is determined at $\alpha = 0.05$ level.

Figure 4a presents the Critical Difference (CD) diagram of the Friedman/Nemenyi test comparing consumer perceptions of new alternative protein sources to meat across different age groups. Significant differences were found between the following pairs:

26–35 years and 36–45 years, 26–35 years and 56–65 years, 26–35 years and 66–75 years, 16–25 years and 56–65 years, and 16–25 years and 66–75 years. These findings indicate a generational divide, with younger age groups (16–35 years) focusing more on sustainable consumption and animal welfare, whilst older age groups (56–75 years) are more concerned with health and nutrition. The analysis showed no statistical difference in preferences between the following pairs of age groups: 26–35 years and 16–25 years, 26–35 years and 46–55 years, 16–25 years and 36–45 years, and 46–55 years and 66–75 years. The lack of significant differences between these pairs suggests shared behaviours and preferences within these age groups and, in cases of adjacent generational groups, it may be due to similar perceptions influenced by shared experiences or life stages.



(**a**) (**b**)

Figure 4. Critical Difference (CD) diagrams of the Friedman/Nemenyi test for perception of new alternative protein sources to meat across different (**a**) age groups and (**b**) educational attainment groups. (**a**,**b**) Groups are ranked from left to right based on the level of their perception of new alternative protein sources to meat (higher rank means a more positive perception). Bold lines indicate no significant difference between connected groups ($p < 0.05$). The CD line at the top shows the threshold for statistical significance; differences exceeding this line are significant.

Figure 4b presents a Critical Difference (CD) diagram of the Friedman/Nemenyi test comparing consumer perceptions of new alternative protein sources to meat across different educational attainment groups. The groups are denoted as HS (Secondary school/High school diploma), VT-Appr (Vocational training/Apprenticeship), Diploma-Clg (College/University/Level 3 (UK) diploma), Bachelors (bachelor's degree), Masters (master's degree), and Doctoral (Doctoral degree). Significant differences were identified between the following pairs: Masters and Diploma-Clg, Masters and HS, Masters and VT-Appr, Bachelors and VT-Appr, and Bachelors and HS. These findings suggest that higher education levels are associated with a stronger preference for health and sustainable alternatives, whilst lower education levels link the introduction of alternative proteins to the promotion of healthier options and technological advancements. No statistical difference in preferences was observed between other pairs, implying that socio-economic factors may influence behaviours and preferences similarly across different educational levels.

The correlation analysis reveals the complex links between what consumers think about the introduction of alternative protein sources to meat across different age groups. The desire for healthier options is strongly linked with all other factors ($r > 0.83$), highlighting that health concerns are a major reason for introducing alternative proteins. In contrast, worries about food allergies and intolerances are less connected to promoting

healthy eating (r = 0.42), personalised nutrition (r = 0.37), and sustainability (r = 0.48), suggesting that these worries are seen as separate motivations. The moderate connections of sensory characteristics (r < 0.65) with other factors highlight the importance of taste and texture in making alternative proteins appealing to consumers. The results of these correlations were used to develop prompts related to motivations for alternative protein sources to meat in the focus group guide (refer to Table 1), considering key consumer concerns and motivations, particularly the strong link between health benefits and other factors. Negative correlations led to generating prompts targeting personal preferences for participants to discuss.

3.4. Consumer Acceptance of Different Alternative Protein Sources to Meat

When asked if respondents were familiar with the three alternative protein sources in the study, namely plant-based, CCDM, and insects, the results revealed that plant-based alternatives, such as burger patties, were recognised by 96% of participants, making them the most familiar option. Edible insects, such as cricket pasta, were chosen by 74% of the respondents, while 62% chose CCDM.

When asked if they had tried these alternative protein sources to meat, 95% of respondents reported that they had tried plant-based alternatives, showing a high level of acceptance for this option. Insect-based alternatives were tried by 23% of participants and CCDM was tried by 5% of respondents.

A breakdown of both variables (heard of and tried yet) by age, sex, educational attainment, and country of residence is shown in Table 5, serving to identify patterns indicating high or low interest in different protein alternatives amongst specific groups of respondents.

Table 5. Variables 'Heard of' and 'Tried yet' for different alternative protein sources in terms of respondents across age, sex, educational attainment, and country of residence (%; *N* = 237).

	Plant-Based Meat Alternative		**Cell-Culture-Derived Meat**		**Edible Insects and Insect-Based Food**	
Demographics	**% (Heard of)**	**% (Tried yet)**	**% (Heard of)**	**% (Tried yet)**	**% (Heard of)**	**% (Tried yet)**
Sex						
Female	99%	97%	63%	4%	73%	19%
Male	95%	95%	61%	5%	77%	31%
Age group (in years)						
16–25	100%	100%	70%	7%	63%	19%
26–35	97%	96%	72%	4%	77%	26%
36–45	97%	93%	67%	7%	93%	23%
46–55	97%	97%	31%	0%	72%	22%
56–65	100%	92%	31%	8%	69%	15%
66–75	86%	86%	57%	14%	86%	43%
Educational attainment						
Doctoral degree	92%	92%	81%	6%	92%	50%
Master's degree	99%	95%	76%	4%	76%	31%
Bachelor's degree	98%	98%	65%	9%	74%	17%
College/University/Level 3 (UK) diploma	100%	100%	47%	3%	73%	7%
Vocational training/Apprenticeship	100%	100%	6%	0%	69%	6%
Secondary school/High school diploma	97%	97%	48%	7%	55%	3%

Table 5. *Cont.*

	Plant-Based Meat Alternative		Cell-Culture-Derived Meat		Edible Insects and Insect-Based Food	
Demographics	**% (Heard of)**	**% (Tried yet)**	**% (Heard of)**	**% (Tried yet)**	**% (Heard of)**	**% (Tried yet)**
Country of residence						
Slovenia	94%	91%	73%	6%	67%	27%
UK	100%	100%	40%	6%	75%	12%
Others	97%	97%	72%	4%	80%	28%

The awareness of plant-based food was consistently high across all demographics, ranging from 94% to 100%. Females showed a slightly higher awareness (99%) than males (95%). Amongst different age groups, the younger age groups (16–25 and 26–35) had the highest awareness (100%) compared to the older groups. Interestingly, educational attainment did not seem to impact awareness significantly. The UK residents had the highest awareness of plant-based food (100%), which was when compared to residents of Slovenia (94%) and other European countries (97%). This divergence can be linked to the increasing percentage of consumers in various European countries who are adopting or showing an interest in plant-based products. A study utilising Google Trends and a data analytics tool to track vegan-related queries across multiple languages placed the UK number one on the list, while Slovenia was 15th [72].

In the case of CCDM, awareness was generally lower than that for plant-based food, ranging from 31% to 81%, with females indicating slightly higher awareness (63%) than males (61%). However, when trying CCDM, males (5%) showed more interest than females (4%). Amongst different age groups, the 16–25 and 26–35 groups had the highest awareness (70% and 72%), whereas the oldest age group (66–75) had the highest proportion of respondents who had tried it (14%). A trend indicating increased awareness with higher educational attainment was observed, with higher education levels between 65% and 81% and lower educational levels below 50%. A striking observation was the similarity in the percentages obtained for awareness of CCDM amongst Slovenian residents (73%) and those in other European countries (72%), while UK residents had a comparatively lower percentage (40%). The low percentages for trying CCDM are unsurprising, considering that CCDM is unavailable in any direct consumer market in the EU.

In contrast, awareness of edible insects fell within the moderate range, with even lower percentages reported when asked about trying them. Males demonstrated higher awareness (77%) than females (73%), which also translated to trying edible insects, as a higher proportion of males (31%) compared to females (19%) had tried them. Across different age groups, the 16–25 and 26–35 groups had the highest percentage of respondents who were aware of edible insects (77% and 93%, respectively), and the 66–75 group had the highest proportion of respondents who had tried edible insects (43%). Awareness of edible insects was higher amongst individuals with a doctoral degree (92%) and a master's degree (76%). When asked about trying edible insects, individuals with a doctoral degree (50%) had the highest percentage compared to the other groups. In terms of geographical comparison, UK residents (75%) and residents of other European countries (80%) had higher awareness of edible insects than Slovenian residents (67%). However, when trying edible insects, Slovenian residents (27%) and residents of other European countries (28%) had higher rates than residents of the UK (12%). In the analysis of alternative protein preferences, awareness of plant-based alternatives showed a moderate positive correlation with trying them ($r = 0.56$), suggesting that increased awareness significantly drove consumers to try these products. There was a weak positive correlation between awareness of plant-based alternatives and trying insect-based alternatives ($r = 0.14$), indicating some crossover in consumer interest. Awareness of edible insects also demonstrated a weak positive correlation with trying them ($r = 0.40$), reflecting that higher awareness somewhat increased the likelihood of trying insect-based

foods. There was a weak positive correlation between awareness of edible insects and trying plant-based alternatives (r = 0.18), suggesting a slight overlap in consumer interest. Awareness of cultured meat showed a moderate positive correlation with trying insect-based alternatives (r = 0.30), indicating a shared consumer openness to novel protein sources. In contrast, the negligible correlation with trying plant-based alternatives (r = 0.01) suggested distinct consumer groups.

3.5. Existing Consumption Patterns for Alternative Protein Sources to Meat

Subsequently, the respondents were presented with questions to evaluate consumers' perceptions regarding the safety of these meat alternatives and how these perceptions might impact their current consumption patterns. Using a five-point Likert scale, the respondents were asked to express their perceived level of safety for each alternative protein source. Based on their responses, the respondents were prompted to indicate the frequency of their consumption using an ordinal scale.

In response to the question, "On a scale of 1 to 5, how strongly do you believe plant-based alternatives are safe for human consumption?", the results showed that the majority of the participants agreed with the statement (53% strongly agreed, while 32.5% agreed), indicating a high degree of certainty in the safety of plant-based alternatives. Meanwhile, 27% remained uncertain or neutral, while a small proportion of respondents disagreed (1.5% strongly disagreed, 4.5% disagreed).

When examining the data about sex, educational attainment, and age groups, the observed trends were similar to the overall findings. Key differences emerged in the oldest age group (66–75), where none of the respondents strongly disagreed and the majority either agreed (57%) or strongly agreed (14%). A similar observation was made within the educational attainment group with a doctoral degree, where no respondents strongly disagreed or disagreed and the majority either agreed (25%) or strongly agreed (50%). These agreement responses were also consistent with those observed for respondents with a master's degree.

In terms of a country-wise comparison, it was interesting to note that none of the respondents from the UK strongly disagreed with this statement, and the UK had the highest proportion of respondents who strongly agreed (38%). In Slovenia, only a few respondents strongly disagreed (3%), and among the remaining respondents who either agreed or strongly agreed, the proportion of those who strongly agreed was lower (34%).

When asked about the consumption patterns of plant-based meat alternatives, the data showed different consumption patterns, with the highest percentage (35%) of respondents occasionally opting for these alternatives, 30% rarely consuming them, 17% consuming them frequently, and 8% showing a strong preference for consumption. In comparison, 10% avoided plant-based alternatives altogether.

Figure 5 presents the findings from the CHAID analysis on the frequency of consumption of plant-based meat alternatives across socio-demographic variables. Responses to consumption frequency were categorised into three groups: Yes (includes 'Often' and 'Very Often'), Maybe (includes 'Sometimes' and 'Seldom/Rarely'), and No ('Never'). The CHAID analysis identified significant variations in plant-based consumption frequency across the population. The results of the CHAID analysis showed significant differences between education and sex but not with the age group. Educational attainment emerged as the principal predictor of consumption frequency ($p < 0.0001$), leading to the initial split in the dataset.

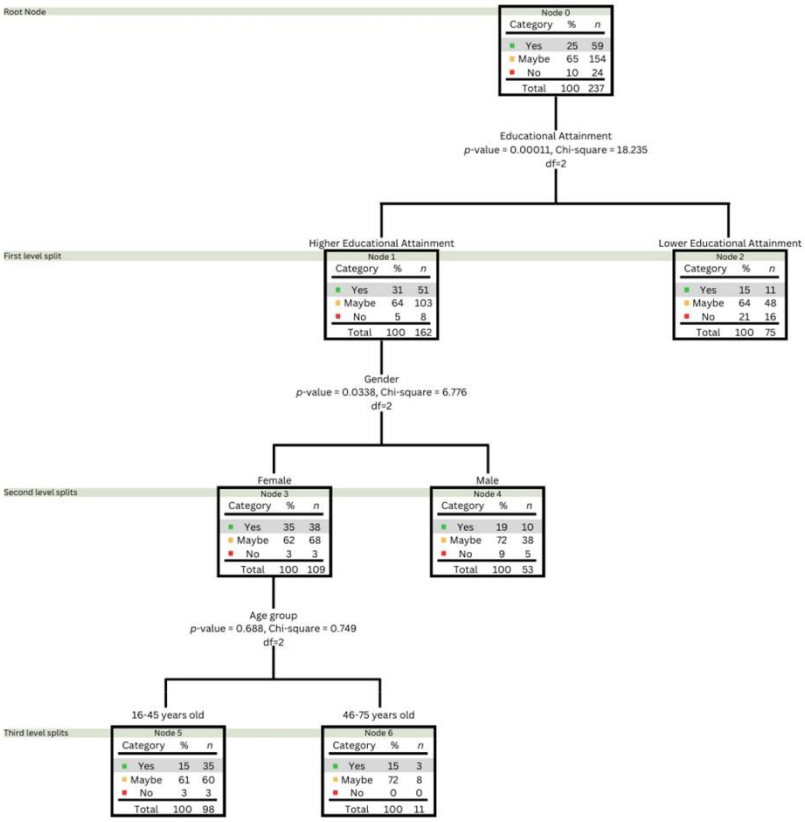


Figure 5. CHAID decision tree analysis of the frequency of consumption of plant-based meat alternatives by socio-demographic variables (educational attainment, gender, age group; based on Chi-square significance). The colour blocks represent the distribution of responses ('Yes'—green, 'Maybe'—orange, 'No'—red) across various splits.

Regarding education, the higher educational group, with 31% of respondents, had a higher acceptance of plant-based meat consumption than the lower educational group (15%). A subsequent analysis based on gender within the higher education cohort revealed a significant disparity (p-value = 0.0338), with females reporting higher frequencies of consumption (35%) than males (19%). Further investigation within the higher-educated female group indicated that age was not a significant factor (p-value = 0.688) for the 16–45 and 46–75 groups. It should be noted that the analysis was deemed valid as the main category of interest ('Yes') had sufficient responses to satisfy the requirements for Chi-square. A similar evaluation approach was provided by Kasza et al. [65] to understand the consumption of insect-based foods among Hungarian consumers.

The questionnaire asked respondents to rate the safety of CCDM for human consumption. The results showed that 49% of the respondents were uncertain or neutral, while 8% disagreed and 15% strongly disagreed with the statement. Conversely, 17% of the respondents agreed and 11% strongly agreed with the statement, i.e., they considered CCDM safe for consumption.

When the data were examined in relation to educational attainment and age groups, a notable trend emerged, revealing that as the age groups increased and educational attainment decreased, the perceptions of safety for CCDM tended to decrease. In terms of sex, there was only a slight deviation, with 5% more males than females perceiving CCDM as safe for consumption.

For country-wise comparison, a difference in trend was observed for residents of the UK and Slovenia. In the case of the UK, 32% of the respondents either strongly disagreed or disagreed, while the majority (59%) remained neutral, with only 8% agreeing with the safety of CCDM. In comparison, for Slovenia, 32% of the respondents remained neutral, and 16% disagreed or strongly disagreed, while a larger proportion (35%) perceived CCDM as safe, agreeing with the statement.

As discussed previously, the relatively lower familiarity, acceptance responses, and perceptions of safety regarding CCDM can be attributed to the varying regulations surrounding them in the European region. To understand where respondents stand as consumers on this issue, they were asked whether they would be open to trying CCDM once it becomes available in supermarkets, using a dichotomous question. The findings revealed that 43% responded affirmatively, while 56% responded negatively.

Respondents were then asked to rate the safety of insects for human consumption with the help of a Likert scale. The results revealed that most respondents perceived insects as safe (26% agreed and 22% strongly agreed), 35% remained uncertain or neutral, 13% disagreed, and only 5% strongly disagreed with the statement.

When the data were analysed concerning sex, the observed trends were similar to the overall findings with only a slight variation, indicating that 10% more male respondents than female respondents agreed it was safe. However, key differences emerged within the age groups. Interestingly, within the oldest age group (66–75), none of the respondents expressed strong disagreement, while none strongly concurred in the 56–65 age group. Similarly, within this age group, although no one strongly disagreed, the majority (63%) remained neutral or uncertain about the safety of edible insects.

Regarding the educational attainment group, no one with a doctoral degree strongly disagreed, and the group had the highest number of respondents who agreed with the statement (36% agreed, 28% strongly agreed). Regarding a country-wise comparison, respondents from the UK and Slovenia had perceptions similar to the overall findings in this case.

Figure 6 presents an overview of respondents' eating habits regarding insect-based meat alternatives in three forms: raw edible insects, whole and cooked edible insects, and insect flour in powdered and cooked form, measured on an ordinal scale.

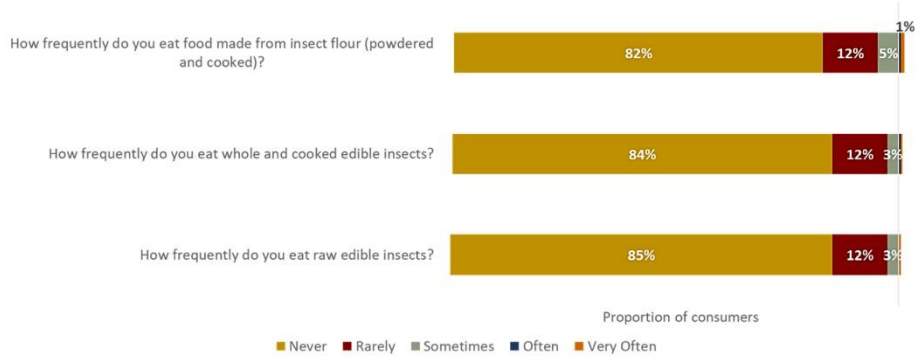


Figure 6. Bar chart illustrating the consumption of insect-based meat alternatives amongst consumers (%; $N = 237$).

When asked how frequently they ate raw edible insects, the results showed that most respondents (85%) never consumed them in this form. Only a small percentage (12%) chose the option that they rarely consumed raw edible insects, while even fewer respondents (3%) chose the option "sometimes". None of the respondents reported eating raw edible insects often or very often.

Similarly, when the respondents were asked about eating whole and cooked edible insects, 84% reported never having tried them in this form. A small proportion (12%) mentioned eating whole and cooked edible insects rarely, while only 3% stated eating them sometimes. None of the respondents reported eating whole and cooked edible insects often or very often.

Regarding food made from insect flour (powdered and cooked), most respondents (82%) reported never consuming such products. A small percentage (12%) mentioned consuming food made from insect flour rarely, while 5% stated eating it sometimes. Only 1% of respondents reported eating food made from insect flour often or very often.

3.6. Motivations and Barriers to Consuming Different Alternative Protein Sources to Meat

Table 6 presents a content analysis of motivations driving the adoption of alternative protein sources based on focus group discussions with participants from the UK and Slovenia. Each theme and sub-theme represent key factors derived from qualitative data and encompasses various aspects that motivate participants to embrace alternative protein sources to meat. The number in the columns indicated as the UK (Freq) and Slovenia (Freq) represents the frequency of times participants from the UK and Slovenian focus groups discussed a specific sub-theme.

Table 6. Content analysis of motivations for adopting alternative protein sources to meat (f; *N* = 12).

Themes	Sub-Themes	UK (Freq)	Slovenia (Freq)
Environmental	Sustainability	6	7
	Climate change awareness	6	4
	Carbon footprinting	4	1
	Increasing population impact	2	1
Health and nutritional concerns	Health benefits	8	6
	Nutritional benefits	6	7
	Digestive health	4	4
	Dietary restrictions	3	4
Economic factors	Affordability	5	6
	Availability	6	4
Convenience	Time constraints	3	4
	Easy meal preparation	4	5
Curiosity	Trying new foods	5	5
	Creativity in food preparation	4	4
	Exploring diversity in food	4	4
Ethical	Animal welfare	4	5
	Social welfare	3	4
Social influence	Family	4	3
	Friends	3	3
Media influence	Advertisement impact	6	4
	Target campaigns	6	3
	Celebrity endorsements	6	2
Preference	Taste	2	3
	Familiarity with ingredients	3	3
	Variety	2	3
	Texture	3	2

In the Slovenian and UK focus groups, participants articulated various reasons for embracing alternative protein sources to meat, with prominent themes centring on health considerations, environmental concerns, economic factors, curiosity, and media influence. For instance, a participant from the UK group, MR, stated, "*I think that one of the biggest issues and shortages that we are probably heading towards, as the population keeps getting bigger, is global food shortages. And I think the way we farm right now we can't manage that population, given the higher demand. Supply and demand are not going to work long term. So, I believe that looking at alternative sources of protein is very important*".

The lowest level of motivation pertained to preferences, which participants in both focus groups perceived more as a barrier than a driving force. They commonly expressed how preferences are hindrances rather than motivations for adopting protein alternatives. For instance, a participant from the Slovenian focus group, LC, stated, "*So maybe that's one of the main reasons I would not really consider eating alternatives. I mean, if I have a steak available and something plant-like, there's still a significant difference in meat's texture, flavour, smell, and everything. So maybe when that difference is smaller or even the same, I think that the population will maybe change its mind and think that's okay, I can have this, or I can have that, it's the same, but until then, I think that the change is not possible*".

The ethical concerns, encompassing both animal welfare and social welfare, received moderate attention and elicited responses from participants. In this study, most participants spoke highly of the potential positive impact of meat alternatives on animal welfare. However, in each focus group, 3–4 participants expressed concerns, particularly in the context of CCDM, about the potential effects it might have on the livelihoods of individuals engaged in livestock and animal rearing.

The media and social influence also garnered moderate attention. Interestingly, participants from both focus groups held comparable perspectives on each theme, emphasising sub-themes similarly. However, variations emerge about media influences, where the Slovenian focus group assigned less significance to target campaigns, influencers, and celebrity endorsements than their UK counterparts. Notably, four out of six participants in the Slovenian group expressed concerns that such media strategies could have a more negative impact than positive if executed "*too aggressively*" or "*forcefully*".

In both focus groups, a prominent barrier identified by most participants was the perception that alternative options, such as plant-based meat and meat grown in a laboratory, were perceived as "*highly processed*" or formulated with "*unknown ingredients*". The participants expressed concerns regarding the limited investigation into the potential consequences of consuming these alternatives, leading to reservations and hesitancy towards their adoption. One participant, IB from the UK focus group, highlighted the contrast between natural and artificial perceptions, stating, "*It's probably the perception of natural versus artificial. That's probably why you'd be more willing to eat things like ants or any sort of natural food, compared to anything that's grown in a lab. So, as long as they can change that perception, we're going to have a struggle where people will be hesitant to try anything that's seen as artificial, compared to something that's natural*".

Regarding insects, aside from the common barriers of disgust and appearance, another significant obstacle influencing their consumption was familiarity. A participant in the Slovenian group, MM, provided insights on this matter, stating, "*It is a matter of habit and I think of our environment and culture where we grew up and what we're used to. For example, in Australia, they eat kangaroo meat, and it's okay for them. So, I think if we were brought up eating insects, it would not be such a dilemma*".

In this study, participants in both focus groups expressed concern about the accessibility of alternative food options and their ability to incorporate them into their diets. They stressed the importance of learning about these alternatives and the proper preparation methods to replicate dishes they have tried elsewhere with ingredients such as insects and possible food combinations.

Affordability also emerged as a prominent barrier, given the global rise in the cost of living. For example, SG from the UK focus group stressed the importance of protein in their diet, expressing a preference for authentic chicken fillets as a high-quality, cost-efficient source of protein over alternative proteins options. NM from the Slovenian focus group echoed this sentiment, stating that the need for protein strongly influences their food choices. Should traditional meat offer a more affordable protein source than alternatives, they would prioritise it.

3.7. Suggestions to Overcome Identified Barriers

After discussing all the possible barriers that participants came up with, they were prompted to provide suggestions for overcoming the obstacles associated with adopting alternative protein sources to meat. In this case, the suggestions were based on options originating from plants, CCDM, and insects.

Table 7 showcases a matrix analysis comprising UK and Slovenian focus group inputs. Each sub-theme corresponds to distinct facets related to overarching themes, and the suggestions put forth by the participants offer strategies to address the identified barriers. The numerical value in parentheses accompanying each suggestion denotes its frequency of discussion amongst participants from the UK and Slovenian focus groups.

Table 7. Matrix analysis of suggestions to overcome barriers to adopting alternative protein sources to meat in the UK and Slovenia (n; *N* = 12).

Themes	Sub-Themes	Participant Suggestions (UK/Slovenia)
Sensory profile	Concerns about texture	Market alternative protein products as distinct options, not just as comparisons to traditional meats (UK: 6, Slovenia: 6)
	Concerns about taste	Introduce a broader range of options in soups, curries, and sauces rather than focusing solely on fillets and steaks (UK: 4, Slovenia: 5)
Awareness	Familiarity with varieties	Address unfamiliarity with different varieties by offering samples in supermarkets for consumers to try (UK: 5, Slovenia: 2)
	Familiarity with cuisine	Provide targeted recipe books and blogs featuring different dishes that can be prepared using alternative protein sources to meat (UK: 3, Slovenia: 3)
Cost and convenience	Cost compared to traditional meat	Implement price reduction initiatives and bulk purchasing incentives (UK: 4, Slovenia: 5)
	Difficulty finding products in supermarkets	Ensure products have a separate section close to the meat range but distinct to avoid confusion (UK: 2, Slovenia: 2)
Knowledge gap	Chemical vs. natural ingredients and processing	Offer transparent information about ingredients and processing methods (UK: 5, Slovenia: 4)
	Misconceptions about alternatives	Provide accessible, comprehensive information for consumers (UK: 3, Slovenia: 3)
	Nutritional value	Emphasise health and nutritional benefits over traditional meat (UK: 3, Slovenia: 4)
	Environmental impact awareness	Share supported sustainable initiatives or provide transparency on resource conservation due to alternative protein consumption (UK: 3, Slovenia: 2)

Table 7. *Cont.*

Themes	Sub-Themes	Participant Suggestions (UK/Slovenia)
Media and social factors	Mainstream media influence	Leverage endorsements by celebrities and influencers (UK: 3, Slovenia: 0)
	Negative effect of campaigns	Design educational campaigns with care to avoid seeming forced (UK: 4, Slovenia: 6)
	Social gatherings	Explore incorporating alternative protein sources to meat into social gatherings inspired by BBQ cookouts, pizza nights, and hotpot outings (UK: 4, Slovenia: 4)
	Influence of cultural norms	Promote a diverse food culture and present alternative protein sources to meat as an experience tied to different cultures (UK: 4, Slovenia: 2)

In the sensory profile domain, participants expressed concerns about the differences in texture and taste of alternative protein sources to meat. They described the alternative proteins as softer (in certain cases, crunchier), crumblier, and grainier, lacking the traditional chewiness and firmness associated with meat. In terms of flavour, particularly the processed options were either mild or had an overwhelmingly dominant flavour that felt 'fake' and 'unnatural'. Participants noted that the taste and texture of these processed alternatives reminded them more of grains, vegetables, and legumes than traditional meat. Some also reported experiencing a nutty or earthy smell coming from these foods. They recommended marketing alternative protein sources as distinct or separate categories, rather than as 'meat substitutes', to highlight their own unique flavours and prevent direct comparisons with traditional meat and meat products. Participants also emphasised the importance of diversifying the current options on the market and offering more choices in soups, curries, and sauces to go beyond fillets and steaks. As GM from the UK focus group articulated, "*Bolognese with veggies. It's about adding a good sauce to the pasta. I think that could create a positive experience*".

In addition to providing dedicated resources such as recipe books and blogs to guide consumers in their culinary explorations, participants suggested introducing product samples in supermarkets to address familiarity as a barrier. As DM from the UK pointed out, "*We're assuming everyone has tried meat-free options probably once. You'd be surprised; many people have never tried these products. If you can get people to try them at the supermarket, for example, with someone offering vegetarian sausages and asking, 'Have you ever tried one of these?' Many people would be surprised. I was honestly quite surprised by how tasty some of these options were myself*".

Discussing cost and convenience, participants expressed concerns regarding the price of alternative protein sources compared to traditional meats. To address this, they put forth recommendations like implementing price reduction initiatives and bulk purchasing incentives. MT from Slovenia underlined, "*I think it's going to be the same with insects. The price point will take precedence. The same applies to lab-grown meat. Even if its quality matches or surpasses that of animal meat, if it ends up being more affordable, I believe people would indeed be more likely to adopt it*".

Participants drew attention to the challenges of locating these products within supermarkets. They proposed the creation of a separate section adjacent to the meat range, distinct enough to avoid any confusion. GM from the UK stated, "*I think that there were a couple of supermarkets near us that tried to mix things up a little bit and have veggie sausages with the meat sausages. But I think there were a lot of complaints because people accidentally picked up the wrong thing. You know, they saw the veggie sausages, and then there were slightly cheaper sausages mixed in the same section. They picked those up and got them home and realised that they were meat*".

A notable knowledge gap emerged concerning ingredients and the processing methods involved, as discussed by MR and IB from the UK concerning the perception of natural

versus artificial. Misconceptions about meat alternatives surfaced, prompting participants to advocate for comprehensive and easily accessible information that could disprove these myths. LC from Slovenia and RG from the UK concurred, affirming, "*Transparent information can aid in countering misinformation*".

This discussion also gave rise to another reservation, particularly concerning CCDM. While participants initially embraced the concepts, their attitudes shifted during the discourse due to a lack of information about the long-term impact on the human body. MM from Slovenia and IB from the UK expressed reservations about consuming CCDM, classifying it as "*not the best idea*". Participants shared this sentiment in both focus groups. As a result, half of the participants (N = 3) from both countries rated these alternatives at the lowest preference level for consumption.

Environmental concerns prominently featured in the participants' discussions, inciting contemplations on the sustainability of alternative protein sources to meat. BP from Slovenia expressed, "*Understanding the environmental and animal welfare impact motivated me to adopt a vegetarian lifestyle; nothing else*". Participants recommended showcasing initiatives that promote sustainability or revealing the resource conservation achieved through the consumption of these foods.

Within the context of media and social factors, participants acknowledged the influential role of media and societal dynamics in shaping perceptions. The UK participants suggested leveraging endorsements by celebrities and influencers to increase awareness. However, participants cautioned against campaigns that might feel forced in both focus group discussions. Exploring the integration of meat alternatives into social gatherings, inspired by existing culinary traditions like BBQ cookouts and pizza nights, emerged as another strategy.

Suggestions from UK and Slovenian participants revealed shared themes such as addressing sensory concerns, enhancing culinary variety, and recognising the importance of knowledge. Both groups emphasised the value of widening food options and the impact of social gatherings. Differences emerged regarding factors like the environment and nutrition. The UK participants prioritised transparent sustainability information and media endorsements, while Slovenian participants favoured well-crafted educational campaigns.

4. Discussion

This study's strength lies in adopting a mixed-methods approach, which is well-established as a means to gain deeper insights into consumer behaviour [73]. This study found that consumers consider health-related and environmental factors as reasons for introducing alternative protein sources to meat. However, environmental concerns were ranked only fifth when evaluating the factors influencing grocery shopping amongst the respondents. During the focus group discussions, participants initially mentioned that environmental factors greatly motivate them. Nevertheless, health and nutritional reasons primarily influenced their choices to reduce meat consumption or opt for alternative dishes. This finding suggests that whilst consumers acknowledge the importance of sustainability, it may not be the sole motivation for their dietary choices.

Pricing and sensory factors were highlighted as important influencers on consumer food choices, aligning with the findings of previous studies [42,74]. As observed in the case of traditional meat consumption, taste and texture are considered paramount by consumers when it comes to alternative proteins [39]. Lang et al. [75] identified that consumers who found plant-based meat appealing in taste and texture showed positive attitudes towards it. While pricing was recognised as an important factor, participants in this study considered it less significant than sensory qualities. It should be noted, however, that this study did not account for the participants' spending potential, which might have provided further insights into these findings.

In examining the socio-demographic variables influencing the perception and consumption of alternative protein sources, notable patterns emerged across age groups, educational attainment levels, and genders. Younger respondents, particularly those be-

tween 16 and 35, demonstrated a higher propensity to try alternative protein sources to meat, suggesting an increased openness to innovative foods. This trend contrasted with older age groups, who showed less inclination towards such alternatives, potentially due to more ingrained dietary habits or scepticism towards non-traditional food sources.

Educational attainment plays a crucial role, as individuals with higher educational credentials perceived these proteins as safer and were more likely to consume them. Specifically, women with higher educational levels expressed a strong preference for plant-based meat alternatives, highlighting a gender-specific trend where educated females are leading in adopting plant-based diets [31,76].

Gender differences were evident in the perception of unconventional proteins such as edible insects, with men displaying a greater inclination towards considering insects safe and being more willing to consume them than women. This finding aligns with findings from Kasza et al. [65], indicating that men typically exhibit lower levels of neophobia, positioning them as early adopters of innovative products. Kulma et al. [77] highlighted that young men tend to be more experimental and open to trying insects, an observation consistent with the findings of this study regarding gender dynamics in entomophagy. Minimally processed or fresh ingredients were also found to be important factors based on the findings of the questionnaire and the focus group discussions. In considering this factor, plant-based alternatives emerged as an interesting point of discussion, boasting the highest acceptance rate in terms of safety and frequency of consumption compared to other meat alternatives. Despite this widespread acceptance, however, plant-based alternatives still lag behind traditional meat products in terms of consumption levels, a trend consistent with findings from other studies [78,79].

In addition to differences in dietary preferences, one key reason participants from the focus groups in both countries gave that accounted for this discrepancy was the possibility of chemical contamination in these foods [80] and concerns about undisclosed chemicals in the ingredient list of plant-based protein alternatives [81]. Most participants agreed that they would instead opt for simple vegetable-based meals rather than vegetables processed to look like meat if they want to avoid traditional meat altogether.

In the case of edible insects, despite their known benefits, notable barriers to their consumption associated with disgust and neophobia are prevalent [82]. Although participants in the focus group did not explicitly express disgust towards eating insects, there was evident hesitation in their responses, corroborating previous research findings [83–85] and the questionnaire findings. Coinciding with the outcomes of Meyer-Rochow and Hakko [86], only a small fraction of respondents indicated any degree of insect consumption in the questionnaire.

Drawing insights from the focus group responses in both the UK and Slovenia, participants suggested that it is more likely for edible insects to be more widely accepted if their presentation is altered within food products or they are integrated into familiar dishes that consumers are more accustomed to in a particular region [87], as demonstrated in studies with powdered grasshopper [88] and termite [89]. This notion also resonates with the discussion by Meyer-Rochow and Hakko [86], who proposed that processing insects into flour or pastes increases the likelihood of consumer acceptance. Further, the study of Ribeiro et al. [32], performed in Portugal and Sweden, indicates that acceptance of products incorporating processed insects was higher than acceptance of whole unprocessed insects. For a category such as insects to create a positive impression, cooperation amongst government bodies, scientists, and businesses is crucial to ensure that products are available to consumers and that information about food safety and consumption of insects is accessible. Piha et al. [57] found greater consumer acceptance of insects in Northern Europe than in Central Europe, citing the influence of institutional frameworks and cultural and dietary differences.

Specifically examining how consumers perceive CCDM, a lab-grown meat alternative, the study found that overall perceptions of CCDM are neutral, with half of the consumers who believe CCDM is safe expressing willingness to try it. Factors such as animal wel-

fare and concerns about environmental sustainability were also primary motivators for consumers who expressed this interest, a finding that again aligns with previous research, such as that discussed by Hocquette et al. [90], which also highlights consumer interest in cultured meat, primarily driven by ethical and environmental concerns, particularly animal welfare. Liu et al. [91] investigated the impact of socio-demographic factors on consumer awareness of meat consumption issues, finding that women, older respondents, and individuals with higher levels of education tend to be more receptive to ethical and environmental concerns associated with meat consumption. These factors also shape perceptions of meat alternatives like CCDM, indicating that attitudes towards conventional meat strongly influence perceptions of meat alternatives. Consumers with critical views of conventional meat are more likely to view CCDM favourably.

In the questionnaire, 5% of respondents reported having tried CCDM, an unexpected finding possibly attributable to their personal experiences outside the European region and their interpretation of what qualifies as CCDM. Some individuals might have travelled internationally to regions where cultured meat is not restricted and had the opportunity to try it there. Additionally, there could be misunderstandings or misperceptions about what constitutes cultured meat [90], with respondents possibly mistaking other meat products for cultured meat due to unclear labelling or misunderstanding [92].

During the focus group discussions, while CCDM was initially welcomed as a beneficial innovation, some participants also debated its potential downsides, such as perceptions of being unnatural and potentially harmful to the human body, lack of knowledge about the production process and impact on the environment, inconsistencies in legislations, as well as concerns about its impact on jobs in traditional animal agriculture, a sentiment consistent with the observations of previous research [93–95]. These concerns also caused hesitation amongst the participants regarding the introduction of CCDM in the European market. If CCDM were to be introduced to European consumers, stakeholders would need to address the ambiguities and gaps surrounding CCDM and engage consumers to address their questions and concerns, to ensure successful market adoption [96,97].

Amongst the participants, there was a unanimous consensus that information about the ingredients in processed meat alternatives should be accessible and available for consumers to educate themselves about these products and gain a clear understanding of them. This finding echoes the sentiments discussed by Fanelli et al. [98], emphasising the importance of ingredient transparency in building consumer trust in food safety.

This study also revealed consensus amongst participants regarding marketing these products as a distinct category rather than being grouped with traditional meat products. This finding agrees with other published findings that consumers were more inclined to try plant-based meat alternatives when labelled as plant-based rather than meat alternatives [99]. An interesting observation emerged concerning supermarkets. All participants in the focus groups expressed an interest in alternative protein products, particularly plant-based options, but discussed the challenge of locating these products on market shelves, especially when time is limited. This observation aligns with the perspective presented by Gravely and Fraser [36], who emphasised that while supermarkets expand the availability of plant-based choices, they employ rudimentary marketing strategies for these products within the store. With current sales reaching USD 11.3 billion at a 6.7% year-on-year (YOY) growth in 2021, and projected sales set to exceed USD 22.5 billion at a 7.2% compound annual growth rate (CAGR) by 2032 [100], this presents a substantial opportunity for supermarkets to address the growing consumer demand.

In addition to the benefits of utilising the influence of product names, descriptions, and packaging [99,101], focus group participants offered three simple solutions to improve the accessibility and visibility of these alternative protein sources to meat: strategic product placement on shelves, dedicated shelf sections, and the presence of on-site sampling representatives. A study by Ejlerskov et al. [102] highlights differences in purchasing behaviour at checkout points of supermarkets among consumers. The study also discusses how variation in socio-demographic variables, particularly age groups, influences grocery

purchasing. These observations are consistent with the results presented in this study. This is an interesting outcome because it indicates that on-site marketing strategies might not prove as effective if insights from one consumer group are generalised for the whole population. It is necessary to consider the perspectives of various consumer groups if stakeholders aim to promote the adoption of alternative protein sources across the population rather than targeting a specific consumer segment.

This study's findings also highlighted the role of media and social gatherings in shaping consumer attitudes, since nearly all participants in the focus groups tried alternative proteins through personal connections. The influence of socio-cultural factors has been widely discussed in the literature [38,103]. Social media has had positive effects in promoting plant-based foods [104] and meat substitutes [105]. Thus, leveraging endorsements or strategies that resonate with societal perceptions could boost the adoption of meat alternatives.

An interesting observation was the variation in responses of the focus group participants in the UK and Slovenia. For instance, the UK participants favoured a more aggressive marketing approach, using mainstream media and celebrity endorsements to increase awareness and acceptance, whereas the Slovenian participants advocated for more subtle and educational marketing strategies. According to the participants, these suggestions were based on their experiences with how campaigns differ in their respective countries, which demonstrates that despite similarities in factors corresponding to the barriers and motivation, strategies to encourage the adoption of alternative protein sources should be tailored to fit the cultural and societal context of each country. Although the consumption of specific protein alternatives, like insects, remains unconventional in the Western setting, insights drawn from the focus group discussions suggest that providing information in a tactful and non-coercive manner could be advantageous. This concept resonates with the conclusions of Gahukar [106], who emphasised the establishment of educational programs, robust entrepreneurial endeavours, academic research, and government support to promote the recognition of insects as a significant commodity in society.

Limitations and Future Directions

We acknowledge certain limitations of our study. The relatively small sample size of participants for both the questionnaire and the focus group affects the generalisability of the findings. In the questionnaire, the representativeness of the results is potentially compromised by the uneven distribution of respondents across countries, as a predominant number of responses from certain regions may introduce geographical bias. Another limitation emerges from the socio-demographic representation, particularly regarding the questionnaire respondents' age groups and educational attainment levels. Despite efforts to ensure that the focus group participants represented diverse age groups, educational backgrounds, and professional levels, the interview guide used for the focus group discussions may have disproportionately reflected the viewpoints of specific consumer groups, thus potentially introducing bias into the responses obtained.

A limitation of this study is the predominance of participants from the UK and Slovenia. Whilst their contributions offer valuable insights, it is important to recognise the potential constraints in generalising the findings to broader geographical regions or different European cultural landscapes, which include varied dietary preferences and traditions. Variations in levels of consumer awareness and acceptance of alternative protein sources can significantly influence perceptions and are likely distinct across different European regions. Consequently, applying these results beyond their immediate social environment would present challenges in predicting outcomes in other locations or for people with contrasting societal dynamics.

Future researchers are encouraged to pursue a more heterogeneous sample of participants, encompassing different countries and ensuring equal representation of various consumer segments. This approach would expand the scope and boundaries for a better understanding of consumer perceptions towards alternative protein sources to meat and

provide a foundation for drawing broader overarching conclusions and implications on a global scale.

5. Conclusions

In this study, combining a questionnaire with focus group discussions gathered detailed insights into motivations and barriers concerning alternative protein sources to meat and facilitated participant-driven suggestions that addressed the identified barriers. In addition, this study drew comparisons from respondents from countries with varying legislative systems within the European region. This study has been centred on understanding how consumers perceive alternative protein sources such as plant-based, CCDM, and insect-based foods. Positive attitudes often arise from health considerations, environmental awareness, and ethical values, while obstacles like texture, safety concerns, and a sense of unnaturalness have been identified. It is important to note that consumer preferences are notably influenced by socio-cultural factors, the media, and the individuals within their immediate circles. A crucial element that fosters consumer acceptance is providing clear and comprehensive information, complemented by imaginative and innovative strategies to enhance the visibility of such products within supermarket premises. These facets should be effectively leveraged when devising consumer-centric strategies within strategic marketing. It is essential to identify the appropriate target audience and tailor strategies accordingly for all knowledge-based and educational initiatives. These components may collectively play an instrumental role in encouraging consumers to adopt alternative protein sources instead of meat.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/foods13111627/s1, Table S1: Questionnaire (core components).

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Informed Consent Statement: Prior to data collection, all participants were informed about the research objectives, data usage, and their rights, including the guarantee of anonymity and data confidentiality. Participants were then asked to provide their consent before proceeding.

Data Availability Statement: All related data and methods are presented in this paper. Additional inquiries should be addressed to the corresponding author.

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Conflicts of Interest: Authors Nayyer Rehman and Victoria Edkins is/was employed by the company WRG Europe. They participated in the EU project FoodTraNet. The role of the company was to conduct the study related to consumer behavior and awareness presented in this paper. The remaining authors declare that research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. FAO. *How to Feed the World in 2050*; Food and Agriculture Organization: Rome, Italy, 2009. Available online: https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf (accessed on 15 January 2022).
2. Boland, M.J.; Rae, A.N.; Vereijken, J.M.; Meuwissen, M.P.M.; Fischer, A.R.H.; van Boekel, M.A.J.S.; Rutherfurd, S.M.; Gruppen, H.; Moughan, P.J.; Hendriks, W.H. The Future Supply of Animal-Derived Protein for Human Consumption. *Trends Food Sci. Technol.* **2013**, *29*, 62–73. [CrossRef]

3. Henchion, M.; Hayes, M.; Mullen, A.; Fenelon, M.; Tiwari, B. Future Protein Supply and Demand: Strategies and Factors Influencing a Sustainable Equilibrium. *Foods* **2017**, *6*, 53. [CrossRef]
4. Sans, P.; Combris, P. World Meat Consumption Patterns: An Overview of the Last Fifty Years (1961–2011). *Meat Sci.* **2015**, *109*, 106–111. [CrossRef]
5. Tilman, D.; Clark, M. Global Diets Link Environmental Sustainability and Human Health. *Nature* **2014**, *515*, 518–522. [CrossRef]
6. Aiking, H. Protein Production: Planet, Profit, plus People? *Am. J. Clin. Nutr.* **2014**, *100*, 483S489S. [CrossRef]
7. Aiking, H.; de Boer, J. The next Protein Transition. *Trends Food Sci. Technol.* **2020**, *105*, 515–522. [CrossRef]
8. Anusha Siddiqui, S.; Bahmid, N.A.; Mahmud, C.M.M.; Boukid, F.; Lamri, M.; Gagaoua, M. Consumer Acceptability of Plant-, Seaweed-, and Insect-Based Foods as Alternatives to Meat: A Critical Compilation of a Decade of Research. *Crit. Rev. Food Sci. Nutr.* **2022**, *63*, 6630–6651. [CrossRef]
9. Smetana, S. Circularity and Environmental Impact of Edible Insects. *J. Insects Food Feed* **2023**, *9*, 1111–1114. [CrossRef]
10. Oonincx, D.G.A.B.; van Broekhoven, S.; van Huis, A.; van Loon, J.J.A. Correction: Feed Conversion, Survival and Development, and Composition of Four Insect Species on Diets Composed of Food By-Products. *PLoS ONE* **2019**, *14*, e0222043. [CrossRef]
11. Hénault-Ethier, L.; Reid, B.; Hotte, N.; Paris, N.; Quinche, M.; Lachance, C.; Fortin, A.; Normandin, É.; Laderriere, V.; Vandenberg, G. Growth Trials on Vegetables, Herbs, and Flowers Using Mealworm Frass, Chicken Manure, and Municipal Compost. *ACS Agric. Sci. Technol.* **2023**, *3*, 249–259. [CrossRef]
12. Van Huis, A. Potential of Insects as Food and Feed in Assuring Food Security. *Annu. Rev. Entomol.* **2013**, *58*, 563–583. [CrossRef]
13. Raheem, D.; Carrascosa, C.; Oluwole, O.B.; Nieuwland, M.; Saraiva, A.; Millán, R.; Raposo, A. Traditional Consumption of and Rearing Edible Insects in Africa, Asia and Europe. *Crit. Rev. Food Sci. Nutr.* **2018**, *59*, 2169–2188. [CrossRef]
14. Post, M.J. Cultured Meat from Stem Cells: Challenges and Prospects. *Meat Sci.* **2012**, *92*, 297–301. [CrossRef]
15. Rodríguez Escobar, M.I.; Cadena, E.; Nhu, T.T.; Cooreman-Algoed, M.; De Smet, S.; Dewulf, J. Analysis of the Cultured Meat Production System in Function of Its Environmental Footprint: Current Status, Gaps and Recommendations. *Foods* **2021**, *10*, 2941. [CrossRef]
16. European Parliamentary Research Service (EPRS). *Alternative Protein Sources for Food and Feed*; European Parliamentary Research Service (EPRS): Rue Wiertz, Belgium, 2024. Available online: https://www.europarl.europa.eu/stoa/en/document/EPRS_STU(2024)757806 (accessed on 2 May 2024).
17. Sinke, P.; Swartz, E.; Sanctorum, H.; van der Giesen, C.; Odegard, I. Ex-Ante Life Cycle Assessment of Commercial-Scale Cultivated Meat Production in 2030. *Int. J. Life Cycle Assess.* **2023**, *28*, 234–254. [CrossRef]
18. Tuomisto, H.L. The Eco-Friendly Burger. *EMBO Rep.* **2018**, *20*, e47395. [CrossRef]
19. de Oliveira Padilha, L.G.; Malek, L.; Umberger, W.J. Consumers' Attitudes towards Lab-Grown Meat, Conventionally Raised Meat and Plant-Based Protein Alternatives. *Food Qual. Prefer.* **2022**, *99*, 104573. [CrossRef]
20. Poore, J.; Nemecek, T. Reducing Food's Environmental Impacts through Producers and Consumers. *Science* **2018**, *360*, 987–992. [CrossRef]
21. Iarc Working Group on the Evaluation of Carcinogenic Risks to Humans; International Agency for Research on Cancer. *Red Meat and Processed Meat*; International Agency For Research On Cancer, World Health Organization: Lyon, France, 2018.
22. Pan, A.; Sun, Q.; Bernstein, A.; Schulze, M.; Manson, J.; Stampfer, M.; Willett, W.; Hu, F. Red Meat Consumption and Mortality. *Arch. Intern. Med.* **2012**, *172*, 555. [CrossRef] [PubMed]
23. Ekmekcioglu, C.; Wallner, P.; Kundi, M.; Weisz, U.; Haas, W.; Hutter, H.-P. Red Meat, Diseases, and Healthy Alternatives: A Critical Review. *Crit. Rev. Food Sci. Nutr.* **2017**, *58*, 247–261. [CrossRef] [PubMed]
24. Aschemann-Witzel, J.; Gantriis, R.F.; Fraga, P.; Perez-Cueto, F.J.A. Plant-Based Food and Protein Trend from a Business Perspective: Markets, Consumers, and the Challenges and Opportunities in the Future. *Crit. Rev. Food Sci. Nutr.* **2020**, *61*, 3119–3128. [CrossRef] [PubMed]
25. Chriki, S.; Hocquette, J.-F. The Myth of Cultured Meat: A Review. *Front. Nutr.* **2020**, *7*, 7. [CrossRef] [PubMed]
26. Circus, V.E.; Robison, R. Exploring Perceptions of Sustainable Proteins and Meat Attachment. *Br. Food J.* **2018**, *121*, 533–545. [CrossRef]
27. Gómez-Luciano, C.A.; de Aguiar, L.K.; Vriesekoop, F.; Urbano, B. Consumers' Willingness to Purchase Three Alternatives to Meat Proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. *Food Qual. Prefer.* **2019**, *78*, 103732. [CrossRef]
28. Hartmann, C.; Siegrist, M. Consumer Perception and Behaviour Regarding Sustainable Protein Consumption: A Systematic Review. *Trends Food Sci. Technol.* **2017**, *61*, 11–25. [CrossRef]
29. Hwang, J.; You, J.; Moon, J.; Jeong, J. Factors Affecting Consumers' Alternative Meats Buying Intentions: Plant-Based Meat Alternative and Cultured Meat. *Sustainability* **2020**, *12*, 5662. [CrossRef]
30. Ismail, I.; Hwang, Y.-H.; Joo, S.-T. Meat Analog as Future Food: A Review. *J. Anim. Sci. Technol.* **2020**, *62*, 111–120. [CrossRef] [PubMed]
31. Michel, F.; Hartmann, C.; Siegrist, M. Consumers' Associations, Perceptions and Acceptance of Meat and Plant-Based Meat Alternatives. *Food Qual. Prefer.* **2021**, *87*, 104063. [CrossRef]
32. Ribeiro, J.C.; Gonçalves, A.T.S.; Moura, A.P.; Varela, P.; Cunha, L.M. Insects as Food and Feed in Portugal and Norway—Cross-Cultural Comparison of Determinants of Acceptance. *Food Qual. Prefer.* **2022**, *102*, 104650. [CrossRef]
33. Tan, H.S.G.; Fischer, A.R.H.; Tinchan, P.; Stieger, M.; Steenbekkers, L.P.A.; van Trijp, H.C.M. Insects as Food: Exploring Cultural Exposure and Individual Experience as Determinants of Acceptance. *Food Qual. Prefer.* **2015**, *42*, 78–89. [CrossRef]

34. Wendin, K.M.; Nyberg, M.E. Factors Influencing Consumer Perception and Acceptability of Insect-Based Foods. *Curr. Opin. Food Sci.* **2021**, *40*, 67–71. [CrossRef]
35. Van Loo, E.J.; Caputo, V.; Lusk, J.L. Consumer Preferences for Farm-Raised Meat, Lab-Grown Meat, and Plant-Based Meat Alternatives: Does Information or Brand Matter? *Food Policy* **2020**, *95*, 101931. [CrossRef]
36. Gravely, E.; Fraser, E. Transitions on the Shopping Floor: Investigating the Role of Canadian Supermarkets in Alternative Protein Consumption. *Appetite* **2018**, *130*, 146–156. [CrossRef]
37. Hunter, E.; Röös, E. Fear of Climate Change Consequences and Predictors of Intentions to Alter Meat Consumption. *Food Policy* **2016**, *62*, 151–160. [CrossRef]
38. Onwezen, M.C. The Application of Systematic Steps for Interventions towards Meat-Reduced Diets. *Trends Food Sci. Technol.* **2022**, *119*, 443–451. [CrossRef]
39. Onwezen, M.C.; Bouwman, E.P.; Reinders, M.J.; Dagevos, H. A Systematic Review on Consumer Acceptance of Alternative Proteins: Pulses, Algae, Insects, Plant-Based Meat Alternatives, and Cultured Meat. *Appetite* **2020**, *159*, 105058. [CrossRef]
40. Siegrist, M.; Sütterlin, B.; Hartmann, C. Perceived Naturalness and Evoked Disgust Influence Acceptance of Cultured Meat. *Meat Sci.* **2018**, *139*, 213–219. [CrossRef]
41. Grasso, A.C.; Hung, Y.; Olthof, M.R.; Verbeke, W.; Brouwer, I.A. Older Consumers' Readiness to Accept Alternative, More Sustainable Protein Sources in the European Union. *Nutrients* **2019**, *11*, 1904. [CrossRef]
42. Verbeke, W. Profiling Consumers Who Are Ready to Adopt Insects as a Meat Substitute in a Western Society. *Food Qual. Prefer.* **2015**, *39*, 147–155. [CrossRef]
43. European Food Safety Authority (EFSA). *Administrative Guidance on the Submission of Applications for Authorisation of a Novel Food pursuant to Article 10 of Regulation (EU) 2015/2283*; EFSA Supporting Publication: Hoboken, NJ, USA, 2018; pp. 1–22. [CrossRef]
44. Delgado Calvo-Flores, L.; Garino, C.; Moreno, F.J.; Broll, H. Insects in Food and Their Relevance Regarding Allergenicity Assessment. *EFSA J.* **2022**, *20*, e200909. [CrossRef]
45. IPIFF. *Edible Insects on the European Market*; IPIFF: Brussels, Belgium. Available online: https://ipiff.org/wp-content/uploads/2020/06/10-06-2020-IPIFF-edible-insects-market-factsheet.pdf (accessed on 23 January 2022).
46. Science, Research and Evidence Directorate. *Consultation on Transitional Arrangements for Edible Insects in Great Britain: Summary of Stakeholder Responses*; Food Standards Agency: London, UK, 2022. Available online: https://www.food.gov.uk/print/pdf/node/12076 (accessed on 7 September 2023).
47. Augustus Bambridge-Sutton. Italian Gov't Bans Cultivated Meat, Restricts Plant-Based Meat Labelling. FoodNavigator. Available online: https://www.foodnavigator.com/Article/2023/11/21/Italy-bans-cultivated-meat-restricts-plant-based-meat-labelling (accessed on 15 January 2024).
48. Floura Southey. 'A Great Achievement for the Dutch Government': First Member State Approves Pre-Market Tastings of Cultivated Meat. FoodNavigator. Available online: https://www.foodnavigator.com/Article/2023/07/19/cultivated-meat-tastings-formally-approved-in-the-netherlands (accessed on 15 January 2024).
49. Meticulous Research. *Europe Plant-Based Food Market by Type [Dairy Alternatives, Plant-Based Meat, Meals, Confectionery, Beverages, Egg Substitutes, Seafood), Source (Soy, Wheat, Pea, Rice), Distribution Channel (B2B, B2C (Convenience Store, Online Retail)]-Forecast to 2029*; Meticulous Research: Pimpri-Chinchwad, India, 2022; pp. 1–191. Available online: https://www.meticulousresearch.com/product/europe-plant-based-food-market-5260 (accessed on 15 September 2023).
50. Regulation (EU) 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers, amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004. *Off. J. Eur. Union* **2011**, *L304*, 29.
51. Floura Southey. France's 'Veggie' Burger Ban Escalates to the European Court of Justice; FoodNavigator. Available online: https://www.foodnavigator.com/Article/2023/08/03/france-s-veggie-burger-ban-escalates-to-the-european-court-of-justice (accessed on 15 January 2024).
52. Cicatiello, C.; De Rosa, B.; Franco, S.; Lacetera, N. Consumer Approach to Insects as Food: Barriers and Potential for Consumption in Italy. *Br. Food J.* **2016**, *118*, 2271–2286. [CrossRef]
53. Gere, A.; Székely, G.; Kovács, S.; Kókai, Z.; Sipos, L. Readiness to Adopt Insects in Hungary: A Case Study. *Food Qual. Prefer.* **2017**, *59*, 81–86. [CrossRef]
54. Ghvanidze, S.; Velikova, N.; Dodd, T.H.; Oldewage-Theron, W. Consumers' Environmental and Ethical Consciousness and the Use of the Related Food Products Information: The Role of Perceived Consumer Effectiveness. *Appetite* **2016**, *107*, 311–322. [CrossRef] [PubMed]
55. Orsi, L.; Voege, L.L.; Stranieri, S. Eating Edible Insects as Sustainable Food? Exploring the Determinants of Consumer Acceptance in Germany. *Food Res. Int.* **2019**, *125*, 108573. [CrossRef] [PubMed]
56. Siddiqui, S.A.; Zannou, O.; Karim, I.; Kasmiati; Awad, N.M.H.; Gołaszewski, J.; Heinz, V.; Smetana, S. Avoiding Food Neophobia and Increasing Consumer Acceptance of New Food Trends—A Decade of Research. *Sustainability* **2022**, *14*, 10391. [CrossRef]
57. Piha, S.; Pohjanheimo, T.; Lähteenmäki-Uutela, A.; Křečková, Z.; Otterbring, T. The Effects of Consumer Knowledge on the Willingness to Buy Insect Food: An Exploratory Cross-Regional Study in Northern and Central Europe. *Food Qual. Prefer.* **2018**, *70*, 1–10. [CrossRef]

58. EU General Data Protection Regulation (GDPR): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the Protection of Natural Persons with Regard to the Processing of Personal Data and on the Free Movement of Such Data, and Repealing Directive 95/46/EC (General Data Protection Regulation), OJ 2016 L 119/1. Available online: https://eur-lex.europa.eu/eli/reg/2016/679/oj (accessed on 27 March 2024).
59. European Commission. *Ethics for Researchers: Facilitating Research Excellence in FP7*; Publications Office of the European Union: Luxembourg, 2013. Available online: https://ec.europa.eu/research/participants/data/ref/fp7/89888/ethics-for-researchers_en.pdf (accessed on 15 January 2022).
60. Social Research Association (SRA). Research Ethics Guidance. Available online: https://the-sra.org.uk/SRA/SRA/Ethics/Research-Ethics-Guidance.aspx (accessed on 10 February 2022).
61. Jarchlo, A.I.; King, L. *Survey of Consumer Perceptions of Alternative, or Novel, Sources of Protein*; Food Standards Agency: London, UK, 2022.
62. Spriestersbach, A.; Röhrig, B.; du Prel, J.-B.; Gerhold-Ay, A.; Blettner, M. Descriptive Statistics. *Dtsch. Ärzteblatt Int.* **2009**, *106*, 578–583. [CrossRef]
63. Eftimov, T.; Korošec, P.; Potočnik, D.; Ogrinc, N.; Heath, D.; Seljak, B.K. How to perform properly statistical analysis on food data? An e-learning tool: Advanced Statistics in Natural Sciences and Technologies. In *Science within Food: Up-to-Date Advances on Research and Educational Ideas*; Formatex Research Center: Badajoz, Spain, 2017; pp. 144–151.
64. Legohérel, P.; Hsu, C.H.C.; Daucé, B. Variety-Seeking: Using the CHAID Segmentation Approach in Analyzing the International Traveler Market. *Tour. Manag.* **2015**, *46*, 359–366. [CrossRef]
65. Kasza, G.; Izsó, T.; Szakos, D.; Nugraha, W.S.; Tamimi, M.H.; Süth, M. Insects as Food—Changes in Consumers' Acceptance of Entomophagy in Hungary between 2016 and 2021. *Appetite* **2023**, *188*, 106770. [CrossRef]
66. Breen, R.L. A Practical Guide to Focus-Group Research. *J. Geogr. High. Educ.* **2006**, *30*, 463–475. [CrossRef]
67. Nyumba, T.; Wilson, K.; Derrick, C.J.; Mukherjee, N. The Use of Focus Group Discussion Methodology: Insights from Two Decades of Application in Conservation. *Methods Ecol. Evol.* **2018**, *9*, 20–32. [CrossRef]
68. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; Wisdom, J.P.; Duan, N.; Hoagwood, K. Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. *Adm. Policy Ment. Health* **2015**, *42*, 533–544. [CrossRef] [PubMed]
69. Attride-Stirling, J. Thematic Networks: An Analytic Tool for Qualitative Research. *Qual. Res.* **2001**, *1*, 385–405. [CrossRef]
70. Braun, V.; Clarke, V. Using Thematic Analysis in Psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]
71. Maguire, M.; Delahunt, B. Doing a Thematic Analysis: A Practical, Step-By-Step Guide for Learning and Teaching Scholars. *AISHE-J. All Irel. J. Teach. Learn. High. Educ.* **2017**, *9*, 3351–33514.
72. Chef's Pencil Staff. *Most Popular Countries and Cities for Vegans in 2020 (Jan-2021 Update)*; Chef's Pencil: New York, NY, USA. Available online: https://www.chefspencil.com/most-popular-countries-and-cities-for-vegans-in-2020-jan-2021-update/ (accessed on 22 August 2023).
73. Nair, S.; Prem, S. A Framework for Mixed-method Research. *Manag. Sci.* **2020**, *8*, 45–53. [CrossRef]
74. Dana, L.M.; Chapman, K.; Dixon, H.; Miller, C.; Neal, B.; Kelly, B.; Ball, K.; Pettigrew, S. The Relative Importance of Primary Food Choice Factors among Different Consumer Groups: A Latent Profile Analysis. *Food Qual. Prefer.* **2021**, *94*, 104199. [CrossRef]
75. Lang, M. Consumer Acceptance of Blending Plant-Based Ingredients into Traditional Meat-Based Foods to Reduce Meat Consumption: Evidence from the Meat-Mushroom Blend. *Food Qual. Prefer.* **2019**, *79*, 103758. [CrossRef]
76. Nevalainen, E.; Niva, M.; Vainio, A. A Transition towards Plant-Based Diets on Its Way? Consumers' Substitutions of Meat in Their Diets in Finland. *Food Qual. Prefer.* **2023**, *104*, 104754. [CrossRef]
77. Kulma, M.; Tůmová, V.; Fialová, A.; Kouřimská, L. Insect Consumption in the Czech Republic: What the Eye Does Not See, the Heart Does Not Grieve Over. *J. Insects Food Feed* **2020**, *6*, 525–535. [CrossRef]
78. Andreani, G.; Sogari, G.; Marti, A.; Froldi, F.; Dagevos, H.; Martini, D. Plant-Based Meat Alternatives: Technological, Nutritional, Environmental, Market, and Social Challenges and Opportunities. *Nutrients* **2023**, *15*, 452. [CrossRef] [PubMed]
79. Szenderák, J.; Fróna, D.; Rákos, M. Consumer Acceptance of Plant-Based Meat Substitutes: A Narrative Review. *Foods* **2022**, *11*, 1274. [CrossRef] [PubMed]
80. Kyriakopoulou, K.; Keppler, J.K.; van der Goot, A.J. Functionality of Ingredients and Additives in Plant-Based Meat Analogues. *Foods* **2021**, *10*, 600. [CrossRef] [PubMed]
81. O'Connor, A. Fake Meat vs. Real Meat. *The New York Times*, 3 December 2019. Available online: https://www.nytimes.com/2019/12/03/well/eat/fake-meat-vs-real-meat.html (accessed on 26 February 2024).
82. Deroy, O.; Reade, B.; Spence, C. The Insectivore's Dilemma, and How to Take the West out of It. *Food Qual. Prefer.* **2015**, *44*, 44–55. [CrossRef]
83. Castro, M.; Chambers, E. Willingness to Eat an Insect Based Product and Impact on Brand Equity: A Global Perspective. *J. Sens. Stud.* **2018**, *34*, e12486. [CrossRef]
84. Modlinska, K.; Adamczyk, D.; Maison, D.; Goncikowska, K.; Pisula, W. Relationship between Acceptance of Insects as an Alternative to Meat and Willingness to Consume Insect-Based Food—A Study on a Representative Sample of the Polish Population. *Foods* **2021**, *10*, 2420. [CrossRef]
85. Tan, H.S.G.; Verbaan, Y.T.; Stieger, M. How Will Better Products Improve the Sensory-Liking and Willingness to Buy Insect-Based Foods? *Food Res. Int.* **2017**, *92*, 95–105. [CrossRef] [PubMed]

86. Meyer-Rochow, V.B.; Hakko, H. Can Edible Grasshoppers and Silkworm Pupae Be Tasted by Humans When Prevented to See and Smell These Insects? *J. Asia-Pac. Entomol.* **2018**, *21*, 616–619. [CrossRef]
87. Hartmann, C.; Shi, J.; Giusto, A.; Siegrist, M. The Psychology of Eating Insects: A Cross-Cultural Comparison between Germany and China. *Food Qual. Prefer.* **2015**, *44*, 148–156. [CrossRef]
88. Haber, M.; Mishyna, M.; Martinez, J.J.I.; Benjamin, O. The Influence of Grasshopper (Schistocerca Gregaria) Powder Enrichment on Bread Nutritional and Sensorial Properties. *LWT* **2019**, *115*, 108395. [CrossRef]
89. Adeboye, A.O.; Fasogbon, B.M.; Adegbuyi, K. Formulation of Vegetable Soup Powder from Clerodendrum Volubile Enriched with Macrotermes Bellicosus (Termite) Flour. *Int. J. Trop. Insect Sci.* **2020**, *41*, 2071–2076. [CrossRef]
90. Hocquette, J.-F.; Chriki, S.; Fournier, D.; Ellies-Oury, M.-P. Will "Cultured Meat" Transform Our Food System towards More Sustainability? *Animal* **2024**, 101145. [CrossRef] [PubMed]
91. Liu, J.; Chriki, S.; Kombolo, M.; Santinello, M.; Pflanzer, S.B.; Hocquette, É.; Ellies-Oury, M.-P.; Hocquette, J.-F. Consumer Perception of the Challenges Facing Livestock Production and Meat Consumption. *Meat Sci.* **2023**, *200*, 109144. [CrossRef] [PubMed]
92. Messer, K.D.; Costanigro, M.; Kaiser, H.M. Labeling Food Processes: The Good, the Bad and the Ugly. *Appl. Econ. Perspect. Policy* **2017**, *39*, 407–427. [CrossRef]
93. Guan, X.; Lei, Q.; Yan, Q.; Li, X.; Zhou, J.; Du, G.; Chen, J. Trends and Ideas in Technology, Regulation and Public Acceptance of Cultured Meat. *Future Foods* **2021**, *3*, 100032. [CrossRef]
94. Bryant, C.J. Culture, Meat, and Cultured Meat. *J. Anim. Sci.* **2020**, *98*, skaa172. [CrossRef] [PubMed]
95. Chriki, S.; Ellies-Oury, M.-P.; Hocquette, J.-F. Is "Cultured Meat" a Viable Alternative to Slaughtering Animals and a Good Comprise between Animal Welfare and Human Expectations? *Anim. Front.* **2022**, *12*, 35–42. [CrossRef] [PubMed]
96. Ketelings, L.; Kremers, S.; de Boer, A. The Barriers and Drivers of a Safe Market Introduction of Cultured Meat: A Qualitative Study. *Food Control* **2021**, *130*, 108299. [CrossRef]
97. Fernandes, A.M.; Teixeira, O.d.S.; Revillion, J.P.; de Souza, Â.R.L. Panorama and Ambiguities of Cultured Meat: An Integrative Approach. *Crit. Rev. Food Sci. Nutr.* **2021**, *62*, 5413–5423. [CrossRef]
98. Fanelli, V.; Mascio, I.; Miazzi, M.M.; Savoia, M.A.; De Giovanni, C.; Montemurro, C. Molecular Approaches to Agri-Food Traceability and Authentication: An Updated Review. *Foods* **2021**, *10*, 1644. [CrossRef] [PubMed]
99. Sucapane, D.; Roux, C.; Sobol, K. Exploring How Product Descriptors and Packaging Colors Impact Consumers' Perceptions of Plant-Based Meat Alternative Products. *Appetite* **2021**, *167*, 105590. [CrossRef] [PubMed]
100. Future Market Insights. Plant-Based Ingredients Market. Available online: https://www.futuremarketinsights.com/reports/plant-based-ingredients-market (accessed on 31 August 2023).
101. Bryant, C.J.; Barnett, J.C. What's in a Name? Consumer Perceptions of in Vitro Meat under Different Names. *Appetite* **2019**, *137*, 104–113. [CrossRef] [PubMed]
102. Ejlerskov, K.; Sharp, S.J.; Stead, M.; Adamson, A.J.; White, M.; Adams, J. Socio-Economic and Age Variations in Response to Supermarket-Led Checkout Food Policies: A Repeated Measures Analysis. *Int. J. Behav. Nutr. Phys. Act.* **2018**, *15*, 125. [CrossRef] [PubMed]
103. de Koning, W.; Dean, D.; Vriesekoop, F.; Aguiar, L.K.; Anderson, M.; Mongondry, P.; Oppong-Gyamfi, M.; Urbano, B.; Luciano, C.A.G.; Jiang, B.; et al. Drivers and Inhibitors in the Acceptance of Meat Alternatives: The Case of Plant and Insect-Based Proteins. *Foods* **2020**, *9*, 1292. [CrossRef] [PubMed]
104. Rini, L.; Bayudan, S.; Faber, I.; Jietse Schouteten, J.; Perez-Cueto, F.J.A.; Bechtold, K.-B.; Gellynck, X.; Bom Frøst, M.; De Steur, H. The Role of Social Media in Driving Beliefs, Attitudes, and Intentions of Meat Reduction towards Plant-Based Meat Behavioral Intentions. *Food Qual. Prefer.* **2024**, *113*, 105059. [CrossRef]
105. Septianto, F.; Kemper, J.A.; Quang, H.P.; Li, S.; Kwon, J. The Impact of Social Media Visual Features on Acceptance of Meat Substitute. *Int. J. Mark. Res.* **2022**, *64*, 147078532211073. [CrossRef]
106. Gahukar, R.T. Chapter 4—Edible Insects Farming: Efficiency and Impact on Family Livelihood, Food Security, and Environment Compared with Livestck and Crops. In *Insects as Sustainable Food Ingredients*; Academic Press: New York, NY, USA, 2016; pp. 85–111. [CrossRef]

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Appendix A – Questionnaire (core components)

1 Which factors are important to you when buying groceries? Choose as many as you like.

A Healthy and nutritious
B Minimally processed / made from mainly natural ingredients
C Environmentally friendly
D Animal friendly / cruelty free such as free-range eggs
E Appearance / taste / smell (sensory appeal)
F Convenience / takes less time to prepare, cook and serve
G Priced better than the others in a product category
H Liked by the majority of the members of a family / household
I New / innovative / unfamiliar / exotic
J Seen on social media, TV, etc. / being recommended by someone you know
K I do not know / I am not sure
L Other: _____

2 *New alternative foods are defined as alternatives to foods prepared or produced by traditional methods. There are currently many foods on the markets that are available as alternatives to traditional meat and dairy products.*
As a consumer, why do you think alternative foods are being introduced to the market? Choose as many as you like.

A In response to consumer demand for healthier alternatives
B To promote healthy eating alternatives
C To meet the demands for personalised nutrition
D In response to the increase in food allergies and intolerances
E To meet consumer demand for new / innovative foods
F For better sensory characteristics (appearance, smell, taste)
G To promote consumption of sustainable alternatives
H To meet consumer demand for sustainable products
I Animal welfare
J Due to technological advancement, such as longer shelf life without preservatives

4 Which alternative foods from the following list have you tried? Choose as many as you like.

A Plant-based alternatives
B Lab-grown meat alternatives
C Insect-based alternatives

5 How strongly do you believe plant-based alternatives are safe for human consumption?

1	2	3	4	5
Strongly disagree		Not sure/ Neutral		Strongly agree

6 How frequently do you eat plant-based alternatives?

1	2	3	4	5
Never		Some-times		Very Often

7 How strongly do you believe lab-grown meat alternatives are safe for human consumption?

1	2	3	4	5
Strongly disagree		Not sure/ Neutral		Strongly agree

8 Lab-grown meat alternatives are not yet widely available to buy. If that changes, would you include lab-grown meat alternatives in your diet?

Yes	No

9 On a scale of 1 to 5, how strongly do you believe insects are safe for human consumption?

1	2	3	4	5
Strongly disagree		Not sure/ Neutral		Strongly agree

10 On a scale of 1 to 5, how frequently do you eat raw edible insects?

1	2	3	4	5
Never		Some-times		Very Often

11 On a scale of 1 to 5, how frequently do you eat whole and cooked edible insects?

1	2	3	4	5
Never		Some-times		Very Often

12 On a scale of 1 to 5, how frequently do you eat food made from insect flour (powdered and cooked)?

1	2	3	4	5

K	To make more profit / use cheaper alternatives for ingredients for the same products	Never	Some-times	Very Often
L	I do not know / I am not sure			
M	Other: _____			
3	Which alternative foods from the following list have you heard of? Choose as many as you like.			
A	Plant-based alternatives e.g., burger patties			
B	Lab-grown meat / cell culture-derived meat			
C	Edible insects / insects as food e.g., cricket pasta			

3.2 Scientific Paper: "Consumer Perceptions and Acceptance of Edible Insects in Slovenia"

The paper titled "Consumer Perceptions and Acceptance of Edible Insects in Slovenia" by Nayyer Rehman and Nives Ogrinc is presented in this chapter. I was responsible for designing the study, conducting data collection, performing statistical analyses, interpreting findings on consumer behaviour, and preparing the manuscript for publication. This article was published in *Foods* in 2024 and explores Slovenian consumer perceptions and acceptance of edible insects as a sustainable protein source, a topic of growing interest in Europe.

Slovenia was selected as the study's setting due to its unique cultural influences, blending Slavic, Mediterranean, Balkan, and Austro-Hungarian traditions, along with a strong environmental focus. These characteristics make Slovenia an ideal case study for examining acceptance of entomophagy in a culturally diverse and environmentally aware population, adding to the literature supporting sustainable food options across European markets.

The study employed a mixed-methods approach, beginning with a comprehensive survey conducted online in Slovenian and English to reach a wide audience. A total of 537 participants provided data on their familiarity with edible insects, factors affecting acceptance, and sociodemographic characteristics, such as age, gender, education, and residence.

The survey design, informed by prior studies on consumer perceptions in Europe, included questions on previous experiences with insect consumption, economic considerations, willingness to adopt entomophagy, and preferences for specific insect types. Statistical analyses included descriptive statistics, Chi-square tests to examine associations with sociodemographic variables, and an ordinal probit model, chosen for its robust fit in evaluating factors influencing consumer interest in edible insects.

Key findings indicated that younger, educated participants and those in rural areas were generally more open to entomophagy. Male respondents showed a higher likelihood of interest in tasting edible insects compared to females, aligning with trends observed in other European countries. The most acceptable insect types included crickets, grasshoppers, and locusts, particularly when presented in non-visible forms such as powders or flours integrated into foods. These findings reflect a clear consumer preference for hidden forms, which help mitigate the psychological barriers associated with whole insect consumption.

The study also found significant price sensitivity among potential consumers. More than half of the respondents expressed willingness to purchase insect-based products if priced similarly to conventional foods, with an additional 40% more inclined to adopt these alternatives if priced lower. This price sensitivity suggests that competitive pricing could play a pivotal role in increasing consumer acceptance. Majority of respondents supported the use of insects as livestock feed, indicating broader openness to insect-based products within food systems beyond direct consumption. The study suggests strategic recommendations such as targeted educational campaigns, transparent labelling, and marketing to discuss environmental benefits while considering cultural preferences.

This research was presented as a poster at the 2nd ISO-FOOD Symposium: ISO-FOOD from Food Sources to Health, held in Portorož, Slovenia, in 2023. The insights gathered in this study contribute to the growing body of literature on entomophagy in Europe. It also provides actionable insights for policymakers, businesses, and researchers seeking to advance sustainable protein sources across European markets.

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Consumer Perceptions and Acceptance of Edible Insects in Slovenia

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Abstract: Slovenia, influenced by Slavic, Mediterranean, and Balkan cultures, along with Austro-Hungarian traditions and strong environmental concerns, is an ideal case study for understanding consumer perceptions of edible insects and increasing their acceptance as an alternative protein source. A survey conducted in Slovenian and English with 537 participants examined existing perceptions and acceptance of edible insects as food and livestock feed. Findings show moderate interest in insects, particularly in non-visible, integrated forms, despite most participants not having tried whole insects. Young, educated individuals and those residing in rural areas have tried insects more often than other sociodemographic groups. Men showed more interest in entomophagy compared to women. Crickets, grasshoppers, and locusts were most acceptable, while cockroaches were least favored. Economic factors are crucial, with a preference for insect-based products priced similarly to conventional foods. The majority also support using insects as livestock feed. These results can aid policymakers at regional and national levels, help businesses market these products, and contribute to the literature on consumer responses in different European regions regarding edible insects as a sustainable food source.

Keywords: consumer perception; consumer acceptance; edible insects; sustainable consumption; food systems; Slovenia

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1. Introduction

As the global population grows and traditional food systems face increasing pressures leading to protein shortage and environmental strain [1,2], the urgency to identify sustainable alternatives becomes critical. Since the 1970s, edible insects have emerged as a promising solution, attracting significant research interest, particularly in the last decade [3]. One reason is that insects are a highly nutritious food source [4], providing between 40 and 75 g/kg of digestible, high-quality protein [5,6], essential amino acids [7], fats and fiber [8]. Moreover, they contain bioactive compounds such as antioxidant enzymes and peptides [9], which may be beneficial in treating cancer and other diseases [10,11]. The low levels of investment and technical expertise required for insect farming make it a promising solution for combating global hunger, particularly among the most vulnerable populations [12], while also offering a more sustainable alternative for livestock [13,14] and aquaculture feed [15].

Insects, as a source of dietary protein [12,16,17], require considerably less land and water [18,19] than traditional livestock, needing only 3.6 m^2 per kg of fresh insects (94.7 m^2 on a dry weight basis) and between 0.42 and 0.82 m^3 of water per kg of fresh insects [20]. They also generate fewer greenhouse gases, producing only 2.3 to 3.1 kg CO_2 equivalents per kg of fresh insects [21]. Also, feeding insects on agricultural by-products and food waste could significantly reduce their price, a significant barrier to market entry [14,18,22–24], while helping mitigate food waste [25–29].

Despite their long history of widespread consumption in several countries [30,31], insects are met with significant skepticism, safety concerns, and unfamiliarity in Western societies [32–35]. Research indicates that the acceptability of insect-based foods is influenced by various factors, including sociodemographic characteristics, psychological factors, environmental awareness, knowledge and awareness, cultural norms, social influences and product features [36–38].

Sociodemographic characteristics such as gender, age, education level, and place of residence significantly impact consumer attitudes [37]. Men are generally more inclined to accept insects than women [39]. Younger individuals, especially those aged 20–40 and those with higher education levels, are also more open to entomophagy, while urban residents tend to be more accepting than those in rural areas [40].

Psychological factors also play a crucial role, with neophobia, disgust, and perceived health risks acting as substantial barriers; however, curiosity towards new food experiences can promote acceptability [41,42]. Positive attitudes, such as dietary habits and intentions to reduce meat consumption, also affect people's willingness to try insect-based foods, although findings in this area are mixed [39,43].

Environmental awareness can positively influence the willingness to try insect-based products, though this effect is not always significant. While some studies suggest that sustainability concerns lead to higher acceptability, others find no considerable impact [38,39,43]. However, providing information on environmental benefits, especially before and after tasting sessions, can positively shift consumer perceptions [44,45].

Cultural compatibility and familiarity with insect consumption also play critical roles in shaping consumer attitudes. For example, previous exposure to entomophagy through knowledge or direct consumption increases acceptability, and positive tasting experiences, especially in social settings, can reduce disgust and food neophobia [46,47].

Finally, the characteristics of insect-based products—such as appearance, taste, visibility, and packaging—significantly influence consumer acceptance. Processed insect products are generally more acceptable than whole insects, and packaging that reduces insect visibility tends to be more favorably received. Additionally, product design, labeling, and pricing are crucial factors in shaping consumer preferences [48,49]. Understanding consumer attitudes is essential because their concerns can directly impact the success of a product [50–52]. Moreover, deeper insights into which sociodemographic groups are more likely to accept entomophagy allow for tailoring educational and marketing strategies that can effectively maximize resource efficiency and market impact [53,54].

While some consumers may respond positively to insect consumption due to its societal, environmental, and health benefits [54], others may require more direct sensory experiences to shift their perceptions [55,56]. Innovations such as using insect flour in baked goods promise to overcome food neophobia and enhance consumer openness to trying and incorporating insects into their diets [57–61].

While several studies have explored consumer acceptance of edible insects across Europe, there is limited understanding of how insect-based products are perceived in Slovenia. Adhering to European Union regulations for edible insects [62,63], Slovenia's strategic location in Europe has resulted in a cultural heritage influenced by Slavic, Mediterranean, Balkan, and Austro-Hungarian traditions, which are also reflected in its food choices [64–66]. A recent survey by the European Investment Bank also revealed that Slovenia is one of only two countries in Europe that considers the environment the top challenge facing the nation [67]. These facts make Slovenia an excellent case study for examining how consumers in regions influenced by long-held traditions and cultures perceive and accept edible insects, an environmentally friendly alternative to traditional meat, and whether sociodemographic variables influence these perceptions.

This study provides the first comprehensive analysis of Slovenian consumer attitudes toward edible insects as food and feed through a questionnaire. Specifically, it examines how variables such as age, education, gender, and rural versus urban residency affect the acceptance of insects as a viable food source. The study also discusses variations in

willingness to pay for these products and consumer attitudes toward products from animals fed on insects. Understanding these dynamics is crucial for policymakers and businesses venturing into edible insects to advance broader environmental objectives.

2. Materials and Methods

After reviewing the existing literature, we found no suitable survey tools in the Slovenian language for assessing the public perception of insect consumption and willingness to incorporate insects into their diets. To address this gap, we created a survey in Slovenian, which was then translated into English to make it accessible and inclusive for all residents. The survey questions were translated and reviewed by native speakers of both languages to maintain consistency and accuracy across translations.

2.1. Survey Design

The survey was created using Google Forms in June 2021. The survey design was based on the study by Kulma et al. [40] in the Czech Republic, comprising six primary questions focused on consumption habits, followed by demographic questions (Supplementary Material: Figures S1 and S2). Designed to be user-friendly, it included closed and multiple-choice questions and allowed respondents to skip sections if they were unfamiliar with entomophagy or chose not to answer.

The questionnaire was organized into three key sections: consumption habits and experiences, economic considerations, and demographic information. The consumption habits and experiences section assessed whether participants had tried eating insects and, if so, their experiences (positive, neutral, or negative) and their willingness to consume insect-based foods in the future. The economic considerations section focused on respondents' price sensitivity, asking whether they would be willing to eat insects based on different pricing scenarios compared to conventional foods. It also gauged the acceptability of consuming various insect species in different forms, such as hidden in food, whole and raw, or whole and cooked, as well as their views on using insects as animal feed. Finally, the demographic information section gathered basic details such as age, gender, education level, and residence.

2.2. Data Collection

The questions were drafted and pre-tested with a small subset of respondents within the research group to ensure clarity and understandability, crucial for gathering meaningful data. The survey was distributed online through university networks and personal connections within the Jožef Stefan Institute and the Jožef Stefan Postgraduate School. Responses were collected between July and August 2021. Five hundred thirty-seven completed web questionnaires were received, with four hundred seventy-five in Slovenian and sixty-two in English.

To adhere to ethical guidelines applicable to surveys aimed at collecting public responses, this study implemented strict measures following the Personal Data Protection Act (ZVOP-1 [68], current version ZVOP-2 [69]) in Slovenia to ensure data confidentiality and anonymity. Before attempting the survey, respondents were informed about the study's objectives, the voluntary nature of their involvement and the use of their responses in an academic context. No personal identifiers, such as names, email addresses, or IP addresses, were collected.

2.3. Statistical Analysis

The data analysis used the R statistical package (version 4.1.2). Descriptive statistics were employed to examine the sociodemographic variables of the participants and the consumption of various insects, which were visualized using a heatmap. We also performed several statistical tests to determine if there were statistical differences between the sociodemographic categories' responses to questions related to the consumption of edible insects. For example, we used Chi-square tests to assess significant associations between categorical

survey responses and sociodemographic variables (gender, age, residence, and education) and independence of observations to verify that all expected frequencies in the contingency tables were at least 5, fulfilling the conditions for valid Chi-square tests. For significant results ($p < 0.05$), we employed pairwise Chi-square tests with Bonferroni correction for each pair of categories within these variables to ensure that observed differences were robust and not due to chance from multiple testing. For significant associations, adjusted residuals were calculated, with values greater than ± 2 indicating significant deviations from expected frequencies.

To examine the relationship between sociodemographic variables and individuals' interest in tasting edible insects, we used an ordinal probit model. This model was chosen because it had lower Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values, indicating a better fit than the ordinal logit model. The response variable, which measured interest in tasting edible insects, was divided into four levels: 'No', 'Somewhat no', 'Somewhat yes', and 'Yes'. The sociodemographic variables included were gender, age, education, and residence. We fitted the model and tested the significance of each variable using *z*-tests on the model coefficients, considering a *p*-value less than 0.05 as statistically significant.

3. Results

The demographic breakdown of the 537 survey participants (Figure 1) shows that the majority were women (60.71%), followed by men (38.55%). Most respondents were aged 26–47 years (64.8%), with the next largest group being those aged 15–25 years (20.3%) and a smaller percentage over 48 years (14.9%). Regarding education, the majority of the respondents had tertiary education (72.62%), with secondary education as the next group (24.39%), with only a small fraction having primary education (2.23%). In terms of residence size, nearly half lived in areas with 100,000 inhabitants or more (45.81%), approximately a quarter in areas with up to 9999 inhabitants (28.68%), and the rest in areas with 10,000 to 99,999 inhabitants (23.09%).

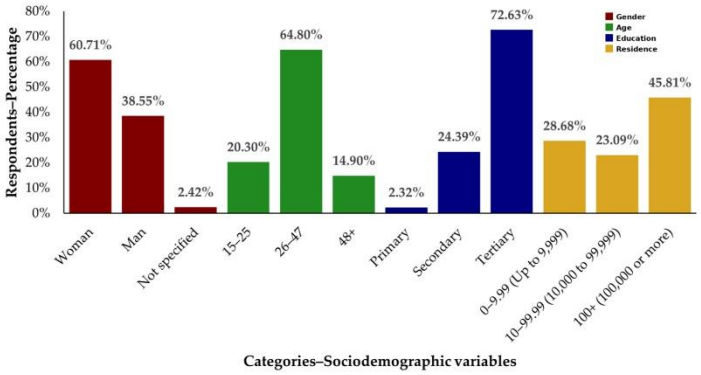


Figure 1. Demographic breakdown of respondents (%, $n = 537$).

Of the 537 respondents, only 96 (17.87%) reported having previous experience with eating insects, while the vast majority, 441 respondents (82.12%), had never tried them (Table 1). The results also showed that more men (19.32%) had eaten insects than women (16.56%). The Chi-square test showed no statistically significant difference across gender ($\chi^2 = 5.75$, $p = 0.12$). Younger respondents (15–25 years) were less likely to have eaten insects (9.17%) compared to those aged 26–47 years (21.84%) and those aged 48 and older (12.50%), with the Chi-square test indicating a statistically significant difference in insect consumption across age groups ($\chi^2 = 10.90$, $p < 0.00$). Individuals with primary education reported the high-

est percentage of having tried insects (33.33%), followed by those with tertiary education (19.23%) and secondary education (12.98%), although the Chi-square test showed no statistically significant difference across education levels ($\chi^2 = 5.44$, $p = 0.14$). The responses varied significantly with population size, with 25% of those living in areas with populations of 0–9.99 thousand and 27.27% of those in areas with populations of 10–99.99 thousand having tried insects, compared to 23.58% in larger populations (>100 thousand). The Chi-square test indicated a statistically significant difference in residence size ($\chi^2 = 11.61$, $p = 0.01$).

Table 1. Associations between sociodemographic variables and trying insects ($n = 537$).

Q1: Have You Ever Tried Eating Insects?					
Sociodemographic Variables	**Categories**	**No (%)**	**Yes (%)**	**Chi-Square (χ^2)**	***p*-Value**
Gender	Man	80.68%	19.32%	5.75	0.12
	Woman	83.44%	16.56%		
	Not specified	33.33%	66.67%		
Age	15–25	90.83%	9.17%	10.90	<0.00
	26–47	78.16%	21.84%		
	48+	87.50%	12.50%		
Education	Primary education	66.67%	33.33%	5.44	0.14
	Secondary education	87.02%	12.98%		
	Tertiary education	80.77%	19.23%		
Residence	0–9.99	86.36%	13.64%	11.61	0.01
	10–99.99	86.29%	13.71%		
	100 and more	76.42%	23.58%		

Post hoc comparisons indicated a significant difference between the age groups 26–47 and 15–25 ($p = 0.01$), while there were no significant differences between the age groups 26–47 and 48+ ($p = 0.25$), or between 15–25 and 48+ ($p = 1.86$). There was a significant difference between residents of areas with 0–9.99 thousand inhabitants and those with 10–99.99 thousand inhabitants ($p < 0.00$). No significant differences were found between residents of areas with 0–9.99 thousand inhabitants and those with more than 100 thousand inhabitants ($p = 0.13$) or between residents of areas with 10–99.99 thousand inhabitants and those with 100 thousand or more inhabitants ($p = 0.22$).

Among those who had eaten insects, experiences varied significantly. Positive experiences, i.e., with a willingness to eat insects again, were reported by 21.66% of respondents. Neutral experiences were reported by 20.83%, who would consider eating insects again under certain conditions, while 27.50% were neutral but preferred not to try insects again. Negative experiences were reported by 15.00%, who expressed no interest in eating insects again.

The survey also found varying responses based on sociodemographic variables (Table 2). Chi-square analysis revealed significant associations between responses to experiences of eating insects and the sociodemographic variables of age and residence. Age was significantly associated with responses to Q2 ($\chi^2 = 10.76$, $p < 0.00$). Younger respondents aged 15–25 reported a higher proportion of neutral experiences, with 35.71% not interested in trying insects again, and 28.57% possibly willing to try again, but no respondents in this age group reported positive experiences. Respondents aged 26–47 had a notable proportion (26.88%) interested in trying insects again, while those aged 48 and older showed the highest proportion of neutral, possibly willing to try again (46.15%). *Post hoc* comparisons indicated that the difference was significant between the age groups 26–47 and 15–25 ($p = 0.01$). No significant differences were observed between the other age groups.

Table 2. Associations between sociodemographic variables and experience with insects (n = 537).

Q2: Please Describe Your Experience with Insects								
Sociodemographic Variables	**Categories**	**Negative, I Am Not Interested in Consuming Insects Anymore. (%)**	**Neutral, Rather Not Interested in Trying Again. (%)**	**Neutral, Possibly Will Try Again. (%)**	**Positive, Interested in Trying Insects Again. (%)**	**Positive, Regularly Consume Insects. (%)**	**Chi-Square (χ^2)**	***p*-Value**
Gender	Man	17.65%	27.45%	13.73%	29.41%	0.00%	3.31	0.35
	Woman	13.43%	25.37%	26.87%	16.42%	1.49%		
	Not specified	0.00%	100.00%	0.00%	0.00%	0.00%		
Age	15–25	0.00%	35.71%	28.57%	0.00%	7.14%	10.76	<0.00
	26–47	17.20%	29.03%	16.13%	26.88%	0.00%		
	48+	15.38%	7.69%	46.15%	7.69%	0.00%		
Education	Primary education	0.00%	33.33%	33.33%	0.00%	33.33%	2.33	0.51
	Secondary education	8.00%	32.00%	24.00%	12.00%	0.00%		
	Tertiary education	17.39%	26.09%	19.57%	25.00%	0.00%		
Residence	0–9.99	4.00%	32.00%	12.00%	36.00%	4.00%	12.69	0.01
	10–99.99	15.38%	19.23%	30.77%	11.54%	0.00%		
	100 and more	18.84%	28.99%	20.29%	20.29%	0.00%		

A significant association was also observed between the experience of eating insects and the residence (χ^2 = 12.69, p = 0.01). Individuals living in areas with populations of 0–9.99 thousand had the highest proportion of positive experiences (36.00%) and the lowest proportion of negative experiences (4.00%). In contrast, respondents from areas with populations of 10–99.99 thousand had the highest proportion of respondents choosing neutral, possibly willing to try again (30.77%). Those from areas with populations of 100 thousand or more had a higher proportion of negative experiences (18.84%) compared to other population sizes. After applying the Bonferroni correction, post hoc comparisons indicated no significant differences between the specific population categories.

For those who had not eaten insects, interest levels varied. No interest in trying edible insects was reported by 31.58%, 29.84% chose 'Somewhat no', 13.17% chose 'Somewhat yes', and 20.15% showed interest in trying edible insects in the future. The survey results indicated varying responses based on sociodemographic variables, as shown in Table 3.

Table 3. Associations between sociodemographic variables and interest in edible insects (n = 537).

Q3: Do You Have Any Interest to Taste Edible Insects in the Future?							
Sociodemographic Variables	**Categories**	**No (%)**	**Somewhat No (%)**	**Somewhat Yes (%)**	**Yes (%)**	**Chi-Square (χ^2)**	***p*-Value**
Gender	Man	28.79%	21.72%	13.64%	32.83%	13.98	<0.00
	Woman	33.76%	34.71%	13.06%	17.52%		
	Not specified	0.00%	50.00%	0.00%	50.00%		
Age	15–25	24.77%	38.53%	15.60%	21.10%	0.74	0.69
	26–47	34.14%	24.77%	13.29%	25.08%		
	48+	30.26%	39.47%	9.21%	19.74%		
Education	Primary education	8.33%	50.00%	25.00%	16.67%	4.47	0.22
	Secondary education	29.46%	34.88%	10.08%	24.03%		
	Tertiary education	32.61%	27.49%	14.02%	23.72%		
Residence	0–9.99	31.54%	31.54%	14.77%	20.81%	7.13	0.07
	10–99.99	25.42%	33.90%	13.56%	26.27%		
	100 and more	33.47%	26.27%	12.71%	24.58%		

A significant association was found between responses to Q3 and the sociodemographic gender ($\chi^2 = 13.98$, $p < 0.00$). Male respondents were more likely to express definite interest (32.83%) than female respondents (17.52%). The proportions of male and female respondents who were somewhat interested were almost the same; however, a higher proportion of female respondents (34.71%) were somewhat uninterested than male respondents (21.72%). In the case of a definite 'No', more women (33.76%) chose this option than men (28.79%). *Post hoc* analysis revealed that significantly more men chose 'Yes' (adjusted residual = 3.98), while significantly fewer women chose 'Yes' (adjusted residual = −3.98).

The ordinal probit model analysis results identified gender as a significant predictor of interest ($\beta = -0.1754$, $p = 0.001$), indicating that men are more likely to express interest in tasting edible insects than women. In contrast, age ($\beta = -0.1117$, $p = 0.207$), education ($\beta = -0.0714$, $p = 0.495$), and residence ($\beta = 0.0035$, $p = 0.954$) were not statistically significant, suggesting these factors do not substantially influence interest. The model also estimated threshold values to mark points on the latent propensity scale where the probability of moving from one interest level to the next changes. The thresholds were −0.9234 ($p < 0.001$) between 'No' and 'Somewhat no', −0.2427 ($p = 0.001$) between 'Somewhat no' and 'Somewhat yes', and −0.9064 ($p < 0.001$) between 'Somewhat yes' and 'Yes'. The significant negative coefficient for gender, combined with these thresholds, indicated that men are generally more likely to progress to higher levels of interest in tasting edible insects than women. Figure 2 shows the predicted probabilities: the blue line represents the predicted probabilities for men, while the purple line represents the predicted probabilities for women. The higher position of the blue line indicates that men have a higher likelihood of interest in tasting edible insects across the range of predictors.

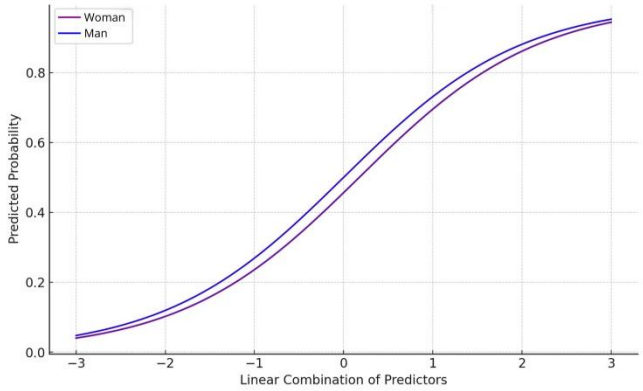


Figure 2. Predicted probabilities of interest levels by gender using the probit model.

In questions investigating the acceptability of consuming various insect types, the responses highlighted a significant preference for ingesting insects in non-visible, integrated forms (Figure 3). Crickets, grasshoppers, and locusts were the most favorably received, with 38.1% of participants open to consuming them in a hidden form, 9.1% accepting them whole and cooked, and 7.6% agreeable to consuming them in any form. This higher acceptance suggests these insects may not trigger disgust as others do, likely due to regional cultural and religious influences [65].

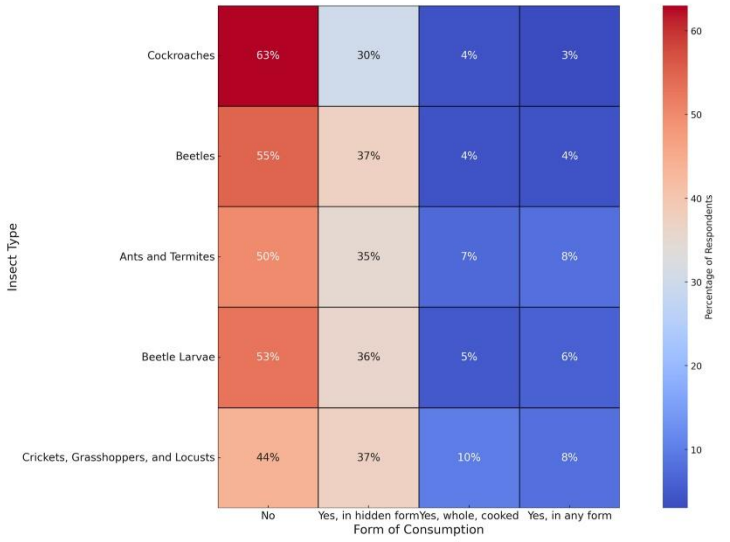


Figure 3. Heatmap of consumer acceptance for different insect types and forms of consumption.

Ants and termites garnered a mixed reception, with 35.4% acceptance in hidden forms, 5.9% whole and cooked, and 7.4% in any form, reflecting perhaps a less pronounced bias due to their smaller size and less conspicuous nature. Beetle larvae and beetles also showed moderate acceptance levels; 36.0% and 36.8% of respondents, respectively, would consider these insects if disguised in food. Specifically, beetle larvae were acceptable to 4.2% of respondents in their whole form and 5.3% in any form, while beetles were acceptable to 3.6% whole and 3.4% in any form.

In contrast, cockroaches showed the lowest acceptability, with only 3.2% of respondents willing to consume them whole and cooked and 2.7% in any form, although 31.6% would consider them if presented in a hidden form. These results indicate strong cultural and psychological barriers against insect visibility in food.

From the 339 respondents who answered questions about the pricing of insects and insect-based foods, 173 (51.03%) indicated they would be willing to purchase such products if priced similarly to their conventional equivalents. Another 134 respondents (39.52%) stated they would consider incorporating insect-based products into their diet if the price was lower than that of conventional products. Only 32 respondents (9.43%) were prepared to buy insect-based products regardless of the higher price. This finding suggests significant price sensitivity among potential consumers of insect-based foods.

Regarding using insects as an alternative protein source for livestock, 325 respondents (60.52%) favored eating meat from livestock fed on insects, and 68 respondents (12.66%) were against it. Meanwhile, 144 respondents (26.81%) did not have an opinion on this topic, indicating some uncertainty or lack of knowledge about the implications of such practices.

4. Discussion

To the best of our knowledge, this survey provides the first online collected and statistically evaluated data on consumer perceptions toward insects in Slovenia, revealing crucial patterns that enhance our understanding of entomophagy in the region. A substantial proportion of Slovenian respondents who had never tried insects indicated a general reluctance or lack of opportunity to engage with this alternative protein source. Similar findings from Poland, Germany, Hungary, Switzerland, and the Czech Republic reflect

consumer reluctance toward entomophagy as a result of cultural influences and limited exposure to insect-based products [70–72].

Approximately only 20% of respondents had tried insects, which could also indicate a limited market presence, with no commercial insect-based products currently available for most consumers to try. Among those who had tried insects, a notable proportion opted for negative or neutral responses and preferred not to try insects again, pointing to the necessity of addressing specific concerns related to neophobia, disgust, and sensory aspects (taste, texture, and presentation), as discussed in the literature [73–77].

Previous research identified sustainability as a key motivator for new consumers to try insect-based foods, particularly due to the reduced environmental impact and resource conservation associated with insect farming [11,19,37,75]. However, cultural and social norms remain significant barriers, especially in Western countries, where insect consumption is often associated with disgust and food neophobia. In contrast, in countries where entomophagy is already practiced, there is already an acceptance of insects as food, and the greater focus lies on the positive sensory attributes, availability, and affordability of insects [51,76].

Experiences of eating insects also varied significantly with age and education. The findings show that individuals in the 26–47 age group [15,34] and those with higher education levels [34,75] had more positive experiences with insects. This finding suggests that educational initiatives focusing on the nutritional and environmental benefits of entomophagy could be particularly effective in these demographics. Although individuals from rural areas had tried insects in a higher proportion than those residing in urban areas, there were no significant differences in their willingness to try insects in the future, possibly due to greater exposure and adoption of global food trends. The results also indicated that although there were no significant differences in gender for trying insects, a higher proportion of men were more likely to rate their experience positively and would try them again. These findings support previous researchers' findings, who also found that male and young participants were more curious and adventurous regarding edible insects [32,39,40,61,78].

The findings also highlight varying degrees of acceptability towards insects and different forms of insect-based products, with the highest acceptance for crickets, grasshoppers, and mealworms, which is consistent with previous observations [79]. While overall willingness to consume insects in recognizable forms was low, a substantial proportion of respondents were open to consuming insects in hidden forms, such as powders and flour, which have shown positive consumer acceptance due to their taste and perceived higher nutritional value [40,45,80].

Price sensitivity emerged as a crucial factor influencing the potential consumption of insect-based products. More than half of the respondents indicated a willingness to purchase these products if priced similarly to equivalent conventional foods, while 40% preferred lower prices, and 10% were willing to pay more. This result emphasizes the need for competitively priced products as one of the strategies to increase acceptance [77].

Most survey respondents supported using insects as an alternative protein source for livestock, aligning with similar findings from a study by Verbeke [39], which noted favorable opinions among farmers, citizens, and agriculture sector stakeholders. Research also indicates acceptance of insect-based feeds in aquaculture across Mediterranean countries such as Spain, Greece, and Italy. Baldi et al. [81] noted that young Italian males and those aware of environmental benefits were more receptive to consuming insect-fed fish. Rumbos et al. [82] reported that most Greek participants at an aquaculture conference supported eating insect-fed fish, motivated by the potential to reduce pressure on wild fish stocks and enhance environmental sustainability.

Given that the findings show a moderate interest in eating insects among Slovenes, marketing efforts should focus on factors influencing consumers' willingness to try insects [83]. Emphasizing positive sensory experiences and offering recipes can help consumers incorporate insects into their meals more easily. Barriers like disgust and fear of

new foods are significant but can be reduced by presenting insects in processed forms, like flour or pastes, and incorporating them into familiar dishes [84,85].

Providing detailed information on the health and nutritional advantages, sustainability, safety, quality, and authenticity of edible insects can make them more appealing as a food choice [86]. These benefits can be highlighted through clear labeling, ingredient transparency, and information on sustainability parameters. Leveraging social media and celebrity endorsements could also position insect-based products as a sustainable alternative for receptive groups [87]. Most importantly, collaboration among government bodies, researchers, and businesses is essential to provide accurate information through educational programs [88], address concerns, and effectively promote the benefits of edible insects.

Limitations and Future Research

Although the study has many strengths and provides insights into a country's residents with diverse influences, it also has some limitations. The limited number of participants, mostly university students and staff, may not accurately represent the opinions of the wider Slovenian population. The study employs a quantitative approach with close-ended questions, which do not always capture the reasons behind participants' choices in the survey. The questionnaire, adapted from the design of another study, covered important topics such as the price and use of insects for feed, but it did not address social reasoning, health and safety concerns, or individual perceptions of the environment. These aspects could have offered deeper insights and allowed for comparisons with other countries, extending the generalizability of the findings to other European nations with similar cultural and regional influences. Additionally, the study did not compare the costs of insect products with traditional foods.

Future research should consider including a larger sample size with a more diverse group, taking into account different ages and educational attainment levels to improve generalizability. The questionnaire should also include environmental concerns, health perceptions, and cultural dietary traditions for a more comprehensive understanding of consumer attitudes. Qualitative research methods could provide a deeper understanding of the rationale behind the responses to the questionnaire. Lastly, comparing insect products with comparable traditional foods and conducting a cost analysis could provide valuable information on consumer price sensitivity and preferences.

5. Conclusions

The findings from this study provide valuable insights into the sociodemographic factors influencing attitudes toward eating insects in Slovenia. Specific demographic groups, such as younger individuals, those with higher education, and men, could be targeted to increase the acceptance and integration of edible insects into mainstream diets. The data suggest that the most widely accepted way to consume insects in Slovenia is in hidden forms, such as insect flour. While market and cultural acceptance still require significant development, there is potential for insects as an alternative protein source. Addressing fears about taste and texture and communicating the benefits and safety of eating insects is crucial. Moreover, collaboration between businesses, researchers, and government will be vital to making insect-based foods a popular choice.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/foods13162629/s1, Figure S1: Edible Insects Survey (Slovenian Version); Figure S2: Edible Insects Survey (English Version).

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References

1. OECD/FAO. *OECD-FAO Agricultural Outlook 2020–2029*; OECD: Paris, France, 2020. [CrossRef]
2. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Toulmin, C. Food security: The challenge of feeding 9 billion people. *Science* **2010**, *327*, 812–818. [CrossRef]
3. Meyer-Rochow, V.B. Can insects help to ease the problem of world food shortage? *Search* **1975**, *6*, 261–262.
4. Belluco, S.; Losasso, C.; Maggioletti, M.; Alonzi, C.C.; Paoletti, M.G.; Ricci, A. Edible insects in a food safety and nutritional perspective: A critical review. *Compr. Rev. Food Sci. Food Saf.* **2013**, *12*, 296–313. [CrossRef]
5. Kouřimská, L.; Adámková, A. Nutritional and sensory quality of edible insects. *NFS J.* **2016**, *4*, 22–26. [CrossRef]
6. Shah, A.A.; Totakul, P.; Matra, M.; Cherdthong, A.; Hanboonsong, Y.; Wanapat, M. Nutritional composition of various insects and potential uses as alternative protein sources in animal diets. *Anim. Biosci.* **2022**, *35*, 317–331. [CrossRef]
7. Orkusz, A. Edible Insects versus Meat—Nutritional Comparison: Knowledge of Their Composition Is the Key to Good Health. *Nutrients* **2021**, *13*, 1207. [CrossRef]
8. Tang, C. Edible insects as a food source: A review. *Food Prod. Process. Nutr.* **2019**, *1*, 8. [CrossRef]
9. Zielińska, E.; Pankiewicz, U.; Sujka, M. Nutritional, Physiochemical, and Biological Value of Muffins Enriched with Edible Insects Flour. *Antioxidants* **2021**, *10*, 1122. [CrossRef]
10. Wu, R.A.; Ding, Q.; Lu, H.; Tan, H.; Sun, N.; Wang, K.; He, R.; Luo, L.; Ma, H.; Li, Z. Caspase 3-mediated cytotoxicity of mealworm larvae (*Tenebrio molitor*) oil extract against human hepatocellular carcinoma and colorectal adenocarcinoma. *J. Ethnopharmacol.* **2020**, *250*, 112438. [CrossRef]
11. Ordoñez-Araque, R.; Egas-Montenegro, E. Edible insects: A food alternative for the sustainable development of the planet. *Int. J. Gastron. Food Sci.* **2021**, *23*, 100304. [CrossRef]
12. Van Huis, A. Prospects of insects as food and feed. *Org. Agric.* **2021**, *11*, 301–308. [CrossRef]
13. Van Huis, A.; Gasco, L. Insects as feed for livestock production. *Science* **2023**, *379*, 138–139. [CrossRef]
14. Kuo, C.; Fisher, B.L. A Literature Review of the Use of Weeds and Agricultural and Food Industry By-Products to Feed Farmed Crickets (Insecta; Orthoptera; Gryllidae). *Front. Sustain. Food Syst.* **2022**, *5*, 810421. [CrossRef]
15. Sogari, G.; Oddon, S.B.; Gasco, L.; van Huis, A.; Spranghers, T.; Mancini, S. Recent advances in insect-based feeds: From animal farming to the acceptance of consumers and stakeholders. *Animal* **2023**, 100904. [CrossRef]
16. Moruzzo, R.; Mancini, S.; Guidi, A. Edible Insects and Sustainable Development Goals. *Insects* **2021**, *12*, 557. [CrossRef]
17. Hamam, M.; D'Amico, M.; Di Vita, G. Advances in the insect industry within a circular bioeconomy context: A research agenda. *Environ. Sci. Eur.* **2024**, *36*, 29. [CrossRef]
18. Dobermann, D.; Swift, J.A.; Field, L.M. Opportunities and Hurdles of Edible Insects for Food and Feed. *Nutr. Bull.* **2017**, *42*, 293–308. [CrossRef]
19. Lange, K.W.; Nakamura, Y. Edible Insects as Future Food: Chances and Challenges. *J. Future Foods* **2021**, *1*, 38–46. [CrossRef]
20. Oonincx, D.G.A.B.; Van Broekhoven, S.; Van Huis, A.; Van Loon, J.J. Feed Conversion, Survival and Development, and Composition of Four Insect Species on Diets Composed of Food By-Products. *PLoS ONE* **2015**, *10*, e0144601. [CrossRef]
21. Oonincx, D.G.A.B.; Van Itterbeeck, J.; Heetkamp, M.J.W.; Van den Brand, H.; Van Loon, J.J.A.; Van Huis, A. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS ONE* **2010**, *5*, e14445. [CrossRef]
22. Varelas, V. Food Wastes as a Potential New Source for Edible Insect Mass Production for Food and Feed: A Review. *Fermentation* **2019**, *5*, 81. [CrossRef]
23. Ojha, S.; Bußler, S.; Schlüter, O.K. Food Waste Valorisation and Circular Economy Concepts in Insect Production and Processing. *Waste Manag.* **2020**, *118*, 600–609. [CrossRef]

24. Mannaa, M.; Mansour, A.; Park, I.; Lee, D.W.; Seo, Y.S. Insect-based agri-food waste valorization: Agricultural applications and roles of insect gut microbiota. *Environ. Sci. Ecotechnol.* **2024**, *17*, 100287. [CrossRef]
25. Oonincx, D.G.A.B.; De Boer, I.J.M. Environmental Impact of the Production of Mealworms as a Protein Source for Humans—A Life Cycle Assessment. *PLoS ONE* **2012**, *7*, e51145. [CrossRef]
26. Smetana, S.; Schmitt, E.; Mathys, A. Sustainable use of Hermetia illucens insect biomass for feed and food: Attributional and consequential life cycle assessment. *Resour. Conserv. Recycl.* **2019**, *144*, 285–296. [CrossRef]
27. Van Broekhoven, S.; Oonincx, D.G.A.B.; Van Huis, A.; Van Loon, J.J.A. Growth performance and feed conversion efficiency of three edible mealworm species (Coleoptera: Tenebrionidae) on diets composed of organic by-products. *J. Insect Physiol.* **2015**, *73*, 1–10. [CrossRef]
28. Čičková, H.; Newton, G.L.; Lacy, R.C.; Kozánek, M. The use of fly larvae for organic waste treatment. *Waste Manag.* **2015**, *35*, 68–80. [CrossRef]
29. Imathiu, S. Benefits and food safety concerns associated with consumption of edible insects. *NFS J.* **2020**, *18*, 1–11. [CrossRef]
30. Olivadese, M.; Dindo, M.L. Edible Insects: A Historical and Cultural Perspective on Entomophagy with a Focus on Western Societies. *Insects* **2023**, *14*, 690. [CrossRef]
31. Shockley, M.; Dossey, A.T. Insects for Human Consumption. In *Mass Production of Beneficial Organisms*; Academic Press: Cambridge, MA, USA, 2014; pp. 617–652. [CrossRef]
32. Kröger, T.; Dupont, J.; Büsing, L.; Fiebelkorn, F. Acceptance of Insect-Based Food Products in Western Societies: A Systematic Review. *Front. Nutr.* **2022**, *8*, 759885. [CrossRef]
33. Durst, P.B.; Johnson, D.V.; Leslie, R.N.; Shono, K. Forest insects as food: Humans bite back. In *Proceedings of the a Workshop on Asia-Pacific Resources and their Potential for Development*; FAO Regional Office for Asia and the Pacific: Chiang Mai, Thailand, 2010; p. 231.
34. Mancini, S.; Moruzzo, R.; Riccioli, F.; Paci, G. European consumers' readiness to adopt insects as food. *A Review. Food Res. Int.* **2019**, *122*, 661–678. [CrossRef]
35. Ribeiro, J.C.; Cunha, L.M.; Sousa-Pinto, B.; Fonseca, J. Allergic risks of consuming edible insects: A systematic review. *Mol. Nutr. Food Res.* **2018**, *62*, 1700030. [CrossRef]
36. Mina, G.; Peira, G.; Bonadonna, A. The Potential Future of Insects in the European Food System: A Systematic Review Based on the Consumer Point of View. *Foods* **2023**, *12*, 646. [CrossRef]
37. Menozzi, D.; Sogari, G.; Veneziani, M.; Simoni, E.; Mora, C. Eating Novel Foods: An Application of the Theory of Planned Behaviour to Predict the Consumption of an Insect-Based Product. *Food Qual. Prefer.* **2017**, *59*, 27–34. [CrossRef]
38. Hartmann, C.; Siegrist, M. Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends Food Sci. Technol.* **2017**, *61*, 11–25. [CrossRef]
39. Verbeke, W. Profiling Consumers Who Are Ready to Adopt Insects as a Meat Substitute in a Western Society. *Food Qual. Prefer.* **2015**, *39*, 147–155. [CrossRef]
40. Kulma, M.; Tůmová, V.; Fialová, A.; Kouřimská, L. Insect Consumption in the Czech Republic: What the Eye Does Not See, the Heart Does Not Grieve Over. *J. Insects Food Feed* **2020**, *6*, 525–535. [CrossRef]
41. Ruby, M.B.; Rozin, P. Disgust, sushi consumption, and other predictors of acceptance of insects as food by Americans and Indians. *Food Qual. Prefer.* **2019**, *74*, 155–162. [CrossRef]
42. Rozin, P.; Fallon, A.E. A perspective on disgust. *Psychol. Rev.* **1987**, *94*, 23–41. [CrossRef]
43. Schösler, H.; de Boer, J.; Boersema, J.J. Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. *Appetite* **2012**, *58*, 39–47. [CrossRef]
44. Looy, H.; Dunkel, F.V.; Wood, J.R. How then shall we eat? Insect-eating attitudes and sustainable foodways. *Agric. Hum. Values* **2014**, *31*, 131–141. [CrossRef]
45. Caparros Megido, R.; Gierts, C.; Blecker, C.; Brostaux, Y.; Haubruge, É.; Alabi, T.; Francis, F. Consumer Acceptance of Insect-Based Alternative Meat Products in Western Countries. *Food Qual. Prefer.* **2016**, *52*, 237–243. [CrossRef]
46. Tan, H.S.G.; Fischer, A.R.H.; Tinchan, P.; Stieger, M.; Steenbekkers, L.P.; Van Trijp, H.C. Insects as food: Exploring cultural exposure and individual experience as determinants of acceptance. *Food Qual. Prefer.* **2015**, *42*, 78–89. [CrossRef]
47. Berger, S.; Wyss, A.M. The influence of social norms on the willingness to eat insects: A field experiment in Denmark and Switzerland. *Appetite* **2020**, *149*, 104607. [CrossRef]
48. Schouteten, J.J.; de Steur, H.; de Pelsmaeker, S.; Lagast, S.; Juvinal, J.G.; De Bourdeaudhuij, I.; Verbeke, W.; Gellynck, X. Emotional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions. *Food Qual. Prefer.* **2016**, *52*, 27–31. [CrossRef]
49. Tan, H.S.G.; van den Berg, E.; Stieger, M. The influence of product preparation, familiarity, and individual traits on the consumer acceptance of insects as food. *Food Qual. Prefer.* **2016**, *52*, 222–231. [CrossRef]
50. House, J. Consumer acceptance of insect-based foods in the Netherlands: Academic and commercial implications. *Appetite* **2016**, *107*, 47–58. [CrossRef]
51. Hartmann, C.; Shi, J.; Giusto, A.; Siegrist, M. The psychology of eating insects: A cross-cultural comparison between Germany and China. *Food Qual. Prefer.* **2015**, *44*, 148–156. [CrossRef]
52. Barsics, F.; Caparros Megido, R.; Brostaux, Y.; Barsics, C.; Blecker, C.; Haubruge, E.; Francis, F. Could New Information Influence Attitudes to Foods Supplemented with Edible Insects? *Br. Food J.* **2017**, *119*, 2027–2039. [CrossRef]

53. Kauppi, S.M.; Pettersen, I.N.; Boks, C. Consumer Acceptance of Edible Insects and Design Interventions as Adoption Strategy. *Int. J. Food Des.* **2019**, *4*, 39–62. [CrossRef]
54. Batat, W.; Peter, P. The Healthy and Sustainable Bugs Appetite: Factors Affecting Entomophagy Acceptance and Adoption in Western Food Cultures. *J. Consum. Mark.* **2020**, *37*, 291–303. [CrossRef]
55. Cunha, L.M.; Ribeiro, J.C. Sensory and Consumer Perspectives on Edible Insects. In *Edible Insects in the Food Sector: Methods, Current Applications and Perspectives*; Springer: Cham, Switzerland, 2019; pp. 57–71. [CrossRef]
56. Wendin, K.M.; Nyberg, M.E. Factors Influencing Consumer Perception and Acceptability of Insect-Based Foods. *Curr. Opin. Food Sci.* **2021**, *40*, 67–71. [CrossRef]
57. Tan, H.S.G.; Tibboel, C.J.; Stieger, M. Why Do Unusual Novel Foods Like Insects Lack Sensory Appeal? Investigating the Underlying Sensory Perceptions. *Food Qual. Prefer.* **2017**, *60*, 48–58. [CrossRef]
58. García-Segovia, P.; Igual, M.; Martínez-Monzó, J. Physicochemical Properties and Consumer Acceptance of Bread Enriched with Alternative Proteins. *Foods* **2020**, *9*, 933. [CrossRef]
59. Hartmann, C.; Siegrist, M. Becoming an Insectivore: Results of an Experiment. *Food Qual. Prefer.* **2016**, *51*, 118–122. [CrossRef]
60. Orsi, L.; Voege, L.L.; Stranieri, S. Eating edible insects as sustainable food? Exploring the determinants of consumer acceptance in Germany. *Food Res. Int.* **2019**, *125*, 108573. [CrossRef]
61. Wilkinson, K.; Muhlhausler, B.; Motley, C.; Crump, A.; Bray, H.; Ankeny, R. Australian consumers' awareness and acceptance of insects as food. *Insects* **2018**, *9*, 44. [CrossRef]
62. Żuk-Gołaszewska, K.; Gałęcki, R.; Obremski, K.; Smetana, S.; Figiel, S.; Gołaszewski, J. Edible Insect Farming in the Context of the EU Regulations and Marketing—An Overview. *Insects* **2022**, *13*, 446. [CrossRef] [PubMed]
63. Lotta, F. Insects as Food: The Legal Framework. In *Edible Insects in the Food Sector: Methods, Current Applications and Perspectives*; Springer Nature: Berlin/Heidelberg, Germany, 2019; pp. 105–118. [CrossRef]
64. Hrnčič, M.K.; Cör, D.; Knez, Ž. Food, Nutrition, and Health in Slovenia. In *Nutritional and Health Aspects of Food in the Balkans*; Academic Press: Cambridge, MA, USA, 2021; pp. 207–225. [CrossRef]
65. Orkusz, A.; Orkusz, M. Edible Insects in Slavic Culture: Between Tradition and Disgust. *Insects* **2024**, *15*, 306. [CrossRef]
66. Milošević, J.; Žeželj, I.; Gorton, M.; Barjolle, D. Understanding the Motives for Food Choice in Western Balkan Countries. *Appetite* **2012**, *58*, 205–214. [CrossRef]
67. European Investment Bank. Slovenes Believe Climate Change Is Now the Number One Challenge Facing the Country, EIB Survey Finds. Available online: https://www.eib.org/en/press/all/2023-464-slovenes-believe-climate-change-is-now-the-number-one-challenge-facing-the-country-eib-survey-finds#:~:text=Climate%20change%20impacts%20and%20environmental (accessed on 17 May 2024).
68. National Assembly of the Republic of Slovenia. Personal Data Protection Act (ZVOP-1). Available online: https://www.ip-rs.si/fileadmin/user_upload/doc/ZVOP-1_in_ZVOP-1a__English_/Personal_Data_Protection_Act_of_Slovenia_status_2013_final_eng.doc (accessed on 28 May 2023).
69. National Assembly of the Republic of Slovenia. Personal Data Protection Act (ZVOP-2). Available online: https://www.ip-rs.si/zakonodaja/zakon-o-varstvu-osebnih-podatkov/ (accessed on 28 May 2023).
70. Gere, A.; Székely, G.; Kovács, S.; Kókai, Z.; Sipos, L. Readiness to Adopt Insects in Hungary: A Case Study. *Food Qual. Prefer.* **2017**, *59*, 81–86. [CrossRef]
71. Piha, S.; Pohjanheimo, T.; Lähteenmäki-Uutela, A.; Křečková, Z.; Otterbring, T. The Effects of Consumer Knowledge on the Willingness to Buy Insect Food: An Exploratory Cross-Regional Study in Northern and Central Europe. *Food Qual. Prefer.* **2018**, *70*, 1–10. [CrossRef]
72. Zielińska, E.; Zieliński, D.; Karaś, M.; Jakubczyk, A. Exploration of Consumer Acceptance of Insects as Food in Poland. *J. Insects Food Feed* **2020**, *6*, 1–10. [CrossRef]
73. Mishyna, M.; Chen, J.; Benjamin, O. Sensory Attributes of Edible Insects and Insect-Based Foods – Future Outlooks for Enhancing Consumer Appeal. *Trends Food Sci. Technol.* **2020**, *95*, 141–148. [CrossRef]
74. Mancini, S.; Sogari, G.; Menozzi, D.; Nuvoloni, R.; Torracca, B.; Moruzzo, R.; Paci, G. Factors Predicting the Intention of Eating an Insect-Based Product. *Foods* **2019**, *8*, 270. [CrossRef] [PubMed]
75. Onwezen, M.C.; Bouwman, E.P.; Reinders, M.J.; Dagevos, H. A Systematic Review on Consumer Acceptance of Alternative Proteins: Pulses, Algae, Insects, Plant-Based Meat Alternatives, and Cultured Meat. *Appetite* **2020**, *159*, 105058. [CrossRef]
76. Florença, S.G.; Guiné, R.P.F.; Gonçalves, F.J.A.; Barroca, M.J.; Ferreira, M.; Costa, C.A.; Correia, P.M.R.; Cardoso, A.P.; Campos, S.; Anjos, O.; et al. The Motivations for Consumption of Edible Insects: A Systematic Review. *Foods* **2022**, *11*, 3643. [CrossRef]
77. Van Huis, A. Edible Insects. In *Handbook of Eating and Drinking*; Springer: Cham, Switzerland, 2020; pp. 965–980. [CrossRef]
78. Schlup, Y.; Brunner, T. Prospects for Insects as Food in Switzerland: A Tobit Regression. *Food Qual. Prefer.* **2018**, *64*, 37–46. [CrossRef]
79. Fischer, A.R.H.; Steenbekkers, L.P.A. All Insects Are Equal, but Some Insects Are More Equal than Others. *Br. Food J.* **2018**, *120*, 852–863. [CrossRef]
80. Borges, M.M.; da Costa, D.V.; Trombete, F.M.; Câmara, A.K.F.I. Edible Insects as a Sustainable Alternative to Food Products: An Insight into Quality Aspects of Reformulated Bakery and Meat Products. *Curr. Opin. Food Sci.* **2022**, *48*, 100864. [CrossRef]
81. Baldi, L.; Mancuso, T.; Peri, M.; Gasco, L.; Trentinaglia, M.T. Consumer Attitude and Acceptance toward Fish Fed with Insects: A Focus on the New Generations. *J. Insects Food Feed* **2021**, *8*, 1–16. [CrossRef]

82. Rumbos, C.I.; Mente, E.; Karapanagiotidis, I.T.; Vlontzos, G.; Athanassiou, C.G. Insect-Based Feed Ingredients for Aquaculture: A Case Study for Their Acceptance in Greece. *Insects* **2021**, *12*, 586. [CrossRef] [PubMed]
83. van Huis, A.; Rumpold, B. Strategies to Convince Consumers to Eat Insects? A Review. *Food Qual. Prefer.* **2023**, *110*, 104927. [CrossRef]
84. Tan, H.S.G.; Verbaan, Y.T.; Stieger, M. How Will Better Products Improve the Sensory-Liking and Willingness to Buy Insect-Based Foods? *Food Res. Int.* **2017**, *92*, 95–105. [CrossRef] [PubMed]
85. Meyer-Rochow, V.B.; Hakko, H. Can Edible Grasshoppers and Silkworm Pupae Be Tasted by Humans When Prevented to See and Smell These Insects? *J. Asia-Pac. Entomol.* **2018**, *21*, 616–619. [CrossRef]
86. Rehman, N.; Edkins, V.; Ogrinc, N. Is Sustainable Consumption a Sufficient Motivator for Consumers to Adopt Meat Alternatives? A Consumer Perspective on Plant-Based, Cell-Culture-Derived, and Insect-Based Alternatives. *Foods* **2024**, *13*, 1627. [CrossRef]
87. de Koning, W.; Dean, D.; Vriesekoop, F.; Aguiar, L.K.; Anderson, M.; Mongondry, P.; Oppong-Gyamfi, M.; Urbano, B.; Luciano, C.A.G.; Jiang, B.; et al. Drivers and Inhibitors in the Acceptance of Meat Alternatives: The Case of Plant and Insect-Based Proteins. *Foods* **2020**, *9*, 1292. [CrossRef]
88. Gahukar, R.T. Chapter 4—Edible Insects Farming: Efficiency and Impact on Family Livelihood, Food Security, and Environment Compared with Livestock and Crops. In *Insects as Sustainable Food Ingredients*; Academic Press: New York, NY, USA, 2016; pp. 85–111. [CrossRef]

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Figure S1: Edible Insects Survey (Slovenian Version)

Raziskava o stališčih in percepcijah do prehranjevanja z žuželkami v zahodnih kulturah

Entomofagija je izraz, ki jo uporabljamo v praksi uživanja žuželk kot hrane, zlasti pri ljudeh. Doslej je bilo zabeleženih več kot 2000 vrst žuželk, ki se uživajo v vseh oblikah in življenjskih obdobjih po vsem svetu v več kot 100 državah (Afrika, Azija, Oceanija in Južna Amerika). Užitne žuželke so hranljive in veljajo za človeka okolju prijazen vir beljakovin, vitaminov in aminokislin. Vseeno je uživanje žuželk v zahodni kulturi še vedno tabu, a čeprav so užitne žuželke le redko na jedilniku, je prehod na prehranjevanje žuželk široko obravnavana tema, saj se članki v medijih pojavljajo skoraj vsak dan. Evropska komisija je že prejela številne prijave novih živil, povezanih z žuželkami. Od tistih žuželk, ki so vstopile v fazo ocene tveganja, je EFSA odobrila suhe rumene mokarje (ličinke Tenebrio molitor) za prehrano ljudi in bi jih lahko v skladu z Uredbo (EU) 2015/2283 šteli za novo živilo. Nekatere evropske države pravzaprav že dovoljujejo prodajo žuželk kot hrano v skladu s „prehodnimi ukrepi“ v skladu z novo zakonodajo o hrani. Kljub temu še vedno ni jasno, ali to odraža pomemben premik zahodnega odnosa do žuželk kot alternativnega vira hrane, kar predstavlja osnovo za nadaljnje raziskave.

Ta vprašalnik je bil oblikovan v znanstvene namene v sodelovanju Univerze za življenjske znanosti v Pragi, Češka z Institutom “Jožef Stefan”. Glavni namen je raziskati stališča in percepcije do prehranjevanja žuželk v zahodnih kulturah. Izpolnjevanje vprašalnika vam bo vzelo približno 5 minut vašega časa. Rezultati ankete so namenjeni samo akademskim raziskavam (prostovoljno sodelovanje), vsi odgovori pa bodo anonimni.

Za vaš čas in sodelovanje se vam najlepše zahvaljujemo!

1. Ali ste kdaj uživali žuželke?
   - O Da. Preskočite na vprašanje 2.
   - O Ne. Preskočite na vprašanje 3.
2. Prosim, opišite vašo izkušnjo pri uživanju žuželk.
   - O Pozitivno, redno uživam žuželke.
   - O Pozitivno, ponovno bi jedel žuželke.
   - O Nevtralno, bi ponovil in če bi mi bilo všeč, bi jih jedel.
   - O Nevtralno, morda bi ponovno jedel žuželke.
   - O Negativno, uživanje žuželk me ne zanima več. Preskočite na vprašanje 6.
   - O Ostalo: Preskočite na vprašanje 4.
3. Ali bi želeli v prihodnosti okusiti užitne žuželke?
   - O Da.
   - O Bolj da kot ne.
   - O Ne. Preskočite na vprašanje 6.
   - O Raje ne.
   - O Ostalo: Preskočite na vprašanje 4.
4. S cenovnega vidika, ali ste pripravljeni jesti žuželke?
   - O Le če bi bila cena nižja od običajnih živil.
   - O Če bi bila cena primerljiva z običajnimi živili.
   - O Tudi če bi bila cena višja od običajnih živil.
5. Izberite sprejemljivost uživanja naslednjih skupin vrst:

	Da, v katerikoli obliki	Da, v skriti obliki	Da, cele in surove	Da, cele in kuhane	Ne
Ščurki	O	O	O	O	O
Hrošči	O	O	O	O	O
Mravlje in termiti	O	O	O	O	O
Ličinke hroščev	O	O	O	O	O
Črički, cvrčalke in kobilice	O	O	O	O	O

6. Kakšno je vaše mnenje o krmljenju živine z žuželkami? Bi uživali meso živine, ki se hrani z žuželkami?
   - O Pozitivno – da, bi.
   - O Negativno – ne, ne bi.
   - O Nimam mnenja o tej temi.
7. Spol
   - O Ženska
   - O Moški
   - O Nedoločeno
8. Starost
   - O 15-25
   - O 26-47
   - O 48+
9. Izobrazba
   - O Primarna izobrazba
   - O Sekundarna izobrazba
   - O Terciarna izobrazba
10. Prebivališče (v tisočih prebivalcev)
    - O 0-9,99
    - O 10-99,99
    - O 100 and more

Figure S2: Edible Insects Survey (English Version)

Attitudes and Perceptions Towards Eating Insects in Western Cultures

Entomophagy refers to eating insects as food, especially by people. At present, more than 2000 insect species are eaten in more than 100 countries (Africa, Asia, Oceania and South America) in all varieties and life stages. Edible insects are nutritious and considered an environmentally sustainable source of protein, vitamins, and amino acids for humans. All the same, insect consumption is still taboo in Western culture, but although edible insects are rarely on the menu, the move towards eating insects is a widely discussed topic, with articles appearing in the media almost daily. The European Commission has already received many insect-related novel food applications. Of those insects that have entered the risk assessment phase, dried yellow mealworms (Tenebrio Molitor larva) have been approved for human consumption by the EFSA and could be considered a novel food pursuant to Regulation (EU) 2015/2283. In fact, some European countries have already permitted the sale of insects as food under the "transition measures" of the Novel Food law. However, it remains to be investigated whether this reflects a significant shift in Western attitudes towards eating insects.

This questionnaire was created solely for scientific purposes by researchers at the Czech University of Life Sciences, Prague and Slovenia's Jožef Stefan Institute, Ljubljana, to explore Western people's attitudes and perceptions towards eating insects. The completion of the questionnaire will take approximately 5 minutes. The survey results are for academic research only (voluntary participation), and all answers will be kept anonymous.

We sincerely thank you for your time and participation!

1. Have you ever tried eating insects?
   - O Yes (Skip to Question 2)
   - O No (Skip to Question 3)
2. Please describe your experience of eating insects.
   - O Positive, I am eating insects regularly
   - O Positive, I am interested in trying insects again
   - O Neutral, rather not interested in trying again
   - O Neutral, possibly will try again
   - O Negative: I am not interested in consuming insects anymore (Skip to Question 6)
   - O Others: Skip to Question 4
3. Do you have any interest in tasting edible insects in the future?
   - O Yes
   - O Somewhat yes
   - O No (Skip to Question 6)
   - O Somewhat no
   - O Others: Skip to Question 4
4. From the point of pricing, you are willing to eat insects:
   - O Only if the price would be lower than conventional foods
   - O If the price would be comparable to conventional foods
   - O Even if the price would be higher than conventional foods
5. Choose an acceptability of consumption of the following species groups:

	Yes, in any form	Yes, in hidden form	Yes, whole, raw	Yes, whole, cooked	No
Cockroaches	O	O	O	O	O
Beetles and bugs	O	O	O	O	O
Ants and termites	O	O	O	O	O
Beetle larvae	O	O	O	O	O
Crickets, katydids and locusts	O	O	O	O	O

6. What is your opinion about feeding livestock with insects? Would you consume meat from livestock fed on insects?
   - O Positive, yes, I would
   - O Negative, no, I would not
   - O I do not have an opinion on this topic
7. Gender
   - O Woman
   - O Man
   - O Not specified
8. Age
   - O 15-25
   - O 26-47
   - O 48+
9. Education
   - O Primary education
   - O Secondary education
   - O Tertiary education
10. Residence (in thousands of inhabitants)
    - O 0-9.99
    - O 10-99.99
    - O 100 and more

3.3 Scientific Paper: "Quality, safety and authenticity of insect protein-based food and feed: insights from the INPROFF Project"

The paper titled "Quality, Safety, and Authenticity of Insect Protein-Based Food and Feed: Insights from the INPROFF Project" by David Heath, Anja Vehar, Lenka Kouřimská, Martin Kulma, Petra Škvorová, Hana Šubrtová Salmonová, Nayyer Rehman, and Nives Ogrinc is presented in this chapter. My contributions to this work included analysing consumer attitudes and perceptions towards insect-based foods, as well as examining regulatory frameworks and policies relevant to insect protein within the EU.

This paper was published in *Exploration of Foods and Foodomics* in 2024 and is part of the INPROFF Project—a collaborative effort between Slovenian and Czech institutions aimed at advancing insect farming as a sustainable protein source for both human and animal consumption. Given that edible insect products offer a potential solution to Europe's protein deficit, the study explored consumer acceptance, the impact of regulatory policies, and industry challenges in quality and safety. This work adds to the expanding literature that supports alternative protein options within European food systems.

The INPROFF project is structured around three thematic pillars: (P1) nutritional enhancement, (P2) safety and quality, and (P3) authenticity, traceability, and consumer acceptance, with each pillar addressing unique challenges in insect-based foods. My focus was primarily within Pillar III, where I assessed consumer preferences and attitudes through a survey of over 500 participants across Europe. The study identified key determinants of consumer acceptance, including familiarity, sensory attributes, and perceived environmental benefits, while also noting the significant role of food neophobia as a barrier.

The research also analysed regulatory factors, highlighting the strict EU Novel Food Regulations (EU 2015/2283), which govern the authorisation of edible insect products. Other critical regulations, such as the animal feed safety standards and labelling requirements under EU 2017/893, further impact the industry. The conclusions of Pillar III emphasised the need for policy adjustments to accommodate the growing market demand for insect protein and suggested strategies to promote greater acceptance among consumers, including transparent labelling and informational campaigns to address cultural resistance.

Key findings of the study underscored moderate acceptance of insect-based foods, with consumer interest varying significantly based on product format (e.g., insect powder vs. whole insects) and presentation. Processed forms, such as powders or hidden ingredients in familiar food products, were found to be more acceptable to European consumers.

The study also revealed a pronounced preference for products with clear environmental benefits, with respondents indicating that sustainability claims could positively influence their willingness to try insect-based foods. These insights contribute to the broader goal of Pillar III by offering actionable recommendations for policymakers and industry stakeholders to improve the marketability and acceptance of insect-based proteins across Europe.

This research was presented as a poster at the 2nd ISO-FOOD Symposium: ISO-FOOD from Food Sources to Health, held in Portorož, Slovenia, in 2023. The INPROFF Project's findings contribute essential insights for advancing sustainable protein sources in the European market, supporting efforts to build consumer trust and address regulatory challenges as insect-based products gain traction in the food industry.

Exploration of Foods and Foodomics

Open Exploration

Open Access Review

Quality, safety and authenticity of insect protein-based food and feed: insights from the INPROFF Project

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Abstract

This paper reviews the nutritional quality and safety of edible farmed insects from the point of view of the Czech-Slovenian bilateral project: Quality, Safety and Authenticity of Insect Protein-based Food and Feed (INPROFF). Insects as a sustainable source of dietary protein for animal feed and even humans, when integrated into the European agrifood system, could offer a solution to Europe's feed protein deficit and help alleviate environmental pressure from increasing protein demand, such as declining availability of land, water, marine and energy resources, the overuse of pesticides and reduced biodiversity. However, despite a growing interest in the European Union (EU) in farming edible insects, many economic, scientific, technological, and social barriers remain. In response, Slovenia, represented by the Jožef Stefan Institute, the Biotechnical Faculty of the University of Ljubljana, and Jata Emona d.o.o. (the leading supplier of feedstuffs for the Slovenian market), a country with no history of insect rearing but an interest in alternative protein, joined with the Czech University of Life Sciences Prague, representing the Czech Republic—a country with a history of insect rearing and research into edible insects—to establish INPROFF a three-year bilateral project that aims to close the knowledge gap regarding the quality and safety of insect-based products and boost the farmed insect food and feed value chain. Specifically, it comprises three thematic pillars: (P1) nutritional enhancement, (P2) safety and quality and (P3) authenticity, traceability, and consumer acceptance. The paper also discusses the gaps in the metrological challenges of analysing

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insects, which will be critical for ensuring safety, quality, and sustainability. The paper finds that although much work has been done, many exciting avenues remain for new research.

Keywords

Farming insects, alternative protein, quality, fermentation, safety, authenticity, traceability, metrology

Introduction

As demand for sustainable protein intensifies, many food scientists propose using farmed insect protein for animal feed and even for human consumption. Moreover, in 2013, the Food and Agriculture Organisation (FAO), a part of the United Nations, published a report recommending consuming insects as a sustainable solution to the shortage of world food supplies [1] and are now generally accepted as a sustainable way to help alleviate Europe's feed protein deficit having a significant role in the EU's protein strategy [2–5].

Unlike wild-caught insects in many parts of the world, farmed insects in Europe are considered (legally) no different from other farmed animals and must comply with National and EU legislation, and although a full review of the EU legislation is beyond the scope of this paper, the growth of the farmed insect industry will be significantly impacted by the legislation. Historically, given that insects were not consumed in the countries that make up the EU, they are covered by Regulation (EU) 2015/2283 on Novel Foods [6], which governs the authorisation and marketing of novel foods, including insects, within the EU following an assessment by the European Food Safety Authority (EFSA) and, as of the time of writing, it includes yellow mealworm (*Tenebrio molitor*), house cricket (*Acheta domesticus*), migratory locust (*Locusta migratoria*) and the buffalo worm (*Alphitobius diaperinus*). Producers must also comply with, among others, regulations regarding general principles and standards governing food and feed safety (Regulation [European Commission (EC)] 178/2002), hygiene rules [Regulation (EC) 852/2004], animal health [Regulation (EU) 2016/429], proper labelling with regards allergen information, nutrition labelling, and country of origin labelling [Regulation (EU) 1169/2011]; importation [Regulation (EU) 2019/626], and use of animal by-products [Regulation (EU) 142/2011] [7–12].

Strict regulations also exist regarding animal feed, including placing feed on the market concerning safety, labelling, and traceability requirements [Regulation (EC) No 767/2009] and a catalogue of authorised feed materials, which includes insects and their products, that can be used in animal feed formulations [Regulation (EU) No 68/2013] [13, 14]. Moreover, in the EU, insect protein is classified as processed animal protein (PAP), and its use, production, and labelling are strictly controlled under specific rules [Regulation (EU) 2017/893] [15]. Insects approved for animal feed in aquaculture include black soldier fly (*Hermetia illucens*), yellow mealworm, common housefly (*Musca domestica*), lesser mealworm (*Alphitobius diaperinus*), house cricket, field cricket (*Gryllus assimilis*) and, as of 2024, the silkworm (*Bombyx mori*) pupae are authorised for use in aquaculture feed. The recent changes to the regulations allowing certain insect PAPs in pig and poultry feed represent a boon for the farmed insect industry. However, ruminants still cannot feed insects due to transmissible spongiform encephalopathies (TSEs). Overall, many producers and promoters of edible insects feel that legislation regarding what substrate (e.g., food waste) insects can be fed is restrictive and is holding back the field [2]. A detailed review of all the regulations relating to EU law is published by the International Platform of Insects for Food and Feed (IPIFF) [16].

Even though insects are now on the market and have passed scrutiny by EFSA, there remain many gaps in the knowledge regarding farmed insects and many challenges in improving their economic viability (feed modification) and acceptability to the consumer. In response, in 2021, the Jožef Stefan Institute (JSI), the Biotechnical Faculty of the University of Ljubljana (UL-BF), the Czech University of Life Sciences Prague (CZU) and Emona Nutrition Research & Development Department of Jata Emona d.o.o. (ENR-JE), Slovenia's leading feed producer established a joint three-year bilateral research project INPROFF: Quality, Safety and Authenticity of Insect Protein-based Food and Feed. The project, jointly funded by the Slovenian Research

Agency (ARIS) and The Czech Science Foundation (GAČR), is designed to generate new knowledge and stimulate scientific cooperation. It employs various strategies to close the knowledge gap regarding the quality and safety of insect-based products. The project focuses on the yellow mealworm, house cricket and migratory locust. These were chosen because they are already on the market and are relevant as both food and feed.

At the project's core are three thematic pillars: (P1) nutritional enhancement, (P2) safety and quality and (P3) authenticity, traceability and consumer acceptance, all of which are underpinned by one horizontal activity: (H1) insect production and characterisation (Figure 1). Pillar I seeks to optimise the nutritional quality of insect biomass by investigating the rearing of insects on both conventional and alternative feeds and through fermentation of their biomass. Pillar II is concerned with the safety of farmed insects by developing advanced analytical protocols to assess their chemical and biological safety. Finally, Pillar III is about developing forensic tools to verify the authenticity of insect-based products, promoting transparency and trust in the market, as well as seeking to understand consumer attitudes and acceptance towards eating insects. Moreover, the project is intended to catalyse future collaborations for continual advancements in insect farming research and innovation.

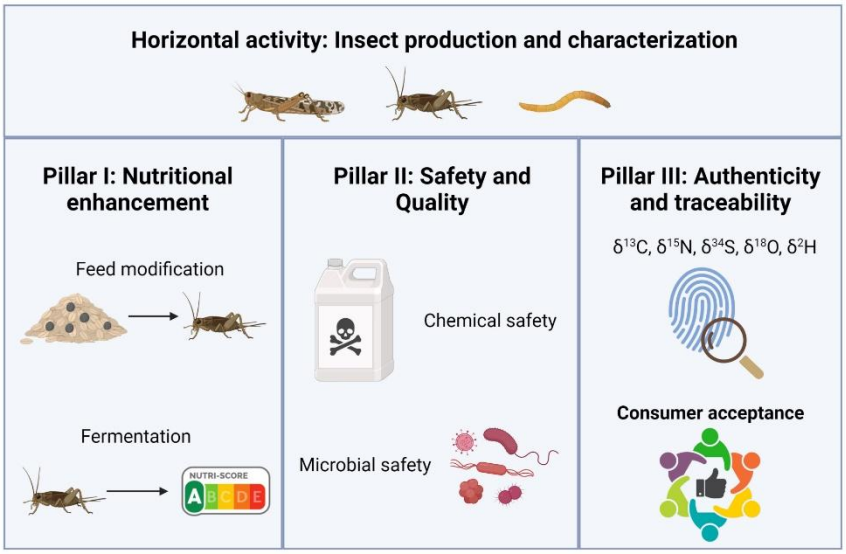


Figure 1. Thematic pillars of the project. Created with BioRender.com

In this paper, we review the current state-of-the-art and challenges regarding farmed edible insects pertaining to the three thematic pillars of the INPROFF project. Among four primary academic peer-reviewed databases: Google Scholar, Scopus, Web of Science, and Science Direct, Scopus was selected as it is one of the leading international and prominent databases, familiarity, and delivered a significant number of hits for the search term "edible insects" (Table 1). The search term "edible insects" although it includes wild-caught species not covered by this review, was a better catch-all term than "farmed insects" and "entomophagy". The search was restricted to the following fields: Title, Abstract, and Author Keywords. Acceptance criteria included all articles published in English between 2004 and 2024. The analysis identified over 2,000 papers going back 20 years (Table 1). A comprehensive list of search terms is provided in the supplementary information (Table S1), while Table S2 presents the search results (hits) for the term "edible insects" along with the studied species. The findings indicate that the most studied species is "*Tenebrio molitor*".

Table 1. Search results (hits) for the search term "edible insects" in different databases and results of connected terms performed in Scopus (Search fields: article title, abstract, keywords)

Search term	Hits (2004–2024)
"Edible insects"	
Google Scholar	1,710
Scopus	2,011
Web of Science	1,401
Science Direct	673
"Insects"	236,679
"Edible insects"	2,011
"Entomophagy"	866
"Farmed insects"	43
"Edible insects" AND …	
"Nutrition" (Pillar I)	315
"Safety" (Pillar II)	362
"Authenticity" (Pillar II)	12
"Metrology"	0

When the number of publications is plotted against years, the results reveal how scientific interest in edible insects has increased significantly since 2014 and the publication of the FAO's paper on *Edible Insects Future Prospects for Food and Feed Security* by van Huis et al. [1] (Figure 2). The retrieved articles were further probed using targeted keywords tailored to each pillar theme to identify significant knowledge gaps, and then they were systematically scrutinised for inclusion in the review. Regarding the different thematic pillars, safety, followed closely by nutrition, produced similar hits. The search term "authenticity" produced a significantly smaller number of hits, while the term "metrology" produced no hits (Table 1). The full results are presented in the supplementary (Table S1).

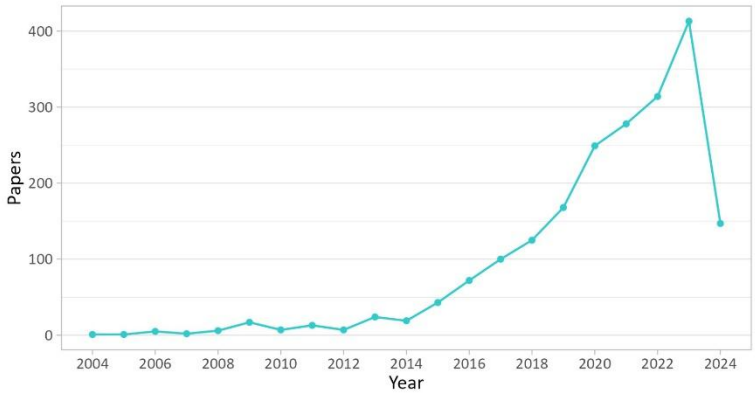


Figure 2. Plot of number of papers vs. publication year (Search fields: article title, abstract, keywords: "edible insects", data: Scopus)

Pillar I: enhancing the nutritional quality of insect biomass

As mentioned, as part of a more sustainable European protein strategy, farmed insect protein content is a viable option for becoming more self-sufficient in protein production for feed and human consumption. Pillar I aims to achieve two objectives: enhancing the nutritional and functional value of insect biomass and adapting insect feed composition to include agri-byproducts, thereby enhancing their nutritional quality. For instance, the INPROFF project explores how fermentation can boost nutritional values, sensorial

properties, and safety/shelf life. It also looks at ways to modify insect feed by adding agricultural by-products to make insects more economically viable and competitive with conventional protein sources, such as soybeans.

The literature review reveals that farmed insects are a rich source of easily digestible quality protein [≈ 40–75 g/kg of dry matter (DM)] equivalent to meat [17, 18]. They can also provide most of the essential amino acids, including lysine, leucine, phenylalanine and tryptophan, fat and lipids (approx. 20–55 g/100 g) [19, 20] along with several essential fatty acids with total polyunsaturated fatty acids (PUFA) accounting for 3–50% [20]. They also contain fibre (8.5–27 g/100 g) and carbohydrates, mostly chitin (2.7 mg and 49.8 mg per kg of fresh weight), as well as minerals (Ca, K, P, Na, Mg, Cu, Fe, Zn, and Mn) and vitamins A, D, E, K, and C and B groups vitamins [20]. Insects also represent an excellent sustainable source of chitin (5–15% w/w) [21]. The latter values were obtained using a reliable electrophoresis assay developed within INPORFF, which overcomes the inherent problem of being unable to distinguish between chitin and cellulose.

Bioactive compounds like antioxidant enzymes and peptides are also present in insects [22], some of which have therapeutic potential [23]. For instance, cantharidin from blister beetles can induce apoptosis in cancer cells by affecting nucleic acid and protein metabolism in hepatocellular carcinoma cells. Cecropin peptides found in some insects have shown cytotoxic effects against leukaemia and lymphoma cells by forming pores in their plasma membranes [24]. Traditional Chinese medicine frequently utilises insect extracts to treat various ailments, including cancer [23]. Not all bioactive compounds are necessarily beneficial. Insects belong to foods with high levels of total purine (3.23–13.22 g/kg DM) and uricogenic purines (adenine and hypoxanthine: (1.55–8.86 g/kg edible DM), which contain amounts analogous to meat (3.61–5.53 g/kg meat DM) and are a problem for those who suffer from gout and kidney stones [25]. From this perspective, the study's authors conclude that the study insects make unsuitable alternatives for low-purine diets.

Although polyphenols are commonly associated with plants, insects also contain polyphenolic compounds, which act as antioxidants with anti-inflammatory, anti-cancer, antityrosinase, antigenotoxic, and pancreatic lipase inhibitory activity [26]. Insects also possess polyphenols serving as pigments and chemical defences, and they can synthesise and store non-dietary phenolic compounds through sclerotisation [27]. They also have the capability to selectively absorb and accumulate flavonoids in their bodies from the larval stage via their host plant, so their diet is important in determining the type and amount of polyphenols present [26]. Research into the content and specific bioactive properties of insect-derived polyphenols remains ongoing.

Nutritionally, the case for insects is strong; however, more rigorous analyses are needed, including assessments of insect nutrients not thoroughly investigated (particularly vitamins), the presence of non-nutrients and anti-nutrients and how they influence the digestibility and bioavailability of nutrients in various species and processed products. A lack of such studies also means there is currently a limited understanding of how insect-based foods affect the human and animal gut microbiome [28]. Imbalances in the human gut microbiome are linked to metabolic and non-communicable diseases, gastrointestinal conditions, allergies, asthma, and even neuropsychiatric disorders [29]. An even more significant gap exists (search hits = 8) in our understanding of the insect gut microbiome.

Insects are also promoted as a more sustainable option than conventional non-plant protein sources [30–32]. For example, the rearing of insects through vertical farming, which, unlike locusts, is particularly suited to the mealworm, requires far less land (3.6 m^2/kg of fresh insects to 94.7 m^2/kg of dry insects), significantly less water (0.42–0.82 m^3 of water depleted per 1 kg of fresh insects); have highly efficient feed conversion rates (50–70%); produce less waste and amenable to further processing and rearing in modern production systems [33–35]. The result is lower greenhouse gas emissions (2.3–3.1 kg CO_2 eq per kg of fresh insects) than other non-plant protein sources [36, 37]. Insects, those in larvae form, can also serve as aqua feed alternatives, replacing traditional non-sustainable options like fish meal [3].

The nutritional content of insects varies based on numerous factors, which means that it can be improved using specific measures in farming technology to improve the efficiency of the animal's diet [38]. For insects to compete economically with other sources of animal feed, it will be necessary to rear them on by-products and waste from the food industry and agriculture, i.e., transforming low-value organic by-products into high-value food or feed [32, 39, 40], thereby reducing costs and increasing the economic viability of insect-based feed [41]. However, this will require the development of nutritionally balanced insect diets. Similarly, insects can also be a source (bio-factories) of other valuable secondary commodities for pharmaceuticals, biofuels and lubricants [42, 43], and their waste (frass) can be used as fertiliser [44, 45].

Farming edible insects allows an opportunity to manipulate the nutrient content of insects via their feed [46, 47]. For example, the transfer of beneficial substances such as carotenoids or omega-3 fatty acids (n-3) from feed to insects has been observed [38, 48]. These fatty acids, omega 3 (n-3) and omega 6 (n-6), are required in mammalian diets because mammals cannot synthesise these de novo. Although essential for health, Western diets contain too little n-3 and too much n-6 PUFA. Increasing the beneficial fatty acids amounts of n-3 PUFA, which would result in more favourable n-6/n-3 ratios, would benefit animal feed and humans since it can reduce coronary heart disease, cancer, autoimmune and inflammatory diseases [49]. For example, Škvorová et al. [47] have shown that rapeseed cake can substitute soybean meal in feeding the field cricket, resulting in higher crude protein levels and lower amounts of palmitic acid.

Fermentation is an effective method for enhancing the nutritional properties of certain foods and is being investigated to extend their shelf life [50, 51], microbiological safety and sensory characteristics [50, 52, 53]. It is also being used as a way of increasing the efficiency of their original bioactive compounds (functional value) via their release or transformation by lactic acid bacteria (LAB) as well as enriching the substrate in their metabolites, e.g., polysaccharides, bioactive peptides, vitamin B12, short-chain fatty acids [54, 55]. These transformations are associated with improving the bioaccessibility and bioavailability of food components and their health-related properties [55].

Moreover, fermentation can also increase the digestibility and stability of waste before being utilised as insect feed by converting food and by-product wastes into ingredients for artificial insect diets [51, 56]. *Companilactobacillus* appears most promising, resulting in a significant increase in free glutamic and aspartic acid. These compounds are responsible for the umami flavour of fermented foods and might stimulate consumer acceptance of insects and their consumption [57]. Hadj Saadoun et al. [58] applied lactic acid fermentation of waste to the puparia and dead adults of black soldier flies. The authors showed that the fermented puparium has a high antimicrobial activity against three pathogenic strains: *Salmonella enterica*, *Listeria monocytogenes*, and *Escherichia coli*. The authors also reported a shift in lipid composition from that typical of insects to one containing fatty acids, while the LAB strains could modify the biomass's protein composition depending on the specific LAB strain and the substrate.

Pillar II: safety and quality

Insect products regulated as novel foods or as feed are considered safe, having undergone an extensive risk assessment process, and, in the EU, where insects are allowed on the market, have to adhere to strict EU regulations [59, 60]. For example, [Regulation (EU) 2023/915] establishes maximum permitted levels in food for the specific contaminants [e.g., toxic elements (cadmium, lead, mercury, inorganic tin, arsenic), plant toxins (erucic acid)], mycotoxins (e.g., aflatoxins, ochratoxin A, fumonisins, and citrinin), processing contaminants [e.g., 3-MCPD, dioxins, dioxin-like polychlorinated biphenyls (PCBs) and nondioxin-like PCBs, polycyclic aromatic hydrocarbons (PAH), and polyfluorinated substances (PFAS)], and others (e.g., melamine and nitrate) [61]. However, despite the work on looking at the safety of insects [32, 46, 62–70], like with any new food or feed, there will be known and unknown so-called emerging risks [70]. A key part of the INPROFF project involves characterising less well-studied contaminants' chemical and biological safety using state-of-the-art instrumentation. This task involves performing target analysis and developing nontarget screening workflows, which have yet to be fully utilised in the literature. The project also

investigates the effect of specific bioactive substances and their cytotoxicity using in vitro gastrointestinal cell cultures.

Farmed insects, fed on cereal-based feeds, could be exposed to toxic elements, pesticide residues, mycotoxins and other biologically produced toxins and biohazards (bacteria, viruses, fungi, parasites), food chemicals and additives of natural or non-natural origin, many of which have the potential to bioaccumulate and physical foreign matter for example from the degradation of production equipment [66, 68, 71, 72]. Modern intensive farming production methods, even for minilivestock (insects), offer many routes for potential sources of contamination across the entire food supply chain, particularly given the many unknowns associated with scaling up insect production systems [70, 73, 74]. For insects destined for feed (e.g., black soldier fly), the risk of exposure will be amplified if, in the future, insects are reared on agri-byproducts, mixed wastes from processing plants, supermarkets and even restaurants [75].

Chemical contamination, especially the biotransfer, bioaccumulation, and biotransformation of contaminants from feed to food [76] and how their uptake is affected by species, life stages, and rearing environment [77] is also underexplored. The same is true concerning the effect that processing methods have on the presence of chemical hazards, even though there is some evidence that processing methods like boiling, frying and roasting increase the safety of edible insects [71]. However, conventional cooking conditions will most likely not be an effective way to eliminate contaminants such as per- and polyfluorinated substances (PFAS), so-called "forever chemicals" [78, 79] with a high potential to bioaccumulate [80]. Other potential risks addressed in food/feed but not yet studied concerning insect rearing include, for example, the uptake of micro and nano plastics from feed [81, 82], which could by themselves be problematic or act as carriers for other contaminants [83, 84]. Reducing such risks will require greater control over their feed and environment and the development of high throughput put and methods capable of detecting a broader range of compounds.

Among the now large number of publications, the majority are target analyses of a few compounds or multi-residue analyses [68, 85]. Targeted methods focus on detecting and quantifying pre-defined compounds or analytes in a sample, which can miss other potentially hazardous groups of contaminants present in the samples. In response, many scientists have turned to suspect and nontarget screening methods to define the chemical characterisation of particular samples [74, 80, 86].

The sheer number of potential organic chemical contaminants and their mixtures, which are constantly changing, also raises problems in assessing risk, and focusing on only a few specific target compounds could mean other hazards go undetected. For this reason, attention is turning towards exploring alternative analytical workflows, such as suspect and non-targeted ones, as part of an exposome concept [87]. Suspect screening involves searching for compounds on a pre-defined list of "suspect" compounds or compound classes, often based on their chemical properties or structural features [88, 89]. Such approaches offer a more comprehensive assessment by detecting unexpected contaminants or adulterants, enhancing the detection of emerging risks that may not be accounted for in targeted analyses, i.e., non-targeted analysis aims to screen and identify compounds present in a sample without prior knowledge. This ability to perform such analysis is partly due to the introduction of Time-of-Flight (ToF) and Orbitrap-mass spectrometry (MS) high-resolution benchtop instruments, which have the advantage of using full-scan acquisition mode with high sensitivity, high resolving power and accurate mass measurement, allowing the rapid characterisation of potentially thousands of compounds [88, 90, 91].

Ideally, all three approaches—targeted, suspect, and nontarget—are sequentially performed on the same set of samples. However, few insect-related studies have been published using the described approaches [74, 80, 86]. For instance, Poma et al. [74] performed targeted screening of organic contaminants [flame retardants, PCBs, dichlorodiphenyltrichloroethane (DDT), dioxin compounds and selected pesticides] and additional suspect pesticide screening of edible insects and insect-based food intended for human consumption. The organic chemical mass fractions of targeted compounds were typically lower than in common animal products. In contrast, the untargeted screening analysis revealed the presence of vinyl toluene, tributylphosphate (present in 75% of the samples), and pirimiphos-methyl

(identified in 50% of the samples)—frequently identified contaminants that would have been missed with a targeted approach. Li and Bischel [80] also performed target and suspect screening to evaluate the bioaccumulation of trace organic contaminants in black soldier fly insect larvae fed on almond hulls, a by-product from the almond industry. Their study showed that the four targeted per- and polyfluoroalkyl substances (PFAS), perfluorobutanoic acid (PFBA), perfluorooctanoic acid (PFOA), perfluorobutanesulfonic acid (PFBS) and perfluorooctanesulfonic acid (PFOS), did not bioaccumulate in the larvae. However, employing a nontarget approach uncovered the presence of other PFAS compounds, specifically hydrogen-substituted polyfluoroalkyl carboxylic acids (H-PFCA), which were found to bioaccumulate in the larvae and were correlated with their presence in the feed (almond husks).

Similarly, Macan Schönleben et al. [86] performed target and suspect pesticide screening of 52 edible insects from Asia, Africa, and Europe. Fifty-six pesticides were determined using target (30) and suspect (26) screening approaches. Notably, in the case of targeted screening, the neonicotinoid imidacloprid had the highest detection frequency (DF, 70%), followed by fipronil (48%). The findings indicated that the levels of dichlorvos and fipronil were in the same order of magnitude as specific maximum residue limit (MRL) values for meat. Most detected compounds were below the defined MRLs. However, it underscores the necessity for further extensive investigations to provide a comprehensive chemical characterisation of potential risks relating to edible insects as well as the need to establish (MRL) values for edible insects. These limited studies that do not focus entirely on target analysis show the importance of suspect screening for providing valuable insights into food/feed chemical characterisation and facilitating a more proactive and holistic approach to ensuring the safety of farmed insects. However, the full potential of applying a nontarget approach is still to be explored.

Biological risks must also be considered when contemplating the use of insects. The microbiota of insects, found in the gut and other anatomical parts, is complex. While the microbiota of some commercially essential insects has been analysed [50, 92–95], more work in this area remains to be done. This task is essential, as insects tend to be consumed entirely, with a few exceptions. Although most pathogenic microbes that infect insects are harmless to humans due to phylogenetic differences, insects can be vectors or carriers of harmful microbes, primarily when insects are reared under poorly controlled hygienic conditions [96]. Among the most harmful bacteria that inhabit all three insect species analysed within the INPROFF project (yellow mealworm, house cricket, and migratory locust), *Salmonella*, *Staphylococcus aureus*, *Clostridium perfringens*, and *Bacillus cereus* could be mentioned. Several bacterial species have been associated with edible insects, both farm-reared and wild-caught, and some of these are not only pathogenic and opportunistic bacteria, but they can also reduce the shelf-life of edible insects [97].

Endospore-forming bacteria in edible insects are also a significant food safety concern as the heat-resistant spores may withstand the standard processing methods adopted for edible insects, like drying, boiling, and deep-frying [98]. In this context, the *Bacillus cereus* group seems to be one of the most suitable parameters for describing food safety and microbial quality [99]. So far, risks associated with foodborne viruses, like hepatitis A, hepatitis E and norovirus, from consuming edible insects are low. However, care must be taken not to introduce the viruses in insect production units through their feed and unsafe handling practices. Insect species deemed fit for mass production may be vectors for parasites, although this risk may not be exceptionally high and is poorly documented [100, 101]. Contamination of edible insects post-processing is also an area of consideration [102].

The study of the pathogenicity of insect-specific viruses in humans is also an area for further study. Insect viruses are assumed to be specific to insect species and cannot replicate in vertebrate cells. Despite this limited specificity, there is a negligible risk of new strains of mammalian-specific viruses emerging due to recombination and rearrangement of genetic material, potentially leading to host switching. Although pathogenic viruses of vertebrates cannot replicate in insects, edible insects can still passively transmit these pathogens [63, 103]. Research into extending the shelf-life of processed or farmed insect-derived foods and feeds and microbial studies on farmed edible insects is still in its early stages [104]. Similarly, there is a gap in our understanding of other microbial risks, e.g., protists [105]. Most microbes in or on insects are not

considered harmful to human consumers. However, the microbial safety of insect-based foods intended for human consumption is still under debate, as insects could be vectors of potentially pathogenic bacteria.

Pillar III: authenticity, traceability, and consumer acceptance

The European Commission estimates that the total cost of food fraud globally is about 40 billion Euros annually [106]. Without the necessary tools, a nascent insect farming industry is ripe for economic fraud, such as product adulteration and mislabelling. The mapping of the insect supply chain in the study performed by Traynor et al. [70] illustrates the complexity that exists. This situation is worsened by the lack of standard procedures for determining the authenticity of insect products [107]. The literature review reveals a significant literature gap when searching "edible insects" and "authenticity" (hits = 12), with few studies investigating the potential fraud in edible insect food supply chains. INPROFF was partly set up to fill this gap by taking advantage of the IJS food authenticity and traceability expertise and applying it to farmed insect products. This task is made possible due to significant progress in developing accurate tools for determining the species-level authenticity of food and detecting adulterants [108–111].

One such tool involves the use of the stable isotope approach. Stable isotopes of light elements (expressed in δ^2H, δ^{13}C, δ^{15}N, δ^{18}O, and δ^{34}S) have been widely used to investigate food authenticity and origin [112], although for farmed edible insects for food and feed its use is limited to a few examples and is more widespread in insect ecology [113]. Nevertheless, the information obtained in ecological studies contributes to the knowledge needed to determine the authenticity of insects for food and feed. For example, the δ^{13}C values are strongly influenced by diet, providing insights about whether the insects fed on C3 or C4 plants [114]. The δ^{34}S values are also related to the food insects consume. The values are influenced by geology, microbial processes in the soil (including aerobic and anaerobic growing conditions), the distance from the sea ("sea spray effect") and fertilisation techniques [115, 116]. The δ^{15}N values of the animals are strongly related to their trophic level [117]. Herbivorous species are expected to have a lower δ^{15}N than carnivorous ones, as ^{15}N accumulates along the trophic chain [112]. The δ^2H and δ^{18}O of water are strictly related parameters [118] that depend on latitude, altitude, and even distance from the sea [119]. For plants, the correlation between δ^2H and δ^{18}O is still valid but not that strict, as the only source of hydrogen is the water absorbed through the stomata [120]. As the sources of oxygen and hydrogen of the insects are both the water they drink and the plants they eat, their δ^2H and δ^{18}O are influenced by such factors.

Pianezze et al. [121] analysed 40 samples of edible insects and four insect-based food items, providing δ^{13}C, δ^{15}N, δ^{34}S, δ^{18}O, and δ^2H data. Due to ingredient and flavour additions, they found δ^2H and δ^{18}O helpful in differentiating natural from seasoned insects. Other parameters, like δ^{13}C, δ^{15}N and δ^{34}S, showed promise in characterising insect diet, geographical origin, and trophic level. Macan Schönleben et al. [86] studied 52 edible insect species from Asia, Africa, and Europe, focusing on δ^{13}C, δ^{15}N, δ^{34}S, and δ^2H for food authenticity and traceability. Linear discriminative analysis differentiated geographical areas, with African samples showing distinct profiles, and accurately classified pesticide presence based on δ^{34}S values at a 76% rate.

INPROFF is developing a crucial component in food authenticity and traceability: establishing a reference dataset based on genuine samples, as highlighted by Donarski et al. [122]. This dataset will serve as a benchmark against which insect-based products in the market can be compared. Moreover, many aspects must be considered when developing such a database, including insect species, diet, environment, developmental stage, and processing techniques.

A study by Fuso et al. [123] further evaluates the analytical tools currently available to authenticate insects and their rearing substrate. The study emphasises the need for specialised analytical methods to detect rearing substrate residues in insect products or to reveal metabolomic changes caused by different feeds. A novel method for authenticating edible insect powders was recently introduced by Tata et al. [124] based on obtaining direct analysis in real-time high-resolution MS (DART-HRMS) signatures, marking it the first application of ambient MS to screen novel foods. The study successfully differentiated between four

test species (house cricket, yellow mealworm, migratory locust and silkworm) with a cross-validation accuracy of 100% for all training samples. A distinct metabolic fingerprint was observed for house cricket in particular. Additionally, Poma et al. [125] explored the potential of entometabolomics in food systems, marking a crucial step towards understanding edible insects' metabolic profiles that can be used to identify the authenticity of insect food.

Consumer acceptance

For humans, the eating of insects, termed "entomophagy", is not new and many species are already consumed by much of the world's population. The literature commonly quotes two billion plus people who regularly consume insects and suggests that insects could become a regular part of the Western diet [64]. However, entomophagy is not a cultural norm in Europe, and convincing those not accustomed to eating insects remains a significant hurdle to their acceptance. However, research is dedicated to making insects more palatable [126]. Today, insect-based products such as pasta, snacks, and protein bars are available on the European market, projected to be two billion euros/year by 2030 [127].

Food scientists have identified various factors influencing consumer acceptance of insect consumption, among which food neophobia and disgust remain the primary barriers to eating insects [128–130]. However, familiarity, tradition, and sensory attributes also affect the willingness to consume insects across different geographical locations and cultures [131]. While Western countries emphasise nutritional value and sustainability, sensory qualities and cultural practices play a more substantial role in regions where entomophagy has a longstanding tradition [132, 133].

The availability of information and prior experience with edible insects can positively shape consumer attitudes [134–136]. In Western societies, incorporating insects into familiar food products and communicating their environmental and nutritional benefits can enhance their acceptance [126, 131]. Additionally, focusing on product development that aligns with the sensory expectations of consumers [137, 138] and sparks curiosity about edible insects [139, 140] can lower the initial resistance towards them. Within the INPROFF project, a study performed by Kulma et al. [141] found that in the case of the Czech Republic, a significant percentage of those taking part described their entomology experience as positive (43.8%), 11.8% stated they regularly consumed insects, a small fraction (6.7%) reported negative experiences, and 37.7% remained neutral. Also, the data showed consumer preference leaned towards insect powder and processed whole insects such as crickets, katydids, and locusts, with cockroaches being the least favoured.

Metrological approach and challenges

All three pillars of the INPROFF project rely on analytical methods, and ensuring robustness between and comparability of the data obtained requires using appropriate metrological tools. Metrology is critical in ensuring that food products meet safety standards and regulatory requirements across the food supply chain, which can only be achieved through accurate, consistent, and traceable measurements. Typically, these include quality reference standards, validated standardised methods, standardised sampling practices, proven calibration methods and, where possible, matrix-specific certified reference materials (CRMs) in addition to reference materials (RMs), and interlaboratory comparisons are used to achieve comparability of analytical results [142]. Despite its importance in food research, this literature review found no specific studies (zero hits) applying metrology to farmed insects or significant discussion regarding its importance to the field.

For food products, including edible insect products, metrology is the foundation for supporting accurate labelling of food products, including nutritional information, ingredient lists, allergens, and expiration dates [143]. As the determinants of general nutritive quality (Pillar I), proximates such as lipids, carbohydrates, proteins, and minerals must be considered. Here, the standards are general reference methods collected under the International Organization for Standardization (ISO) system [144]. Moreover, within lipids and proteins, the content of essential components, such as essential amino acids and essential fatty acids, are determined by amino acid analysis and multidimensional gas chromatography [145]. In the

case of trace nutrients such as elements and vitamins, the methodology is much less standardised and under ongoing development [143].

Analytical methods for many known organic contaminants (Pillar II) in food have undergone extensive validation and standardisation [146]. Among the "new age" pollutants, pesticides are probably the most studied and multi-trace residue analysis methods are preferred over single-residue methods [147]. However, as already discussed earlier under Pillar II, the range of these pollutants is not complete and is expanding as the knowledge of the risks of consuming novel foods such as insects increases. Also, contaminants can transform in, for example, animal-derived food and predicting the structure and toxicity of their transformation products is a developing trend [148].

In trace analysis, quantitation is also more susceptible to analytical errors and statistical imprecision and demand methods with increased sensitivity and specificity, which, especially for the latter, is effectively achieved through chromatography (most commonly liquid) hyphenated to MS. However, although liquid chromatography-MS (LC-MS) is a highly specific and sensitive analytical technique, matrix effects are often caused by the alteration of ionisation efficiency of target analytes in the presence of co-eluting compounds in the same matrix and often impede signal intensity and even mass accuracy. Accordingly, the evaluation of matrix effects is explicitly suggested by regulative bodies like the United States Food and Drug Administration (US FDA) guidelines on bioanalytical analysis [149].

One of the most common approaches to account for uncertainty issues in target analysis is using an internal standard (IS). These are typically suitable surrogate compounds with properties similar to the target analyte, such as chemical structure, solubility, and volatility. In MS, they are ideally isotopically labelled chemicals (^{13}C, ^{15}N, or ^{2}H) since they are absent in samples but have the same characteristics. In MS-based target analysis of organic micropollutants, the addition of IS is used to compensate for losses of physicochemically similar compounds when internal calibration approaches are used. When targeting more extensive groups of contaminants, the set of IS should ideally cover the whole range of the chemical space to be explored (retention time, mass range, ionisation mode, and physicochemical properties). However, besides being impossible to account for all substances potentially present in the sample, only a limited number of compounds are commercially available in isotope-labelled form, and high price also limits their application [150].

The trend towards non-targeted high-resolution MS (HRMS) also raises metrological issues. Regarding nontarget analysis and suspect screening, methods focus on compound identification rather than quantitation. One of the most important scopes of NTA is that it can directly support chemical risk characterisation but must provide quantitative estimates. Even though limited quantitative NTA methods exist, they do not fully consider estimation uncertainty, and most nontarget approaches still need harmonisation and validation [151, 152]. Equally, in the case of new threats such as from nanoparticles and micro-/nanoplastics, as also discussed in Pillar II, their detection and quantification are limited by the complexity of the food matrix absence of suitable standards, making their identification and quantification challenging and represent major bottlenecks [153].

From a microbial risk perspective, appropriate ISO norms and standardised procedures exist to determine biological safety for classical food hygiene parameters [154]. For example, total aerobic and anaerobic bacterial counts, counts of *Staphylococcus aureus*, *E. coli* and *Enterobacteriaceae*, *Clostridium perfringens*, spore-forming bacteria, enterococci, and the presence of *Salmonella* were determined. *Bacillus cereus* (a microbial quality indicator) was detected according to ČSN EN ISO 7932 [155], identified by 16S rDNA sequencing, and its pathogenic potential was studied by detecting virulence-associated genes.

Another challenge is maintaining consistency and reproducibility in constructing microbial communities, especially in highly diverse microbial communities as in the case of fermentation [156, 157] or studying the effects of consuming insects on human gut microbiome [28] human and feed modification on the insect microbiome [41, 158] or for biotechnological applications [159]. Another trend that calls for the establishment of metrological tools is highlighted by Mattarozzi et al. [160], namely, the rapid development of point-of-need devices and low-cost portable testing, frequently intended for use by non-

experts. While this trend benefits the food industry enormously (e.g., faster results, on-site testing, improved food safety, cost reductions, enhanced traceability, and empowering non-experts), it leaves many metrological questions open regarding accuracy and reliability, standardisation, calibration, validation, and regulatory acceptance [160].

Metrology is particularly important for Pillar III since accurate measurements are essential to support the certification systems that ensure authenticity, prevent misleading claims, and prevent adulteration. Semiautomated and fast stable isotope-ratio analysis (SIRA) in continuous-flow mode with an elemental analyser (EA) interfaced with isotope-ratio MS (IRMS) has become a routine and invaluable tool for food authenticity and traceability (Pillar III) [161–163]. Several standardised analytical techniques have been officially recognised as well-established, validated and acknowledged by the Association of Official Agricultural Chemists (AOAC), the European Committee for Standardization (CEN), or EU methods [162]. Importantly, accurate measurements of relative stable isotope ratios of hydrogen (expressed as δ^{2}H), carbon (δ^{13}C), nitrogen (δ^{15}N), oxygen (δ^{18}O), and sulfur (δ^{34}S) require normalisation using at least two isotopic RMs with contrasting isotopic compositions to (i) anchor δ-values to conventional isotope—delta scales and (ii) compensate for differences in responses of analytical instrumentation, which commonly compress isotope—delta scales [164–166]. The new guidelines for reporting HCNOS isotopic delta values with JSI participation were recently published [167]. While authenticity identification usually works successfully with one or two stable isotope parameters, geographical origin determination often requires multiple stable isotope parameters and even the inclusion of elemental composition or heavier isotopes such as strontium. Other metrological tools include participation in interlaboratory [168] and the Consultative Committee for Metrology in Chemistry and Biology (CCQM) organised assessment [169] and development of new RMs of plant and animal origin [170].

From a metrological perspective and across all three thematic pillars, there is a notable deficiency in suitable RMs and interlaboratory trials, including collaborative trials, which aim to verify the performance of an analytical method, and proficiency testing, which focuses on assessing participants' performance [146]. RMs (and CRMs) represent one of the main metrological tools supporting reliable measurements regarding calibration, method validation and quality control, guaranteeing metrological traceability, method validation and quality control [146]. Ideally, RMs must be chemically as similar as possible to the sample to account for matrix effects, i.e., based on the studied insects.

While there has been an increase in the production of new RMs in recent years, there remains a shortage of RMs tailored explicitly for the agrifood sector despite the persistent demand to create new RMs with varied matrix/analyte combinations to meet evolving analytical needs. This necessity arises from several factors, including advancements in analytical techniques, the emergence of new parameters of interest (e.g., nanoparticles and micro/nanoplastics), the evolution of methods for food profiling for quality, authenticity, and traceability purposes, and the imperative to study emerging contaminants as discussed in this review highlights the emerging needs for new RMs. Addressing these methodological gaps presents a significant opportunity for future research [143, 146].

Conclusions

In this review, we addressed the current progress and challenges relating to farmed insects as food and feed, identified through the lens of the INPROFF project's core themes: nutrition enhancement, quality and safety, and authenticity. Three things quickly become apparent. The first is that interest in farming insects in a European context continues to grow; second, that much research has been and is being done, resulting in a significant body of research; and third, but just as important, there remains much to be learnt, and farming insects creates unique issues. The argument for accepting insects as alternative proteins for feed is economical, while as food, the issues remain regarding their negative perception. Both could be resolved, for example, in the former case by substitution and fortification (valorisation) of feed and the latter by incorporating insects as ingredients and developing new foods with increased functionality as added value or by improving their sensorial qualities thereby sidestepping any potential neophobia and possibly by also taking a more heuristic approach to increase acceptance.

The safety of farmed insects still poses nutritional, chemical, and biological challenges and gaps in our understanding to be filled, something that will become more significant if insects are reared on by-products of agriculture and waste streams from food processing. More work is needed to understand the transfer of contaminants from raw materials during production and processing, including exogenous and endogenous nonbiological and biological risks. The large number of potential contaminants also drives the development of nontarget analytical workflows based on high-resolution mass spectrometry methods. Also important is addressing the gaps in metrological challenges of analysing insects (and novel foods in general), which will be critical for ensuring safety, quality, and sustainability as they continue to gain prominence in the food industry. Finally, authenticity and adulteration are only now being addressed. Fortunately, many authenticating tools developed for other food groups based on chemical, isotopic and genetic methods can be adapted to farmed insects.

Abbreviations

AOAC: Association of Official Agricultural Chemists

ARIS: Slovenian Research Agency

CCQM: Consultative Committee for Metrology in Chemistry and Biology

CEN: European Committee for Standardization

CRMs: certified reference materials

CZU: Czech University of Life Sciences Prague

DART-HRMS: direct analysis in real-time high-resolution mass spectrometry

DDT: dichlorodiphenyltrichloroethane

DM: dry matter

EA: elemental analyser

EC: European Commission

EFSA: European Food Safety Authority

EU: European Union

FAO: Food and Agriculture Organisation

GAČR: The Czech Science Foundation

H-PFCA: hydrogen-substituted polyfluoroalkyl carboxylic acids

HRMS: high-resolution mass spectrometry

INPROFF: Quality, Safety and Authenticity of Insect Protein-Based Food and Feed

IPIFF: International Platform of Insects for Food and Feed

IRMS: isotope-ratio mass spectrometry

IS: internal standard

ISO: International Organization for Standardization

JSI: Jožef Stefan Institute

LAB: lactic acid bacteria

LC-MS: liquid chromatography-mass spectrometry

MRL: maximum residue limit

MS: mass spectrometry

PAH: polycyclic aromatic hydrocarbons

PAP: processed animal protein

PCBs: polychlorinated biphenyls

PFAS: polyfluorinated substances

PFBA: perfluorobutanoic acid

PFBS: perfluorobutanesulfonic acid

PFOA: perfluorooctanoic acid

PFOS: perfluorooctanesulfonic acid

PUFA: polyunsaturated fatty acids

RM: reference materials

SIRA: stable isotope-ratio analysis

ToF: Time-of-Flight

TSEs: transmissible spongiform encephalopathies

US FDA: United States Food and Drug Administration

Supplementary materials

The supplementary material for this article is available at: https://www.explorationpub.com/uploads/Article/file/101041_sup_1.pdf.

Declarations

Author contributions

DH: Conceptualisation, Investigation, Writing—original draft, Writing—review & editing. NO: Conceptualisation, Investigation, Writing—original draft, Writing—review & editing. All other authors, LK, MK, PŠ, AV, HŠS, BL, NR, PJ, BJ, MČ, NPU, and EH were responsible for writing and editing. All authors have reviewed and approved the submitted manuscript.

Conflicts of interest

Nives Ogrinc who is a guest editor for the special issue "Metrological Aspects in the Analysis of Nutrients, Functional Compounds, Additives and Contaminants in Food and Feed" of *Exploration of Foods and Foodomics* had no involvement in the decision-making or the review process of this manuscript. The other authors declare that they have no conflicts of interest.

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References

1. van Huis A, Van Itterbeeck J, Klunder H, Mertens E, Halloran A, Muir G, et al. Edible insects: future prospects for food and feed security. Rome: Food and Agriculture Organization of the United Nations; 2013.
2. Sogari G, Bellezza Oddon S, Gasco L, van Huis A, Spranghers T, Mancini S. Review: Recent advances in insect-based feeds: from animal farming to the acceptance of consumers and stakeholders. Animal. 2023;17:100904. [DOI] [PubMed]
3. van Huis A, Gasco L. Insects as feed for livestock production. Science. 2023;379:138–9. [DOI] [PubMed]
4. Albaladejo Román A. EU protein strategy. EPRS. 2023:1–8.
5. Wiesner E. DRAFT REPORT European Protein Strategy (2023/2015(INI)) Committee on Agriculture and Rural Development [Internet]. European Parliament; [cited 2024 Mar 27]. Available from: https://www.europarl.europa.eu/doceo/document/AGRI-PR-742624_EN.pdf
6. Radley-Gardner O, Beale H, Zimmermann R, editors. REGULATION (EU) 2015/2283 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2015 [Internet]. The European Parliament and the Council of the European Union; 2015 [cited 2024 Mar 28]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2283
7. Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety [Internet]. The European Parliament and the Council of the European Union; 2002 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/eli/reg/2002/178/oj
8. Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs [Internet]. The European Parliament and the Council of the European Union; 2004 [cited 2024 Mar 28]. Available from: https://eur-lex.europa.eu/eli/reg/2004/852/oj
9. Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law') (Text with EEA relevance) [Internet]. European Parliament and the Council; 2016 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/eli/reg/2016/429/oj
10. REGULATION (EU) No 1169/2011 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2011 [Internet]. European Parliament and the Council; 2011 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:304:0018:0063:en:PDF
11. COMMISSION IMPLEMENTING REGULATION (EU) 2019/626 of 5 March 2019 [Internet]. Official Journal of the European Union; 2019 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0626
12. COMMISSION REGULATION (EU) No 142/2011 of 25 February 2011 [Internet]. European Parliament and the Council; 2011 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0142

13. Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC (Text with EEA relevance) [Internet]. European Parliament and the Council; 2009 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009R0767
14. Commission Regulation (EU) No 68/2013 of 16 January 2013 on the Catalogue of feed materials Text with EEA relevance [Internet]. European Commission; 2013 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013R0068
15. Commission Regulation (EU) 2017/893 of 24 May 2017 amending Annexes I and IV to Regulation (EC) No 999/2001 of the European Parliament and of the Council and Annexes X, XIV and XV to Commission Regulation (EU) No 142/2011 as regards the provisions on processed animal protein (Text with EEA relevance.) [Internet]. European Parliament and the Council; 2017 [cited 2024 May 23]. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32017R0893
16. IPIFF Guide on Good Hygene and Practices. IPIFF; 2024 [cited 2024 Mar 28]. Available from: https://ipiff.org/good-hygiene-practices/
17. Kouřimská L, Adámková A. Nutritional and sensory quality of edible insects. NFS J. 2016;4:22–6. [DOI]
18. Shah AA, Totakul P, Matra M, Cherdthong A, Hanboonsong Y, Wanapat M. Nutritional composition of various insects and potential uses as alternative protein sources in animal diets. Anim Biosci. 2022;35:317–31. [DOI] [PubMed] [PMC]
19. Orkusz A. Edible Insects versus Meat-Nutritional Comparison: Knowledge of Their Composition Is the Key to Good Health. Nutrients. 2021;13:1207. [DOI] [PubMed] [PMC]
20. Tang C, Yang D, Liao H, Sun H, Liu C, Wei L, et al. Edible insects as a food source: a review. Food Prod Process and Nutr. 2019;1:8. [DOI]
21. Kvasnička F, Kouřimská L, Bleha R, Škvorová P, Kulma M, Rajchl A. Electrophoretic determination of chitin in insects. J Chromatogr A. 2023;1695:463952. [DOI] [PubMed]
22. Zielińska E, Pankiewicz U, Sujka M. Nutritional, Physiochemical, and Biological Value of Muffins Enriched with Edible Insects Flour. Antioxidants (Basel). 2021;10:1122. [DOI] [PubMed] [PMC]
23. Wu RA, Ding Q, Lu H, Tan H, Sun N, Wang K, et al. Caspase 3-mediated cytotoxicity of mealworm larvae (Tenebrio molitor) oil extract against human hepatocellular carcinoma and colorectal adenocarcinoma. J Ethnopharmacol. 2020;250:112438. [DOI] [PubMed]
24. Ordoñez-Araque R, Egas-Montenegro E. Edible insects: A food alternative for the sustainable development of the planet. Int J Gastron Food Sci. 2021;23:100304. [DOI]
25. Sabolová M, Kulma M, Škvorová P, Veselá K, Kurečka M, Kouřimská L. Investigating purine and uric acid contents of various development stages of artificially reared edible insects. J Ins Food Feed. 2023;9:77–85. [DOI]
26. Aiello D, Barbera M, Bongiorno D, Cammarata M, Censi V, Indelicato S, et al. Edible Insects an Alternative Nutritional Source of Bioactive Compounds: A Review. Molecules. 2023;28:699. [DOI]
27. Nino MC, Reddivari L, Ferruzzi MG, Liceaga AM. Targeted Phenolic Characterization and Antioxidant Bioactivity of Extracts from Edible *Acheta domesticus*. Foods. 2021;10:2295. [DOI] [PubMed] [PMC]
28. Young W, Arojju SK, McNeill MR, Rettedal E, Gathercole J, Bell N, et al. Feeding Bugs to Bugs: Edible Insects Modify the Human Gut Microbiome in an *in vitro* Fermentation Model. Front Microbiol. 2020;11:1763. [DOI] [PubMed] [PMC]
29. Durack J, Lynch SV. The gut microbiome: Relationships with disease and opportunities for therapy. J Exp Med. 2019;216:20–40. [DOI] [PubMed] [PMC]
30. Hamam M, D'Amico M, Di Vita G. Advances in the insect industry within a circular bioeconomy context: a research agenda. Environ Sci Eur. 2024;36:1–22. [DOI]

31. van Huis A. Prospects of insects as food and feed. Org Agr. 2021;11:301–8. [DOI]
32. van Huis A, Oonincx DGAB. The environmental sustainability of insects as food and feed. A review. Agron Sustain Dev. 2017;37:43. [DOI]
33. Oonincx DG, van Broekhoven S, van Huis A, van Loon JJ. Feed Conversion, Survival and Development, and Composition of Four Insect Species on Diets Composed of Food By-Products. PLoS One. 2015;10: e0144601. [DOI] [PubMed] [PMC]
34. Bava L, Jucker C, Gislon G, Lupi D, Savoldelli S, Zucali M, et al. Rearing of *Hermetia Illucens* on Different Organic By-Products: Influence on Growth, Waste Reduction, and Environmental Impact. Animals (Basel). 2019;9:289. [DOI] [PubMed] [PMC]
35. Halloran A, Hanboonsong Y, Roos N, Bruun S. Life cycle assessment of cricket farming in north-eastern Thailand. J Clea Prod. 2017;156:83–94. [DOI]
36. Suckling J, Druckman A, Moore CD, Driscoll D. The environmental impact of rearing crickets for live pet food in the UK, and implications of a transition to a hybrid business model combining production for live pet food with production for human consumption. Int J Life Cycle Assess. 2020;25:1693–709. [DOI]
37. Oonincx DG, de Boer IJ. Environmental impact of the production of mealworms as a protein source for humans - a life cycle assessment. PLoS One. 2012;7:e51145. [DOI] [PubMed] [PMC]
38. Oonincx DGAB, Finke MD. Nutritional value of insects and ways to manipulate their composition. JIFF. 2021;7:639–59. [DOI]
39. Barbi S, Macavei LI, Fuso A, Luparelli AV, Caligiani A, Ferrari AM, et al. Valorization of seasonal agri-food leftovers through insects. Sci Total Environ. 2020;709:136209. [DOI] [PubMed]
40. Kuo C, Fisher BL. A Literature Review of the Use of Weeds and Agricultural and Food Industry By-Products to Feed Farmed Crickets (Insecta; Orthoptera; Gryllidae). Front Sustain Food Syst. 2022;5: 810421. [DOI]
41. Mannaa M, Mansour A, Park I, Lee DW, Seo YS. Insect-based agri-food waste valorization: Agricultural applications and roles of insect gut microbiota. Environ Sci Ecotechnol. 2023;17: 100287. [DOI] [PubMed] [PMC]
42. Närvänen E, Mesiranta N, Mattila M, Heikkinen A, editors. Food Waste Management: Solving the Wicked Problem. Cham: Springer International Publishing; 2020.
43. Pérez-Grisales MS, Uribe Soto SI. Insects as sources of food and bioproducts: a review from Colombia. JoBAZ. 2022;83:56. [DOI]
44. Antoniadis V, Molla A, Grammenou A, Apostolidis V, Athanassiou CG, Rumbos CI, et al. Insect Frass as a Novel Organic Soil Fertilizer for the Cultivation of Spinach (Spinacia oleracea): Effects on Soil Properties, Plant Physiological Parameters, and Nutrient Status. J Soil Sci Plant Nutr. 2023;23: 5935–44. [DOI]
45. Chavez M, Uchanski M. Insect left-over substrate as plant fertiliser. JIFF. 2021;7:683–94. [DOI]
46. van Huis A. Insects as food and feed, a new emerging agricultural sector: a review. JIFF. 2020;6: 27–44. [DOI]
47. Škvorová P, Kulma M, Božik M, Kurečka M, Plachý V, Slavíková D, et al. Evaluation of rapeseed cake as a protein substitute in the feed of edible crickets: A case study using *Gryllus assimilis*. Food Chem. 2024;441:138254. [DOI]
48. Oonincx DGAB, Laurent S, Veenenbos ME, van Loon JJA. Dietary enrichment of edible insects with omega 3 fatty acids. Insect Sci. 2020;27:500–9. [DOI] [PubMed] [PMC]
49. Liput KP, Lepczyński A, Ogłuszka M, Nawrocka A, Poławska E, Grzesiak A, et al. Effects of Dietary n-3 and n-6 Polyunsaturated Fatty Acids in Inflammation and Cancerogenesis. Int J Mol Sci. 2021;22: 6965. [DOI] [PubMed] [PMC]
50. Borremans A, Lenaerts S, Crauwels S, Lievens B, Van Campenhout L. Marination and fermentation of yellow mealworm larvae (*Tenebrio molitor*). Food Control. 2018;92:47–52. [DOI]

51. Varelas V. Food Wastes as a Potential new Source for Edible Insect Mass Production for Food and Feed: A review. Fermentation. 2019;5:81. [DOI]
52. De Smet J, Lenaerts S, Borremans A, Scholliers J, Van Der Borght M, Van Campenhout L. Stability assessment and laboratory scale fermentation of pastes produced on a pilot scale from mealworms (*Tenebrio molitor*). LWT. 2019;102:113–21. [DOI]
53. Di Cagno R, Coda R, De Angelis M, Gobbetti M. Exploitation of vegetables and fruits through lactic acid fermentation. Food Microbiol. 2013;33:1–10. [DOI] [PubMed]
54. Hsu MF, Chiang BH. Effect of Bacillus subtilis natto–fermented *Radix astragali* on collagen production in human skin fibroblasts. Process Biochemistry. 2009;44:83–90. [DOI]
55. Septembre-Malaterre A, Remize F, Poucheret P. Fruits and vegetables, as a source of nutritional compounds and phytochemicals: Changes in bioactive compounds during lactic fermentation. Food Res Int. 2018;104:86–99. [DOI]
56. Quan J, Wang Y, Cheng X, Li C, Yuan Z. Revealing the effects of fermented food waste on the growth and intestinal microorganisms of black soldier fly (*Hermetia illucens*) larvae. Waste Manage. 2023; 171:580–9. [DOI]
57. An B, Sam C, Dries V, Ruben S, Christel V, Mik V, et al. Comparison of Six Commercial Meat Starter Cultures for the Fermentation of Yellow Mealworm (*Tenebrio molitor*) Paste. Microorganisms. 2019; 7:540. [DOI]
58. Hadj Saadoun J, Luparelli AV, Caligiani A, Macavei LI, Maistrello L, Neviani E, et al. Antimicrobial Biomasses from Lactic Acid Fermentation of Black Soldier Fly Prepupae and Related By-Products. Microorganisms. 2020;8:1785. [DOI] [PubMed] [PMC]
59. Lähteenmäki-Uutela A, Grmelová N. European Law on Insects in Food and Feed. Eur Food Feed Law Rev. 2016;11:2–8.
60. EU Legislation – General Overview [Internet]. IPIFF; 2024 [cited 2024 Apr 8]. Available from: https://ipiff.org/insects-eu-legislation-general/
61. Commission Regulation (EU) 2023/915 of 25 April 2023 on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006 (Text with EEA relevance) [Internet]. The European Comission; 2023 [cited 2024 Apr 15]. Available from: https://eur-lex.europa.eu/eli/reg/2023/915/oj
62. Halloran A, Roos N, Eilenberg J, Cerutti A, Bruun S. Life cycle assessment of edible insects for food protein: a review. Agron Sustain Dev. 2016;36:57. [DOI] [PubMed] [PMC]
63. van der Fels-Klerx HJ, Camenzuli L, Belluco S, Meijer N, Ricci A. Food Safety Issues Related to Uses of Insects for Feeds and Foods. Compr Rev Food Sci Food Saf. 2018;17:1172–83. [DOI] [PubMed]
64. Melgar-Lalanne G, Hernández-Álvarez AJ, Salinas-Castro A. Edible Insects Processing: Traditional and Innovative Technologies. Compr Rev Food Sci Food Saf. 2019;18:1166–91. [DOI] [PubMed]
65. Raheem D, Carrascosa C, Oluwole OB, Nieuwland M, Saraiva A, Millán R, et al. Traditional consumption of and rearing edible insects in Africa, Asia and Europe. Crit Rev Food Sci Nutr. 2019; 59:2169–88. [DOI] [PubMed]
66. Baiano A. Edible insects: An overview on nutritional characteristics, safety, farming, production technologies, regulatory framework, and socio-economic and ethical implications. Tre Food Sci Tec. 2020;100:35–50. [DOI]
67. Wade M, Hoelle J. A review of edible insect industrialization: scales of production and implications for sustainability. Environ Res Lett. 2020;15:123013. [DOI]
68. Meyer AM, Meijer N, Hoek-van Den Hil EF, Van Der Fels-Klerx HJ. Chemical food safety hazards of insects reared for food and feed. JIFF. 2021;7:823–31. [DOI]
69. Meyer-Rochow VB, Jung C. Insects Used as Food and Feed: Isn't That What We All Need? Foods. 2020;9:1003. [DOI]

70. Traynor A, Burns DT, Wu D, Karoonuthaisiri N, Petchkongkaew A, Elliott CT. An analysis of emerging food safety and fraud risks of novel insect proteins within complex supply chains. npj Sci Food. 2024; 8:7. [DOI]
71. Murefu TR, Macheka L, Musundire R, Manditsera FA. Safety of wild harvested and reared edible insects: A review. Food Cont. 2019;101:209–24. [DOI]
72. Vandeweyer D, De Smet J, Van Looveren N, Van Campenhout L. Biological contaminants in insects as food and feed. JIFF. 2021;7:807–22. [DOI]
73. Malematja E, Manyelo TG, Sebola NA, Kolobe SD, Mabelebele M. The accumulation of heavy metals in feeder insects and their impact on animal production. Sci Total Environ. 2023;885:163716. [DOI]
74. Poma G, Cuykx M, Amato E, Calaprice C, Focant JF, Covaci A. Evaluation of hazardous chemicals in edible insects and insect-based food intended for human consumption. Food Chem Toxicol. 2017; 100:70–9. [DOI] [PubMed]
75. Van Looveren N, Verbaet L, Frooninckx L, Van Miert S, Van Campenhout L, Van Der Borght M, et al. Effect of heat treatment on microbiological safety of supermarket food waste as substrate for black soldier fly larvae (Hermetia illucens). Waste Manag. 2023;164:209–18. [DOI] [PubMed] [PMC]
76. Imathiu S. Benefits and food safety concerns associated with consumption of edible insects. NFS J. 2020;18:1–11. [DOI]
77. Lange KW, Nakamura Y. Edible insects as future food: chances and challenges. J Future Foods. 2021; 1:38–46. [DOI]
78. Taylor MD, Nilsson S, Bräunig J, Bowles KC, Cole V, Moltschaniwskyj NA, et al. Do conventional cooking methods alter concentrations of per- and polyfluoroalkyl substances (PFASs) in seafood? Food Chem Toxicol. 2019;127:280–7. [DOI] [PubMed]
79. Vendl C, Pottier P, Taylor MD, Bräunig J, Gibson MJ, Hesselson D, et al. Thermal processing reduces PFAS concentrations in blue food - A systematic review and meta-analysis. Environ Pollut. 2022;304: 119081. [DOI] [PubMed]
80. Li W, Bischel HN. Are resource recovery insects safe for feed and food? A screening approach for bioaccumulative trace organic contaminants. Sci Total Environ. 2022;837:155850. [DOI] [PubMed]
81. Sahai H, Bueno MJM, Del Mar Gómez-Ramos M, Fernández-Alba AR, Hernando MD. Quantification of nanoplastic uptake and distribution in the root, stem and leaves of the edible herb Lepidum sativum. Sci Total Environ. 2024;912:168903. [DOI] [PubMed]
82. Vitali C, Peters RJB, Janssen HG, Nielen MWF. Microplastics and nanoplastics in food, water, and beverages; part I. occurrence. TrAC Trends in Anal Chem. 2023;159:116670. [DOI]
83. Peng X, Yang T, Guo S, Zhou J, Chen G, Zhu Z, et al. Revealing chemical release from plastic debris in animals' digestive systems using nontarget and suspect screening and simulating digestive fluids. Environmental Pollution. 2024;348:123793. [DOI]
84. Sahai H, García Valverde M, Murcia Morales M, Hernando MD, Aguilera Del Real AM, Fernández-Alba AR. Exploring sorption of pesticides and PAHs in microplastics derived from plastic mulch films used in modern agriculture. Chemosphere. 2023;333:138959. [DOI]
85. De Paepe E, Wauters J, Van Der Borght M, Claes J, Huysman S, Croubels S, et al. Ultra-high-performance liquid chromatography coupled to quadrupole orbitrap high-resolution mass spectrometry for multi-residue screening of pesticides, (veterinary) drugs and mycotoxins in edible insects. Food Chem. 2019;293:187–96. [DOI] [PubMed]
86. Macan Schönleben A, Yin S, Strak E, Johnson A, Belova L, Ait Bamai Y, et al. Stable isotope ratios and current-use pesticide levels in edible insects: Implications on chemical food safety. Food Res Int. 2024;179:114020. [DOI] [PubMed]
87. Marder ME. The exposome—An introduction to concepts, frameworks, characterization, and research applications. In: Wexler P, editor. Encyclopedia of Toxicology (Fourth Edition). Academic Press; 2024. pp. 573–8. [DOI]

88. Díaz R, Ibáñez M, Sancho JV, Hernández F. Target and non-target screening strategies for organic contaminants, residues and illicit substances in food, environmental and human biological samples by UHPLC-QTOF-MS. Anal Methods. 2012;4:196–209. [DOI]
89. Zhang Y, Chen T, Chen D, Liang W, Lu X, Zhao C, et al. Suspect and nontarget screening of mycotoxins and their modified forms in wheat products based on ultrahigh-performance liquid chromatography-high resolution mass spectrometry. J Chromatogr A. 2023;1708:464370. [DOI] [PubMed]
90. Kaufmann A. Analytical performance of the various acquisition modes in Orbitrap MS and MS/MS. J Mass Spectrom. 2018;53:ii. [DOI]
91. Steiner D, Malachová A, Sulyok M, Krska R. Challenges and future directions in LC-MS-based multiclass method development for the quantification of food contaminants. Anal Bioanal Chem. 2021;413:25–34. [DOI]
92. Grabowski NT, Klein G. Microbiological analysis of raw edible insects. JIFF. 2017;3:7–14. [DOI]
93. Milanović V, Cardinali F, Aquilanti L, Garofalo C, Roncolini A, Sabbatini R, et al. A Glimpse into the Microbiota of Marketed Ready-to-Eat Crickets (*Acheta domesticus*). Indian J Microbiol. 2020;60:115–8. [DOI]
94. Nyangena DN, Mutungi C, Imathiu S, Kinyuru J, Affognon H, Ekesi S, et al. Effects of Traditional Processing Techniques on the Nutritional and Microbiological Quality of Four Edible Insect Species Used for Food and Feed in East Africa. Foods. 2020;9:574. [DOI] [PubMed] [PMC]
95. Osimani A, Milanović V, Garofalo C, Cardinali F, Roncolini A, Sabbatini R, et al. Revealing the microbiota of marketed edible insects through PCR-DGGE, metagenomic sequencing and real-time PCR. Int J Food Microbiol. 2018;276:54–62. [DOI] [PubMed]
96. Zurek L, Gorham JR. Insects As Vectors Of Foodborne Pathogens. In: Wiley Handbook of Science and Technology for Homeland Security. John Wiley & Sons, Ltd; 2008. p. 1. [DOI]
97. Maciel-Vergara G, Jensen AB, Lecocq A, Eilenberg J. Diseases in edible insect rearing systems. JIFF. 2021;7:621–38. [DOI]
98. Osimani A, Aquilanti L. Spore-forming bacteria in insect-based foods. Curr Opin Food Sci. 2021;37:112–7. [DOI]
99. Fasolato L, Cardazzo B, Carraro L, Fontana F, Novelli E, Balzan S. Edible processed insects from e-commerce: Food safety with a focus on the *Bacillus cereus* group. Food Microbiology. 2018;76:296–303. [DOI]
100. Gałęcki R, Sokół R. A parasitological evaluation of edible insects and their role in the transmission of parasitic diseases to humans and animals. PLoS One. 2019;14:e0219303. [DOI] [PubMed] [PMC]
101. Herren P, Hesketh H, Meyling NV, Dunn AM. Environment-host-parasite interactions in mass-reared insects. Trends Parasitol. 2023;39:588–602. [DOI] [PubMed]
102. Liceaga AM. Processing insects for use in the food and feed industry. Curr Opin Insect Sci. 2021;48:32–6. [DOI] [PubMed]
103. Doi H, Gałęcki R, Mulia RN. The merits of entomophagy in the post COVID-19 world. Trends Food Sci Technol. 2021;110:849–54. [DOI] [PubMed] [PMC]
104. Ojha S, Bußler S, Psarianos M, Rossi G, Schlüter OK. Edible insect processing pathways and implementation of emerging technologies. JIFF. 2021;7:877–900. [DOI]
105. Bessette E, Williams B. Protists in the Insect Rearing Industry: Benign Passengers or Potential Risk? Insects. 2022;13:482. [DOI]
106. The EU Food Fraud Network and The System for Administrative Assistance - Foof Fraud [Internet]. European comission; 2018 [cited 2024 Apr 4]. Available from: https://food.ec.europa.eu/system/files/2020-05/ff_ffn_annual-report_2018.pdf
107. Frigerio J, Agostinetto G, Sandionigi A, Mezzasalma V, Berterame NM, Casiraghi M, et al. The hidden 'plant side' of insect novel foods: A DNA-based assessment. Food Res Int. 2020;128:108751. [DOI]

108. Hamzić Gregorčič S, Potočnik D, Camin F, Ogrinc N. Milk Authentication: Stable Isotope Composition of Hydrogen and Oxygen in Milks and Their Constituents. Molecules. 2020;25:4000. [DOI] [PubMed] [PMC]
109. Potočnik D, Nečemer M, Perišić I, Jagodic M, Mazej D, Camin F, et al. Geographical verification of Slovenian milk using stable isotope ratio, multi-element and multivariate modelling approaches. Food Chem. 2020;326:126958. [DOI] [PubMed]
110. Strojnik L, Potočnik D, Jagodic Hudobivnik M, Mazej D, Japelj B, Škrk N, et al. Geographical identification of strawberries based on stable isotope ratio and multi-elemental analysis coupled with multivariate statistical analysis: A Slovenian case study. Food Chem. 2022;381:132204. [DOI] [PubMed]
111. Krajnc B, Bontempo L, Luis Araus J, Giovanetti M, Alegria C, Lauteri M, et al. Selective Methods to Investigate Authenticity and Geographical Origin of Mediterranean Food Products. Food Rev Int. 2021;37:656–82. [DOI]
112. Danezis GP, Tsagkaris AS, Camin F, Brusic V, Georgiou CA. Food authentication: Techniques, trends & emerging approaches. TrAC Trends Anal Chem. 2016;85:123–32. [DOI]
113. Quinby BM, Creighton JC, Flaherty EA. Stable isotope ecology in insects: a review. Ecol Entomol. 2020;45:1231–46. [DOI]
114. Knobbe N, Vogl J, Pritzkow W, Panne U, Fry H, Lochotzke HM, et al. C and N stable isotope variation in urine and milk of cattle depending on the diet. Anal Bioanal Chem. 2006;386:104–8. [DOI]
115. Krouse HR, Mayer B. Sulphur and Oxygen Isotopes in Sulphate. In: Cook PG, Herczeg AL, editors. Environmental Tracers in Subsurface Hydrology. Boston, MA: Springer US; 2000. pp. 195–231. [DOI]
116. Rubenstein DR, Hobson KA. From birds to butterflies: animal movement patterns and stable isotopes. Trends Ecol Evol. 2004;19:256–63. [DOI]
117. O'Brien DM. Stable Isotope Ratios as Biomarkers of Diet for Health Research. Annu Rev Nutr. 2015; 35:565–94. [DOI] [PubMed] [PMC]
118. Araguas LA, Danesi P, Froehlich K, Rozanski K. Global monitoring of the isotopic composition of precipitation. J Radioanal Nucl Chem. 1996;205:189–200. [DOI]
119. Bowen GJ, Ehleringer JR, Chesson LA, Stange E, Cerling TE. Stable isotope ratios of tap water in the contiguous United States. Water Res Res. 2007;43:2006WR005186. [DOI]
120. Barbour M. Stable oxygen isotope composition of plant tissue: a review. Funct Plant Biol. 2007;34: 83–94. [DOI]
121. Pianezze S, Perini M, Bontempo L, Piasentier E, Poma G, Covaci A, et al. Stable isotope ratio analysis for the characterisation of edible insects. J Ins Food Feed. 2021;7:955–64. [DOI]
122. Donarski J, Camin F, Fauhl-Hassek C, Posey R, Sudnik M. Sampling guidelines for building and curating food authenticity databases. Trends Food Sci Technol. 2019;90:187–93. [DOI]
123. Fuso A, Leni G, Prandi B, Lolli V, Caligiani A. Novel foods/feeds and novel frauds: The case of edible insects. Trends Food Sci Technol. 2024;147:104457. [DOI]
124. Tata A, Massaro A, Marzoli F, Miano B, Bragolusi M, Piro R, et al. Authentication of Edible Insects' Powders by the Combination of DART-HRMS Signatures: The First Application of Ambient Mass Spectrometry to Screening of Novel Food. Foods. 2022;11:2264. [DOI]
125. Poma G, Cuykx M, Da Silva KM, Iturrospe E, Van Nuijs ALN, Van Huis A, et al. Edible insects in the metabolomics era. First steps towards the implementation of entometabolomics in food systems. Trends Food Sci Technol. 2022;119:371–7. [DOI]
126. Alhujaili A, Nocella G, Macready A. Insects as Food: Consumers' Acceptance and Marketing. Foods. 2023;12:886. [DOI] [PubMed] [PMC]

127. Europe Edible Insects Market to Reach $2.98 Billion by 2030. Europe Edible Insects Market by Product (Insect Powder, Insect Meal, Insect Oil), Insect Type (Crickets, Black Soldier Fly, Mealworms, Ants, Grasshoppers), Application (Animal Feed, Pet Food, Protein Bar & Shakes, Bakery, Confectionery) - Forecast to 2030 [Internet]. California: Meticulous Research; 2023 [cited 2024 Apr 8]. Available from: https://www.meticulousresearch.com/pressrelease/795/europe-edible-insects-market-2030
128. La Barbera F, Verneau F, Amato M, Grunert K. Understanding Westerners' disgust for the eating of insects: The role of food neophobia and implicit associations. Food Qual Preference. 2018;64:120–5. [DOI]
129. Lorini C, Ricotta L, Vettori V, Del Riccio M, Biamonte MA, Bonaccorsi G. Insights into the Predictors of Attitude toward Entomophagy: The Potential Role of Health Literacy: A Cross-Sectional Study Conducted in a Sample of Students of the University of Florence. IJERPH. 2021;18:5306. [DOI]
130. Ardoin R, Prinyawiwatkul W. Consumer perceptions of insect consumption: a review of western research since 2015. Int J of Food Sci Tech. 2021;56:4942–58. [DOI]
131. Van Huis A, Rumpold B. Strategies to convince consumers to eat insects? A review. Food Qual Preference. 2023;110:104927. [DOI]
132. Kröger T, Dupont J, Büsing L, Fiebelkorn F. Acceptance of Insect-Based Food Products in Western Societies: A Systematic Review. Front Nutr. 2022;8:759885. [DOI] [PubMed] [PMC]
133. Tan HSG, van den Berg E, Stieger M. The influence of product preparation, familiarity and individual traits on the consumer acceptance of insects as food. Food Qual Preference. 2016;52:222–31. [DOI]
134. Suzuki S, Park J. Consumer evaluation of healthy, unpleasant-tasting food and the post-taste effect of positive information. Food Qual Preference. 2018;66:107–10. [DOI]
135. Woolf E, Maya C, Yoon J, Shertukde S, Toia T, Zhao J, et al. Information and taste interventions for improving consumer acceptance of edible insects: a pilot study. J Ins Food Feed. 2020;7:129–40. [DOI]
136. Hartmann C, Siegrist M. Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. Trends Food Sci Technol. 2017;61:11–25. [DOI]
137. Mishyna M, Chen J, Benjamin O. Sensory attributes of edible insects and insect-based foods – Future outlooks for enhancing consumer appeal. Trends Food Sci Technol. 2020;95:141–8. [DOI]
138. Schouteten JJ, De Steur H, De Pelsmaeker S, Lagast S, Juvinal JG, De Bourdeaudhuij I, et al. Emotional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions. Food Qual Preference. 2016;52:27–31. [DOI]
139. Stone H, FitzGibbon L, Millan E, Murayama K. Encouraging willingness to try insect foods with a utility-value intervention. Appetite. 2023;190:107002. [DOI]
140. Sogari G, Menozzi D, Mora C. Exploring young foodie' knowledge and attitude regarding entomophagy: A qualitative study in Italy. Int J Gas Food Sci. 2017;7:16–9. [DOI]
141. Kulma M, Tůmová V, Fialová A, Kouřimská L. Insect consumption in the Czech Republic: what the eye does not see, the heart does not grieve over. J Ins Food Feed. 2020;6:525–35. [DOI]
142. Iyengar V. Metrological concepts for enhancing the reliability of food and nutritional measurements. J Food Compos Anal. 2007;20:449–50. [DOI]
143. Tsimidou MZ, Ordoudi SA, Mantzouridou FTh, Nenadis N, Stelzl T, Rychlik M, et al. Strategic Priorities of the Scientific Plan of the European Research Infrastructure METROFOOD-RI for Promoting Metrology in Food and Nutrition. Foods. 2022;11:599. [DOI]
144. Management system standards [Internet]. [Cited 2024 Apr 15]. Available from: https://www.iso.org/management-system-standards.html
145. Nolvachai Y, Kulsing C, Marriott PJ. Multidimensional gas chromatography in food analysis. TrAC Trends Anal Chem. 2017;96:124–37. [DOI]
146. Sorbo A, Pucci E, Nobili C, Taglieri I, Passeri D, Zoani C. Food Safety Assessment: Overview of Metrological Issues and Regulatory Aspects in the European Union. Separations. 2022;9:53. [DOI]

147. Ismail B, Reuhs BL, Nielsen SS. Analysis of Food Contaminants, Residues, and Chemical Constituents of Concern. In: Nielsen SS, editor. Food Analysis. Boston, MA: Springer US; 2010. pp. 317–49. [DOI]
148. Jia Q, Liao GQ, Chen L, Qian YZ, Yan X, Qiu J. Pesticide residues in animal-derived food: Current state and perspectives. Food Chem. 2024;438:137974. [DOI] [PubMed]
149. Zhou W, Yang S, Wang PG. Matrix effects and application of matrix effect factor. Bioanalysis. 2017;9:1839–44. [DOI] [PubMed]
150. Hollender J, Schymanski EL, Ahrens L, Alygizakis N, Béen F, Bijlsma L, et al. NORMAN guidance on suspect and non-target screening in environmental monitoring. Environ Sci Eur. 2023;35:75. [DOI]
151. Fisher CM, Peter KT, Newton SR, Schaub AJ, Sobus JR. Approaches for assessing performance of high-resolution mass spectrometry–based non-targeted analysis methods. Anal Bioanal Chem. 2022;414:6455–71. [DOI]
152. McCord JP, Groff LC, Sobus JR. Quantitative non-targeted analysis: Bridging the gap between contaminant discovery and risk characterization. Environ Int. 2022;158:107011. [DOI]
153. Sohail M, Urooj Z, Noreen S, Baig MMFA, Zhang X, Li B. Micro- and nanoplastics: Contamination routes of food products and critical interpretation of detection strategies. Sci Total Environ. 2023;891:164596. [DOI]
154. Lombard B, Leclercq A. The Role of Standardization Bodies in the Harmonization of Analytical Methods in Food Microbiology. In: Barbosa-Cánovas G, Mortimer A, Lineback D, Spiess W, Buckle K, Colonna P, editors. Global Issues in Food Science and Technology. San Diego: Academic Press; 2009. pp. 177–97. [DOI]
155. ISO 7932:2004/Amd 1:2020 Microbiology of food and animal feeding stuffs Horizontal method for the enumeration of presumptive Bacillus cereus Colony-count technique at 30 degrees C [Internet]. ISO; 2020 [cited 2024 Apr 15]. Available from: https://www.iso.org/standard/76664.html
156. Wolfe BE. Using Cultivated Microbial Communities To Dissect Microbiome Assembly: Challenges, Limitations, and the Path Ahead. mSystems. 2018;3:e00161-17. [DOI] [PubMed] [PMC]
157. Karkaria BD, Fedorec AJH, Barnes CP. Automated design of synthetic microbial communities. Nat Commun. 2021;12:672. [DOI] [PubMed] [PMC]
158. Luo J, Cheng Y, Guo L, Wang A, Lu M, Xu L. Variation of gut microbiota caused by an imbalance diet is detrimental to bugs' survival. Sci Total Environ. 2021;771:144880. [DOI] [PubMed]
159. Krishnan M, Bharathiraja C, Pandiarajan J, Prasanna VA, Rajendhran J, Gunasekaran P. Insect gut microbiome - An unexploited reserve for biotechnological application. Asian Pac J Trop Biomed. 2014;4:S16–21. [DOI] [PubMed] [PMC]
160. Mattarozzi M, Laski E, Bertucci A, Giannetto M, Bianchi F, Zoani C, et al. Metrological traceability in process analytical technologies and point-of-need technologies for food safety and quality control: not a straightforward issue. Anal Bioanal Chem. 2023;415:119–35. [DOI] [PubMed] [PMC]
161. Carter J, Chesson LA. Food Forensics Stable Isotopes as a Guide to Authenticity and Origin. 1st ed. Boca Raton: CRC Press; 2017. [DOI]
162. Camin F, Boner M, Bontempo L, Fauhl-Hassek C, Kelly SD, Riedl J, et al. Stable isotope techniques for verifying the declared geographical origin of food in legal cases. Trends Food Sci Technol. 2017;61:176–87. [DOI]
163. Kelly S, Brodie C, Hilkert A. Isotopic-Spectroscopic Technique: Stable Isotope-Ratio Mass Spectrometry (IRMS). In: Sun DW, editor. Modern Techniques for Food Authentication (Second Edition). Academic Press; 2018. pp. 349–13. [DOI]
164. Brand WA, Coplen TB, Vogl J, Rosner M, Prohaska T. Assessment of international reference materials for isotope-ratio analysis (IUPAC Technical Report). Pure and Applied Chemistry. 2014;86:425–67. [DOI]
165. Dunn PJH, Malinovsky D, Goenaga-Infante H. Calibration hierarchies for light element isotope delta reference materials. Rapid Commun Mass Spectrom. 2020;34:e8711. [DOI] [PubMed]

166. Meier-Augenstein W, Schimmelmann A. A guide for proper utilisation of stable isotope reference materials. Isotopes Environ Health Stud. 2019;55:113–28. [DOI] [PubMed]
167. Skrzypek G, Allison CE, Böhlke JK, Bontempo L, Brewer P, Camin F, et al. Minimum requirements for publishing hydrogen, carbon, nitrogen, oxygen and sulfur stable-isotope delta results (IUPAC Technical Report). Pure Appl Chem. 2022;94:1249–55. [DOI]
168. Dunn PJH, Hill S, Cowen S, Goenaga-Infante H, Sargent M, Gören AC, et al. Lessons learned from inter-laboratory studies of carbon isotope analysis of honey. Sci Justice. 2019;59:9–19. [DOI] [PubMed]
169. Chartrand MMG, Chubchenko I, Dunn PJH, Garrido BC, Hai L, Liu FH, et al. Final report on CCQM-K167: carbon isotope delta measurements of vanillin. Metrologia. 2022;59:08004.
170. Schimmelmann A, Qi H, Dunn PJH, Camin F, Bontempo L, Potočnik D, et al. Food Matrix Reference Materials for Hydrogen, Carbon, Nitrogen, Oxygen, and Sulfur Stable Isotope-Ratio Measurements: Collagens, Flours, Honeys, and Vegetable Oils. J Agric Food Chem. 2020;68:10852–64. [DOI]

Quality, safety and authenticity of insect protein-based food and feed: insights from the INPROFF Project

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Table S1. Search results (hits) for the search term "edible insects" AND targeted keywords tailored to each pillar theme

Pillar I: Enhancing Nutritional quality of insect biomass		**Pillar II: Safety and Quality**		**Pillar III: Authenticity, traceability and consumer acceptance**	
Search terms: "edible insects" AND	Hits	Search terms: "edible insects" AND	Hits	Search terms: "edible insects" AND	Hits
"nutritional value"	338	"safety"	362	"authenticity"	12
"sensorial properties"	5	"chemical safety"	13	"traceability"	4
"shelf life"	43	"microbiological safety"	12	"adulteration"	8
"feed"	515	"toxic elements"	5	"labelling"	24
"feed modification"	0	"plant toxins"	3	"stable isotopes"	6
"proteins"	1,178	"mycotoxins"	28	"origin"	60
"amino acids"	282	"contaminants"	35	"entomophagy"	556
"fatty acids"	286	"chemical contaminants"	5	"consumer acceptance"	124
"fibre"	130	"pesticide residues"	12		
"chitin"	103	"biohazard"	1	Metrological approach and challenges	
"minerals"	218	"agricultural by-products"	5	Search terms: "edible insects" AND	Hits
"elements"	85	"food waste"	28	"metrology"	0
"vitamins"	161	"microplastic"	2	"reference material"	2
"bioactive compounds"	64	"suspect screening"	1		
"anti-nutrients"	11	"HRMS"	4		
"gut microbiome"	8	"microbiota"	59		
"fermentation"	49	"pathogenic microorganisms"	9		
		"viruses"	16		

Table S2. Search results (hits) for the search term "edible insects" AND studied species

Search term: "edible insects" AND	**Hits**
"*Tenebrio molitor*"	333
"Locusta migratoria"	60
"Acheta domesticus"	158

3.4 Scientific Paper: "Drivers and Barriers Influencing Adherence to the Mediterranean Diet: A Comparative Study across Five Countries"

The paper titled "Drivers and Barriers Influencing Adherence to the Mediterranean Diet: A Comparative Study across Five Countries" by Chiara Biggi, Beatrice Biasini, Nives Ogrinc, Lidija Strojnik, Isabella Endrizzi, Leonardo Menghi, Ikram Khémiri, Amani Mankai, Fethi Ben Slama, Henda Jamoussi, Katerina Riviou, Kaoutar Elfazazi, Nayyer Rehman, Francesca Scazzina, and Davide Menozzi is presented in this chapter. I contributed to the literature review on consumer behaviour and the importance of the Mediterranean diet (MD) for dietary health, as well as critical insights in the discussion section on consumer attitudes and MD adherence trends across different regions. This article was published in *Nutrients* in 2024 and examines MD adherence in Greece, Italy, Morocco, Slovenia, and Tunisia.

The study aims to understand the complex drivers and barriers influencing consumer adoption of the MD, a dietary pattern prioritising plant-based, minimally processed foods, and linked to substantial health benefits, such as improved cardiovascular health and reduced chronic disease risk. Although the MD is widely regarded as beneficial, adherence has declined even in its traditional regions, making it essential to explore the motivations and barriers faced by consumers to support more effective and targeted interventions.

The study employed a robust mixed-methods approach, beginning with qualitative focus groups in each country to capture local perspectives on MD adherence, including attitudes towards health, sustainability, and cultural significance. These focus groups provided nuanced insights into regional differences and were instrumental in shaping an extensive online survey distributed to 4,025 participants across the five countries.

The survey integrated the MEDAS questionnaire to assess MD adherence and adapted parts from the Food Choice Questionnaire (FCQ) to explore drivers such as health, cost, sensory appeal, and convenience. Questions examined deeper social and cultural influences, such as family traditions, fast food availability, and social dining practices. Statistical analysis via structural equation modelling (SEM) enabled the evaluation of predictors of MD adherence, incorporating variables such as consumer motivations, sustainability attitudes, and food neophobia to provide a comprehensive picture of consumer behaviour.

Key findings revealed moderate-to-low adherence to the MD, with Italy and Morocco exhibiting the highest adherence and Slovenia the lowest. Health motivations, sustainable food choices, and awareness of environment emerged as strong positive predictors, particularly in Italy and Morocco, where cultural ties remain relatively strong. Sensory appeal, convenience, and price presented significant barriers, especially in Tunisia and Greece, where economic constraints and Westernised diets create challenges for consumers.

Cross-country comparisons highlighted that while the MD's cultural heritage resonates in certain regions, economic and lifestyle factors such as high costs, limited availability ingredients, and accessibility to fast food can impede adherence, particularly among younger populations. The study recommends tailored interventions such as policy adjustments to improve food affordability, education campaigns emphasising health benefits, and strategies to integrate MD principles into modern lifestyles.

This work was a result of collaboration between multiple projects, primarily centred around the EU-funded PROMEDLIFE project through the PRIMA programme. These extensive collaborative efforts reflect a larger commitment to advancing sustainable dietary patterns across Europe and underscore the study's relevance within the European Union's broader health and sustainability goals.

nutrients

MDPI

Article

Drivers and Barriers Influencing Adherence to the Mediterranean Diet: A Comparative Study across Five Countries

Chiara Biggi [1], Beatrice Biasini [1], Nives Ogrinc [2], Lidija Strojnik [2], Isabella Endrizzi [3], Leonardo Menghi [4], Ikram Khémiri [5,6], Amani Mankai [5,7], Fethi Ben Slama [5,7], Henda Jamoussi [5,8], Katerina Riviou [9], Kaoutar Elfazazi [10], Nayyer Rehman [11], Francesca Scazzina [1] and Davide Menozzi [1,*]

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Abstract: Given the global decline in adherence to the Mediterranean Diet (MD), even within its native region, it is key to identify the factors influencing this trend to mitigate the negative health outcomes associated with westernized diets. To this end, 4025 individuals (49.6% women, 42.6 ± 14.2 y/o) from Greece, Italy, Morocco, Slovenia, and Tunisia remotely completed a series of measures assessing motives, attitudes, and psychosocial factors related to MD adherence, which was evaluated using the MEDAS questionnaire. The results suggested medium-to-low adherence across all countries, with the highest adherence in Italy and Morocco and the lowest in Slovenia. Structural equation modeling revealed that positive attitudes toward the healthiness of food were the strongest predictors of adherence, whereas picky eating was a significant negative predictor in all countries except Greece. Adherence to the MD was positively influenced by health motivations in Morocco and weight control in Slovenia and Greece, while sensory appeal negatively influenced adherence in Italy. Additionally, price and convenience were significant barriers in Tunisia and Greece, whereas a preference for local and seasonal foods promoted adherence in Morocco and Greece. Overall, our findings underscore the need for country-specific interventions and policies that address distinct local factors and motivations to ease favorable shifts in dietary patterns toward MD principles.

Keywords: Mediterranean diet; attitude; behavior; picky eating; food choice motives; sustainability food choice motives

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1. Introduction

The Mediterranean Diet (MD) is deeply rooted in the cultural and agricultural traditions of countries around the Mediterranean Sea [1]. The MD was first described by Ancel Keys in the 1960s, based on eating habits in Greece and Southern Italy. This diet is known for being low in saturated fats and high in vegetable oils. It includes plenty of vegetables, fruits, nuts, seeds, legumes, whole grains, and olive oil, with moderate amounts of fish, poultry and alcohol (mainly wine), and limited dairy, red meat, processed meats, and sweets [2,3].

It has long been followed by these populations for its emphasis on the quality and origin of food, using fresh, locally sourced, and seasonal ingredients. Not only does the MD improve physical health but it also promotes social interactions through communal meals, enhancing social and mental well-being [4,5]. The positive social impact and the improvement in healthiness due to adherence to the Mediterranean Diet (MD) are supported by several epidemiological studies [6]. The MD has been linked to many health benefits, particularly its ability to reduce the risk of heart disease [7]. It improves cardiovascular health by lowering LDL cholesterol and reducing inflammation, as well as decreasing the risk of stroke [8–10]. The MD has also been found to positively impact reproductive health and metabolic health [11], diabetes management [12], and certain cancers [13]. Beyond physical health, it potentially lowers the risk of cognitive dysfunction and neurodegenerative disorders, particularly Alzheimer's disease [5].

Moreover, the MD has a relatively low environmental footprint concerning water, nitrogen, and carbon due to its focus on mainly plant-based options and legumes. When the Mediterranean diet is embraced not only for its health benefits but also as an environmentally sustainable dietary choice, it can positively contribute to biodiversity preservation and foster local economic sustainability [14,15].

Despite its well-known benefits, the adoption of the MD has been gradually decreasing [16], as well as in several countries around the Mediterranean Basin [17–19]. In fact, Kamiński et al. [20] found that the MD ranked 16th in their global diet popularity study. These findings may tentatively be attributed to the indirect consequences of social and cultural changes, increasing urbanization [21], as well as to the globalization of food systems within Mediterranean countries [22–24]. People have shifted toward a more western type of diet, with an associated reduced consumption of fruits and vegetables [25], in favor of more convenient, quick to prepare, and processed alternatives.

One of the main causes for this could be attributed to limited awareness and understanding of the health benefits of the MD [26]. Understanding consumer behavior is essential because attitudes, preferences, and awareness directly influence dietary choices. Often, cultural habits and personal food preferences make it challenging for people to adopt a new dietary pattern, even when they are aware of its benefits. The discrepancy between consumers' attitude and awareness of healthy eating may act as a barrier to its adoption, potentially shifting consumers' habits away from MD regime [27]. By addressing consumer needs and preferences, strategies can be developed to enhance the appeal and accessibility of the MD.

Given this context, there is a growing need for new studies to elucidate the main predictors of the decline in the MD adherence within its native regions. This need is further underscored by a recent systematic review on drivers and barriers to adherence to the MD [28], in which only ~22% of the studies (4 out of 18) included in the assessment were conducted in Mediterranean countries, namely in Europe (i.e., Greece, Italy, and Spain). Another literature review [14] has shown the need for large-scale studies of MD adherence in African Mediterranean countries, as they were underrepresented in the current literature. In particular, the study indicates the need for understanding the main determinants of adherence to the MD in these countries to help in designing appropriate local and national policies and interventions to promote it [14]. Indeed, given the substantial cultural and socioeconomic diversity of countries in the Mediterranean basin, it is evident that well-known mediators or barriers affecting MD adherence (e.g., sustainability beliefs, food

choice motives, and attitudes toward healthy eating) may operate differently according to the context.

The present study applied quantitative research methods to investigate the main drivers and barriers affecting the adoption of healthy eating habits in five Mediterranean countries (Greece, Italy, Morocco, Slovenia, and Tunisia). A survey was performed to identify consumers' motivations, attitudes, drivers, and barriers toward dietary patterns inspired by the MD, including the role of picky eating (PE), attitude toward healthiness of food, and local determinants of food choices. An online questionnaire was administered to a sample of 4025 individuals (approximately 800 subjects for each country) in their native languages (i.e., Greek, Italian, Arab/French, and Slovenian).

The identification of barriers and motivators influencing the adoption of healthy eating habits and their role in enhancing the discrepancy between consumers' attitude and awareness in addition to the suggestion of effective strategies to foster healthy eating habits are among the main purposes of the present study.

2. Theoretical Framework and Research Hypothesis

A preliminary qualitative phase, developed with three focus groups in each of the five countries, allowed us to identify the main drivers and barriers able to influence the adoption of healthy eating and MD pattern [29].

Potential motives for choosing food were derived from the studies applying the Food Choice Questionnaire (FCQ), as described by Steptoe et al. [30], as well as the adapted version developed by Pieniak et al. [31] for the case of traditional food products. The selection of items was based on findings from the exploratory focus group discussions [29] and from the literature review. In our case, seven dimensions were included, namely weight control, price, convenience, natural content, health, sensory appeal, and familiarity. Health, weight, and natural content have been found to be positively related with vegetable consumption [32]. As extensively discussed in Section 1, the MD is also associated with several health benefits; the natural content was found to be a significant driver to the MD in a Portuguese immigrant community in the US [33]. Therefore, our hypotheses for these dimensions were as follows:

Hypothesis 1. *Those giving higher importance to the health factor have a higher adherence to the Mediterranean Diet.*

Hypothesis 2. *Those giving higher importance to the natural content factor have a higher adherence to the Mediterranean Diet.*

Hypothesis 3. *Those giving higher importance to the weight control factor have a higher adherence to the Mediterranean Diet.*

In different studies carried out in the US, convenience and sensory appeal were observed to be significant barriers to the MD [33,34]. Convenience, familiarity, and price have been identified as relevant barriers for the adoption of sustainable dietary behaviors in different Mediterranean countries, like France [35] and Italy [36]. Therefore, we considered the following hypotheses:

Hypothesis 4. *Those giving higher importance to the sensory appeal factor have a lower adherence to the Mediterranean Diet.*

Hypothesis 5. *Those giving higher importance to the convenience factor have a lower adherence to the Mediterranean Diet.*

Hypothesis 6. *Those giving higher importance to the price factor have a lower adherence to the Mediterranean Diet.*

Hypothesis 7. *Those giving higher importance to the familiarity factor have a lower adherence to the Mediterranean Diet.*

Several studies have highlighted the relationship between adherence to the MD and sustainable dietary behaviors [37]. The ethical dimension, given the importance of the environmental and social sustainability connected with the MD, was assessed following the short version of the Sustainable Food Choice Questionnaire (SUS-FCQ) developed by Verain et al. [38]. The SUS-FCQ distinguishes general sustainability, covering environmental, ethical, and animal welfare aspects as well as local and seasonal motives. Hence, Hypotheses 8–9 are as follows:

Hypothesis 8. *Those giving higher importance to the general sustainability factor have a higher adherence to the Mediterranean Diet.*

Hypothesis 9. *Those giving higher importance to the local and seasonality factors have a higher adherence to the Mediterranean Diet.*

Thus, attitude toward the behavior is a precursor of the intention to perform the behavior and of the behavior itself [39]. In our case, we investigated the effect of a general interest in eating healthily [40] and the effect of attitude toward the adoption of the MD [41] on the MD adherence and we suggested the following:

Hypothesis 10. *Those with a more favorable attitude toward the Mediterranean Diet have a higher adherence to the Mediterranean Diet.*

Hypothesis 11. *Those with a more favorable attitude toward healthy eating have a higher adherence to the Mediterranean Diet.*

Finally, the analysis examined the predictive value of picky eating as a selective eating behavior that may hinder adherence to the MD. Picky eating refers to unwillingness to include a wide range of both familiar and unfamiliar foods in the diet [42] and was confirmed to be an important barrier to dietary variety and quality. Several studies, indeed, evidenced a close negative link between picky eating and habitually consumed fruit and vegetables or overall dietary variety [43,44]. Moreover, Menghi et al. [42] reported evidence negatively linking adult picky eating to adherence to the MD within Italian adults. Hence, our hypothesis was as follows:

Hypothesis 12. *Adult picky eating is negatively associated with adherence to the Mediterranean Diet.*

The model was tested in the five countries, followed a similar pattern to the one developed by Pieniak et al. [31] for traditional food products, also allowing us to test the association of the motives for food choice with both adherence to the Mediterranean Diet and attitude toward the Mediterranean Diet (Figure 1).

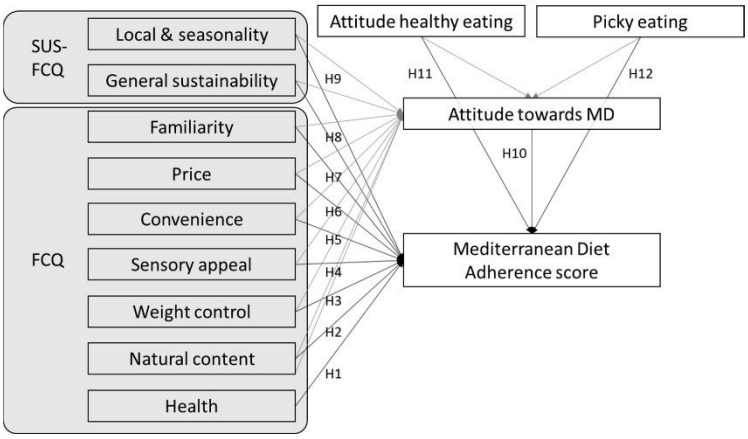


Figure 1. Hypothetical model linking food choice motives with attitude and behavior toward adherence to the Mediterranean Diet.

3. Materials and Methods

3.1. Data Collection and Sample

The present study was approved by the local institutional Ethical Committee (REB—Research Ethics Board, 28-2023-N, 29 March 2023) and conducted according to the ethical principles stated in the Declaration of Helsinki. Data collection was conducted in all of the five countries (Italy, Greece, Morocco, Slovenia, and Tunisia) during the period October–November 2023, by an external agency. Representative samples were drawn from the national adult populations (aged 18–79) across age, sex, and geographical regions. To be part of the study, respondents were asked to electronically provide the informed consent, which was shown at the invitation page of the online survey. All participants were informed that no data could be identified or linked to individual persons and that data would be analyzed anonymously. The following screening out questions were established at the beginning of the survey: the survey was initially limited to those residing from at least one year in the country of residence for food habits adaptation. Then, we collected data from adults and aged people considering the age range provided by PubMed, thus excluding those younger than 18 years old and those 80 years old or older. Finally, we excluded those who were not at all responsible for food purchases for their family.

A quality check was performed on the final sample data to avoid the low-quality responses, following recommendations to assess and improve data quality in online questionnaires [45,46]. As a priori screening, an instructed response item was inserted in a long matrix (i.e., to demonstrate that you are not a robot, for this statement, please select "Strongly agree"). As a posteriori screening, subjects presenting straight-line patterns followed by fast responders were excluded from the final sample as they were deemed to be careless. Straight liners were identified based on a standard deviation equal to 0 calculated on the answers given to two question matrices (i.e., one referred to the attitude toward healthfulness of foods and one referred to drivers and barriers to the adoption of the Mediterranean diet) in each country. Indeed, both these two matrices included items with opposite meanings (i.e., "The healthiness of food has little impact on my food choices" and "I am very particular about the healthiness of food I eat"; "Mediterranean Diet contains lower-priced foods" and "Mediterranean Diet contains high-priced foods"), implying different answers by careful respondents and thus resulting in a standard deviation different to 0. Subsequently, fast responders were determined for each country as those who completed

the survey in less than 40% of the median time calculated from participants who responded within a maximum of 60 min, similarly to what has been reported previously [47].

3.2. Measures

An online questionnaire was designed on a theory-driven approach. The questionnaire is provided in the Supplementary Materials. All the items were selected either from previously validated measures within the countries involved (e.g., [42]), or have been adapted from previous studies on attitudes, intentions, and behaviors toward healthy eating (e.g., [40]) and the Mediterranean diet (e.g., [41]). For this latter scenario, the items were first translated from English into the native language by the partners and then back-translated from the native languages in English by a professional agency. Any discrepancies between the two English versions allowed for the identification of critical translations into the native languages, which were resolved by the partners to fully ensure the linguistic validity and consistency of the questionnaire. A first pilot administration test was performed in Italy, which confirmed the clarity and internal validity of the measures. Data collection was conducted using the platform Qualtrics (©2020 Qualtrics LLC, Seattle, WA, USA; Provo, UT, USA). The measures employed were as follows.

3.2.1. The Food Choice Questionnaire

The food choice motives were investigated using the Food Choice Questionnaire (FCQ). The FCQ, developed by Steptoe et al. [30], was designed as an instrument to assess the relative importance of a range of factors related to dietary choice to individuals. We adapted the version by Pieniak et al. [31]. Twenty-one items were included, representing seven domains: health, convenience, sensory appeal, natural content, price, weight control, and familiarity. Items (e.g., "It is important to me that the food I eat on a typical day contains a lot of vitamins and minerals") were measured on a 7-point scale (1—Not at all important; 7—Extremely important) and scores for each domain were computed by averaging the relative items, with higher values being indicative of higher importance associated with the domain.

3.2.2. The Sustainable Food Choice Questionnaire

The Sustainable Food Choice Questionnaire (SUS-FCQ) was developed as an addition to the FCQ considering the full concept of sustainability [38]. Therefore, we assessed the sustainable food choice motives with ten items (e.g., "It is important to me that the food I eat on a typical day is produced without animals being in pain") on a 7-point scale (1—Not at all important; 7—Extremely important) representative of four factors (i.e., animal welfare, ethical concerns, environmental welfare, and local and seasonal). The first three factors (i.e., animal welfare, ethical concerns, and environmental welfare) were averaged into a single score of "General sustainability", following the approach of Verain et al. [38], with higher values indicative of higher importance associated with the general sustainability domain. The factor "animal welfare", as well as the "general sustainability" score, was computed either with and without the item "Is produced in Halal way", in order to consider this factor in the Muslim-majority countries.

3.2.3. Health and Taste Attitude Scale

General interest in eating healthily was assessed using the "General Health Interest" subscale of the Health and Taste Attitude Scales (HTAS) by Roininen et al. [40]. This domain comprises eight items (e.g., "I always follow a healthy and balanced diet", and "It is important for me that my diet is low in fat"), which were measured on a 7-point scale (1—Strongly disagree; 7—Strongly agree). Prior to computing a global score by averaging individual ratings, negatively keyed items (n = 4) were reversed.

3.2.4. Adult Picky Eating Questionnaire

Picky eating was measured using the 20-item version of the Adult Picky Eating Questionnaire (APEQ) [42,48,49]. Adult picky eating measures unwillingness to eat unfamiliar foods or try novel foods and the APEQ is organized into four domains: meal presentation, food variety, meal disengagement, and taste aversion, which comprehensively assess various facets of picky eating behaviors (e.g., 'I have a strong preference for specific food presentation', 'I eat a limited number of items from each food group'). Respondents rated each item on a 5-point scale (1—Never; 2—Rarely; 3—Sometimes; 4—Often; and 5—Always). A global score was computed by averaging the 20 items, with higher values indicating a higher level of picky eating.

3.2.5. Assessment of Attitudes, Adherence, Drivers, and Barriers to the Mediterranean Diet

We assessed the direct measure of attitude toward the adoption of the Mediterranean diet with six semantic differentials, using a 7-point bipolar scale, e.g., "Following the Mediterranean Diet for me would be: Disgusting–Tasting" [41].

Adherence to the MD was assessed through the 14-item MEDAS questionnaire [50]. The objective of this section, which consists of 14 items (e.g., "How many teaspoons of olive oil do you consume in a given day (including that used for frying, salads, out-of-house meals, etc.)?"), was to understand how closely the population adheres to the recommendations of the MD pattern regarding daily or weekly consumption of typical MD foods. The frequencies of consumption were assessed for the following items: olive oil, fruit, vegetables, pasta and grains, legumes, fish, white meat, eggs, milk and dairy products, sugary beverages, red meat, and sweets. Each question was scored 0 or 1 (e.g., one point was given for using 4 or more tablespoons of olive oil/day). According to the MEDAS screener responses, a score was calculated, ranging from 0 to 14. Higher scores indicate higher adherence to the MD [50].

We then asked, on a 7-point scale, to what extent the respondents agreed or not (1 = Strongly disagree–7 = Strongly agree) to a set of items listing the possible drivers and barriers to the adoption of the Mediterranean diet. Each domain was assessed using between one and four items. When multiple-items were used, a single score for the driver/barrier was computed by averaging the relative items, with higher values indicative of higher importance associated. Among the drivers, factors such as health (e.g., "Mediterranean Diet has a positive effect on cholesterol"), diet quality (e.g., "Mediterranean Diet includes healthier and more nutritious foods"), applicability (e.g., "Mediterranean Diet is tastier and more sustainable than other types of diets"), lifestyle (e.g., "Mediterranean Diet increases consumption of homemade foods"), affordability (e.g., "Food access is easier in Mediterranean Diet"), and the environment lifestyle (e.g., "Mediterranean Diet has a positive effect on the environment"), were investigated. The barriers investigated were health (e.g., "Mediterranean Diet contains more allergenic foods"), lifestyle (e.g., "Following Mediterranean Diet is difficult due to conflict with cultural habits/beliefs/norms"), and affordability (e.g., "Mediterranean Diet contains high-priced foods") [51].

3.2.6. Anthropometric and Sociodemographic Variables

Finally, anthropometric and sociodemographic information was self-reported by the respondents. Age, height, and weight were assessed as continuous variables, while others were assessed as categorical variables, including nationality, sex (i.e., "male", "female", and "other"), educational attainment (i.e., "lower secondary education or below", "upper secondary education", "Bachelor's or equivalent level", "postgraduate MSc or PhD"), income level (i.e., "A lot of difficulties getting to the end of the month", "Some difficulty getting to the end of the month", "No difficulty in reaching the end of the month", "Manage to save money every month", "I refuse to answer"), and geographical area of residence (6 categories: from "large urbanization area" to "remote rural area"). Using weight and height data, the subjects' BMIs were computed and weight status was defined by applying the WHO's standard cutoffs [52]. The subjects were asked to express the degree of respon-

sibility for food purchasing and meal preparation (4 categories each: "always", "often", "sometimes", and "never"), the habitual frequency of eating out and eating fast foods (7 categories each: from "Never" to "5 or more times per week"), the influence of religious beliefs and/or ethical concerns (4 categories: i.e., "Are your food habits affected": "by religious beliefs", "by ethical concerns", "by religious beliefs and ethical concerns", "not affected by any religious beliefs and/or ethical concerns"), and dietary regimes (i.e., omnivore, lacto-vegetarian, ovo-vegetarian, lacto–ovo vegetarian, pescatarian, vegan, flexitarian, and others).

3.3. Statistical Analysis

Descriptive and inferential statistics were performed on the surveyed variables. After having evaluated the internal consistency of the constructs with Cronbach's alpha, we have computed the average values of the following variables, as already described in Section 3.2: picky eating, attitude toward the adoption of the Mediterranean Diet (MD), attitude toward the healthiness of foods, the food choice motives, and the drivers and barriers to the adoption of the MD. Adherence to the MD was assessed using the 14-item MEDAS questionnaire [50]. The respondents were then classified according to three categories of adherence to the MD calculated as follows: low MD adherence (scores from 0–5), medium MD adherence (scores from 6–9), high adherence (scores $\geq$ 10) [53]. The normality of the data distribution was evaluated and rejected through the Kolmogorov-Smirnov test. Thus, results were expressed as median and interquartile ranges (IQRs), whereas mean $\pm$ SD are reported in Appendix A. The non-parametric Kruskal–Wallis H test with the Bonferroni post hoc test was used to explore and compare differences between variables among subjects in different countries. ANOVA F-test was used to assess the equality of means across countries of the selected variables, whereas post-hoc Tukey's Honest Significant Difference (HSD) test was used to assess the significance of differences between pairs of countries' mean values (see Appendix A).

For predicting the antecedents of adherence to the MD and testing the hypotheses described in Figure 1, we have applied the Structural Equation Model (SEM) analysis on five models, one for each country. SEM allows to discern and assess the effects of a set of variables acting on a specified outcome via multiple causal pathways [54]. The effects of the variables were labelled as "beta" for the unstandardized coefficients, and β for the standardized coefficients. The goodness-of-fit of the models was tested by χ^2 and degrees of freedom (*df*), Tucker-Lewis Index (TLI), comparative fix index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR), while the coefficient of determination (R^2) was used to assess the explained variance of the endogenous variables. In particular, model adequacy and goodness is generally confirmed when CFI and TLI > 0.95, and SRMR and RMSEA < 0.08 [54]. Data analysis was conducted using the IBM® SPSS® Amos™ 24.0 software with the maximum likelihood estimator [55], and a $p < 0.05$ was considered as statistically significant.

4. Results

The description of results is organized, initially introducing the descriptive statistics, including the general food habits. Then, food choice motives followed by picky eating (presenting the correlation between its four domains) and adherence to the Mediterranean Diet (according to the MEDAS score) are presented. Finally, factors predicting adherence to the Mediterranean Diet and barriers and motives to adherence to the Mediterranean Diet are described.

4.1. Descriptive Statistics

The socio-demographics of the five samples are reported in the Table A1 in Appendix A. After excluding respondents who accessed the survey but did not complete it due to exclusion criteria or because they incorrectly selected the instructed response item (n = 4993), straight liners (n = 174), and fast respondents (n = 51), the total final sample consisted

of 4025 subjects, which were almost equally distributed across the five countries (Greece n = 800, Italy n = 802, Morocco n = 803, Slovenia n = 806, and Tunisia n = 814). The total sample showed sex equity, made up of 49.6% females and 50.1% males. The mean age of the total sample was 42.6 ± 14.2 years old, while the lowest mean age was recorded in the Tunisian (37.1 ± 11.4 years old) and Moroccan (35.6 ± 10.9 years old) samples, which instead involved 44 (5.4% of the Tunisian sample) and 27 (3.4% of the Moroccan sample) individuals being 60 to 79 years old, respectively. The largest involvement of the 60–79 age category was recorded in Italy, where this category constituted 30% of the Italian sample. Concerning education, 40.8% of the total sample reported having an "upper secondary education" and only 6.1% indicated having a "Lower secondary education or below". The "Small urban area" option was selected as the geographical area or origin by 23% of respondents, while, with respect to the level of income, "Some difficulty getting to the end of the month" option was indicated by 38.8% of the total sample.

The general food habits of respondents were assessed through general food-related questions. The level of involvement in food purchasing was registered as "high" for 52% of respondents in the total sample, while 39% of subjects indicated being "always involved" in meal preparation. Greece and Italy presented the highest level of involvement in both food purchasing and meal preparation. Conversely, Morocco and Tunisia registered the highest levels of occasional involvement (Figure 2a,b).



(**a**) (**b**)

Figure 2. Level of involvement (%) in (**a**) food purchasing and (**b**) meal preparation within each country (Greece, Italy, Morocco, Slovenia, and Tunisia) and the total sample (total).

The influence of religious beliefs and/or ethical concerns over food habits registered the highest frequency at a country-level in Tunisia and Morocco, in which 55% of respondents reported to be affected by "religious beliefs", 22% by "both religious and ethical", and a lower % (2% for Morocco and 4% for Tunisia) by ethical concerns. Overall, 58% of the total sample was not affected by the aforementioned beliefs and concerns.

The "omnivore" option was the most frequently reported food diet, being selected by 89.3% of the total sample. Both in the total (72%) and single country samples, most of the respondents declared not to be under a low-calorie regime for weight loss or maintenance. For those that indicated being under a restricted calories diet regime, few of them reported being under the supervision of a healthcare professional, compared to those who ran the diet without this supervision.

Collectively, eating out of home was practiced "2–3 times per month" by 25.5% of respondents, followed by the option "less than once a month" selected by 25.4% of the total respondents. At a country level, Greek and Tunisian respondents reported the highest percentages of frequency of consumption of fast foods.

4.1.1. Food Choice Motives and Picky Eating

The relative importance of food choice motives was evaluated considering the median values of a range of factors related to dietary choice for individuals (Table 1), whereas the mean values are reported in Table A2 (Appendix A). All scales showed as acceptable/good (α = 0.702; 0.844) up to good/excellent (α = 0.851; 0.909) internal consistency (Cronbach's alpha). Further details are provided in Appendix A Table A3.

Table 1. Food Choice Questionnaire (FCQ) and Sustainable Food Choice Questionnaire (SUS-FCQ) motives, Adult Picky Eating Questionnaire (APEQ), Attitude toward Mediterranean Diet (AMD), and Health and Taste Attitude Scales (HTAS), median values (IQR) across the five countries.

	Greece (n = 800)	Italy (n = 802)	Morocco (n = 803)	Slovenia (n = 806)	Tunisia (n = 814)	Total (n = 4025)
FCQ						
Health	6.0 (5.0–6.9) [a]	5.7 (5.0–6.7) [a]	6.3 (5.3–7.0) [b]	5.7 (4.7–6.7) [a]	6.0 (5.0–7.0) [a]	6.0 (5.0–7.0)
Convenience	5.3 (4.3–6.0) [a]	5.3 (4.7–6.0) [a]	5.3 (4.3–6.3) [a]	5.3 (4.3–6.0) [a]	5.0 (5.0–7.0) [b]	5.3 (4.3–6.0)
Sensory appeal	6.0 (5.3–6.7) [a,b]	6.0 (5.3–6.7) [a]	6.3 (5.3–7.0) [b]	5.7 (5.0–6.3) [c]	6.0 (5.0–7.0) [a,b]	6.0 (5.0–6.7)
Natural content	6.0 (5.0–7.0) [a,b]	6.0 (5.0–7.0) [a]	6.0 (5.0–7.0) [a]	6.0 (4.7–6.7) [b]	6.0 (4.7–7.0) [a,b]	6.0 (5.0–7.0)
Price	6.0 (5.0–6.7) [a]	5.7 (4.7–6.3) [b]	5.7 (4.7–6.3) [b]	5.7 (4.7–6.3) [b]	5.3 (4.7–6.3) [b]	5.7 (4.7–6.3)
Weight control	5.3 (4.3–6.3) [a]	5.0 (4.0–6.0) [b]	5.0 (4.0–6.0) [b]	4.7 (3.7–5.7) [c]	4.7 (3.3–5.7) [c]	5.0 (4.0–6.0)
Familiarity	5.0 (4.3–6.0) [a]	4.7 (3.7–5.3) [b]	5.0 (4.0–6.0) [c]	5.0 (4.3–6.0) [a]	4.7 (3.3–5.3) [b]	5.0 (4.0–5.7)
SUS-FCQ						
General sustainability (+halal) [1]	5.4 (4.6–6.1) [a]	5.7 (4.9–6.3) [b]	6.1 (5.1–6.9) [c]	5.2 (4.1–6.1) [a]	6.0 (5.1–6.7) [c]	5.7 (4.7–6.4)
General sustainability [2]	5.7 (4.8–6.7) [a]	6.0 (5.2–6.8) [b]	6.0 (5.0–6.8) [b,c]	5.7 (4.5–6.5) [a]	6.0 (4.8–6.7) [a,c]	5.8 (4.8–6.7)
Animal welfare (+halal) [1]	5.0 (4.0–5.7) [a]	5.0 (4.0–6.0) [a]	6.0 (5.0–7.0) [b]	4.7 (3.3–6.0) [a]	6.0 (5.0–7.0) [b]	5.3 (4.0–6.3)
Animal welfare [2]	5.5 (4.0–7.0) [a]	6.0 (5.0–7.0) [b]	5.5 (4.0–7.0) [a]	5.5 (4.0–7.0) [a]	5.5 (4.0–7.0) [a]	5.5 (4.0–7.0)
Ethical concern	6.0 (5.0–7.0) [a]	6.0 (5.0–7.0) [b]	6.5 (5.0–7.0) [b]	6.0 (4.5–7.0) [a]	6.0 (5.0–7.0) [b]	6.0 (5.0–7.0)
Environmental welfare	6.0 (5.0–7.0) [a]	6.0 (5.0–7.0) [b]	6.0 (5.0–7.0) [b]	6.0 (4.5–7.0) [a]	6.0 (5.0–7.0) [b]	6.0 (5.0–7.0)
Local and seasonal	5.3 (4.3–6.0) [a]	5.7 (4.7–6.3) [b]	5.0 (4.0–6.0) [a]	5.3 (4.3–6.3) [b]	4.7 (3.3–5.7) [c]	5.3 (4.0–6.0)
APEQ						
Picky eating	2.3 (1.9–2.7) [a]	2.2 (1.7–2.6) [a,b]	2.8 (2.4–3.1) [c]	2.1 (1.8–2.5) [b]	2.7 (2.4–3.0) [c]	2.4 (2.0–2.8)
Meal presentation	2.3 (1.9–2.7) [a]	2.1 (1.6–2.6) [b]	2.7 (2.3–3.1) [c]	2.0 (1.6–2.4) [d]	2.7 (2.3–3.1) [c]	2.4 (1.9–2.9)
Food variety	2.3 (1.8–2.8) [a]	2.3 (1.5–2.8) [a]	2.8 (2.3–3.0) [b]	2.3 (1.8–2.8) [a]	2.8 (2.3–3.0) [b]	2.5 (1.8–3.0)
Meal disengagement	2.0 (1.3–2.7) [a]	1.7 (1.0–2.3) [b]	2.3 (2.0–3.0) [c]	2.0 (1.7–2.7) [a]	2.3 (2.0–3.0) [c]	2.0 (1.7–2.7)
Taste aversion	2.3 (1.8–2.8) [a]	2.4 (1.8–3.0) [a]	3.0 (2.5–3.3) [b]	2.2 (1.8–2.7) [c]	3.0 (2.5–3.3) [b]	2.5 (2.0–3.0)
AMD						
Attitude toward MD	7.0 (6.0–7.0) [a]	6.8 (6.0–7.0) [a]	5.5 (4.3–6.8) [b]	6.0 (5.0–7.0) [c]	6.0 (4.3–6.8) [b]	6.3 (5.0–7.0)
HTAS						
Attitude healthy eating	4.6 (4.0–5.3) [a]	4.8 (4.1–5.5) [b]	4.8 (4.3–5.5) [b]	4.4 (3.9–5.1) [c]	5.0 (4.3–5.6) [d]	4.8 (4.1–5.4)

The food choice motives scale and the sustainable food choice motives scale were recorded on a 7-point scale (1—Not at all important; 7—Extremely important). The picky eating items were recorded on a 5-point scale (1—Never; 2—Rarely; 3—Sometimes; 4—Often; 5—Always). Attitude toward the adoption of the MD and attitude toward healthy eating were recorded on 7-point scales. Note: [1] includes the item "Is produced in Halal way"; [2] does not include the item "Is produced in Halal way". Medians followed by a common letter are not significantly different, while different letters indicate statistically significant differences between countries (Kruskal–Wallis H test with the Bonferroni post hoc test, $p < 0.05$).

Overall, the highest median values were registered for the "natural content" and the "sensory appeal", reflecting the same tendency of country levels where these factors accounted for almost all the highest values registered, compared to the other food choice motives. In Slovenia, the highest median value was registered for the "natural content" dimension, while the "price" factor was the second most reported dimension in Greece, according to the mean value 5.76 ± 1.07 (Table A2). In Morocco, Tunisia, and Greece, the "health" motive was also among the most important dimensions according to the median

values. The lowest median values were registered for familiarity and weight control, compared to the other food choice motives, in both total sample and single country levels.

Regarding the sustainability-related dimensions, the general sustainability factors "ethical concerns" and "environmental welfare" registered the highest median values in all countries. Excluding the halal item, the "animal welfare" factor reported significantly higher median values in Italy. The same also applied for the general sustainability factor with significantly higher median scores reported in Italy and Morocco. The "local and seasonal" factor registered the lowest median values in all the countries compared to the other motives; in Italy and Slovenia, these items reported higher values compared to the other countries (Table 1).

Four domains of picky eating (PE) were investigated, i.e., meal presentation, food variety, meal disengagement, and taste aversion. In general, PE behaviors are relatively more endorsed in Morocco and Tunisia and less so in Slovenia and Italy. When considering the four dimensions, overall, taste aversion (e.g., rejection of bitter foods, sour foods, texture preference, etc.) is the facet of PE with the highest values across the five countries, followed by food variety (e.g., eating a limited number of food items, lack of food variety, etc.), and meal presentation (e.g., preference for specific food presentation, colors, specific sequence, etc.). Meal disengagement (e.g., mealtimes avoidance, etc.) is the least important factor in almost all countries (Table 1).

Overall, the outcomes of this section (FCQ, SUS-FCQ, and APEQ), investigating the main food choice motives and picky eating across countries, have shown the following (Tables 1 and A2):

- Sensory appeal, health, and natural content were the most important food choice motives across the studied countries;
- Weight control and familiarity were the least important factors;
- Ethical concerns and environmental welfare were the most important sustainability food choice motives in all countries;
- Animal welfare was the least important sustainability food choice motive in Greece, Italy, and Slovenia and became relatively more important, especially in Italy, when the halal item was excluded;
- The local and seasonal dimension was the least relevant sustainability food choice motive in all countries;
- Picky eating was more endorsed in Morocco and Tunisia and relatively less so in Italy and Slovenia;
- Considering its four dimensions, taste aversion was the facet of PE with the highest values across the five countries, followed by food variety;
- Meal disengagement is the least important PE factor in almost all countries.

4.1.2. Adherence to the Mediterranean Diet

Adherence to the MD was calculated according to the MEDAS screener responses on a 0–14 score range. In Morocco and Tunisia, the maximum score was 13 since the question of wine consumption was not included for cultural reasons (Figure 3).

Overall, results showed a medium-to-low adherence to the MD, ranging from the lowest median value registered in Slovenia, which was significantly lower compared to the other countries, as opposed to Italy and Morocco that showed the highest levels of adherence. Slovenia and Tunisia showed the highest percentages of individuals with poor adherence to the MD (39% and 19.4%, respectively), whereas consumers showing high MD adherence were more frequently found in Italy (16.5%) and Morocco (14.6%). Respondents in Greece and Morocco are more frequently in the category with medium adherence to the MD (74.6% and 73.6%, respectively) (Table 2).

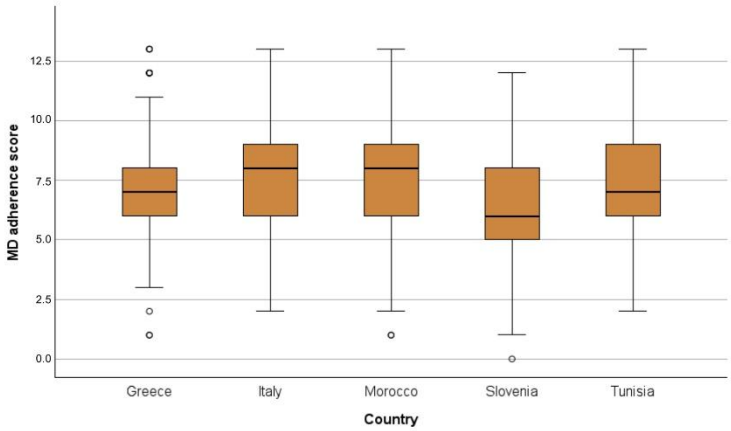


Figure 3. Adherence the Mediterranean Diet (MD) scores; box-plots (MD adherence scores ranging from 0 to 14, except for Morocco and Tunisia from 0 to 13).

Table 2. Adherence to the Mediterranean Diet (MD) scores across the five countries: mean, standard deviation (SD), median, and interquartile range (IQR). Levels of adherence to the MD [53].

		Greece (*n* = 800)	**Italy (*n* = 802)**	**Morocco (*n* = 803)**	**Slovenia (*n* = 806)**	**Tunisia (*n* = 814)**	**Total (*n* = 4025)**
Mean (SD)		7.17 (1.79) [b]	7.67 (1.89) [a]	7.62 (1.84) [a]	6.06 (2.05) [c]	7.21 (1.91) [b]	7.14 (1.98)
Median (IQR)		7.00 (6.00–8.00) [b]	8.00 (6.00–9.00) [a]	8.00 (6.00–9.00) [a]	6.00 (5.00–8.00) [c]	7.00 (6.00–9.00) [b]	7.00 (6.00–8.00)
Low adherence (scores 0–5)	N	132	95	95	314	158	794
	%	16.5	11.8	11.8	39.0	19.4	19.7
Medium adherence (scores 6–9)	N	597	575	591	458	564	2785
	%	74.6	71.7	73.6	56.8	69.3	69.2
High adherence (scores ≥ 10)	N	71	132	117	34	92	446
	%	8.9	16.5	14.6	4.2	11.3	11.1

Note: Means followed by a common letter are not significantly different; different letters indicate statistically significant differences between countries (post-hoc Tukey HSD test, $p < 0.001$). Medians followed by a common letter are not significantly different, while different letters indicate statistically significant differences between countries (Kruskal–Wallis non parametric test, $p < 0.001$).

4.2. Factors Predicting Adherence to the Mediterranean Diet

Separate structural equation models were performed to determine the effects of predictors to the adherence score to the MD across the five countries. The analysis was set based on the theoretical context, including as exogenous variables picky eating [42–44,48], attitude toward the adoption of the MD [41], interest in eating healthily [40], the food choice motives based on the Food Choice Questionnaire (FCQ) [30,31], and the sustainable food choice motives [38], as postulated in Figure 1. Table 3 provides the standardized coefficients (β), *p*-value, R-squared, and the model fit indices, whereas the unstandardized coefficients and standard errors are provided in Table A4 (see Appendix A).

Table 3. Structural equation models predicting the attitude toward the Mediterranean Diet (MD) via an adherence score to the MD: standardized coefficients (β), *p*-value, R-squared, and model fit indices across the five countries.

Predictors	Greece (*n* = 800)		Italy (*n* = 802)		Morocco (*n* = 803)		Slovenia (*n* = 806)		Tunisia (*n* = 814)	
Attitude toward MD	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
Health	0.001	0.978	−0.006	0.899	0.047	0.309	0.024	0.591	0.109	0.008
Natural content	0.139	0.004	−0.033	0.503	0.009	0.847	0.114	0.019	0.083	0.049
Weight control	0.041	0.370	−0.005	0.904	0.000	0.997	−0.078	0.088	−0.050	0.242
Sensory appeal	0.076	0.055	0.056	0.158	−0.019	0.665	0.076	0.061	−0.045	0.254
Convenience	−0.065	0.108	−0.021	0.604	0.077	0.067	0.104	0.013	0.017	0.674
Price	0.027	0.486	−0.046	0.236	0.019	0.646	−0.071	0.073	0.066	0.088
Familiarity	0.006	0.885	0.143	<0.001	−0.001	0.980	−0.033	0.405	0.013	0.748
General sustainability	−0.006	0.883	0.164	<0.001	0.000	0.992	0.003	0.948	−0.055	0.182
Local and seasonal	0.086	0.047	0.073	0.097	0.026	0.553	0.091	0.047	0.023	0.584
Attitude healthy eating	0.038	0.400	0.058	0.219	0.021	0.611	0.092	0.054	0.046	0.294
Picky eating	−0.090	0.010	−0.115	0.002	0.022	0.542	−0.090	0.012	−0.046	0.207
R^2	0.095		0.096		0.016		0.083		0.035	
Adherence to the MD	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
Health	0.049	0.278	0.052	0.213	0.111	0.010	0.112	0.005	0.072	0.071
Natural content	0.079	0.081	0.220	<0.001	0.087	0.043	0.061	0.160	0.130	0.001
Weight control	0.109	0.012	0.051	0.223	0.063	0.115	0.092	0.024	0.045	0.275
Sensory appeal	−0.033	0.371	−0.117	0.002	−0.077	0.057	−0.066	0.068	−0.028	0.463
Convenience	−0.099	0.009	−0.066	0.080	−0.032	0.426	−0.047	0.209	−0.029	0.453
Price	−0.030	0.402	−0.050	0.165	−0.067	0.090	−0.001	0.979	−0.110	0.003
Familiarity	−0.057	0.144	−0.047	0.222	−0.032	0.425	−0.033	0.360	0.022	0.589
General sustainability	−0.016	0.677	−0.067	0.113	0.005	0.906	0.030	0.469	−0.019	0.634
Local and seasonal	0.082	0.046	0.073	0.077	0.102	0.013	0.046	0.262	0.057	0.159
Attitude toward MD	0.073	0.029	0.114	<0.001	0.032	0.333	0.151	<0.001	0.050	0.139
Attitude healthy eating	0.238	<0.001	0.218	<0.001	0.178	<0.001	0.260	<0.001	0.148	<0.001
Picky eating	−0.030	0.371	−0.070	0.044	−0.072	0.039	−0.094	0.003	−0.079	0.024
R^2	0.190		0.221		0.120		0.266		0.110	
Model fit indices:										
χ^2 (df)	9.061 (9)		19.801 (7)		35.224 (8)		15.428 (10)		12.362 (5)	
CFI	1.000		0.996		0.988		0.998		0.996	
TLI	1.000		0.953		0.886		0.986		0.942	
RMSEA	0.003		0.048		0.065		0.026		0.043	
(90% CI)	(0.000–0.040)		(0.024–0.073)		(0.044–0.088)		(0.000–0.050)		(0.012–0.073)	
SMRM	0.018		0.031		0.039		0.020		0.015	

As reported in Table 3, model fit indices showed an overall satisfactory goodness of fit for the models tested [54]. The models accounted for a share of the variance in adherence to the MD, ranging from 11% in Tunisia up to 26.6% in Slovenia, followed by Italy (22.1%), Greece (19.0%), and Morocco (12%). The results clearly indicated that attitude toward healthy eating was the most relevant and significant predictor of adherence to the MD in all countries. This means that consumers' interest in eating healthily (e.g., "I always follow a healthy and balanced diet", "It is important for me that my diet is low in fat", etc.) is a relevant predictor of adherence to the MD. Furthermore, attitude toward the adoption of the MD was also a significant positive predictor of the MD adherence score in Slovenia, Italy, and Greece. In those countries, those more in favor of the adoption of the MD also have higher MD adherence scores. Conversely, this was not the case for Tunisia and Morocco. The coefficients associated with picky eating (Table 3) showed a negative effect of this exogenous variable over adherence to the MD in Slovenia, Italy, Morocco, and Tunisia. In Greece, this factor is negatively related with the respondents' attitude toward the MD but not with the behavior itself. PE was also found to negatively influence the participants' attitude toward the MD in Italy and Slovenia.

Among the food choice motives, health motives affected Moroccan, Slovenian, and (to a lesser extent) Tunisian respondents' MD adherence. Natural content was associated with significant coefficients in Italy, where it was the strongest predictor; Tunisia and Morocco showed the positive effect of this motive on the MD adherence in these countries. Considering Greek and Slovenian respondents, both showed a positive effect of weight control over adherence to the MD. In Italy, the sensory appeal exhibited a negative effect on adherence to the MD. Price and convenience were negatively associated with adherence to the MD in Tunisia and Greece, respectively.

Looking at the sustainable food choice motives, the local and seasonality factors showed a positive effect on adherence to the MD in Greece and Morocco, whereas it was only slightly affecting the Italian respondents' scores ($p = 0.077$). As indicated by the p-values reported in correspondence with general sustainability (Table 3) motives, no effects were shown on respondents' MD adherence, whereas a positive effect was found on the attitude toward the MD in Italy.

4.3. Barriers and Motives to Adherence to the Mediterranean Diet

Among the barriers to the MD, health, restrictiveness, convenience, taste, food culture, affordability and access were investigated, while health, diet quality, applicability, lifestyle, affordability, and environment were evaluated as drivers considering the median values (Table 4), whilst the mean values are reported in Table A5 (Appendix A).

Table 4. Main drivers and barriers to the Mediterranean Diet (MD): Median values (IQR).

Drivers and Barriers to the MD	Greece (n = 800)	Italy (n = 802)	Morocco (n = 803)	Slovenia (n = 806)	Tunisia (n = 814)	Total (n = 4025)
Drivers						
Health (positive effect on cholesterol, lowers LDL, and reduces health risks)	6.0 (5.0–6.7) [a]	6.0 (5.3–6.3) [a]	5.0 (4.3–6.0) [b]	5.7 (4.7–6.0) [c]	5.0 (4.0–6.0) [d]	5.7 (4.7–6.3)
Diet quality (healthier, more nutritious food, higher F&Vs, and lower meat consumption)	6.0 (5.7–7.0) [a]	6.0 (5.7–6.7) [a]	5.7 (5.0–6.3) [b]	6.0 (5.0–6.3) [b]	5.7 (4.7–6.0) [c]	6.0 (5.0–6.7)
Applicability (tastier and more sustainable than other diets)	6.0 (5.0–7.0) [a]	6.0 (6.0–7.0) [a]	6.0 (5.0–6.0) [b]	5.0 (4.0–6.0) [c]	6.0 (5.0–7.0) [b]	6.0 (5.0–7.0)
Lifestyle (homemade, unprocessed, additive-free, socialization, and family relations)	6.0 (5.3–6.3) [a]	6.0 (5.0–6.3) [a,d]	5.7 (5.0–6.3) [b]	5.3 (4.3–6.0) [c]	5.7 (5.0–6.3) [b,d]	5.7 (5.0–6.3)
Affordability (easier food access, and lower-priced food)	5.0 (4.5–6.0) [a]	5.5 (4.5–6.0) [b]	5.0 (4.5–6.0) [b]	4.0 (3.5–5.0) [c]	5.0 (4.5–6.0) [a,b]	5.0 (4.0–6.0)
Environment (positive for environment, better carbon footprint, and local food)	5.3 (4.5–6.0) [a]	5.5 (4.8–6.3) [b]	5.3 (4.8–6.0) [a]	4.8 (4.0–5.5) [c]	5.3 (4.5–6.0) [a]	5.3 (4.5–6.0)
Barriers						
Health (contain allergenic foods)	4.0 (3.0–5.0) [a]	4.0 (3.0–5.0) [a]	4.0 (3.0–4.5) [a]	4.0 (2.5–4.5) [b]	4.0 (3.0–5.0) [a]	4.0 (3.0–4.5)
Restrictiveness (insufficient food variety, restrictive, and difficult diversify food recipes)	2.3 (1.7–3.3) [a]	2.0 (1.3–3.0) [b]	3.3 (2.3–4.3) [c]	3.0 (2.0–4.0) [d]	3.0 (2.0–4.0) [d]	2.7 (2.0–3.7)
Convenience (difficult to prepare and time-consuming)	3.0 (2.0–4.0) [a]	3.0 (2.0–4.0) [a]	4.0 (3.0–5.0) [b]	4.0 (2.0–4.0) [c]	4.0 (2.0–5.0) [b,c]	3.0 (2.0–5.0)
Taste (contains unpleasant-tasting foods)	2.0 (1.0–3.0) [a]	2.0 (1.0–2.0) [b]	3.0 (2.0–4.0) [c]	2.0 (2.0–4.0) [d]	2.0 (1.0–3.0) [e]	2.0 (1.0–3.0)
Food culture (conflict with cultural habits)	2.0 (2.0–4.0) [a]	2.0 (1.0–3.0) [b]	3.0 (2.0–5.0) [c]	2.0 (1.0–4.0) [a]	2.0 (2.0–4.0) [a]	2.0 (1.0–4.0)

Table 4. *Cont.*

Drivers and Barriers to the MD	Greece (n = 800)	Italy (n = 802)	Morocco (n = 803)	Slovenia (n = 806)	Tunisia (n = 814)	Total (n = 4025)
Affordability (contains high-priced foods)	4.0 (3.0–5.0) [a]	3.0 (2.0–4.0) [b]	4.0 (3.0–5.0) [a]	4.0 (3.0–5.0) [a]	4.0 (3.0–5.0) [a]	4.0 (2.0–5.0)
Access (limited options in shops and restaurants)	3.0 (2.0–4.0) [a]	2.0 (1.0–3.5) [b]	4.0 (3.0–5.0) [c]	4.0 (3.0–5.0) [c]	3.5 (2.0–4.5) [d]	3.5 (2.0–4.5)

Notes: The items were all recorded on a 7-point scale (1—Not at all important; 7—Extremely important). Medians followed by a common letter are not significantly different, while different letters indicate statistically significant differences between countries (Kruskal–Wallis H test with the Bonferroni post hoc test, $p < 0.05$).

Overall, participants in all the Mediterranean countries involved perceived more benefits compared to barriers to the adoption of MD. Drivers' average scores range from 4.13 ("Affordability" in Slovenia) to 6.08 ("Diet quality" in Greece), while barriers' average scores ranged from 2.04 ("Taste" in Italy) to 4.03 ("Health" in Italy) (Table A5).

In general, diet quality (having healthier and more nutritious food, higher F&Vs, and lower meat consumption), applicability (tastier and more sustainable diet), and lifestyle (homemade, unprocessed, additive-free food, socialization, and family relationships) were identified as the most frequently reported advantages of the MD. Health benefits (positive effect on cholesterol, lowers LDL, and reduces health risks) were the second highest perceived driver in Slovenia. Considering the differences between countries, diet quality, applicability, lifestyle, and health benefits recorded the highest scores in Italy and Greece compared to the other countries (Table 4). The environmental (positive for environment, better carbon footprint, and local food) and affordability benefits (easier food access and lower-priced food) that were, respectively, the second least and the least perceived, received the highest scores in Italy. Overall, the perceived benefits of the MD had similar patterns within the Greek and Italian samples and within the Tunisian and Moroccan ones.

Among the factors limiting the adoption of the MD, health (contains allergenic foods) and affordability (contains high-priced foods) were the most relevant barriers to the MD for the consumers in all countries. In general, taste (contains unpleasant-tasting foods), food culture (conflict with cultural habits), and restrictiveness (insufficient food variety, restrictive, and difficult to diversity food recipes) were the least relevant barriers for the respondents in all countries. The differences between countries (Table 4) indicated that health was a highly perceived barrier in all countries except Slovenia and that affordability was strongly perceived as a barrier in all countries, with significantly lower values in Italy. Convenience (difficulty in terms of preparation and time-consumption) was relatively more strongly perceived as a barrier in Tunisia and Morocco, whereas access (limited options in shops and restaurants) was a relevant barrier in Slovenia and Morocco. In general, respondents in Italy and Greece reported the lowest perceived barriers to adopting the MD, while those in Morocco reported the highest.

5. Discussion

The results of our study showed that attitude toward healthy eating is a significant predictor of adherence to the MD in all the countries involved. This result supports H11 (Figure 1), confirming that those with a more favorable attitude toward healthy eating have a higher adherence to the MD, as also documented by Roininen et al. [40].

Similarly, a positive effect was observed for the exogenous variable "attitude towards the adoption of the MD", being a forecaster of adherence to the MD itself. The results registered in Slovenia, Italy, and Greece confirm H10. These findings are coherent with the existing literature regarding the attitude–behavior relationship [39]. Considering the other two countries (Morocco and Tunisia) where lower non-significant paths have been found, adherence to the MD was not affected by consumers' evaluation of adherence to the MD itself. In these countries, the food culture barrier, intended as the conflict between following the MD and cultural habits, registered its highest values, despite being one of

the less relevant barriers among the other countries. Therefore, it is likely that for Tunisian and Moroccan respondents with a positive attitude toward the MD, it is not a sufficient driver for adhering more closely to this dietary behavior. Consequently, these results pose evidence for the attitude–behavior gap in the evaluation of healthy eating and the adoption of relative behavior, in particular when the behavior is not perfectly aligned with individuals' cultural values. This finding seems to support the recent theoretical discussions about the importance of individuals' goals in forming the motivation to consider performing a particular behavior [56]. For these countries, the recovery or rediscovery of traditional recipes in line with the MD and the gastronomic culture of these populations could represent a strategy to bridge this attitude–behavior gap.

Adult picky eating showed a negative effect on adherence to the MD with significant values in Slovenia, Tunisia, Morocco, and Italy; these findings support H12, confirming that those less prone to eating unfamiliar and novel foods show negative association with adherence to the MD. Menghi et al. [42] have also documented a negative link between adult PE and adherence to the MD in Italy. In our study, this negative influence was also found in the other countries, except for Greece. In this latter country, PE was a significant antecedent of consumers' attitude toward the adoption of the MD. Therefore, in Greece, we found that the effect of adult PE on adherence to the MD is likely to be mediated by the consumers' attitude. In other words, those who are unwilling to eat familiar foods or try novel foods have a more negative attitude toward the MD and, given this attitude, are also showing lower adherence to the MD.

Regarding the other exogenous variables included in the model, among food choice motives [30,31], the health dimension was found to be positively correlated with adherence to the MD in Morocco and Slovenia, confirming H1 for those countries. Researchers in the literature have indeed indicated a positive relation between the health dimension and both the consumption of vegetables and the association of the MD with health benefits [6,32]. Therefore, those giving more importance to those healthy aspects in food choices have a higher adherence to the MD.

Subjects paying more attention to the natural content showed higher adherence to the MD in Italy, Morocco and Tunisia, thus confirming H2 for those countries and the results of studies conducted in other countries [33]. H3 was confirmed in Greece and Slovenia, indicating that, for those two countries, a positive effect of the weight control dimension on the respondents' adherence to the MD is observable, similarly to what was found in the US [33].

The familiarity factor is not a significant predictor of MD adoption; therefore, H7 was not supported by the results. Instead, the food choice motives related to the sensory appeal, price, and convenience have evidenced negative effects on adherence to the MD in different countries. The sensory appeal dimension negatively affected adherence to the MD in Italy, confirming H4. This means that those indicating a preference for food that smells nice, with a pleasant texture and that tastes well, exhibited a lower MD adherence. A weaker negative influence of this dimension was found in Morocco and Slovenia too. This result indicates that, in those countries, increasing the sensory appeal of the foods related with the MD could be associated with an increase in the MD score [34].

In Tunisia, consumers expressing a higher importance for the price factor, such as preference for cheaper food and good value for money, showed a lower adherence to the MD, thus supporting H6. Affordability was also found to be a significant barrier to the MD in all countries. As already found in France [35] and Italy [36], convenience, familiarity, and price have been identified as relevant barriers for the adoption of sustainable dietary behaviors in different Mediterranean countries. In Italy, another study has shown that the monthly expenditure of the MD is slightly higher in the overall budget compared to the current expenditure allocated to food by the Italian population, with a substantial difference in the distribution of budget according to the different food groups [17]. A higher need for food expenditure to achieve higher adherence to the MD was also found in Spain [57]; these results may suggest that, in the poorest regions or sub-population groups, where

access to MD is less affordable in relative terms, fiscal measures should be proposed in the form of income supplements for the lowest income levels.

Similarly, Greek consumers that showed a higher preference for convenience dimension (e.g., easy-to-cook) were linked to a lower MD adoption, as postulated in H5. Convenience was also found to be a significant barrier to the MD in all countries. In Greece, the production of more convenient and easy-to-handle food (e.g., snacks) with ingredients linked to the MD could possibly increase the adherence to this dietary pattern. In Slovenia, the convenience factor positively affected the attitude toward the MD, indicating that ready-to-eat or easy-to-cook products with ingredients typical from the Mediterranean basin could increase the consumers' attitude toward the MD and, in turn, lead to higher MD scores.

Looking at the sustainable food choice motives, the local and seasonal dimension was found to positively affect the MD adoption in Morocco and Greece. A weaker positive correlation was found in Italy too, thus confirming H9. Moroccan, Greek, and Italian consumers who expressed a higher attention to local, regional, and seasonal products showed a higher adherence score to the MD. This result confirms recent findings showing the relationship between adherence to the MD and sustainable dietary behaviors [37], as well as the revision and restructuring of the Mediterranean Diet Pyramid incorporating the sustainability and environmental impact of this dietary pattern [58]. However, H8 was not supported, since the positive effect of the general sustainability was only found in Italy on the consumers' attitude toward the MD, not on the behavior itself. In other words, Italian consumers that are more interested in animal/environmental welfare and ethical concerns also have a more positive attitude toward the adoption of the MD; as a result, more favorable evaluation also exhibited higher MD scores.

Overall, our results demonstrate regional differences in the factors affecting, as well as in the barriers preventing, the adoption of the MD. In general, since attitudes toward healthy eating were found to be the most relevant predictor of adherence to the MD in the five countries, designing intervention strategies aimed at providing information to increase consumers' awareness about the health impact of balanced and healthier dietary behavior is highly recommended. Although Sogari et al. [59] found that health messages did not influence US young adults to eat more whole grain food products, such informative strategies could be more effective in other population groups. A meta-analysis found that, when it comes to food products in particular, the use of gain frames (i.e., messages framed to promote the advantages of consuming a particular food) elicits stronger responses from consumers than the use of loss frames (i.e., messages framed to stress the negative outcomes of not consuming that particular food) [60]. Thus, promoting consumers' information regarding the benefits of the MD adoption and stimulating their beliefs regarding the topic could contribute to increasing their attitude toward adherence to the MD and, in this way, the behavior itself. This might not be the case in countries such as Morocco and Tunisia, where this dimension was not found to affect the adoption to the MD. Given the variety of outcomes gained in the different countries involved regarding food choice motives, a tailored approach may be recommended to specifically promote some categories of less frequently consumed foodstuffs. Finally, given that the "variety of food consumption" is a pillar in the MD and having found a negative influence of PE on its adoption, strategies based on exposure could be a valuable option to promote adherence to the MD.

Other more practical approaches might be targeted to the implementation of a nutritional intervention program that introduces MD-inspired meals in workplace and school canteens. Studies have shown that such programs can successfully and sustainably introduce new dietary habits among working populations and adolescents with a minimal level of intervention [61,62]. Peer support interventions can also be applied as practical measures to promote the MD, in particular, for populations whose behavior is strongly influenced by subjective norm [59]. A 12-month randomized controlled trial targeting non-Mediterranean populations at high cardiovascular disease risk and with low MD adherence compared three intervention strategies: peer support, dietician-led, and minimal support groups. The

study observed significant improvements in BMI, HbA1c levels, and blood pressure. These findings indicate that peer support strategies can facilitate dietary behavior changes toward adopting an MD [63].

To accommodate diverse dietary preferences, such as those of picky eaters, various meal delivery kits now include MD-based options specifically designed to adhere to the MD while also prioritizing convenience. Additionally, modern recipe books offering time-saving MD recipes can greatly benefit consumers looking for easy and quick meal options. Resources such as dietary guides from the Harvard School of Public Health provide examples of diet plans that follow MD principles, offering practical advice for incorporating the diet into daily routines [64].

Policy interventions have also proven crucial for promoting the MD, particularly among the lowest socioeconomic groups [57,65]. It has been suggested that the combination of policies, including taxes on specific foods aimed at discouraging unhealthy eating (e.g., sweetened beverages) and eliminating/reducing taxes (e.g., value-added tax) or introducing subsidies for healthy options (e.g., fruits and vegetables), can effectively promote healthier diets while providing support to the most vulnerable groups [66].

Strengths, Limitations, and Future Directions

To the authors' knowledge, no previous studies have assessed adherence to the MD in large representative samples across different European and African Mediterranean countries. Food choice motives and attitudinal variables associated with eating habits were also evaluated to provide a better overview of the factors facilitating or discouraging Mediterranean dietary behaviors in the studied countries. The results could possibly help in designing appropriate local and national policies and interventions to promote MD.

Despite the novelty of our research, some inherent limitations need to be outlined. A major limitation of this study is the lack of use of validated psychometric measures across countries, in particular for the APEQ and the SUS-FCQ. However, a partial validity of the used measures is supported by the values of Cronbach's alphas. Nevertheless, future studies should address this issue. A second limitation has to do with the sampling method. While the sample size is adequate across countries, it is not fully representative of the studied population. For instance, the average education level is relatively high, with 39.2% of Tunisians holding a postgraduate MSc or PhD. Similarly, participants from Morocco and Tunisia are younger than those from other countries. It is also known that age affects adherence to the MD, albeit controversially. Moreover, we cannot fully exclude selection bias, in the sense that those who participated in the survey could be more interested in the topic discussed than the general population, thus giving a partial picture of the problem. Therefore, the results might have been influenced by this factor too and possible future investigations should engage older age groups in those countries to improve sample representativeness. Another limitation is related to the cross-sectional design, which does not allow for determining the temporal direction of the associations. Although this is a quite common practice [65], future studies should apply longitudinal studies to predict the prospective behavior. Finally, given the relatively low variance explained by the models across all countries, novel studies are needed to identify a more comprehensive regional list of predictors including, e.g., variables widely applied such as subjective norms, perceived behavioral control, and other psycho-social variables.

Future research direction should consider factors such as the demographics, attitudes, nutrition literacy, and psychosocial traits of consumers that significantly influence the likelihood of adopting the MD principles [28]. However, the evidence remains inconclusive for certain factors. For instance, the relationship between age, gender, and MD adherence is still debated. While some studies suggest that being female and older is associated with higher adherence to the MD, others report contradictory findings or no gender differences [14]. Nevertheless, further insights on how lifestyle behaviors and age-related factors influence MD adherence could enhance the discussion [67]. Likewise, although the positive impact of awareness and literacy regarding the MD's health benefits on dietary variety and quality

is well documented [28], less is known about the psychological traits that may impede adherence. A significant body of the literature suggests that traits associated with selective eating negatively affect habitual intake of prototypical MD food groups [68]. However, previous studies reporting such negative effects are either limited to childhood [69] or to a specific geographical area [42]. Thus, it remains unclear as to whether selective eating traits contribute equally to the observed decline in MD adherence among adults across the Mediterranean region.

6. Conclusions

Given the increasing importance of achieving health and sustainable goals, the promotion of more sustainable dietary behavior, including the MD, assumes a central role. By preventing the abandonment of such a diet and implementing its adoption, especially in the Mediterranean countries, it is therefore crucial and is strictly linked to the understanding of factors predicting such behavior.

The present study confirmed, from a cross-country perspective, the relative importance of specific food choice motives (positively or negatively affecting the adoption of the MD) and of other attitudinal factors (i.e., attitudes toward the healthfulness of food, attitudes toward the MD, and adult picky eating) in attaining this goal.

Overall, the research reported a medium-to-low adherence score to the MD, with a largely prevalent share of low to medium MD adherence values for consumers registered in the five countries (Greece, Italy, Morocco, Slovenia, and Tunisia). Attitudes toward healthy eating were found to be the most relevant predictor of adherence to the MD in the five countries. This result suggests that policies or intervention strategies aiming at increasing consumers' awareness about the health impact of balanced dietary behavior would likely increase adherence to the MD. Attitude toward the adoption of the MD is also a significant predictor in the European countries involved in the study but not in the Northern African ones, whereas pick eating negatively affects adherence to the MD in all countries except Greece. Finally, our results demonstrate regional differences in the factors affecting, as well as in the barriers preventing, the adoption of the MD. Given the variety of outcomes across the five countries regarding the influence of food choice motives on adherence to the MD, a tailored approach may be recommended for policy design.

Supplementary Materials: The questionnaire can be downloaded at https://www.mdpi.com/article/10.3390/nu16152405/s1.

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Appendix A

Table A1. Sample characteristics, number (n), percentage (%), mean and standard deviations (sd).

Predictors	Greece (*n* = 800)		Italy (*n* = 802)		Morocco (*n* = 803)		Slovenia (*n* = 806)		Tunisia (*n* = 814)	
Sex	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Females	414	51.8	406	50.6	404	50.3	410	50.9	362	44.5
Males	382	47.8	394	49.1	396	49.3	395	49.0	448	55.0
Other, or prefer not to reply	4	0.5	2	0.2	3	0.4	1	0.1	4	0.5
Age (categories)	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
18–29	150	18.8	123	15.3	305	38.0	107	13.3	232	28.5
30–44	246	30.8	186	23.2	320	39.9	241	29.9	387	47.5
45–59	279	34.9	252	31.4	151	18.8	261	32.4	151	18.6
60–79	125	15.6	241	30.0	27	3.4	197	24.4	44	5.4
Age (mean, sd)	43.9	13.5	48.7	15.4	35.6	10.9	47.4	14.4	37.1	11.4
Education level	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Lower secondary or below	23	2.9	59	7.4	76	9.5	60	7.4	27	3.3
Upper secondary	344	43.0	417	52.0	293	36.5	381	47.3	206	25.3
Bachelor's or equivalent	265	33.1	88	11.0	286	35.6	135	16.7	249	30.6
Postgraduate MSc or PhD	155	19.4	237	29.6	137	17.1	202	25.1	319	39.2
Other	13	1.6	1	0.1	11	1.4	28	3.5	13	1.6
Geographical area	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Large urbanization area	232	29.0	96	12.0	244	30.4	14	1.7	187	23.0
Metropolitan area	101	12.6	63	7.9	197	24.5	17	2.1	157	19.3
Medium-sized urban area	119	14.9	84	10.5	184	22.9	144	17.9	196	24.1
Small urban area	219	27.4	239	29.8	120	14.9	182	22.6	164	20.1
Nearby rural area	90	11.3	255	31.8	36	4.5	344	42.7	85	10.4
Remote rural area	39	4.9	65	8.1	22	2.7	105	13.0	25	3.1
Income level	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
A lot of difficulties getting to the end of the month	154	19.3	59	7.4	188	23.4	83	10.3	198	24.3
Some difficulty getting to the end of the month	400	50.0	260	32.4	287	35.7	240	29.8	374	45.9
No difficulty in reaching the end of the month	169	21.1	300	37.4	161	20.0	264	32.8	112	13.8
Manage to save money every month	49	6.1	157	19.6	96	12.0	182	22.6	72	8.8
I refuse to answer	28	3.5	26	3.2	71	8.8	37	4.6	58	7.1
BMI (mean, sd)	26.0	4.8	24.4	5.1	24.7	4.8	26.3	5.1	25.8	6.2

Table A2. Food Choice Questionnaire (FCQ) and Sustainable Food Choice Questionnaire (SUS-FCQ) motives, Adult Picky Eating Questionnaire (APEQ), Attitude toward Mediterranean Diet (AMD), Health and Taste Attitude Scales (HTAS), mean values (SD) across the five countries.

	Greece (n = 800)	Italy (n = 802)	Morocco (n = 803)	Slovenia (n = 806)	Tunisia (n = 814)	Total (n = 4025)
FCQ						
Health	5.75 (1.10) [a,b]	5.71 (1.02) [a]	5.88 (1.28) [b]	5.61 (1.19) [a]	5.66 (1.35) [a]	5.72 (1.20)
Convenience	5.21 (1.19) [a,b]	5.30 (1.16) [b]	5.08 (1.42) [a]	5.18 (1.30) [a,b]	4.87 (1.51) [c]	5.13 (1.33)
Sensory appeal	5.87 (1.03) [a]	5.81 (0.98) [a]	5.93 (1.15) [a]	5.56 (1.12) [b]	5.80 (1.17) [a]	5.79 (1.10)
Natural content	5.71 (1.21) [a,b]	5.79 (1.21) [b]	5.74 (1.33) [a,b]	5.57 (1.34) [a]	5.59 (1.36) [a]	5.68 (1.30)
Price	5.76 (1.07) [a]	5.47 (1.10) [b]	5.46 (1.26) [b]	5.50 (1.15) [b]	5.36 (1.23) [b]	5.51 (1.17)
Weight control	5.15 (1.38) [a]	4.86 (1.46) [b]	4.69 (1.63) [b]	4.48 (1.52) [c]	4.46 (1.57) [c]	4.73 (1.54)
Familiarity	5.04 (1.21) [a]	4.54 (1.28) [b]	4.78 (1.43) [c]	5.03 (1.13) [a]	4.44 (1.45) [b]	4.76 (1.33)
SUS-FCQ						
General sustainability (+halal) [1]	5.24 (1.22) [a]	5.42 (1.19) [b]	5.80 (1.23) [c]	5.06 (1.46) [d]	5.76 (1.13) [c]	5.46 (1.28)
General sustainability [2]	5.53 (1.26) [a]	5.79 (1.24) [b]	5.65 (1.36) [a,b]	5.34 (1.49) [c]	5.60 (1.29) [a]	5.58 (1.34)
Animal welfare (+halal) [1]	4.70 (1.41) [a,c]	4.83 (1.33) [a]	5.70 (1.39) [b]	4.58 (1.63) [c]	5.69 (1.30) [b]	5.10 (1.50)
Animal welfare [2]	5.32 (1.55) [a]	5.63 (1.46) [b]	5.20 (1.88) [a]	5.15 (1.72) [a]	5.18 (1.84) [a]	5.30 (1.71)
Ethical concern	5.68 (1.29) [a]	5.83 (1.31) [a,b]	5.89 (1.41) [b]	5.48 (1.56) [c]	5.76 (1.45) [a]	5.73 (1.41)
Environmental welfare	5.61 (1.38) [a]	5.89 (1.3) [b]	5.84 (1.48) [b]	5.39 (1.54) [a]	5.86 (1.42) [b]	5.72 (1.44)
Local and seasonal	5.12 (1.34) [a]	5.43 (1.21) [b]	4.89 (1.54) [c]	5.29 (1.38) [a,b]	4.48 (1.63) [d]	5.04 (1.47)
APEQ						
Picky eating	2.29 (0.58) [a]	2.20 (0.64) [b]	2.75 (0.52) [c]	2.14 (0.54) [b]	2.70 (0.48) [c]	2.42 (0.61)
Meal presentation	2.30 (0.66) [a]	2.17 (0.72) [b]	2.77 (0.66) [c]	2.05 (0.62) [d]	2.67 (0.64) [e]	2.39 (0.71)
Food variety	2.29 (0.74) [a]	2.21 (0.80) [a]	2.65 (0.71) [b]	2.20 (0.74) [a]	2.64 (0.66) [b]	2.40 (0.76)
Meal disengagement	2.09 (0.77) [a]	1.83 (0.80) [b]	2.48 (0.79) [c]	2.09 (0.73) [a]	2.46 (0.74) [c]	2.19 (0.80)
Taste aversion	2.37 (0.69) [a]	2.42 (0.78) [a]	2.91 (0.67) [b]	2.24 (0.61) [c]	2.90 (0.64) [b]	2.57 (0.74)
AMD						
Attitude toward MD	6.22 (1.36) [a]	6.29 (1.17) [a]	5.14 (1.75) [b]	5.71 (1.39) [c]	5.26 (1.78) [b]	5.72 (1.58)
HTAS						
Attitude healthy eating	4.64 (0.91) [a]	4.80 (0.97) [b]	4.82 (0.90) [b]	4.47 (0.94) [c]	4.95 (0.98) [d]	4.74 (0.95)

The food choice motives scale and the sustainable food choice motives scale were recorded on a 7-point scale (1—Not at all important; 7—Extremely important). The picky eating items were recorded on a 5-point scale (1—Never; 2—Rarely; 3—Sometimes; 4—Often; 5—Always). Attitude toward the adoption of the MD and attitude toward healthy eating were recorded on 7-point scales. Note: [1] includes the item "Is produced in halal way"; [2] does not include the item "Is produced in halal way". Means followed by a common letter are not significantly different; different letters indicate statistically significant differences between countries (post-hoc Tukey HSD test, $p < 0.05$).

Table A3. Cronbach's alpha of the selected variables across the five countries.

	Greece (n = 800)	Italy (n = 802)	Morocco (n = 803)	Slovenia (n = 806)	Tunisia (n = 814)	Total (n = 4025)
Health	0.889	0.842	0.830	0.867	0.851	0.855
Natural content	0.873	0.909	0.796	0.900	0.768	0.844
Weight control	0.886	0.909	0.840	0.899	0.765	0.856
Sensory appeal	0.823	0.828	0.783	0.802	0.750	0.787
Convenience	0.770	0.836	0.794	0.856	0.788	0.807
Price	0.790	0.856	0.712	0.811	0.702	0.767
Familiarity	0.758	0.822	0.747	0.761	0.706	0.761
General sustainability	0.920	0.939	0.875	0.947	0.830	0.912
Local and seasonal	0.842	0.859	0.751	0.881	0.772	0.815
Attitude toward MD	0.953	0.919	0.888	0.922	0.916	0.922
Attitude healthy eating	0.774	0.798	0.718	0.770	0.721	0.746
Picky eating	0.877	0.898	0.798	0.874	0.756	0.873

Table A4. Structural equation models predicting the attitude toward the Mediterranean Diet (MD) and the adherence score to the MD: unstandardized coefficients (beta), standard errors (se).

Predictors	Greece (n = 800)		Italy (n = 802)		Morocco (n = 803)		Slovenia (n = 806)		Tunisia (n = 814)	
Attitude toward MD	**beta**	**se**	**beta**	**se**	**beta**	**se**	**beta**	**se**	**beta**	**se**
Health	0.002	0.059	−0.007	0.053	0.064	0.063	0.028	0.053	0.143	0.054
Natural content	0.156	0.054	−0.032	0.048	0.012	0.061	0.118	0.051	0.109	0.056
Weight control	0.041	0.045	−0.004	0.037	0.000	0.046	−0.071	0.042	−0.057	0.049
Sensory appeal	0.101	0.052	0.067	0.048	−0.028	0.066	0.094	0.050	−0.069	0.061
Convenience	−0.074	0.046	−0.021	0.041	0.095	0.052	0.111	0.044	0.020	0.047
Price	0.034	0.049	−0.049	0.041	0.027	0.058	−0.086	0.048	0.095	0.056
Familiarity	0.007	0.047	0.132	0.038	−0.001	0.052	−0.041	0.049	0.017	0.051
General sustainability	−0.007	0.045	0.156	0.043	−0.001	0.055	0.003	0.043	−0.075	0.057
Local and seasonal	0.088	0.044	0.072	0.043	0.030	0.050	0.092	0.046	0.025	0.046
Attitude healthy eating	0.057	0.068	0.070	0.057	0.041	0.080	0.135	0.070	0.084	0.080
Picky eating	−0.213	0.083	−0.209	0.068	0.075	0.124	−0.230	0.092	−0.170	0.134
Adherence to the MD	**beta**	**se**	**beta**	**se**	**beta**	**se**	**beta**	**se**	**beta**	**se**
Health	0.078	0.072	0.099	0.080	0.161	0.063	0.196	0.069	0.101	0.056
Natural content	0.117	0.067	0.349	0.072	0.122	0.060	0.094	0.067	0.183	0.057
Weight control	0.140	0.056	0.068	0.056	0.072	0.046	0.126	0.055	0.055	0.050
Sensory appeal	−0.058	0.065	−0.227	0.072	−0.124	0.065	−0.122	0.067	−0.046	0.063
Convenience	−0.150	0.057	−0.109	0.062	−0.041	0.052	−0.074	0.059	−0.036	0.049
Price	−0.051	0.061	−0.086	0.062	−0.098	0.058	−0.002	0.063	−0.170	0.057
Familiarity	−0.084	0.058	−0.071	0.058	−0.041	0.051	−0.059	0.065	0.029	0.053
General sustainability	−0.023	0.055	−0.104	0.065	0.006	0.054	0.041	0.057	−0.028	0.058
Local and seasonal	0.109	0.055	0.115	0.065	0.124	0.050	0.069	0.061	0.067	0.047
Attitude toward MD	0.095	0.044	0.185	0.053	0.034	0.035	0.223	0.047	0.053	0.036
Attitude healthy eating	0.465	0.084	0.426	0.085	0.365	0.079	0.566	0.093	0.289	0.082
Picky eating	−0.092	0.103	−0.207	0.102	−0.253	0.122	−0.356	0.122	−0.313	0.138

Table A5. Main drivers and barriers to the Mediterranean Diet (MD): mean values (SD).

Drivers and Barriers to the MD	Greece (n = 800)	Italy (n = 802)	Morocco (n = 803)	Slovenia (n = 806)	Tunisia (n = 814)	Total (n = 4025)
Drivers						
Health (positive effect on cholesterol, lowers LDL, and reduces health risks)	5.85 (1.00) ^{a}	5.80 (1.00) ^{a}	5.07 (1.17) ^{b}	5.42 (1.20) ^{c}	4.82 (1.32) ^{d}	5.39 (1.21)
Diet quality (healthier, more nutritious food, higher F&Vs, and lower meat consumption)	6.08 (0.86) ^{a}	6.07 (0.80) ^{a}	5.62 (0.98) ^{b}	5.65 (1.02) ^{b}	5.39 (1.09) ^{c}	5.76 (0.99)
Applicability (tastier and more sustainable than other diets)	5.97 (1.04) ^{a}	6.02 (1.04) ^{a}	5.57 (1.21) ^{b}	5.22 (1.32) ^{c}	5.59 (1.21) ^{b}	5.67 (1.21)
Lifestyle (homemade, unprocessed, additive-free, socialization, and family relations)	5.78 (0.92) ^{a}	5.72 (0.95) ^{a,c}	5.54 (1.07) ^{b}	5.18 (1.14) ^{d}	5.62 (1.00) ^{b,c}	5.57 (1.04)
Affordability (easier food access and lower-priced food)	5.00 (1.15) ^{a}	5.25 (1.15) ^{b}	5.15 (1.17) ^{a,b}	4.13 (1.27) ^{c}	5.14 (1.17) ^{a,b}	4.93 (1.25)
Environment (positive for environment, better carbon footprint, and local food)	5.29 (1.00) ^{a}	5.46 (0.98) ^{b}	5.30 (0.92) ^{a}	4.77 (1.12) ^{c}	5.18 (0.97) ^{a}	5.20 (1.03)
Barriers						
Health (contain allergenic foods)	3.92 (1.26) ^{a}	4.03 (1.38) ^{a}	3.95 (1.27) ^{a}	3.63 (1.31) ^{b}	3.94 (1.30) ^{a}	3.89 (1.31)
Restrictiveness (insufficient food variety, restrictive, difficult diversify food recipes)	2.60 (1.17) ^{a}	2.39 (1.29) ^{b}	3.47 (1.36) ^{c}	3.00 (1.15) ^{d}	3.11 (1.31) ^{d}	2.91 (1.31)
Convenience (difficult to prepare and time-consuming)	3.19 (1.50) ^{a}	2.98 (1.56) ^{a}	3.88 (1.59) ^{b}	3.44 (1.44) ^{c}	3.70 (1.71) ^{b}	3.44 (1.60)
Taste (contains unpleasant-tasting foods)	2.18 (1.32) ^{a}	2.04 (1.45) ^{a}	3.11 (1.79) ^{b}	2.63 (1.44) ^{c}	2.53 (1.63) ^{c}	2.50 (1.58)
Food culture (conflict with cultural habits)	2.66 (1.49) ^{a}	2.27 (1.45) ^{b}	3.39 (1.76) ^{c}	2.71 (1.46) ^{a,d}	2.91 (1.72) ^{d}	2.79 (1.62)
Affordability (contains high-priced foods)	3.83 (1.49) ^{a}	3.18 (1.62) ^{b}	3.96 (1.63) ^{a}	4.00 (1.54) ^{a}	3.86 (1.66) ^{a}	3.77 (1.62)
Access (limited options in shops and restaurants)	3.20 (1.38) ^{a}	2.52 (1.46) ^{b}	3.85 (1.52) ^{c}	3.81 (1.40) ^{c}	3.53 (1.56) ^{d}	3.38 (1.55)

Notes: The items were all recorded on a 7-point scale (1—Not at all important; 7—Extremely important). Means followed by a common letter are not significantly different; different letters indicate statistically significant differences between countries (post-hoc Tukey HSD test, $p < 0.05$).

References

1. Trichopoulou, A. Mediterranean diet as intangible heritage of humanity: 10 years on. *Nutr. Metab. Cardiovasc. Dis.* **2021**, *31*, 1943–1948. [CrossRef] [PubMed]
2. Willett, W.C.; Sacks, F.; Trichopoulou, A.; Drescher, G.; Ferro-Luzzi, A.; Helsing, E.; Trichopoulos, D. Mediterranean diet pyramid: A cultural model for healthy eating. *Am. J. Clin. Nutr.* **1995**, *61*, 1402S–1406S. [CrossRef] [PubMed]
3. Sikalidis, A.K.; Kelleher, A.H.; Kristo, A.S. Mediterranean Diet. *Encyclopedia* **2021**, *1*, 371–387. [CrossRef]
4. Ventriglio, A.; Sancassiani, F.; Contu, M.P.; Latorre, M.; Di Slavatore, M.; Fornaro, M.; Bhugra, D. Mediterranean Diet and its Benefits on Health and Mental Health: A Literature Review. *Clin. Pract. Epidemiol. Ment. Health* **2020**, *16*, 156–164. [CrossRef] [PubMed]
5. Guasch-Ferré, M.; Willett, W.C. The Mediterranean diet and health: A comprehensive overview. *J. Intern. Med.* **2021**, *290*, 549–566. [CrossRef] [PubMed]
6. Galbete, C.; Schwingshackl, L.; Schwedhelm, C.; Boeing, H.; Schulze, M.B. Evaluating Mediterranean diet and risk of chronic disease in cohort studies: An umbrella review of meta-analyses. *Eur. J. Epidemiol.* **2018**, *33*, 909–931. [CrossRef] [PubMed]
7. Davis, C.; Bryan, J.; Hodgson, J.; Murphy, K. Definition of the Mediterranean Diet; A Literature Review. *Nutrients* **2015**, *7*, 9139–9153. [CrossRef]
8. Becerra-Tomás, N.; Blanco Mejía, S.; Viguiliouk, E.; Khan, T.; Kendall, C.W.C.; Kahleova, H.; Rahelić, D.; Sievenpiper, J.L.; Salas-Salvadó, J. Mediterranean diet, cardiovascular disease and mortality in diabetes: A systematic review and meta-analysis of prospective cohort studies and randomized clinical trials. *Crit. Rev. Food Sci. Nutr.* **2020**, *60*, 1207–1227. [CrossRef] [PubMed]
9. Gerber, M.; Hoffman, R. The Mediterranean diet: Health, science and society. *Br. J. Nutr.* **2015**, *113* (Suppl. S2), S4–S10. [CrossRef]
10. Dinu, M.; Pagliai, G.; Casini, A.; Sofi, F. Mediterranean diet and multiple health outcomes: An umbrella review of meta-analyses of observational studies and randomised trials. *Eur. J. Clin. Nutr.* **2018**, *72*, 30–43. [CrossRef]
11. Gantenbein, K.V.; Kanaka-Gantenbein, C. Mediterranean Diet as an Antioxidant: The Impact on Metabolic Health and Overall Wellbeing. *Nutrients* **2021**, *13*, 1951. [CrossRef]
12. Martín-Peláez, S.; Fito, M.; Castaner, O. Mediterranean Diet Effects on Type 2 Diabetes Prevention, Disease Progression, and Related Mechanisms. A Review. *Nutrients* **2020**, *12*, 2236. [CrossRef] [PubMed]
13. Morze, J.; Danielewicz, A.; Przybyłowicz, K.; Zeng, H.; Hoffmann, G.; Schwingshackl, L. An updated systematic review and meta-analysis on adherence to mediterranean diet and risk of cancer. *Eur. J. Nutr.* **2021**, *60*, 1561–1586. [CrossRef]
14. Obeid, C.A.; Gubbels, J.S.; Jaalouk, D.; Kremers, S.P.J.; Oenema, A. Adherence to the Mediterranean diet among adults in Mediterranean countries: A systematic literature review. *Eur. J. Nutr.* **2022**, *61*, 3327–3344. [CrossRef]
15. Dernini, S.; Berry, E.M.; Serra-Majem, L.; La Vecchia, C.; Capone, R.; Medina, F.X.; Aranceta-Bartrina, J.; Belahsen, R.; Burlingame, B.; Calabrese, G.; et al. Med Diet 4.0: The Mediterranean diet with four sustainable benefits. *Public Health Nutr.* **2017**, *20*, 1322–1330. [CrossRef] [PubMed]
16. Burlingame, B.; Gitz, V.; Meybeck, A. *Mediterranean Food Consumption Patterns. Diet, Environment, Society, Economy and Health*; FAO: Rome, Italy, 2015.
17. Germani, A.; Vitiello, V.; Giusti, A.M.; Pinto, A.; Donini, L.M.; Del Balzo, V. Environmental and economic sustainability of the Mediterranean diet. *Int. J. Food Sci. Nutr.* **2014**, *65*, 1008–1012. [CrossRef] [PubMed]
18. Quarta, S.; Massaro, M.; Chervenkov, M.; Ivanova, T.; Dimitrova, D.; Jorge, R.; Andrade, V.; Philippou, E.; Zisimou, C.; Maksimova, V.; et al. Persistent Moderate-to-Weak Mediterranean Diet Adherence and Low Scoring for Plant-Based Foods across Several Southern European Countries: Are We Overlooking the Mediterranean Diet Recommendations? *Nutrients* **2021**, *13*, 1432. [CrossRef]
19. Deligiannidou, G.-E.; Philippou, E.; Vasiari, E.; de Andrade, V.L.; Massaro, M.; Chervenkov, M.; Ivanova, T.; Jorge, R.; Dimitrova, D.; Ruskovska, T.; et al. Exploring the Relationship between Mediterranean Diet Adherence and Subjective Well-Being among Greek and Cypriot Adults. *Nutrients* **2024**, *16*, 1238. [CrossRef]
20. Kamiński, M.; Skonieczna-Żydecka, K.; Nowak, J.K.; Stachowska, E. Global and local diet popularity rankings, their secular trends, and seasonal variation in Google Trends data. *Nutrition* **2020**, *79–80*, 110759. [CrossRef]
21. García-Nieto, A.P.; Geijzendorffer, I.R.; Baró, F.; Roche, P.K.; Bondeau, A.; Cramer, W. Impacts of urbanization around Mediterranean cities: Changes in ecosystem service supply. *Ecol. Indic.* **2018**, *91*, 589–606. [CrossRef]
22. Bonaccio, M.; Di Castelnuovo, A.; Bonanni, A.; Costanzo, S.; De Lucia, F.; Persichillo, M.; Zito, F.; Donati, M.B.; de Gaetano, G.; Iacoviello, L. Decline of the Mediterranean diet at a time of economic crisis. Results from the Moli-sani study. *Nutr. Metab. Cardiovasc. Dis.* **2014**, *24*, 853–860. [CrossRef] [PubMed]
23. di Giuseppe, R.; Bonanni, A.; Olivieri, M.; Di Castelnuovo, A.; Donati, M.B.; de Gaetano, G.; Cerletti, C.; Iacoviello, L. Adherence to Mediterranean diet and anthropometric and metabolic parameters in an observational study in the "Alto Molise" region: The MOLI-SAL project. *Nutr. Metab. Cardiovasc. Dis.* **2008**, *18*, 415–421. [CrossRef] [PubMed]
24. Sofi, F.; Vecchio, S.; Giuliani, G.; Martinelli, F.; Marcucci, R.; Gori, A.M.; Fedi, S.; Casini, A.; Surrenti, C.; Abbate, R.; et al. Dietary habits, lifestyle and cardiovascular risk factors in a clinically healthy Italian population: The "Florence" diet is not Mediterranean. *Eur. J. Clin. Nutr.* **2005**, *59*, 584–591. [CrossRef] [PubMed]
25. Statovci, D.; Aguilera, M.; MacSharry, J.; Melgar, S. The Impact of Western Diet and Nutrients on the Microbiota and Immune Response at Mucosal Interfaces. *Front. Immunol.* **2017**, *8*, 838. [CrossRef] [PubMed]

26. Bonaccio, M.; Di Castelnuovo, A.; Costanzo, S.; De Lucia, F.; Olivieri, M.; Donati, M.B.; de Gaetano, G.; Iacoviello, L.; Bonanni, A. Nutrition knowledge is associated with higher adherence to Mediterranean diet and lower prevalence of obesity. Results from the Moli-sani study. *Appetite* **2013**, *68*, 139–146. [CrossRef] [PubMed]
27. Biasini, B.; Rosi, A.; Menozzi, D.; Scazzina, F. Adherence to the Mediterranean Diet in Association with Self-Perception of Diet Sustainability, Anthropometric and Sociodemographic Factors: A Cross-Sectional Study in Italian Adults. *Nutrients* **2021**, *13*, 3282. [CrossRef] [PubMed]
28. Tsofliou, F.; Vlachos, D.; Hughes, C.; Appleton, K.M. Barriers and Facilitators Associated with the Adoption of and Adherence to a Mediterranean Style Diet in Adults: A Systematic Review of Published Observational and Qualitative Studies. *Nutrients* **2022**, *14*, 4314. [CrossRef] [PubMed]
29. Menozzi, D.; Fugazza, S.C.; Biggi, C.; Biasini, B.; Riviou, K.; Younes, N.; Kaoutar, E.; Nadia, H.; Strojnik, L.; Korošec, M.; et al. *Report on Consumers' Food Habits and Attitudes towards Healthy/Local Foods*; PROMEDLIFE Project, Deliverable 2.2, 2023.
30. Steptoe, A.; Pollard, T.M.; Wardle, J. Development of a Measure of the Motives Underlying the Selection of Food: The Food Choice Questionnaire. *Appetite* **1995**, *25*, 267–284. [CrossRef] [PubMed]
31. Pieniak, Z.; Verbeke, W.; Vanhonacker, F.; Guerrero, L.; Hersleth, M. Association between traditional food consumption and motives for food choice in six European countries. *Appetite* **2009**, *53*, 101–108. [CrossRef] [PubMed]
32. dos Santos, Q.; Perez-Cueto, F.J.A.; Rodrigues, V.M.; Appleton, K.; Giboreau, A.; Saulais, L.; Monteleone, E.; Dinnella, C.; Brugarolas, M.; Hartwell, H. Impact of a nudging intervention and factors associated with vegetable dish choice among European adolescents. *Eur. J. Nutr.* **2020**, *59*, 231–247. [CrossRef]
33. Couto, R.M.; Frugé, A.D.; Greene, M.W. Adherence to the Mediterranean Diet in a Portuguese Immigrant Community in the Central Valley of California. *Nutrients* **2021**, *13*, 1989. [CrossRef]
34. Knight, C.J.; Jackson, O.; Rahman, I.; Burnett, D.O.; Frugé, A.D.; Greene, M.W. The Mediterranean Diet in the Stroke Belt: A Cross-Sectional Study on Adherence and Perceived Knowledge, Barriers, and Benefits. *Nutrients* **2019**, *11*, 1847. [CrossRef] [PubMed]
35. Marty, L.; Chambaron, S.; de Lauzon-Guillain, B.; Nicklaus, S. The motivational roots of sustainable diets: Analysis of food choice motives associated to health, environmental and socio-cultural aspects of diet sustainability in a sample of French adults. *Clean. Responsible Consum.* **2022**, *5*, 100059. [CrossRef]
36. Biasini, B.; Rosi, A.; Scazzina, F.; Menozzi, D. Predicting the Adoption of a Sustainable Diet in Adults: A Cross-Sectional Study in Italy. *Nutrients* **2023**, *15*, 2784. [CrossRef] [PubMed]
37. Franchini, C.; Biasini, B.; Sogari, G.; Wongprawmas, R.; Andreani, G.; Dolgopolova, I.; Gómez, M.I.; Roosen, J.; Menozzi, D.; Mora, C.; et al. Adherence to the Mediterranean Diet and its association with sustainable dietary behaviors, sociodemographic factors, and lifestyle: A cross-sectional study in US University students. *Nutr. J.* **2024**, *23*, 56. [CrossRef] [PubMed]
38. Verain, M.C.D.; Snoek, H.M.; Onwezen, M.C.; Reinders, M.J.; Bouwman, E.P. Sustainable food choice motives: The development and cross-country validation of the Sustainable Food Choice Questionnaire (SUS-FCQ). *Food Qual. Prefer.* **2021**, *93*, 104267. [CrossRef]
39. Fishbein, M.; Ajzen, I. *Predicting and Changing Behavior: The Reasoned Action Approach*; Taylor & Francis Group: New York, NY, USA, 2011; ISBN 9780203838020.
40. Roininen, K.; Lähteenmäki, L.; Tuorila, H. Quantification of consumer attitudes to health and hedonic characteristics of foods. *Appetite* **1999**, *33*, 71–88. [CrossRef] [PubMed]
41. Carfora, V.; Morandi, M.; Jelić, A.; Catellani, P. The psychosocial antecedents of the adherence to the Mediterranean diet. *Public Health Nutr.* **2022**, *25*, 2742–2757. [CrossRef]
42. Menghi, L.; Endrizzi, I.; Cliceri, D.; Zampini, M.; Giacalone, D.; Gasperi, F. Validating the Italian version of the Adult Picky Eating Questionnaire. *Food Qual. Prefer.* **2022**, *101*, 104647. [CrossRef]
43. Zickgraf, H.F.; Franklin, M.E.; Rozin, P. Adult picky eaters with symptoms of avoidant/restrictive food intake disorder: Comparable distress and comorbidity but different eating behaviors compared to those with disordered eating symptoms. *J. Eat. Disord.* **2016**, *4*, 26. [CrossRef]
44. Ellis, J.M.; Galloway, A.T.; Zickgraf, H.F.; Whited, M.C. Picky eating and fruit and vegetable consumption in college students. *Eat. Behav.* **2018**, *30*, 5–8. [CrossRef] [PubMed]
45. Jaeger, S.R.; Cardello, A. V Factors affecting data quality of online questionnaires: Issues and metrics for sensory and consumer research. *Food Qual. Prefer.* **2022**, *102*, 104676. [CrossRef]
46. Ward, M.K.; Meade, A.W. Dealing with Careless Responding in Survey Data: Prevention, Identification, and Recommended Best Practices. *Annu. Rev. Psychol.* **2023**, *74*, 577–596. [CrossRef] [PubMed]
47. Wongprawmas, R.; Andreani, G.; Franchini, C.; Biasini, B.; Rosi, A.; Dolgopolova, I.; Roosen, J.; Menozzi, D.; Gómez, M.I.; Scazzina, F.; et al. Nudging Italian university students towards healthy and sustainable food choices: An online experiment. *Food Qual. Prefer.* **2023**, *111*, 104971. [CrossRef]
48. Ellis, J.M.; Galloway, A.T.; Webb, R.M.; Martz, D.M. Measuring adult picky eating: The development of a multidimensional self-report instrument. *Psychol. Assess.* **2017**, *29*, 955–966. [CrossRef] [PubMed]
49. He, J.; Ellis, J.M.; Zickgraf, H.F.; Fan, X. Translating, modifying, and validating the Adult Picky Eating Questionnaire for use in China. *Eat. Behav.* **2019**, *33*, 78–84. [CrossRef] [PubMed]

50. Martínez-González, M.A.; García-Arellano, A.; Toledo, E.; Salas-Salvadó, J.; Buil-Cosiales, P.; Corella, D.; Covas, M.I.; Schröder, H.; Arós, F.; Gómez-Gracia, E.; et al. A 14-item Mediterranean diet assessment tool and obesity indexes among high-risk subjects: The PREDIMED trial. *PLoS ONE* **2012**, *7*, e43134. [CrossRef] [PubMed]
51. Scannell, N.; Villani, A.; Mantzioris, E.; Swanepoel, L. Understanding the Self-Perceived Barriers and Enablers toward Adopting a Mediterranean Diet in Australia: An Application of the Theory of Planned Behaviour Framework. *Int. J. Environ. Res. Public Health* **2020**, *17*, 932. [CrossRef]
52. WHO Cut-Off for BMI According to WHO Standards 2010. Available online: https://gateway.euro.who.int/en/indicators/mn_survey_19-cut-off-for-bmi-according-to-who-standards/ (accessed on 4 June 2024).
53. Turki, S.; Bouzekri, K.; Trabelsi, T.; El Ati, J. Assessment of Mediterranean Diet Adherence and Lifestyle Change during COVID-19 National Lockdown in Tunisian Adult Population. *Nutrients* **2022**, *14*, 4151. [CrossRef]
54. Kline, R.B. *Principles and Practice of Structural Equation Modeling*, 4th ed.; Methodology in the Social Sciences; Guilford Press: New York, NY, USA, 2016; ISBN 978-1-4625-2334-4/978-1-4625-2335-1/978-1-4625-2300-9.
55. Byrne, B.M. *Structural Equation Modeling with AMOS: Basic Concepts, Applications, and Programming*, 2nd ed.; Multivariate applications series; Routledge/Taylor & Francis Group: New York, NY, USA, 2010; ISBN 978-0-8058-6373-4/978-0-8058-6372-7.
56. Ajzen, I.; Kruglanski, A.W. Reasoned action in the service of goal pursuit. *Psychol. Rev.* **2019**, *126*, 774–786. [CrossRef]
57. Rubini, A.; Vilaplana-Prieto, C.; Flor-Alemany, M.; Yeguas-Rosa, L.; Hernández-González, M.; Félix-García, F.J.; Félix-Redondo, F.J.; Fernández-Bergés, D. Assessment of the Cost of the Mediterranean Diet in a Low-Income Region: Adherence and Relationship with Available Incomes. *BMC Public Health* **2022**, *22*, 58. [CrossRef]
58. Serra-Majem, L.; Tomaino, L.; Dernini, S.; Berry, E.M.; Lairon, D.; Ngo de la Cruz, J.; Bach-Faig, A.; Donini, L.M.; Medina, F.-X.; Belahsen, R.; et al. Updating the Mediterranean Diet Pyramid towards Sustainability: Focus on Environmental Concerns. *Int. J. Environ. Res. Public Health* **2020**, *17*, 8758. [CrossRef] [PubMed]
59. Sogari, G.; Wongprawmas, R.; Andreani, G.; Lefebvre, M.; Pellegrini, N.; Gómez, M.I.; Mora, C.; Menozzi, D. Intention and behavior toward eating whole grain pasta on a college dining campus: Theory of Planned Behavior and message framing. *Bio-Based Appl. Econ.* **2024**.
60. Dolgopolova, I.; Li, B.; Pirhonen, H.; Roosen, J. The effect of attribute framing on consumers' attitudes and intentions toward food: A Meta-analysis. *Bio-Based Appl. Econ.* **2022**, *10*, 253–264. [CrossRef]
61. Bonaccorsi, G.; Furlan, F.; Scocuzza, M.; Lorini, C. Adherence to Mediterranean Diet among Students from Primary and Middle School in the Province of Taranto, 2016–2018. *Int. J. Environ. Res. Public Health* **2020**, *17*, 5437. [CrossRef]
62. Vitale, M.; Bianchi, M.A.; Rapetti, V.; Pepe, J.M.; Giacco, A.; Giacco, R.; Riccardi, G. A nutritional intervention programme at a worksite canteen to promote a healthful lifestyle inspired by the traditional Mediterranean diet. *Int. J. Food Sci. Nutr.* **2018**, *69*, 117–124. [CrossRef] [PubMed]
63. McEvoy, C.T.; Moore, S.; Erwin, C.; Kontogianni, M.; Wallace, S.M.; Appleton, K.M.; Cupples, M.; Hunter, S.; Kee, F.; McCance, D.R.; et al. Trial to Encourage Adoption and Maintenance of a MEditerranean Diet (TEAM-MED): A randomised pilot trial of a peer support intervention for dietary behaviour change in adults from a Northern European population at high CVD risk. *Br. J. Nutr.* **2022**, *128*, 1322–1334. [CrossRef]
64. McManu, K.D. A Practical Guide to the Mediterranean Diet. Available online: https://www.health.harvard.edu/blog/a-practical-guide-to-the-mediterranean-diet-2019032116194 (accessed on 7 June 2024).
65. Biasini, B.; Rosi, A.; Giopp, F.; Turgut, R.; Scazzina, F.; Menozzi, D. Understanding, promoting and predicting sustainable diets: A systematic review. *Trends Food Sci. Technol.* **2021**, *111*, 191–207. [CrossRef]
66. Afshin, A.; Peñalvo, J.L.; Del Gobbo, L.; Silva, J.; Michaelson, M.; O'Flaherty, M.; Capewell, S.; Spiegelman, D.; Danaei, G.; Mozaffarian, D. The prospective impact of food pricing on improving dietary consumption: A systematic review and meta-analysis. *PLoS ONE* **2017**, *12*, e0172277. [CrossRef]
67. Cacciatore, S.; Gava, G.; Calvani, R.; Marzetti, E.; Coelho-Júnior, H.J.; Picca, A.; Esposito, I.; Ciciarello, F.; Salini, S.; Russo, A.; et al. Lower Adherence to a Mediterranean Diet Is Associated with High Adiposity in Community-Dwelling Older Adults: Results from the Longevity Check-Up (Lookup) 7+ Project. *Nutrients* **2023**, *15*, 4892. [CrossRef]
68. Taylor, C.M.; Wernimont, S.M.; Northstone, K.; Emmett, P.M. Picky/fussy eating in children: Review of definitions, assessment, prevalence and dietary intakes. *Appetite* **2015**, *95*, 349–359. [CrossRef] [PubMed]
69. Di Nucci, A.; Pilloni, S.; Scognamiglio, U.; Rossi, L. Adherence to Mediterranean Diet and Food Neophobia Occurrence in Children: A Study Carried out in Italy. *Nutrients* **2023**, *15*, 5078. [CrossRef] [PubMed]

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PROMEDLIFE Questionnaire

[Language preference]

Please select your preferred language:

- Arab
- Greek
- French
- Italian
- Slovenian

[Brief introduction to the questionnaire]

Dear Participant,

we would like to invite you to take part in a research study involving the administration of a questionnaire with questions concerning certain socio-demographic and lifestyle aspects (dietary habits and preferences, physical activity) conducted as part of the PRIMA European project "PROMEDLIFE".

Before you decide to participate in this study, it is important that you have all the information you need to participate in an informed and responsible manner. We ask you to read the following and to contact Prof. Davide Menozzi (davide.menozzi@unipr.it) with any questions you may have, indicating "PROMEDLIFE STUDY" in the subject line of the email.

Participation is completely voluntary and all information collected will be kept private and confidential. Data from the study are collected anonymously and will only be used for research purposes.

Brief Description and Objectives. *The research project aims to investigate lifestyle (dietary habits and preferences, physical activity) in relation to socio-demographic characteristics.*

What does participation in the study entail? *Participation in this research project entails the honest and sincere fulfilment of an online questionnaire about your socio-demographic and lifestyle characteristics.*

Benefits, inconveniences and/or potential risks of participation. *Participation in the study does not entail any kind of risk or inconvenience.*

Withdrawal from the study*. You have the right to withdraw your consent to participate in this study at any time, even without prior notice or specific reason.*

Return*. You have the right to request information on the results and outcome of the search.*

Measures envisaged to protect anonymity*. The data will be collected anonymously and used exclusively for scientific and statistical purposes and in compliance with current data protection*

legislation. The research results will be published in summary form and under no circumstances will any brief quotations be attributable to individual persons.

Contact. *Please contact Prof. Davide Menozzi (davide.menozzi@unipr.it) for any further information or clarification you may require.*

1. If you agree to these terms and conditions, please select 'I agree' to continue the survey.

- I agree → question n.3
- I don't agree

2. You stated to not consent with the participation terms and do not want to participate in the survey. Are you sure?[1]

- Yes (screen out)
- No, I want to try again

[Screening questions]

3. Please indicate where you live

- Italy (for Italian survey only)
- Greece (for Greek survey only)
- Slovenia (for Slovenian survey only)
- Tunisia (for Tunisian survey only)
- Morocco (for Moroccan survey only)
- Other (screen out)

4. Please indicate how long have you been living in Italy/Greece/Slovenia/Tunisia/Morocco.

- < 1 year[2] (screen out)
- 1-5 years
- >5 years

5. What is your age[3]**?** (A drop-down menu will be shown):

- <18 years (screen out)
- ...
- >79 years (screen out)

6. Are you responsible for food purchases for your family or yourself[4]**?**

- Always
- Often
- Sometimes

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[1] Henn et al, 2022 (doi: 10.1016/j.foodqual.2021.104455)
[2] The idea is to limit the survey to those residing from at least one year in the country of residence for food habits adaptation
[3] Definition of adults based on "adult"[Mesh] in Pubmed excluding "aged, 80 and over"[Mesh].
[4] This screening condition is defined in the Grant Agreement.

- Never (screen out)

[General food-related questions]

7. Are you responsible for meal preparation for your family or yourself?

- Always
- Often
- Sometimes
- Never

8. Do you consider yourself…

- Omnivore (general food regimen, both plants and animals are included)
- Lacto-vegetarian (meat, poultry, fish, eggs are excluded; dairy products such as milk, cheese, yoghurt, and butter are included).
- Ovo-vegetarian (meat, poultry, fish, and dairy products are excluded; eggs are included).
- Lacto-ovo vegetarian (meat, poultry, and fish are excluded; dairy products and eggs are included).
- Pescatarian (meat, poultry, dairy products, and eggs are excluded; fish is included).
- Vegan (meat, poultry, fish, eggs and dairy products are excluded)
- Flexitarian (a plant-based diet with the occasional inclusion of animal products)
- Others (please specify) _____

9. Please indicate if your food habits are affected by any religious beliefs and/or ethical concerns

- Yes, they are affected by religious beliefs
- Yes, they are affected by ethical concerns
- Yes, they are affected by religious beliefs and ethical concerns
- No, they are not affected by any religious beliefs and/or ethical concerns

10. Are you currently on a low-calorie diet for weight loss or weight loss maintenance?

- Yes, under the supervision of a healthcare professional
- Yes, without the supervision of a healthcare professional
- No
- Other (please specify)_____

11. How often do you eat meals (breakfast, lunch or dinner) out of home*?

*This includes, for example, meals eaten in restaurants, canteens or self-service restaurants and not meals cooked at home and eaten at work.

- Never
- Less than once a month
- Once a month
- 2-3 times per month
- 1-2 times per week

- 3-4 times per week
- 5 or more times per week

12. How often do you eat fast foods?

- Never
- Less than once a month
- Once a month
- 2-3 times per month
- 1-2 times per week
- 3-4 times per week
- 5 or more times per week

[Food choice motives]

Please answer to the following items on a 7-point scale (1 – Not at all important; 7 – Extremely important)[5]

It is important to me that the food I eat on a typical day…

		1	2	3	4	5	6	7
	[Health]							
1.	Contains a lot of vitamins and minerals							
2.	Keeps me healthy							
3.	Is nutritious							
	[Convenience]							
4.	Is easy to plan, buy and prepare							
5.	Can be cooked very easily							
6.	Takes very little or no time to prepare							
	[Sensory appeal]							
7.	Smells nice							
8.	Has a pleasant texture							
9.	Tastes well							
	[Natural content]							
10.	Contains no additives							
11.	Contains natural ingredients							
12.	Contains no artificial ingredients							
	[Price]							
13.	Is not expensive							
14.	Is cheap							

[5] Adapted version by Pieniak et al, 2009 (http://dx.doi.org/10.1016/j.appet.2009.05.019).

15.	Is good value for money							
	[Weight control]							
16.	Is low in calories							
17.	Helps me control my weight							
18.	Is low in fat							
	[Familiarity]							
19.	Is what I usually eat							
20.	Is familiar							
21.	Is like the food I ate when I was a child							
	[Ethical concern]							
22.	Is produced using ethical production methods (e.g. sustainable, animal friendly, without child labour, etc.)							
23.	Supports the local economy							
24.	Is produced/packaged in an environmentally friendly way							

[Sustainable food choice motives][6]

Please answer to the following items on a 7-point scale (1 not at all important, 7 Extremely important).
It is important to me that the food I eat on a typical day…

	[General sustainability]	**1**	**2**	**3**	**4**	**5**	**6**	**7**
	[Animal welfare]							
1.	Is produced without animals being in pain							
2.	Is produced in an animal friendly way							
3.	Is produced in Halal way							
	[Ethical concern]							
1.	Is produced without exploitation							
2.	Is produced without child labour							
	[Environmental welfare]							
1.	Is prepared in an environmentally friendly way							
2.	Is produced in an environmentally friendly way							
	[Local and seasonal]							
1.	Is a local/regional product							
2.	Is a seasonal product							
3.	Comes from close by (little transport distance)							

[6] Verain et al, 2021, doi: 10.1016/j.foodqual.2021.104267 (short version used)

[Attitudes toward healthfulness of foods][7]

Please indicate to what extent you agree or disagree with each of the following statements on a 7-point scale: 1 "Strongly disagree" to 7 - Strongly agree".

	[General health interest - interest in eating healthily]	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1.	The healthiness of food has little impact on my food choices. **[R]**							
2.	I am very particular about the healthiness of food I eat.							
3.	I eat what I like and I do not worry much about the healthiness of food. **[R]**							
4.	It is important for me that my diet is low in fat.							
5.	I always follow a healthy and balanced diet.							
6.	It is important for me that my daily diet contains a lot of vitamins and minerals.							
7.	The healthiness of snacks makes no difference to me. **[R]**							
8.	I do not avoid foods, even if they may raise my cholesterol. **[R]**							

[Picky eating]

Please indicate to what extent the following statements apply to you (1 - Never; 2 – Rarely; 3 – Sometimes; 4 – Often; 5 – Always).

	[Meal presentation_1]	**1**	**2**	**3**	**4**	**5**
1.	I have a strong preference toward specific food presentation					
	[Food variety_1]					
2.	I eat a limited number of items from each food group					
	[Meal disengagement_1]					
3.	I am often disengaged/uninvolved when sitting at the table for mealtime					
	[Taste aversion_1]					
4.	I reject bitter foods, even if they are only slightly bitter					
	[Meal presentation_2]					
5.	I prefer foods of a particular color					
	[Food variety_2]					
6.	My usual diet lacks a variety of food groups					
	[Meal disengagement_2]					
7.	I usually feel that I have something better to do than eating					
	[Taste aversion_2]					
8.	I reject sour foods					
	[Meal presentation_3]					
9.	I cringe, cry, or gag after seeing or eating certain foods					
	[Food variety_3]					

[7] Roininen et al, 1999 (doi: 10.1006/appe.1999.0232)

10.	I do not like trying new foods					
	[Meal disengagement_3]					
11.	I avoid mealtimes					
	[Meal presentation_4]					
12.	I am sad or disappointed when food is not prepared/cooked in the "right way".					
	[Food variety_4]					
13.	I eat from a very narrow range of foods (<10 different foods).					
	[Meal presentation_5]					
14.	I am immediately suspicious of food and feel the need to carefully inspect the majority of food.					
	[Meal presentation_6]					
15.	I eat foods in a specific sequence.					
	[Meal presentation_7]					
16.	I will not eat a food if I saw someone else touch it.					
	[Taste aversion_3]					
17.	I prefer textures that are hard, dry or crunchy					
	[Taste aversion_4]					
18.	I avoid foods that are mushy or slippery					
	[Taste aversion_5]					
19.	I prefer only pureed or smooth foods					
	[Taste aversion_6]					
20.	I prefer only sweet or salty foods that do not have a significant amount of other flavors					

[Questionnaire to evaluate the adherence to the Mediterranean Diet – MEDAS questionnaire as used by Turki et al, 2022[8]]

Please answer to the following statements.

	Questions	**Alternative answers** (the score is not shown to the participant)
1.	Do you use olive oil as your main culinary fat?	○ Yes **[1 point]** ○ No
2.	How many teaspoons of olive oil do you consume in a given day (including that used for frying, salads, out-of-house meals, etc.)?	○ 4 or more **[1 point]** ○ 2 or 3 ○ Less than 1
3.	How many portions of vegetables (cooked and raw potatoes and beans are not included) do you eat per day? (One serving = 200 g = half a large plate)	○ 3 or more **[1 point]** ○ 1 or 2 **[1 point]** ○ Less than 1
4.	How many servings of fresh fruit (including natural fruit juices) do you consume per day? (Serving size = one unit of medium-sized fruit, one large cup of sliced fruit, one slice of medium-sized melon/watermelon, or one cup of fresh juice)	○ 3 or more **[1 point]** ○ 1 or 2 ○ Less than 1
5.	How many servings of red meat (veal, beef, mutton, pork[9])/ hamburgers/other meat products (salami, merguez, sausage…) do you consume per day? (One serving = 100 to 150 g = one quarter to half of a meal dish)	○ Less than 1 **[1 point]** ○ 2 to 4 ○ 5 to 6 ○ 7 or more
6.	How many portions of butter, margarine or cream do you consume per day? (One portion = 12 g = one dessert spoon for butter and margarine, 2 tablespoons for cream)	○ Less than 1 **[1 point]** ○ 1 ○ More than 1
7.	How much sugary drinks (industrial juices)/carbonated drinks/sodas do you consume per day? (One serving equals 330 mL)	○ Less than 1 **[1 point]** ○ 1 ○ More than 1
8.	How many glasses/cups of wine do you consume per week?[10]	○ More than 14 glasses (more than 2 glasses per day) **[1 point]** ○ 7 to 14 glasses (1 or 2 glasses per day) **[1 point]** ○ 2 to 6 glasses (sometimes but not every day) ○ One glass or less (occasionally)

[8] Turki, S., Bouzekri, K., Trabelsi, T., & El Ati, J. (2022). Assessment of Mediterranean Diet Adherence and Lifestyle Change during COVID-19 National Lockdown in Tunisian Adult Population. Nutrients, 14(19), 4151.
[9] Only in Italy, Greece and Slovenia.
[10] Not included in Tunisia and Morocco.

		○ None
9.	How many portions of legumes (lentils, beans, chickpeas, peas…) do you consume per week? (One portion = 150 g = one dish or glass)	○ 3 or more **[1 point]** ○ 1 to 2 ○ Less than 1
10.	How many portions of fish and seafood do you eat per week? (One portion = 100 to 150 g = a quarter to half of a meal dish)	○ 3 or more **[1 point]** ○ 1 to 2 ○ Less than 1
11.	How many times a week do you consume industrial (not homemade) desserts/confectionery/pastries? (Including cakes, biscuits, ice cream, etc.)	○ Less than 1 **[1 point]** ○ 1 to 2 **[1 point]** ○ 3 or more
12.	How many servings of nuts (unsalted) do you consume per week? (Including unsalted peanuts, almonds, hazelnuts, walnuts, etc. One serving = 30 g = one handful)	○ 3 or more **[1 point]** ○ 1 to 2 ○ Less than 1
13.	Do you prefer to consume chicken, turkey, or rabbit meat, or a vegetarian protein source, rather than red meat or derived products?	○ Yes **[1 point]** ○ No
14.	How many times a week do you eat dishes cooked with tomatoes or tomato sauce, onion and/or garlic and olive oil?	○ Twice or more **[1 point]** ○ Once or less

[Questionnaire to evaluate drivers and barriers to the Mediterranean Diet][11]

This figure[12] represents the Mediterranean Diet, a dietary pattern linked to the traditional food styles of countries bordering the Mediterranean Sea. Preference for local, seasonal, fresh and minimally processed food is emphasised, supporting biodiversity and eco-friendly and traditional foods. This dietary pattern is based on the consumption of:

· numerous plant foods (fruit, vegetables, bread, other cereals, potatoes, legumes);
· olive oil as the main source of fat;
· milk products and dairy products (mainly cheese and yogurt);
· fish and poultry in moderate quantities;
· up to four eggs per week;
· an extremely reduced quantity of red meat;
. an occasional consumption of sweets
· a moderate quantity of wine mainly during meals.



[11] Scannell et al, 2020 (doi:10.3390/ijerph17249321)
[12] Serra-Majem et al, 2020, doi: 10.3390/ijerph17238758.

Please indicate to what extend according to you the following statements are true or fault, on a 7 point scale (1 = Strongly disagree – 7 = Strongly agree)

DRIVERS								
		1	2	3	4	5	6	7
[HEALTH]								
1.	Mediterranean Diet has a positive effect on cholesterol.							
2.	Mediterranean Diet lowers LDL (bad) cholesterol levels.							
3.	Mediterranean Diet reduces the risk of cardiovascular disease, diabetes, mental illness, depression, cancer, and obesity.							
[DIET QUALITY]								
4.	Mediterranean Diet includes healthier and more nutritious foods.							
5.	Mediterranean Diet is defined by a higher fruit and vegetable consumption and lower red meat consumption.							
6.	Mediterranean Diet includes more beneficial oils for health.							
[APPLICABILITY]								
7.	Mediterranean Diet is tastier and more sustainable than other types of diets.							
[LIFESTYLE]								
8.	Mediterranean Diet increases consumption of homemade foods.							
9.	Mediterranean Diet includes more unprocessed and additive-free foods.							
10.	Mediterranean Diet is associated with higher socialization and family relationships.							
[AFFORDABILITY]								
11.	Food access is easier in Mediterranean Diet.							
12.	Mediterranean Diet contains lower-priced foods.							
[ENVIRONMENT]								
13.	Mediterranean Diet has a positive effect on the environment.							
14.	Mediterranean Diet reduces human impact on the environment.							
15.	Mediterranean Diet is associated with better carbon footprint.							
16. F	To demonstrate that you are not a robot, for this statement, please select "Strongly agree"							
17.	Mediterranean Diet contains more local foods.							
BARRIERS								
[HEALTH]								

18.	Mediterranean Diet contains more allergenic foods.							
19.	Mediterranean Diet is not applicable for vegans.							
20.	Food variety in Mediterranean Diet is insufficient.							
21.	Preparing meals suitable for Mediterranean Diet is difficult and time-consuming.							
22.	Mediterranean Diet is restrictive.							
23.	Mediterranean Diet contains unpleasant-tasting foods.							
24.	It is difficult to diversify food recipes in Mediterranean Diet.							
[LIFESTYLE]								
24.	Following Mediterranean Diet is difficult due to conflict with cultural habits/beliefs/norms.							
[AFFORDABILITY]								
25.	Mediterranean Diet contains high-priced foods.							
26.	There are limited options in shops for foods in Mediterranean Diet.							
27.	There are limited options in restaurants for foods in Mediterranean Diet.							

[Attitude towards the MD][13]

Following the Mediterranean Diet for me would be:

Please indicate your opinion using the following 7-point scale.

1. Disgusting - □ □ □ □ □ □ □ - Tasty
2. Unpleasant - □ □ □ □ □ □ □ - Pleasant
3. Disadvantageous - □ □ □ □ □ □ □ - Advantageous
4. Useless – □ □ □ □ □ □ □ - Useful

[Clinical questions]

1. **Please indicate if you have any medically diagnosed chronic disease.**
   - Yes
   - No
2. **Please indicate if you have any food intolerances or allergies**
   - Yes
   - No

[13] See Carfora et al, 2022, doi:10.1017/S1368980022000878.

3. **To your knowledge, do you have vitamins and/or minerals deficiencies (e.g., iron, vitamin B12, vitamin D etc.)**
   - Yes
   - No

4. **Do you take any food supplements? (e.g., iron, vitamin B12, vitamin D, omega 3, etc.)**
   - Yes
   - No

5. **Please indicate your smoking habits**[14]
   - Never
   - I quit
   - Sometimes
   - Usually

10. **Please indicate your weight (in kg)** **(a drop-down menu will be shown)** _____

11. **Please indicate your height (in cm)** **(a drop-down menu will be shown)**_____

[Food insecurity Experience Scale - FIES]

During the last 12 months, was there a time when:

		Yes	No	I Don't know	I refuse to answer
	[WORRIED]				
1	You were worried you would not have enough food to eat because of a lack of money or other resources.				
	[HEALTHY]				
2	Still thinking about the last 12 months, was there a time when you were unable to eat healthy and nutritious food because of a lack of money or other resources				
	[FEW FOODS]				
3	You ate only a few kinds of foods because of a lack of money or other resources				
	[SKIPPED]				
4	You had to skip a meal because there was not enough money or other resources to get food				
	[ATE LESS]				
5	Still thinking about the last 12 MONTHS, was there a time when you ate less than you thought you should because of a lack of money or other resources				
	[RUN OUT]				

[14] Menghi et al, 2022 (doi: 10.1016/j.foodqual.2022.104647).

6	Your household ran out of food because of a lack of money or other resources				
	[HUNGRY]				
7	You were hungry but did not eat because there was not enough money or other resources for food				
	[WHOLE DAY]				
8	During the last 12 MONTHS, was there a time when you went without eating for a whole day because of a lack of money or other resources?				

[Socio-demographic questions]

1. Please indicate your sex:

- Female
- Male go to question n. 3a/b/c/d/e
- Other go to question n. 3a/b/c/d/e
- Prefer not to answer go to question n. 3a/b/c/d/e

2. Please indicate if you are:

- Pregnant
- Breastfeeding
- In perimenopause (<12 consecutive months from the last menstruation)
- In menopause (≥ 12 consecutive months from the last menstruation)
- None of the above

3a. Please indicate your geographical area of residence (Italy)

- North-West (Piemonte, Valle d'Aosta, Liguria e Lombardia)
- North-East (Emilia-Romagna, Veneto, Trentino-Alto Adige, Friuli Venezia Giulia)
- Centre (Toscana, Marche, Umbria, and Lazio)
- South (Abruzzo, Molise, Campania, Puglia, Calabria, and Basilicata)
- Islands (Sicilia and Sardegna)

3b.Please indicate your geographical area of residence (Greece)

- Attica / Αττική
- Central Greece / Στερεά Ελλάδα
- Central Macedonia / Κεντρική Μακεδονία
- Crete / Κρήτη
- Eastern Macedonia and Thrace / Ανατολική Μακεδονία και Θράκη
- Epirus / Ήπειρος
- Ionian Islands / Ιόνια νησιά
- North Aegean / Βόρειο Αιγαίο
- Peloponnese / Πελοπόννησος
- South Aegean / Νότιο Αιγαίο
- Thessaly / Θεσσαλία

- Western Greece / Δυτική Ελλάδα
- Western Macedonia / Δυτική Μακεδονία
- Monastic community of Mount Athos / Άγιον Όρος

3c.Please indicate your geographical area of residence (Slovenia)

- Eastern Slovenia (Vzhodna Slovenija – including the Mura, Drava, Carinthia, Savinja, Central Sava, Lower Sava, Southeast Slovenia, and Littoral–Inner Carniola regions).
- Western Slovenia (Zahodna Slovenija – including the Central Slovenia, Upper Carniola, Gorizia, and Coastal–Karst regions)

3d.Please indicate your geographical area of residence (Morocco)

- Northwest (Rabat-Salé-Zemmour-Zaer, Gharb-Chrarda-Béni Hssen, Tangier-Tetouan)
- Eastern (Oriental)
- Centre-North (Fès-Boulemane, Taza-Al Hoceima-Taounate)
- Centre (Grand Casablanca, Chaouia-Ouardigha, Tadla-Azilal)
- Centre-South (Meknès-Tafilalet)
- South (Souss-Massa-Drâa, Guelmim-Es Semara, Laâyoune-Boujdour-Sakia El Hamra, Oued Ed-Dahab-Lagouira)
- Tensfit (Marrakesh-Tensift-El Haouz, Doukkala-Abda)

3e1.Please indicate in which geographical area you live (Tunisian Governorates)

- North East (Bizerte, Tunis, Aryanah, Menouba, Ben Arous, Zaghouan and Nabeul)
- North West (Béja, Kef, Siliana and Jendouba)
- Center East (Monastir, Mahdia, Sfax and Sousse)
- Center West (Sidi Bouzid, Kairouan and Kasserine)
- South East (Gabes, Medenine and Tataouine)
- South West (Gafsa, Kebili and Tozeur)

4. Please choose from the following the type of area you live in:[15]

- Large urbanization area (more than 1.5 million inhabitants)
- Metropolitan area (between 500,000 and 1.5 million inhabitants)
- Medium-sized urban area (between 200,000 and 500,000 inhabitants)
- Small urban area (between 50,000 and 200,000 inhabitants)
- Nearby rural area (<50,000 inhabitants but less than 60 minutes by car from a center of at least 50,000 inhabitants)
- Remote rural area (<50,000 inhabitants but more than 60 minutes by car from a center of at least 50,000 inhabitants)

[15] Definition retrieved from FAO, 2018 (https://www.fao.org/3/ca6392en/ca6392en.pdf) and from Childs et al, 2022 (doi: 10.34172/hpp.2022.02).

5. Please indicate your educational attainment[16]

- Not attending school
- Primary school license
- Lower secondary school diploma (middle school diploma)
- Secondary school diploma (secondary school diploma)
- Diploma of technical or professional institution
- Bachelor's degree, 1st level academic diploma/school for linguistic mediators
- One-cycle degree, Master's Degree
- Post-graduate degree (e.g., PhD, Medical Specialisation Schools etc.)
- Other:_____

6. Please indicate your occupation[17]

- Unemployed
- Student
- Full-time worker (mostly sedentary work)
- Full-time worker (mostly dynamic, non-sedentary job)
- Part-time worker (mostly sedentary job)
- Part-time worker (mostly dynamic, non-sedentary job)
- Retired

7. Please indicate your level of income[18] (average monthly income of your family)

- A lot of difficulties getting to the end of the month
- Some difficulty getting to the end of the month
- No difficulty in reaching the end of the month
- Manage to save money every month
- I refuse to answer

8. How many people (including you) are part of your household?

- 1 (only me)
- 2
- 3
- 4
- 5
- >5

---

[16] Greece: https://gpseducation.oecd.org/Content/MapOfEducationSystem/GRC/GRC_2011_EN.pdf
Italy: https://it.wikipedia.org/wiki/Classificazione_internazionale_standard_dell%27istruzione
Morocco: https://education-profiles.org/northern-africa-and-western-asia/morocco/~morocco
Slovenia: https://www.eurydice.si/publikacije/The-Education-System-in-the-Republic-of-Slovenia-2018-19.pdf
Tunisia: https://education-profiles.org/northern-africa-and-western-asia/tunisia/~tunisia

[17] We identify two categories of workers to differentiate the office workers from those with a manual/factory type of job.

[18] From Sgroi et al, 2022, doi: 10.1016/j.jafr.2022.100371

9. How many people under the age of 18 are in your household?

- None
- 1
- 2
- 3
- 4
- 5
- >5

[Physical activities in your free time][19]

The following questions concern how physically active you are in your free time and during transport (including your commute to and from work)

[MVPA question]

1. On a typical week, how much time do you spend in total on moderate and vigorous physical activities where your heartbeat increases and you breathe faster (e.g. brisk walking, cycling as a means of transport or as exercise, heavy gardening, running, or recreational sports).

Only include activities that lasted at least 10 minutes at a time.

- Less than ½ an hour (less than 30 minutes) per week (go to 3)
- ½ an hour - 1 ½ hour (30-90 minutes) per week (go to 2.1)
- 1 ½ - 2 ½ hours (90-150 minutes) per week (go to 2.2)
- 2 ½ - 5 hours (150-300 minutes) per week (go to 2.3)
- More than 5 hours (more than 300 minutes) per week (go to 2.3)

[VPA question]

2.1. How much of the time that you spend on physical activities in a typical week, which you indicated above, do you spend in total on vigorous physical activities? This includes activities that get your heart racing, make you sweat, and leave you so short of breath that speaking becomes difficult (e.g., swimming, running, cycling at high speeds, cardio training, weightlifting, or team sports such as football).

Only include activities that lasted at least 10 minutes at a time.

- Less than ½ an hour (less than 30 minutes) per week
- ½ an hour - 1 hour (30-60 minutes) per week
- 1 - 1 ½ hour (60-90 minutes) per week

2.2. How much of the time that you spend on physical activities in a typical week, which you indicated above, do you spend in total on vigorous physical activities? This includes activities

[19] https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-018-5538-y#Sec22

that get your heart racing, make you sweat, and leave you so short of breath that speaking becomes difficult (e.g., swimming, running, cycling at high speeds, cardio training, weightlifting, or team sports such as football).

Only include activities that lasted at least 10 minutes at a time.

- Less than ½ an hour (less than 30 minutes) per week
- ½ an hour - 1 hour (30-60 minutes) per week
- 1 - 1 ½ hour (60-90 minutes) per week
- 1 ½ - 2 ½ hours (90-150 minutes) per week

2.3. How much of the time that you spend on physical activities in a typical week, which you indicated above, do you spend in total on vigorous physical activities? This includes activities that get your heart racing, make you sweat, and leave you so short of breath that speaking becomes difficult (e.g., swimming, running, cycling at high speeds, cardio training, weightlifting, or team sports such as football).

Only include activities that lasted at least 10 minutes at a time.

- Less than ½ an hour (less than 30 minutes) per week
- ½ an hour - 1 hour (30-60 minutes) per week
- 1 - 1 ½ hour (60-90 minutes) per week
- 1 ½ - 2 ½ hours (90-150 minutes) per week
- More than 2 ½ hours (more than 150 minutes) per week

[Survey end]

The survey has ended, thank you for participating in the research, your input is valuable.

[Only for the pre-test]

If you have any suggestions or comments to improve the survey, please write them in the box below.

3.5 Scientific Paper: "Using podcasts to bridge the gap between science communication and specialized scientific fields: a case study of mass spectrometry"

The paper titled "Using Podcasts to Bridge the Gap Between Science Communication and Specialised Scientific Fields: A Case Study of Mass Spectrometry" by Nayyer Rehman, Victoria Edkins, and Nives Ogrinc is presented in this chapter. I was responsible for conceptualising the podcast series, designing the questionnaire, conducting interviews, collecting data, performing analyses, and preparing the manuscript for publication.

This article was published in *Frontiers in Communication* and investigates the effectiveness of podcasts as a medium to communicate complex scientific topics, focusing on the field of mass spectrometry. Podcasts were chosen for their popularity and ability to make scientific knowledge accessible. This study assessed public engagement with science-based podcasts, explored factors that influence listener perceptions, and identified strategies to make scientific content relatable for non-specialists. Appendix A.1 provides example of an infographic on how science can be communicated effectively using podcasts.

A mixed-methods approach was used to create four podcast episodes to discuss mass spectrometry in food safety, environmental analysis, diagnostics, and pharmaceuticals. The episodes featured interviews with experts selected for their diverse backgrounds in career stage, gender, and nationality. My role included guiding each expert interview with semi-structured questions to encourage the sharing of personal insights and motivations alongside scientific information, helping to humanise the science for listeners.

The podcast episodes were between 10 to 30 minutes to appeal to different listening habits. After the podcast production, I developed and distributed a detailed online questionnaire to gather feedback on listener engagement, comprehension, and preferences. The survey reached 80 European participants via social media channels, capturing data on listening frequency, familiarity with scientific topics, and content preferences.

Key findings indicated that listeners responded positively to episodes with personal narratives and real-world applications, which helped make mass spectrometry more relatable. Participants also highlighted the importance of a conversational tone and shorter episode lengths for easy integration into daily routines. Statistical analysis, including Chi-square tests and paired t-tests, revealed significant associations between listener demographics and engagement levels.

The results also indicated improvements in self-reported understanding, as listeners' comprehension of mass spectrometry increased after engaging with the podcast. This effect was particularly noted among participants with prior scientific exposure, suggesting that familiarity with science enhances receptivity to specialised content.

This research was shared as an oral and poster presentation at the 14th Jožef Stefan International Postgraduate School Students' Conference in 2022, held in Kamnik, Slovenia, and as a poster at the 24th International Mass Spectrometry Conference in Maastricht, Netherlands. The *Mass Spec Pod* podcast series is available on the FoodTraNet website.

This series led to a collaboration with the FoodTraNet Industrial Liaison Group, resulting in *Pills as Podcasts*, also on the website. This series has been featured in outreach and dissemination activities of our project. It includes four senior researchers from Barilla (Italy), Food Forensics (UK), Organic Services GmbH (Germany), and Inštitut za okoljevarstvo in senzorje (Slovenia). The series discussed their research in respective industries, their career progression, and advice for young researchers on how to follow similar paths.

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Using podcasts to bridge the gap between science communication and specialized scientific fields: a case study of mass spectrometry

Nayyer Rehman[1,2], Victoria Edkins[1] and Nives Ogrinc[2,3]*

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This study aimed to evaluate the use of podcasts in disseminating specialized scientific fields, such as mass spectrometry. Four podcasts featuring interviews with researchers working with mass spectrometry were produced. A mixed methods approach, comprising questionnaires and interviews, was used to gather listener feedback. Findings indicate that audience engagement is affected by factors like familiarity with science and relatability in content; therefore, to attract a wider audience, content must be presented to balance technical aspects with real-life examples to which listeners can relate. These findings will benefit researchers and stakeholders seeking to disseminate complex scientific topics using podcasts.

KEYWORDS

science podcasts, podcasting, mass spectrometry, public engagement, science communication

1 Introduction

The digital age has revolutionized how scientific information is shared with the public (Osterrieder, 2013; Collins et al., 2016; Jensen and Gerber, 2020). Among the emerging mediums in this digital landscape, the podcast has become a cultural phenomenon (Sullivan, 2019). Since their introduction in 2004 (Berry, 2016; MacKenzie, 2019), podcasts have become popular among scientists and researchers to communicate their research work to the public (Birch and Weitkamp, 2010; Davies and Hara, 2017; Llinares et al., 2018, p. 3; Kwok, 2019; MacKenzie, 2019; Quintana and Heathers, 2021).

Despite similarities to traditional broadcasting (Bottomley, 2015; Berry, 2016; Llinares et al., 2018, p. 2), podcasts offer increased flexibility since creators and listeners are not restricted by specific times (Llinares et al., 2018, p. 2). Software and tools that are freely available and easy to use can assist in the production of podcasts without requiring formal training (Boulos et al., 2006). Furthermore, there is no restriction on the number of speakers or the location (Boulos et al., 2006; Quintana and Heathers, 2021). The convenience and accessibility of podcasts through mobile apps and platforms like Apple Music, Spotify, and Google have made it easier for listeners to access them at any time (McGarr, 2009; Sullivan, 2019; Wade Morris, 2021). Apart from cognitive development through gaining information and being curious, podcast listeners have also expressed an openness to new experiences, social acceptance, and efficient use of their time as reasons for listening to podcasts (McClung and Johnson, 2010; Chan-Olmsted and Wang, 2020; Tobin and Guadagno, 2022).

Podcasts can cover various topics, with formats and languages tailored to specific audiences (Berry, 2016). The versatility of this approach is especially valuable when it comes to communicating scientific information (Chan-Olmsted and Wang, 2020). Currently, there are hundreds of science podcast series available, and this number continues to grow each year (MacKenzie, 2019; Quintana and Heathers, 2021). Between 2004 and 2010, 952 English-language science podcasts were published worldwide, including 532 from the US and 162 from the UK (MacKenzie, 2019).

While there is no set formula for gauging the success of a science podcast yet (MacKenzie, 2019), several metrics can help indicate its performance. A key metric is the podcast's overall ranking and number of followers, which indicates listener engagement (García-Marín, 2020). The BBC World Service, for example, hosts two weekly science podcasts with a social media following of 60 million Facebook fans, 40 million Twitter followers, and 160,000 Instagram fans (BBC, 2023a,b), demonstrating their continued success. The question is—what factors have contributed to their engagement and retention?

Reviewing the literature on this topic makes it clear that humor and storytelling narratives have benefited science communication (Picardi and Regina, 2008; Riesch, 2014; Drew, 2017; Barrios-O'Neill, 2018). Swiatek (2018) explains the importance of building a narrative akin to having a casual phone conversation. However, the question remains: could these factors also increase engagement for podcasts centered around specialized scientific content?

It is known that familiarity with science is a significant driver of public engagement with scientific research (Kouper, 2010; Weingart et al., 2021). For example, those with a strong interest in scientific content are more likely to make logical decisions and choices in their daily tasks based on scientific reasoning (Chantler et al., 2007; Shaw and McNamara, 2021). However, there is limited research on whether familiarity with sciences or having a scientific background influences people's choice of podcasts.

While the popularity of podcasts has been linked to the trendiness of topics (García-Marín, 2020) or the popularity of featured guests (Handley and Chapman, 2012, p. 246), communicating scientific subjects that can be categorized as specialized scientific subjects is equally important. However, these subjects present a unique challenge; engaging audiences with topics that may not be trendy or receive mainstream media coverage in such a way that makes them understandable to a diverse audience rather than to a specialized group (Weingart et al., 2021).

For this purpose, mass spectrometry, an analytical technique used to determine molecular compositions of various substances, was chosen to assess listener perception of specialized scientific content-based podcasts. Many scientific fields that play a role in the lives of the public make use of mass spectrometry, such as environmental analysis (Ogrinc et al., 2005), novel food safety (Schönleben et al., 2024), food and water quality assessment (Kaufmann, 2011; Kovačič et al., 2023), pharmaceutical research (Swales et al., 2019), and in critical areas such as personalized medicine (Heeren, 2015) and cancer research (Ogrinc et al., 2021). However, despite its recognition as a powerful analytical tool, the public remains unaware of its capabilities (Daughton, 2001).

This study has three objectives. First, it aims to assess public engagement with podcasts focused on specialized scientific fields, using mass spectrometry as a case study. Second, the study examines factors influencing how podcast listeners engage with scientific content, focusing on their prior familiarity with sciences. Third, it seeks to identify potential strategies to attract more listeners. The results of this study will enhance the effectiveness of creating science-based podcasts and bridge the gap between the public and their understanding of specialized scientific subjects.

2 Manuscript formatting

2.1 Methodology

The methodology discusses how the study podcasts were created and details the mixed methods approach used to gather feedback. Data was collected through questionnaires and interviews, followed by subsequent data analysis.

2.1.1 Podcast creation

The creation of the podcast series began with the development of four unique episodes to highlight the wide-ranging impact of mass spectrometry on various scientific fields. The episodes were designed to appeal to different listener preferences, with one being 10 min long, two being 15 min, and one lasting 30 min. This way, we could cover episodes comprising a quick update to more in-depth discussions. Each episode focused on a specific application of mass spectrometry in food and environmental analysis, proteomics and diagnostics, pharmaceuticals and forensics, and cancer research.

Experts were carefully chosen to ensure a balanced representation of gender, career stage, and geographical diversity. Each expert was invited to participate and provided a detailed briefing on the podcast's topic and objectives. The final selection of experts included two early-career researchers (one male, one female) and two experienced researchers (one male, one female) representing the Netherlands, Slovenia, France, and Belgium. All guests were required to sign a consent form for recording and publication, with provisions allowing them to review and approve the final edited version of their episodes to ensure accuracy and comfort with the shared content. A semi-structured interview guide (Table 1) was also provided to facilitate discussions. This format allowed guests to elaborate on their work experiences and discuss their motivations, challenges, and insights as researchers. Beyond addressing specific queries concerning their research fields, the interviews were designed to encourage researchers to articulate their views on the importance of mass spectrometry in society, enhancing the educational value of each episode.

Interviews were scheduled and conducted via Zoom to facilitate the involvement of international experts without geographical constraints. Post-recording, the audio was edited using Audacity, a popular open-source software for podcast production. Background noise and speech errors were removed to enhance clarity, and background music was added along with speed adjustments to create a more engaging listening experience.

2.1.2 Data collection

For this study, a closed-ended questionnaire was developed to gather insights into listeners' preferences and their perceptions of mass spectrometry as presented in podcasts (Supplementary material S1). Initially, we provided a brief overview of the confidentiality and data protection measures according to Articles 6–8 of the GDPR guidelines (Intersoft Consulting, 2013), adhering to the Ethics for Researchers (European Commission, 2013) and the Ethical Guidelines for Social

TABLE 1 Semi-structured interview guide for mass spectrometry podcast series.

Topic of discussion	Prompts for questions
Motivation and challenges	Development of interest in research and science Key motivations for pursuing a scientific career Challenges faced on the path to becoming a scientist
Role and experiences	Brief description of current role at (name of institute) Obstacles faced in the role Balancing hands-on experiments/ research with any management responsibilities
Understanding mass spectrometry and its applications	Explanation of mass spectrometry and how it is used Contribution of mass spectrometry in their expertise Contribution of mass spectrometry in other fields of interest to them.
Public accessibility to research and the technology	Public resources for finding detailed information about ongoing research Requests from commercial companies and other research institutes Requests for sample testing from individuals
Current projects	Interesting projects/collaborations/breakthroughs
Future of mass spectrometry	Importance and relevance of mass spectrometry to the scientific community Potential alternatives to mass spectrometry in the future
Perspectives	Balancing work commitments with other aspects of life Advice for aspiring scientists in scientific fields

Research (Social Research Association, 2021). This presentation ensured that participants made decisions based on informed consent to participate in this study. The questionnaire explored general podcast listening habits, including the frequency of listening and preferred podcast length, to assess respondent engagement. Respondents then listened to four episodes from the mass spectrometry podcast series to become familiar with the content. We also included questions to assess how well the guests explained the complex topic of mass spectrometry and the overall conversation style. To understand how different scientific narratives and personal stories from the researchers influenced listener engagement, we included questions about the diversity of experiences among the researchers featured in the podcasts.

The questionnaire, designed on Typeform, was pilot tested within the research group to refine its clarity and relevance, while mass spectrometry experts ensured content validity and the topic was covered comprehensively. Reliability was assessed using Cronbach's alpha, showing high internal consistency with a value of 0.72. To verify response authenticity, incomplete or duplicate entries were eliminated, and one response was removed. The questionnaire was distributed via LinkedIn and Twitter from August to October 2022, collecting 80 responses from participants in the European region. The inclusion criteria allowed participation from both regular and non-regular podcast listeners, including those without a scientific background.

Table 2 outlines the demographic details of the questionnaire respondents ($N = 80$), covering age groups, educational levels, and countries of residence. The largest age group was 26–35 at 42%, followed by 16–25 at 21%. Most respondents were highly educated: 34% held a Master's degree, 28% had a Doctorate, and 31% had a Bachelor's degree or college education. The geographical distribution shows that 30% of respondents were from the United Kingdom, making it the most represented country, followed by Germany (16%), Belgium (11%), and Poland and the Netherlands (10% each). Minor contributions from Slovenia, Italy, France, and Denmark each account for 5% of the sample, while responses from Romania and Norway are grouped under "Others" at 2% due to their lower representation.

TABLE 2 Demographic characteristics of questionnaire respondents (%; $N = 80$).

Demographics		%
Age group (in years)	16–25	21
	26–35	42
	36–45	16
	46–55	14
	56 +	7
Educational attainment	Doctoral degree	28
	Master's degree	34
	Bachelor's / College degree	31
	Vocational training / High school	9
Country of residence	United Kingdom	30
	Germany	16
	Belgium	11
	Poland	10
	Netherlands	10
	Slovenia	5
	Italy	5
	France	5
	Denmark	5
	Others	2

Following the questionnaire, personal interviews were conducted using a semi-structured format to assess the listeners' more profound opinions on the podcasts. Participants for these interviews were selected based on a screening criterion that required them to have listened to a podcast series on a commercial platform such as Apple,

Spotify, or SoundCloud within the past 6 months to ensure they had recent experience listening to podcasts.

Each interview incorporated predefined prompts (Supplementary material S2) to guide the discussion. Participants elaborated on specific aspects of the scientific content they found noteworthy while providing feedback on non-scientific variables. We recruited six participants ($N=6$) from those who completed the questionnaire, using snowball sampling to ensure demographic diversity. The group included three females and three males, evenly split between the 16–35 and 36–55 age groups. Educational backgrounds were also varied, with two participants each from natural sciences, business and accounting, and social sciences and humanities. Geographically, the participants included one from Slovenia and the Netherlands and two from Germany and the UK.

The interviews were conducted remotely from December 2022 to January 2023. Before each session, participants were given an overview of the study's objectives, confidentiality protocols, and data processing and storage guidelines. This step was implemented to secure informed consent and ensure participants fully understood the use of the data collected from the interviews. Each interview lasted 30–45 min, during which participants were encouraged to share their experiences and perceptions freely. To ensure confidentiality and data integrity, all interview transcripts were anonymized.

2.1.3 Data analysis

The data from the questionnaire was analyzed using R software (Version 4.2.2). Descriptive statistics, including mean, median, frequency, and percentages, were used to understand the non-scientific and scientific aspects of the podcasts. We also conducted paired sample t-tests to evaluate changes in knowledge about mass spectrometry before and after listening to the podcasts. The normality of data was confirmed using the Shapiro–Wilk test to determine the validity of the t-test results. Cohen's d was calculated to measure the effect size of the changes in knowledge. Chi-square tests were used to explore the relationship between these knowledge changes and sociodemographic variables like educational attainment and age. We verified that the chi-square tests met the necessary assumptions and only p-values below 0.05 were considered statistically significant.

For the interview data, thematic analysis was conducted using MaxQDA software for systematic coding and data organization. First, we identified initial "thematic categories" or "codes" based on the raw data. These codes were refined by identifying recurrent patterns across participants and integrating examples from the raw data to develop thematic categories. For accuracy, we did thorough checks by reviewing the transcriptions against the original audio files, with each transcript reviewed twice. For intra-coder reliability, the same researchers recoded the data three different times and compared the results for consistency (Attride-Stirling, 2001; Braun and Clarke, 2006; Maguire and Delahunt, 2017).

Graphical representations were created using Power BI to interpret the data and identify patterns. All findings were categorized into scientific and non-scientific elements, followed by recommendations for improving the communication of complex scientific information through podcasts. Finally, to maintain response integrity, ellipses (…) were used to indicate the exclusion of larger text sections or interviewer prompts in quotations. All participants were represented using combinations of letters or alphanumeric identifiers to ensure anonymity.

2.2 Results and discussion

2.2.1 Engagement with non-scientific elements

Apart from the frequency of podcast consumption and preferred duration for podcasts, respondents were questioned about the conversation style and evaluated for their receptivity to personal statements made by the guests, such as the challenges they encountered in their journey as scientists. These components were then examined in the interview sessions with the participants.

2.2.1.1 Frequency of listening to podcasts and preferred duration

When respondents were asked to rate their frequency of listening to podcasts over the past 6 months, the results revealed a diverse range of habits: 28% listened "Seldom/Rarely", 25% "Sometimes", and 23% "Often". The remaining 24% were evenly split between those who listened "Very Often" and those who chose "Never". When considering preferred podcast durations, a clear trend emerged favoring shorter episodes. Most respondents (81%) preferred podcasts under 30 min, with the majority (56%) preferring podcasts between 15 and 30 min and a quarter favoring episodes less than 15 min. Within the smaller segment (19%) who preferred longer podcasts, most preferred episodes between 30 and 45 min (11%), and 8% opted for hour-long podcasts. Table 3 shows a distribution of these factors across different age groups and educational attainment levels.

Analyzing the data across different age groups highlighted notable contrasts. The oldest age group (56+) showed a distinct pattern: 40% never listened to podcasts, while 60% listened often. In the youngest age group (16–25), 35% listened "Seldom/Rarely", and 29% each chose "Sometimes" and "Often". The 26–35 age group also showed varied preferences, with 38% listening "Seldom/Rarely", 26% "Sometimes", and 15% choosing both "Often" and "Very Often". The 36–45 age group's responses were more balanced, with 31% each listening "Never" and "Sometimes", but none listening "Very Often". In contrast, 37% of those aged 46–55 listened "Very Often", the highest percentage in any group.

Preferences for podcast durations also varied by age. Respondents aged 56 and older preferred podcasts lasting 16–30 min (60%). In the 46–55 age group, 37% preferred episodes of 15 min or less, and 27% chose podcasts lasting 46–60 min. The 36–45 age group strongly favored 16–30 min episodes (77%). Among those aged 26–35, 65% preferred 16–30 min podcasts, with 12% opting for 46–60 min. For the 16–25 age group, 47% favored 16–30 min, with none preferring the 46–60 min duration.

Educational attainment also influenced listening habits. Respondents with a Doctoral degree had the highest frequency of listening "Often" (36%) and "Very Often" (27%). Those with a Master's degree tended to listen "Seldom/Rarely" (44%), with only 11% listening "Often". Respondents with a Bachelor's or College degree preferred listening "Sometimes" (33%) and "Often" (25%). Responses were more evenly distributed for those with vocational training or high school education, with 29% listening "Never" and "Seldom/Rarely".

Preferred podcast durations varied considerably across educational levels. Those with Doctoral degrees preferred a range of durations, with 32% each favoring episodes of 15 min or less and 16–30 min and 23% opting for 31–45 min. Master's degree holders mainly preferred 16–30 min (70%). Respondents with a Bachelor's or

TABLE 3 Frequency of listening to podcasts and preferred duration across different age groups and educational attainment levels (%; $N = 80$).

	Frequency of listening (%)					Preferred duration (%)			
Category / group	Never	Seldom / rarely	Sometimes	Often	Very often	15 min or less	16–30 min	31–45 min	46–60 min
Age (years old)									
16–25	0%	35%	29%	29%	7%	35%	47%	18%	0%
26–35	6%	38%	26%	15%	15%	20%	65%	3%	12%
36–45	31%	7%	31%	31%	0%	8%	77%	15%	0%
46–55	18%	18%	18%	9%	37%	37%	18%	27%	18%
56+	40%	0%	0%	60%	0%	40%	60%	0%	0%
Educational attainment levels									
Bachelor's / College degree	17%	21%	33%	25%	4%	21%	62%	17%	0%
Doctoral degree	9%	14%	14%	36%	27%	32%	32%	23%	13%
Master's degree	7%	44%	30%	11%	8%	22%	70%	0%	8%
Vocational training / High school	29%	29%	14%	14%	14%	29%	57%	0%	14%

College degree also favored 16–30 min (62%). Those with Vocational training or High school education leaned towards 16–30 min (57%), with 29% preferring episodes of 15 min or less.

Interviews revealed that most participants preferred podcasts under 30 min, citing decreased attention spans and numerous distractions. Many mentioned that shorter episodes (less than 30 min) were "reasonable" and "manageable" within their daily routines ($N = 4$). Participants commonly appreciated the ability to listen while multitasking, such as during meals or while checking emails ($N = 12$). This finding aligns with Perks and Turner (2018), who stated that frequent podcast listeners often integrate podcasts into their multitasking habits. However, one participant preferred longer episodes, enjoying the "in-depth discussions" and "detailed analyses" that hour-long podcasts provide. The data suggests that while shorter podcasts are broadly preferred, a market for longer content still appeals to those who favor extended listening sessions.

The study's findings also align with prior research conducted by Sutton-Brady et al. (2009), who found the short-form podcast model to be a successful learning tool for postgraduate and undergraduate students. This preference for shorter podcasts may be attributed to various factors, such as technological advancements, fast-paced modern lifestyles, and the motivation and interest of listeners (Lodge and Harrison, 2019).

2.2.1.2 Podcast tone and conversation style

Respondents rated the conversation style, i.e., language, structure, formality, and patterns in discussion podcasts on mass spectrometry using a 5-point scale. The results showed that 85% of respondents found the tone "About right", 13% "slightly too formal", and 3% "slightly too informal". There were no extreme opinions on the tone being too formal or informal.

All respondents aged 16–25 and 36–45 found the tone "About right". In the 26–35 age group, 82% approved, but 18% found it slightly too formal. In the 46–55 group, 73% were satisfied, 18% thought it was slightly too formal, and 9% slightly too informal. Among those 56% and over, responses were split: 40% found the tone "About right", 40% slightly too formal, and 20% slightly too informal. Most respondents found the tone "About right" regarding educational attainment levels. All respondents with vocational training or a high school diploma agreed with this view. Among bachelor's or college degree holders, 96% approved of the tone, while 4% found it "Slightly too informal". Among those with a master's degree, 85% were satisfied, but 15% thought it "slightly too formal". Doctoral degree holders were less uniform in their opinions: 68% approved, 27% found it "slightly too formal", and 5% slightly too informal.

The chemistry between speakers was highlighted by some participants ($N = 4$) as crucial for an engaging podcast. Their unanimous preference for the second podcast stemmed from its conversational style and the integration of personal stories and everyday examples, noting it as a key factor in its success. LL31 emphasized dynamic interaction, stating, "*The conversation was lively and engaging, and I truly believe that chemistry between the speakers is crucial for a good podcast. The second one had it perfect.*"

All participants ($N = 6$) found the podcasts more engaging due to the inclusion of narratives and anecdotes. Some other participants ($N = 3$) found them entertaining and informative, especially regarding practical applications of the scientific process discussed. Another commended the second episode for its intricate and exuberant presentation, emphasizing its clarity. According to Drew (2017), incorporating humor and storytelling enhances podcast engagement, especially those covering scientific topics. This study supports that finding, demonstrating that a conversational style that includes personal narratives and humor can make complex topics more

understandable and accessible to a wider audience (Kaplan et al., 2020).

2.2.1.3 Perspective on different experiences

Respondents were asked to use a 5-point Likert scale to identify any disparities in the challenges faced by podcast guests to explore listeners' perceptions of these differences. Results indicated that 38% of respondents remained neutral, while 24% disagreed and 13% strongly disagreed that there were notable differences. Conversely, 11% agreed, and 15% strongly agreed that disparities existed. Personal interviews provided further insights, revealing that variations in experiences seemed more related to career stages—differentiating between seasoned and early-career researchers—than any other factor. Participants were particularly intrigued by discussions about work-life balance, which they felt was a common issue affecting everyone today.

When asked about the unique aspects of discussing work-life balance in this context, more than half of the participants ($N = 4$) noted that they perceived all guests, regardless of their career stage, as finding it a struggle. They also noted the stress of managing family and work commitments in research fields that require research and management. CT25 recalled, "*I remember when you asked about achieving work-life balance; it was interesting to learn how professors maintain that balance in their lives.*"

Other participants ($N = 4$) highlighted different aspects that made the podcasts engaging. Some ($N = 2$) praised the use of storytelling by some of the guests, commenting on how it seemed as if the speakers were truly fans of their work and were eager to learn more themselves. Another participant found the podcast intriguing due to its mention of a diverse team, noting the interest in how the guest worked with people from different backgrounds who contributed new ideas and commending this openness to diversity in their workplace.

2.2.2 Engagement with scientific elements

Respondents were asked about several key factors to understand how listeners perceived the scientific content in the podcasts. These included the amount of information provided, their knowledge levels before and after listening, and how well they grasped concepts related to mass spectrometry and its applications. During the interview, participants also discussed whether their familiarity with scientific subjects influenced their interest and comprehension of the podcasts.

2.2.2.1 The amount of information given in the podcasts

Respondents were asked to rate, using a 5-point Likert scale, whether they felt that "Overall, the guests gave the right amount of detail to help the audience understand their field of work". The responses revealed that 35% strongly agreed, 40% agreed, 19% were neutral, and 6% disagreed.

Most participants ($N = 5$) described the podcast's content as "clear", "to the point", and "concise". They noted that the information on mass spectrometry and its applications was "appropriate" and "easy to follow", providing a good understanding of the subject. One participant felt that the information was sufficient, highlighting the adequacy of the subject knowledge and its applications. In contrast, others ($N = 4$) indicated that the content was accessible even to those without a scientific background. One participant remarked that more information would have been overwhelming, leading to a loss of interest, especially for those who do not have a scientific background. The feedback suggests that the podcast effectively balanced detail and clarity, making complex topics understandable to a broad audience.

2.2.2.2 Knowledge of mass spectrometry before and after listening to the podcasts

The questionnaire utilized an ordinal scale to evaluate participants' comprehension of mass spectrometry before and after listening to the educational podcasts. The shifts in knowledge, depicted in Figure 1 as a heatmap, show a significant transformation. Most respondents (53%) initially acknowledged they had no prior knowledge, described as "I knew nothing." Another 14% indicated they "knew very little," and 8% had a basic familiarity ("I knew a little"). Only a minority felt they had a substantial understanding, with 19% indicating "I knew quite a bit" and 8% opting for "I knew a great deal". Following the podcasts, the distribution of reported knowledge improved significantly: 34% of respondents reported learning "quite a bit". The majority (43%) said they learned "a little", and 24% felt they learned "very little". Importantly, there were no responses at the extremes of learning "nothing" or "a great deal", emphasizing moderation in learning outcomes.

Results from the paired sample t-test confirm these self-reported shifts. The average pre-podcast knowledge score was 2.15, with a standard deviation of 1.42, illustrating participants' wide range of initial understanding. Post-podcast, this average increased to 3.10, and the standard deviation narrowed to 0.76, indicating a more uniform understanding across the group. This improvement was statistically significant, evidenced by a paired sample t-test (t-statistic: -5.48, p-value: 4.88×10^{-7}).

A Chi-squared test revealed significant initial associations between knowledge levels and demographic factors such as educational attainment ($\chi^2 = 36.27$, $p < 0.00$) and age ($\chi^2 = 30.13$, $p = 0.017$). These findings suggest that educational background and age significantly influenced participants' initial understanding. However, no significant associations were detected between these demographic factors and knowledge gains post-podcast, indicating that the educational content effectively bridged initial knowledge disparities. These podcasts enhanced listeners' understanding of mass spectrometry regardless of age and educational background, demonstrating that carefully designed podcasts effectively elevate scientific literacy on specialized subjects among diverse audiences.

2.2.2.3 Understanding of mass spectrometry and its applications

Using a 5-point Likert scale, participants were asked to indicate their level of understanding of both the explanation of mass spectrometry and its applications. For the explanation of mass spectrometry, 44% of respondents strongly agreed they understood it, 48% agreed, 2% were neutral, and 16% disagreed. None of the participants strongly disagreed. Regarding the applications of mass spectrometry, 23% strongly agreed that they understood, 28% agreed, 33% were neutral, and 18% disagreed, with no one strongly disagreeing.

A heat map (Figure 2) illustrates these findings, showing that 43% of respondents agreed or strongly agreed that they understood the explanation and applications of mass spectrometry. Interestingly, among those who strongly agreed they understood mass spectrometry, none disagreed about understanding its applications, but 13% of those who agreed they understood mass spectrometry did not understand its applications. Approximately 21% of participants were neutral about

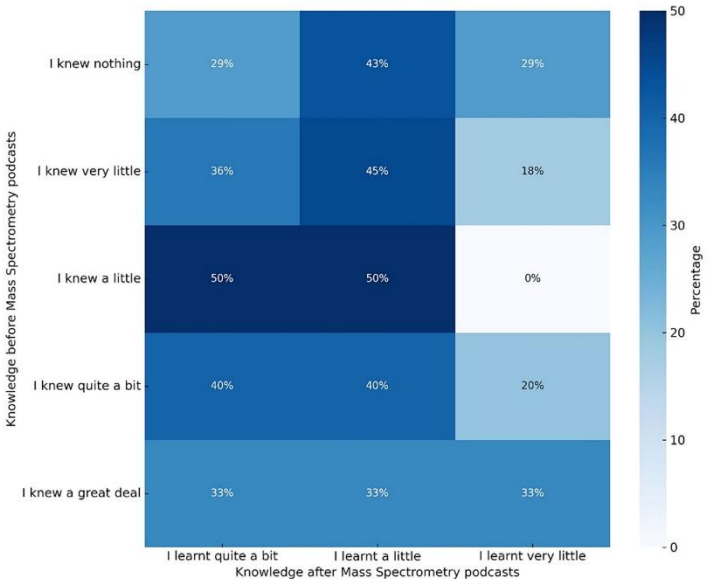


FIGURE 1
Knowledge of mass spectrometry amongst respondents before and after listening to the podcasts.

their understanding of both. Among these neutral respondents, 27% disagreed with the applications, and 8% agreed. Half of those who disagreed with understanding mass spectrometry also disagreed about the applications, while the other half were neutral or agreed.

A paired sample t-test compared the responses for understanding mass spectrometry and its applications, revealing a statistically significant difference ($p = 0.017$). The mean understanding score for mass spectrometry was 3.75, compared to 3.55 for its applications. However, the effect size, measured by Cohen's d, was 0.20, indicating a slight difference. Further analysis of confidence intervals adds context to these findings. The 95% confidence interval for understanding mass spectrometry ranged from 3.53 to 3.97; its applications ranged from 3.32 to 3.78. The confidence interval between these means ranged from −0.12 to 0.52, including zero, which suggests the actual difference might be negligible and the respondents' understanding of mass spectrometry and its applications are similar.

2.2.2.4 Role of familiarity in understanding scientific content

The study revealed that participants particularly valued podcast content that resonated with them on a personal level. Some participants ($N = 4$) highlighted how discussions around why guests opted for science in their careers and how their work shaped their life's trajectory were surprisingly relatable, aligning with Murray's (2019) findings that podcasts can serve as a means for listeners to hear experts in a more personal and relatable manner, which is more effective than merely reading their profiles and academic work.

Most participants ($N = 5$) appreciated the practical applications of mass spectrometry, especially in everyday contexts such as food quality assessment. For instance, the technology's role in verifying the freshness of produce resonated with those interested in a healthy lifestyle, while discussions on personalized medicine were particularly relevant for participants with personal or family experiences of rare diseases. However, the feedback was not uniformly positive. Many participants ($N = 4$) critiqued the first episode for its lack of depth and practical examples, noting that this diminished its relatability and engagement. This criticism underscores findings by Stocklmayer and Bryant (2012) that scientific content is more engaging when presented in a context relevant to the audience's daily lives.

The diversity of perspectives, especially the enthusiasm of researchers featured in the podcasts, was another aspect that all participants ($N = 6$) found enriching. This aspect enhanced their understanding of mass spectrometry and maintained their interest in what might otherwise have been a daunting topic. This approach reflects Bandura's (2001) social cognitive theory, which suggests that motivational dialogue can significantly enhance comprehension and encourage the practical application of learned concepts. These findings also suggest that a listener's pre-existing familiarity with scientific topics plays a crucial role in their engagement with content. As Wade and Kidd (2019) conclude, curiosity can drive interest towards scientific topics, expanding the listener's knowledge and increasing engagement with unfamiliar or specialized content areas. Despite the inherently technical nature of the podcasts, the content appealed to those with a specific interest in the field. This niche appeal highlights

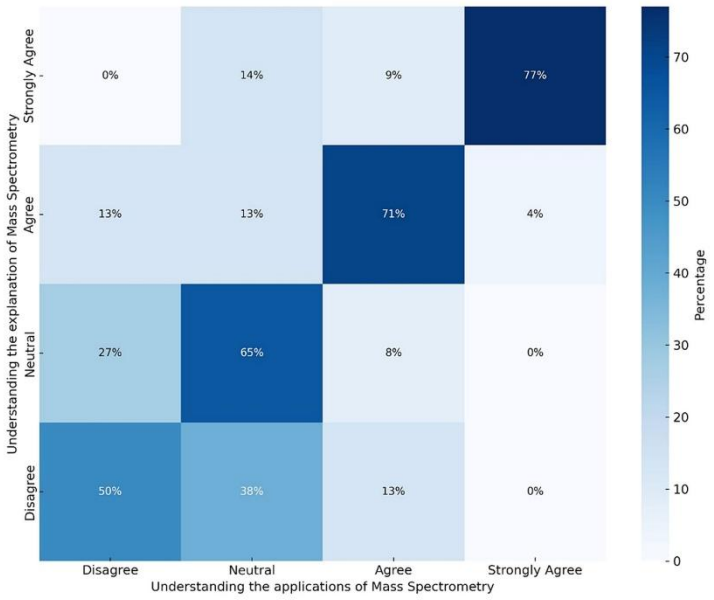


FIGURE 2
Perception of mass spectrometry and its applications amongst respondents.

the importance of aligning scientific content with the audience's existing interests and backgrounds to foster engagement.

2.2.3 Suggested improvements for the podcasts

The participants provided several suggestions for improvements to make the podcasts more appealing to a broader audience. A common theme in the feedback was the use of technical terms, particularly "mass spectrometry". Many participants ($N=4$) suggested changing the name to make it more accessible, with MK28 participant recommending, "*If you use more layperson's terms, more people will listen to these podcasts.*" Another participant proposed renaming it to "A Day in the Life of a Scientist" to make it more relatable.

Participants ($N=3$) suggested focusing more on practical applications of mass spectrometry to make the podcast more engaging. They emphasized the importance of understanding how mass spectrometry is used across various fields, with CF31 stating, "*As I understand, it is used for so many other things as well, and I would like to know more.*" Additionally, they recommended creating a series format that avoids repetitive details and instead introduces guests while discussing their fields and interesting cases they have encountered.

Another suggestion was to include elements that would allow listeners to learn more about the personal lives of the guests and their interest in the field, aiming to make the podcast series more enjoyable and relatable. Participants ($N=3$) expressed a keen interest in understanding how the guests chose their careers. They proposed that including questions such as, "*How did you become involved in this field?*" would provide valuable insights. One participant explained that if the guests had pursued their careers in greater detail, it would offer a deeper understanding of the various paths available in the field of research, making the content more relatable and inspiring for the audience.

To improve the format, some participants ($N=2$) suggested altering the podcast format to include group discussions, which they found more interesting than one-on-one conversations. Additionally, the absence of video was noted as a drawback. Participants believed that a video podcast could capture the body language and excitement of guests, adding an emotional connection that is often missing in audio-only formats.

Participants ($N=2$) also suggested discussing stress management in highly scientific fields, noting that this information would be valuable to listeners in similar work environments. Participant MV26 mentioned, "*I would love to hear about how to cope with stress and the feelings of imposter syndrome.*" Participants emphasized that hearing multiple people discuss stress and coping mechanisms can be reassuring and helpful, particularly in mental health. They noted that such discussions are not limited to scientific fields and have broader implications for well-being in other non-scientific fields.

The results show that most listeners are more interested in personal stories than in the science itself. Engaging storytelling is an important element of successful science podcasts. Personal stories can make scientific content more relatable and compelling, keeping

listeners entertained while they learn (Bray et al., 2012). Keeping this in mind ensures that the audience remains interested and invested in the content. Also, the observation that listeners are more interested in personal stories than science suggests significant value in integrating human narratives with scientific content. By doing so, science podcasts can achieve a balanced approach that educates, engages, and inspires their audience providing a platform for experts to discuss their work from their perspectives (Besley and Nisbet, 2011; Middleton, 2016; DeMarco, 2022).

2.2.4 Study limitations and future research

A limitation of this study is the low number of participants for the questionnaire, with the majority belonging to younger age groups and having higher educational attainment. This distribution could be explained by the requirement to listen to podcasts before attempting the questionnaire, which takes up a considerable amount of time for a topic that may or may not interest the listeners. Research findings may also be biased due to the distribution of questionnaires via personal networks and social media channels. Since the questionnaire and podcast were circulated through links shared by the researchers, the sampled population may not be representative and may include individuals who already had some knowledge about mass spectrometry, further introducing potential bias. Another limitation is the measurement of knowledge. While we included questions in the survey to gauge participants' understanding of mass spectrometry, we relied solely on their responses as the metric without a further formal investigation in the form of an examination to evaluate knowledge acquisition. Lastly, the study's focus on mass spectrometry podcasts may limit the applicability of the findings to other scientific disciplines. Different fields have unique challenges and opportunities for podcast-based science communication, and further research is needed to explore these variations.

Future researchers can build upon these findings by addressing these limitations. Expanding the participant pool to include a more diverse demographic range and reducing reliance on personal networks and social media channels for recruitment will help provide a more representative sample. Further research should also consider the impact of different podcast formats, such as video podcasts versus audio-only formats, on listener engagement and comprehension. Investigating the effectiveness of incorporating multimedia elements, like visual aids or interactive components, could also provide insights into optimizing podcast delivery for complex scientific content. Additionally, longitudinal studies tracking changes in listeners' knowledge and perceptions over time would help understand the long-term educational impact of scientific podcasts. Such studies should assess whether repeated exposure to scientific podcasts leads to increased scientific literacy and interest in scientific careers.

3 Conclusion

Based on the results of this study, podcasts were found to be effective tools for educating and informing listeners about specialized scientific topics. All respondents indicated learning at least some level of detail about mass spectrometry from these podcasts. For the discussion of technical research, incorporating humor and storytelling elements was appreciated by the listeners, enhancing engagement and comprehension. The study also found that most participants showed a positive acceptance of the conversational style and the duration of the mass spectrometry podcasts. These preferences varied depending on the listeners' age group and educational attainment level, highlighting the importance of tailoring podcasts to the target audience. Younger listeners and those with higher educational attainment tended to prefer shorter, conversational episodes that included relatable narratives and practical applications.

Overall, the findings suggest that well-designed scientific podcasts have the potential to bridge knowledge gaps and make complex topics more relatable and engaging. To maximize their impact, science communicators should consider incorporating the elements discussed in this study.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

NR: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft. VE: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing. NO: Conceptualization, Funding acquisition, Methodology, Supervision, Validation, Writing – review & editing.

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Conflict of interest

NR and VE were employed by WRG Europe Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2024.1384389/full#supplementary-material

References

Attride-Stirling, J. (2001). Thematic networks: an analytic tool for qualitative research. *Qual. Res.* 1, 385–405. doi: 10.1177/146879410100100307

Bandura, A. (2001). Social cognitive theory: an agentic perspective. *Annu. Rev. Psychol.* 52, 1–26. doi: 10.1146/annurev.psych.52.1.1

Barrios-O'Neill, D. (2018). "Wild listening: ecology of a science podcast" in Podcasting: New aural cultures and digital media. eds. D. Llinares, N. Fox and R. Berry (Cham: Palgrave Macmillan), 147–172.

BBC. (2023a). BBC world service – CrowdScience – Downloads. Available at: https://www.bbc.co.uk/programmes/p04d42rc/episodes/downloads (accessed August 30, 2023).

BBC. (2023b). BBC world service – Science in action – Downloads. Available at: https://www.bbc.co.uk/programmes/p002vsnb/episodes/downloads (accessed August 30, 2023).

Berry, R. (2016). Podcasting: considering the evolution of the medium and its association with the word "radio". *Radio J. Int. Stud. Broadcast Audio Media* 14, 7–22. doi: 10.1386/rjao.14.1.7_1

Besley, J. C., and Nisbet, M. (2011). How scientists view the public, the media, and the political process. *Public Underst. Sci.* 22, 644–659. doi: 10.1177/0963662511418743

Birch, H., and Weitkamp, E. (2010). Podologues: conversations created by science podcasts. *New Media Soc.* 12, 889–909. doi: 10.1177/1461444809356333

Bottomley, A. J. (2015). Podcasting: a decade in the life of a "new" audio medium: introduction. *J. Radio Audio Media* 22, 164–169. doi: 10.1080/19376529.2015.1082880

Boulos, M. N. K., Maramba, I., and Wheeler, S. (2006). Wikis, blogs and podcasts: a new generation of web-based tools for virtual collaborative clinical practice and education. *BMC Med. Educ.* 6:41. doi: 10.1186/1472-6920-6-41

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Bray, B., France, B., and Gilbert, J. K. (2012). Identifying the essential elements of effective science communication: what do the experts say? *Int. J. Sci. Educ., Part B: Commun. Public Engagem.* 2, 23–41. doi: 10.1080/21548455.2011.611627

Chan-Olmsted, S., and Wang, R. (2020). Understanding podcast users: consumption motives and behaviors. *New Media Soc.* 24, 684–704. doi: 10.1177/1461444820963776

Chantler, T. E. A., Lees, A., Moxon, E. R., Mant, D., Pollard, A. J., and Fitzpatrick, R. (2007). The role familiarity with science and medicine plays in parents' decision making about enrolling a child in vaccine research. *Qual. Health Res.* 17, 311–322. doi: 10.1177/1049732306298561

Collins, K., Shiffman, D., and Rock, J. (2016). How are scientists using social media in the workplace? *PLoS One* 11:e0162680. doi: 10.1371/journal.pone.0162680

Daughton, C. G. (2001). Emerging pollutants, and communicating the science of environmental chemistry and mass spectrometry: pharmaceuticals in the environment. *J. Am. Soc. Mass Spectrom.* 12, 1067–1076. doi: 10.1016/s1044-0305(01)00287-2

Davies, S. R., and Hara, N. (2017). Public science in a wired world: how online media are shaping science communication. *Sci. Commun.* 39, 563–568. doi: 10.1177/1075547017736892

DeMarco, C. (2022). Hear here! The case for podcasting in research. J. Res. Adm., 53, 30–61. Available at: https://www.srainternational.org/blogs/srai-jra1/2022/01/27/hear-here-the-case-for-podcasting-in-research (accessed January 20, 2023).

Drew, C. (2017). Educational podcasts: a genre analysis. *E-Learn. Digital Media* 14, 201–211. doi: 10.1177/2042753017736177

European Commission. (2013). Ethics for researchers: Facilitating research excellence in FP7. Available at: https://ec.europa.eu/research/participants/data/ref/fp7/89888/ethics-for-researchers_en.pdf (accessed February 10, 2022).

García-Marín, D. (2020). Mapping the factors that determine engagement in podcasting: design from the users and podcasters' experience. *Commun. Soc.* 33, 49–63. doi: 10.15581/003.33.2.49-63

Handley, A., and Chapman, C. C. (2012). Content rules, vol. 13. *2nd* Edn. Hoboken, NJ: John Wiley & Sons, 246.

Heeren, R. M. A. (2015). Getting the picture: the coming of age of imaging MS. *Int. J. Mass Spectrom.* 377, 672–680. doi: 10.1016/j.ijms.2014.04.021

Intersoft Consulting. (2013). *Chapter 2 – Principles | general data protection regulation (GDPR)*. General Data Protection Regulation (GDPR). Available at: https://gdpr-info.eu/chapter-2/ (accessed February 25, 2022).

Jensen, E. A., and Gerber, A. (2020). Evidence-based science communication. *Front. Commun.* 4:78. doi: 10.3389/fcomm.2019.00078

Kaplan, H., Verma, D., and Sargsyan, Z. (2020). What traditional lectures can learn from podcasts. *J. Grad. Med. Educ.* 12, 250–253. doi: 10.4300/JGME-D-19-00619.1

Kaufmann, A. (2011). The current role of high-resolution mass spectrometry in food analysis. *Anal. Bioanal. Chem.* 403, 1233–1249. doi: 10.1007/s00216-011-5629-4

Kouper, I. (2010). Science blogs and public engagement with science: practices, challenges, and opportunities. *J. Sci. Commun.* 9:A02. doi: 10.22323/2.09010202

Kovačič, A., Andreasidou, E., Brus, A., Vehar, A., Potočnik, D., Hudobivnik, M. J., et al. (2023). Contaminant uptake in wastewater irrigated tomatoes. *J. Hazard. Mater.* 448:130964. doi: 10.1016/j.jhazmat.2023.130964

Kwok, R. (2019). How to make your podcast stand out in a crowded market. *Nature* 565, 387–389. doi: 10.1038/d41586-019-00128-7

Llinares, D., Fox, N., and Berry, R. (2018). "Introduction: podcasting and podcasts—parameters of a new aural culture" in Podcasting: New aural cultures and digital media. eds. D. Llinares, N. Fox and R. Berry (Cham: Palgrave Macmillan), 1–13.

Lodge, J. M., and Harrison, W. J. (2019). The role of attention in learning in the digital age. *Yale J. Biol. Med.* 92, 21–28. Available at: https://www.ncbi.nlm.nih.gov/pubmed/30923470

MacKenzie, L. E. (2019). Science podcasts: analysis of global production and output from 2004 to 2018. *R. Soc. Open Sci.* 6:180932. doi: 10.1098/rsos.180932

Maguire, M., and Delahunt, B. (2017). Doing a thematic analysis: a practical, step-by-step guide for learning and teaching scholars. *AISHE J.* 9. Available at: http://ojs.aishe.org/index.php/aishe-j/article/view/335 (accessed February 25, 2022).

McClung, S., and Johnson, K. (2010). Examining the motives of podcast users. *J. Radio Audio Media* 17, 82–95. doi: 10.1080/19376521003719391

McGarr, O. (2009). A review of podcasting in higher education: its influence on the traditional lecture. *Australas. J. Educ. Technol.* 25, 309–321. doi: 10.14742/ajet.1136

Middleton, A. (2016). Reconsidering the role of recorded audio as a rich, flexible and engaging learning space. *Res. Learn. Technol.* 24:28035. doi: 10.3402/rlt.v24.28035

Murray, S. (2019). Coming-of-age in a coming-of-age: the collective individualism of podcasting's intimate soundwork. *Pop. Commun.* 17, 301–316. doi: 10.1080/15405702.2019.1622117

Ogrinc, N., Fontolan, G., Faganeli, J., and Covelli, S. (2005). Carbon and nitrogen isotope compositions of organic matter in coastal marine sediments (the Gulf of Trieste, N Adriatic Sea): indicators of sources and preservation. *Mar. Chem.* 95, 163–181. doi: 10.1016/j.marchem.2004.09.003

Ogrinc, N., Saudemont, P., Takáts, Z., Salzet, M., and Fournier, I. (2021). Cancer surgery 2.0: guidance by real-time molecular technologies. *Trends Mol. Med.* 27, 602–615. doi: 10.1016/j.molmed.2021.04.001

Osterrieder, A. (2013). The value and use of social media as communication tool in the plant sciences. *Plant Methods* 9:26. doi: 10.1186/1746-4811-9-26

Perks, L. G., and Turner, J. S. (2018). Podcasts and productivity: a qualitative uses and gratifications study. *Mass Commun. Soc.* 22, 96–116. doi: 10.1080/15205436.2018.1490434

Picardi, I., and Regina, S. (2008). Science via podcast. *J. Sci. Commun.* 7:C05. doi: 10.22323/2.07020305

Quintana, D. S., and Heathers, J. A. J. (2021). How podcasts can benefit scientific communities. *Trends Cogn. Sci.* 25, 3–5. doi: 10.1016/j.tics.2020.10.003

Riesch, H. (2014). Why did the proton cross the road? Humour and science communication. *Public Underst. Sci.* 24, 768–775. doi: 10.1177/0963662514546299

Schönleben, A. M., Yin, S., Strak, E., Johnson, A., Belova, L., Bamai, Y. A., et al. (2024). Stable isotope ratios and current-use pesticide levels in edible insects: implications on chemical food safety. *Food Res. Int.* 179:114020. doi: 10.1016/j.foodres.2024.114020

Shaw, M. P., and McNamara, S. W. T. (2021). "I can just get all the bits that I need": practitioners' use of open-access sport science podcasts. *Front. Educ.* 6:666865. doi: 10.3389/feduc.2021.666865

Social Research Association. (2021). Research ethics guidance. Available at: https://the-sra.org.uk/SRA/SRA/Ethics/Research-Ethics-Guidance.aspx (accessed February 10, 2022).

Stocklmayer, S. M., and Bryant, C. (2012). Science and the public—what should people know? *Int. J. Sci. Educ., Part B* 2, 81–101. doi: 10.1080/09500693.2010.543186

Sullivan, J. L. (2019). The platforms of podcasting: past and present. *Soc. Media Soc.* 5:205630511988000. doi: 10.1177/2056305119880002

Sutton-Brady, C., Scott, K. M., Taylor, L., Carabetta, G., and Clark, S. (2009). The value of using short-format podcasts to enhance learning and teaching. *Res. Learn. Technol.* 17, 219–232. doi: 10.1080/09687760903247609

Swales, J. G., Hamm, G., Clench, M. R., and Goodwin, R. J. A. (2019). Mass spectrometry imaging and its application in pharmaceutical research and development: a concise review. *Int. J. Mass Spectrom.* 437, 99–112. doi: 10.1016/j.ijms.2018.02.007

Swiatek, L. (2018). "The podcast as an intimate bridging medium" in Podcasting: New aural cultures and digital media. eds. D. Llinares, N. Fox and R. Berry (Cham: Palgrave Macmillan), 173–187.

Tobin, S. J., and Guadagno, R. E. (2022). Why people listen: motivations and outcomes of podcast listening. *PLoS One* 17:e0265806. doi: 10.1371/journal.pone.0265806

Wade, S., and Kidd, C. (2019). The role of prior knowledge and curiosity in learning. *Psychon. Bull. Rev.* 26, 1377–1387. doi: 10.3758/s13423-019-01598-6

Wade Morris, J. (2021). Infrastructures of discovery: examining podcast ratings and rankings. *Cult. Stud.* 35, 728–749. doi: 10.1080/09502386.2021.1895246

Weingart, P., Joubert, M., and Connoway, K. (2021). Public engagement with science—origins, motives and impact in academic literature and science policy. *PLoS One* 16:e0254201. doi: 10.1371/journal.pone.0254201

frontiers

Supplementary Material

S1 Podcast Questionnaire

Core Questions

Approximately, how often did you listen to podcasts in the last six months (not including the mass spectrometry podcasts)?

Very often	Often	Sometimes	Seldom/ Rarely	Never

The mass spectrometry podcasts that you listened to differed in duration. What is your preferred duration of podcast?

A 15 minutes or less

B 16-30 minutes

C 31-45 minutes

D 46-60 minutes

E Longer than 60 minutes

The tone of the discussion in these podcasts was _____.

Much too formal	Slightly too formal	About right	Slightly too informal	Much too informal

Overall, the guests gave the right amount of detail to help the audience understand their field of work.

1 Strongly disagree

2 Disagree

3 Neutral

4 Agree

5 Strongly agree

On a scale of 1 to 5, how much do you agree with the following statements?

I understood the explanation of what mass spectrometry is.

1 Strongly disagree

2 Disagree

3 Neutral

4 Agree

5 Strongly agree

I understood the explanation of what mass spectrometry is used for.

1 Strongly disagree

2 Disagree

3	Neutral
4	Agree
5	Strongly agree

What was your level of knowledge about mass spectrometry before you listened to the podcasts?

A	I knew a great deal
B	I knew quite a bit
C	I knew a little
D	I knew very little
E	I knew nothing

How much did you learn about mass spectrometry from listening to the podcasts?

A	I learnt a great deal
B	I learnt quite a bit
C	I learnt a little
D	I learnt very little
E	I learnt nothing

How much do you agree with the following statement? The challenges faced by the researchers interviewed for the podcasts differed.

1	Strongly disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly agree

S2 Personal interviews guide

Topic of discussion	Prompts for the interview
Background	General discussion on the educational background and interests.
Familiarity with natural sciences	Understanding of natural sciences and its various fields.
	Familiarity with scientific content.
	Engaging with scientific content.
Familiarity with mass Spectrometry	Describe existing knowledge level regarding mass spectrometry.
	Recall instances of coming across mass spectrometry (optional).
Learning from the podcasts	Overall impression of the series.
	Extent of new knowledge from the series.
	Recalling snippets or segments.
Reflection on choices	Favorite podcast in the series.
	Least favorite podcast in the series.
	Identifying elements that contribute to these choices like humor, narrative or style of conversation.
	Additional reasons for ranking a podcast as most favorite or least favourite.
	Reasons why podcasts on fields like mass spectrometry might not attract listeners on public platforms.
Recommendations	Enhancing podcasting experience based on individual experiences.
	Role of topic and content in popularity of a podcast.
	Role of marketing, branding or endorsements in popularity of a podcast.

Chapter 4

Conclusions

The overarching aim of this thesis was to assess consumer behaviour towards adopting or rejecting new food technologies and to explore strategies that can be implemented in this regard.

In the first part, the research examines what consumers prioritise in their daily shopping and different dietary lifestyles that incorporate foods perceived as more sustainable and ethical at the initial step. In the second step, it investigates their motivations to adopt product categories under new food technologies. In the third step, the barriers to adoption are explored, and finally, suggestions to address these barriers are discussed directly with consumers to mitigate existing consumer scepticism, especially regarding new foods and technologies, and to build trust and, ultimately, acceptance.

The use of a questionnaire in different parts of this thesis served as the first critical step to evaluate existing consumer attitudes and perceptions. The focus groups provided depth, allowing participants to share their thoughts in detail, leading to richer insights. This approach captured not only the "what" but also the "why" behind consumer choices, offering a clearer understanding of the beliefs and perceptions that shape their decisions.

An interesting aspect of this study was the varied regulatory landscape across the countries involved. While some nations adhered closely to EU regulations, others followed their own guidelines. These differences were reflected in the discussions, influencing what participants shared and how they approached the topic.

The next part of the research turned to how these findings could be communicated effectively. With the rise of digital tools like podcasts and social media, the study explored how these platforms can make complex scientific information easier to understand and more engaging. The results, as discussed in Section 3.5 of Chapter 3, highlight the importance of clear, relatable, and transparent communication, which is essential for building trust with the public. In other words, when consumers understand the story behind new food technologies, how they are developed, and why they matter, they are far more likely to accept and embrace them.

Figure 4.1 presents a framework for communicating with consumers, addressing various aspects of innovation in the field of food, including new food technologies. At its centre, this framework places the consumer, emphasising the need for communication that directly addresses their needs and concerns.

The framework encompasses four main areas, covering topics ranging from new foods and technologies to food labelling, packaging innovations, and the principles of the circular economy. Supporting these main pillars, the framework employs a blend of research methods to understand what consumers want or expect. Examples include conducting qualitative studies like interviews and focus groups to evaluate in-depth consumer opinions and using quantitative research to identify trends and gather measurable data.

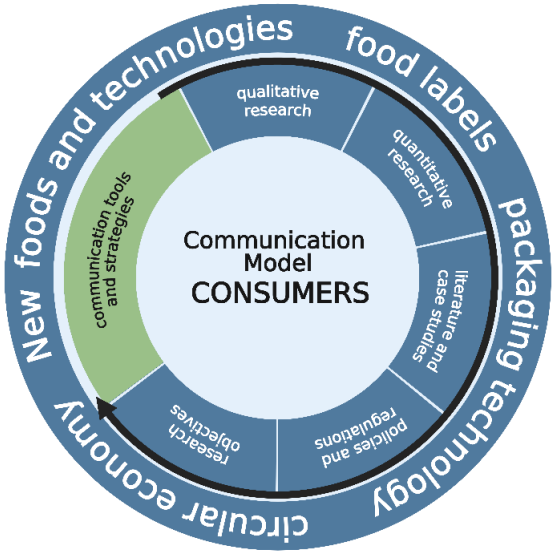


Figure 4.1: Framework for establishing communication with consumers (Own Illustration).

This framework begins with the use of literature and real-world case studies to shape the research design and develop tools such as questionnaires and interview guides. An interesting insight from this research was the involvement of policies and regulations, as these factors radically influenced consumer responses as seen in the studies covered in this dissertation. The green section of the framework emphasises the use of modern communication methods, including podcasts, social media, mobile apps, and websites, to convey complex scientific information effectively.

The findings of this research are presented in six papers, five of which have been published in international, peer-reviewed scientific journals and constitute Chapter 3 of this dissertation. The research has also been shared at various international and student conferences through oral and poster presentations. The research work included in this dissertation addresses the following topics, which validate key hypotheses and are interrelated:

1. **The influence of consumer awareness and understanding on the acceptance of new foods and technologies**: One of the objectives of this work was to understand how consumer awareness and perception influence the acceptance of new food technologies particularly alternative proteins. In this regard, the three most common alternative protein sources were investigated, which include plant-based proteins, CCDM, and edible insects. The findings revealed that while there is growing interest in sustainable food solutions, consumer acceptance is strongly tied to the level of awareness and understanding. When consumers are provided with transparent, informative content about the environmental and health benefits of these products, their openness to integrating them into their diets increases. This supports Hypothesis 1, which posits that increased awareness and understanding among consumers correlate with a 20–30% higher acceptance rate of new foods and technologies. The evidence showed that informed consumers were more likely to overcome scepticism and consider alternative proteins as viable choices, affirming the importance of targeted educational efforts.

2. **The role of environmental considerations in shaping consumer acceptance of new foods and technologies**: Multiple aspects of the studies covered in this dissertation have had environment and sustainability as key focal points. These have become crucial in tackling the challenges associated with fulfilling the nutritional requirements of a growing population. This also means that it is now imperative to focus on dietary lifestyles that incorporate new foods or sustainable alternatives, as well as new food technologies or foods from unconventional sources. The findings highlighted that incorporating knowledge of the environmental impact can have a positive influence on consumers. However, several biases, including individual preferences and cultural hesitations, still exist, making many hesitant to embrace unfamiliar foods. Accessibility and availability of knowledge explaining why certain alternatives can be beneficial can help ease this transition. This supports Hypothesis 2, which emphasises that integrating sustainability-related benefits with other motivators can increase consumer acceptance rates by at least 25%. It showed that consumers appreciate the idea of sustainability and seek practical solutions for their diets. Highlighting these aspects can help overcome personal and cultural barriers and increase interest in adopting different foods and food technologies.

3. **The role of communication tools in enhancing consumer trust and acceptance of new food technologies**: Another key area of this study focused on the role of communication tools in fostering consumer trust and acceptance of new food technologies. Through the use of digital platforms such as podcasts, the research demonstrated that complex scientific information could be made accessible and engaging. This finding supported Hypothesis 3, which suggested that active consumer engagement through digital communication tools, by identifying barriers and developing strategies to address them, can enhance acceptance rates by 10–20%. Podcasts, in particular, proved effective in demystifying technical subjects and fostering relatability, which helped bridge the gap between scientific content and everyday consumer understanding. Feedback from focus groups reinforced the idea that clear, transparent communication addresses consumer concerns and builds trust, highlighting the need for the strategic use of modern communication tools in promoting new food technologies.

4.1 Scientific Relevance

This dissertation tackles one of the biggest challenges in sustainable food consumption: understanding what drives consumer acceptance and how to address barriers related to it. By adopting a mixed-methods approach, it is one of the first studies to provide a holistic understanding of consumer perceptions in Europe, allowing a deeper look at what influences food choices beyond just the technical details of food technologies.

The study focused on three major sources of alternative proteins: plant-based, cultured meat, and insect-based proteins. These are all at different stages of market introduction, especially in Europe. While grouped as "alternative proteins," each faces unique challenges from consumers. For example, regulatory frameworks play a huge role in shaping consumer views regarding CCDM.

In the case of plant-based proteins, despite their acknowledged purpose, they are still not fully integrated into diets as they are often viewed as chemically made. Similarly, while insect-based proteins have long been recognised as viable and are widely consumed in parts of Asia and Africa, they continue to face scepticism in Europe.

This reflects how consumer perceptions are not only influenced by the technical and environmental merits of these innovations but also by how they are communicated. Addressing underlying scepticism through effective communication strategies is essential for broader acceptance of these products.

Adding to its scientific relevance, this dissertation is also among the first to explore the intersection of science communication and public engagement in highly specialised fields relevant to food research. Mass spectrometry, a critical tool in analysing and authenticating new food technologies, was explored as a topic in a podcast series and evaluated for its engagement. The podcasts featured researchers from diverse sociodemographic backgrounds who discussed using technologies in various fields in a conversational manner.

The feedback for this series exemplified how complex scientific concepts can be translated into accessible and engaging narratives. This not only enhanced public understanding of a specialised field but also highlighted the potential of effective science communication in building consumer trust.

4.2 Future Work

This dissertation highlights the current consumer preferences for food technologies and communication strategies to accompany them. However, understanding how these preferences evolve over time remains essential. One solution is to undertake extensive longitudinal studies that track changes in consumer attitudes towards new food technologies, especially those that have been subjected to changes in regulations in the EU, such as CCDM and edible insects.

Longitudinal studies could also contribute to research on plant-based proteins, particularly in the context of different dietary styles followed by consumers and how plant-based proteins can meet their nutritional needs. This approach could facilitate broader acceptance of these products into daily life if studies involving consumers have a positive impact and are made directly available to the public.

The impact of cultural and regional differences in consumer acceptance presents another important aspect of this research. While this dissertation has focused on European consumers, attitudes towards sustainability and new food technologies can vary significantly across different regions.

Future research examining how these trends manifest in areas such as North and South America, Asia, or Africa could provide valuable insights into how the food industry can adapt to and respond to the unique needs and expectations of various cultural groups. These distinctions can aid in product development tailored to consumers with shared cultural or regional commonalities, enabling the creation of communication strategies aligned with local values.

As research in the food sector continues to advance, the potential impact of new technologies through comprehensive life cycle assessments is also critically important. Many of these innovations have the potential to cause radical transformations in existing food systems, but their impact should be assessed critically and shared with consumers to increase public interest and trust.

Future studies examining these technologies in greater detail, with a focus on consumer perspectives, could provide a more comprehensive understanding of their roles in sustainable food systems and the resulting regulatory frameworks.

Additionally, while this dissertation has emphasised the importance of effective communication, further research could explore and evaluate more effective methods and channels for reaching diverse consumer demographics. The rise of artificial intelligence and its impact on digital platforms and social media presents new opportunities and challenges.

However, the benefits of engaging consumers through relatable content remain evident, as supported by existing research and literature.

It is crucial that information, when made relatable, remains factual and does not shift into opinions that could lead to misinformation. Investigating the negative aspects of these tools, including how they could be misused to spread misinformation if not carefully employed, would also be worthwhile.

This dissertation makes it evident that areas of research impacting sustainability in any aspect should involve consumers directly. This is the only way forward to ensure that food technologies can be successfully integrated into the market. Advancing knowledge in these directions will help bridge the gap between technological innovation and consumer trust, ensuring that sustainable food solutions are not only developed but embraced, paving the way for a more resilient, informed, and conscious global food system.

Appendix A

Example of a Podcast Infographic

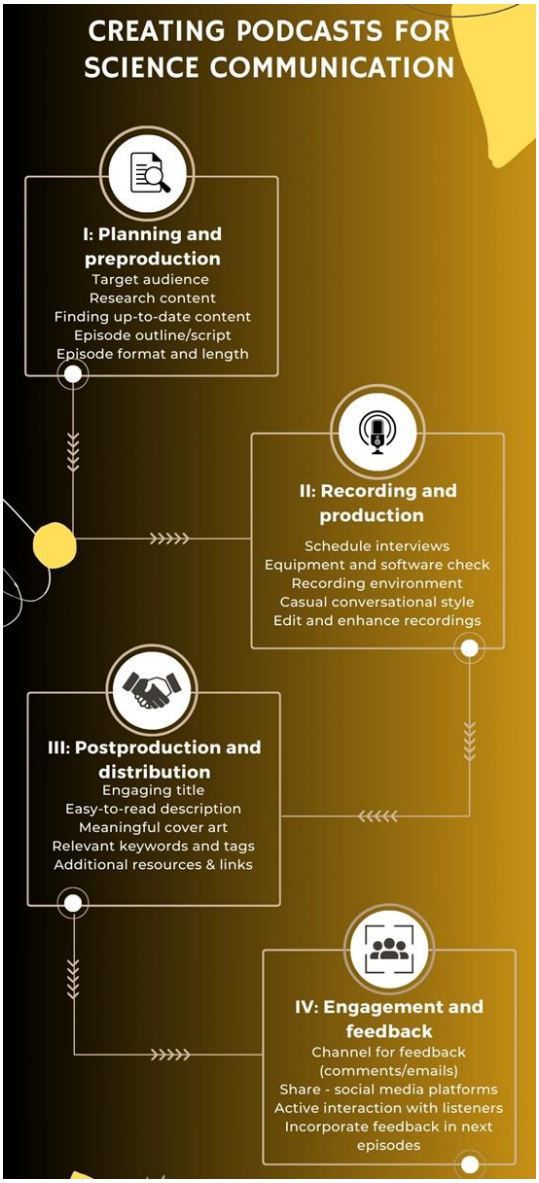


Figure A.1: Example of a podcast infographics for science communication.

References

Adamsson, V., Cederholm, T., Vessby, B., & Risérus, U. (2014). Influence of a healthy Nordic diet on serum fatty acid composition and associations with blood lipoproteins: Results from the NORDIET study. *Food & Nutrition Research, 58*(1), 24114. https://doi.org/10.3402/fnr.v58.24114

Adamsson, V., Reumark, A., Cederholm, T., Vessby, B., Risérus, U., & Johansson, G. (2012). What is a healthy Nordic diet? Foods and nutrients in the NORDIET study. *Food & Nutrition Research, 56*(1), 18189. https://doi.org/10.3402/fnr.v56i0.18189

Aiking, H. (2014). Protein production: Planet, profit, plus people? *American Journal of Clinical Nutrition, 100*, 483S–489S. https://doi.org/10.3945/ajcn.113.071209

Aiking, H., & de Boer, J. (2020). The next protein transition. *Trends in Food Science & Technology, 105*, 515–522. https://doi.org/10.1016/j.tifs.2018.07.008

Albertsen, L., Wiedmann, K. P., & Schmidt, S. (2020). The impact of innovation-related perception on consumer acceptance of food innovations: Development of an integrated framework of the consumer acceptance process. *Food Quality and Preference, 84*, 103958. https://doi.org/10.1016/j.foodqual.2020.103958

Albuquerque, T. G., Oliveira, M. B. P., & Costa, H. S. (2018). 25 years of European Union (EU) quality schemes for agricultural products and foodstuffs across EU Member States. *Journal of the Science of Food and Agriculture, 98*(7), 2475–2489. https://doi.org/10.1002/jsfa.8811

Allgaier, J. (2016, April). Science on YouTube: What do people find when they are searching for climate science and climate manipulation. *14th International Conference on Public Communication of Science and Technology (PCST)* (pp. 26–28). Retrieved January 1, 2025, from https://www.academia.edu/download/46197448/PCST_Paper__97.pdf

Annunziata, A., Ianuario, S., & Pascale, P. (2011). Consumers' attitudes toward labelling of ethical products: The case of organic and Fair Trade products. *Journal of Food Products Marketing, 17*(5), 518–535. https://doi.org/10.1080/10454446.2011.618790

Anusha Siddiqui, S., Bahmid, N. A., Mahmud, C. M. M., Boukid, F., Lamri, M., & Gagaoua, M. (2022). Consumer acceptability of plant-, seaweed-, and insect-based foods as alternatives to meat: A critical compilation of a decade of research. *Critical Reviews in Food Science and Nutrition, 1*(1), 1–22. https://doi.org/10.1080/10408398.2022.2036096

Arfini, F., Antonioli, F., Cozzi, E., Donati, M., Guareschi, M., Mancini, M. C., & Veneziani, M. (2019). Sustainability, innovation and rural development: The case of Parmigiano-Reggiano PDO. *Sustainability, 11*(18), 4978. https://doi.org/10.3390/su11184978

Around, E., & Are, V. (2018). The biggest pandemic risk? Viral misinformation. *Nature, 562(7727), 309–309.* https://doi.org/10.1038/d41586-018-07034-4

Aschemann-Witzel, J., Gantriis, R. F., Fraga, P., & Perez-Cueto, F. J. (2021). Plant-based food and protein trends from a business perspective: Markets, consumers, and the challenges and opportunities in the future. *Critical Reviews in Food Science and Nutrition, 61*(18), 3119–3128. https://doi.org/10.1080/10408398.2020.1793730

Augustus Bambridge-Sutton. (2023). *Italian gov't bans cultivated meat, restricts plant-based meat labelling.* FoodNavigator. Retrieved January 1, 2025, from https://www.foodnavigator.com/Article/2023/11/21/Italy-bans-cultivated-meat-restricts-plant-based-meat-labelling

Aung, M. M., & Chang, Y. S. (2014). Traceability in a food supply chain: Safety and quality perspectives. *Food Control, 39*, 172–184. https://doi.org/10.1016/j.foodcont.2013.11.007

Auxier, B., & Anderson, M. (2021). *Social media use in 2021.* Pew Research Center. Retrieved January 1, 2025, from https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2021/04/PI_2021.04.07_Social-Media-Use_FINAL.pdf

Avermaete, T., & Vandermosten, G. (2016). Traditional Belgian beers in a global market economy. In *Traditional Food Production and Rural Sustainable Development* (pp. 239–254). Routledge. https://doi.org/10.4324/9781315550374

Avraamidou, L., & Osborne, J. (2009). The role of narrative in communicating science. *International Journal of Science Education, 31*(12), 1683–1707. https://doi.org/10.1080/09500690802380695

Bandura, A. (1969). Social-learning theory of identificatory processes. In D. A. Goslin (Ed.), *Handbook of socialization theory and research* (pp. 213–262). Rand McNally.

Bandura, A. (1977). *Social learning theory.* Prentice-Hall. Retrieved February 1, 2025, from https://www.asecib.ase.ro/mps/Bandura_SocialLearningTheory.pdf

Barrios-O'Neill, D. (2018). Wild listening: Ecology of a science podcast. In D. Llinares, N. Fox, & R. Berry (Eds.), *Podcasting: New aural cultures and digital media* (pp. 147–172). Palgrave Macmillan. https://doi.org/10.1007/978-3-319-90056-8_8

Baumgartner, J., Zannettou, S., Keegan, B., Squire, M., & Blackburn, J. (2020, May). The Pushshift Reddit dataset. In *Proceedings of the International AAAI Conference on Web and Social Media* (Vol. 14, pp. 830–839). https://doi.org/10.1609/icwsm.v14i1.7347

BBC News. (2021). *Covid: Fertility fears are 'widespread' in young women over vaccine.* Retrieved January 1, 2025, from https://www.bbc.co.uk/news/health-57552527

Becerra-Tomás, N., Blanco Mejía, S., Viguiliouk, E., Khan, T., Kendall, C. W., Kahleova, H., ... & Salas-Salvadó, J. (2020). Mediterranean diet, cardiovascular disease and mortality in diabetes: A systematic review and meta-analysis of prospective cohort studies and randomized clinical trials. *Critical Reviews in Food Science and Nutrition, 60*(7), 1207–1227. https://doi.org/10.1080/10408398.2019.1565281

Becker, T. C. (2009). European food quality policy: The importance of geographical indications, organic certification and food quality assurance schemes in European countries. *Estey Journal of International Law and Trade Policy, 10*(1), 111–130. https://doi.org/10.22004/ag.econ.48796

Berry, E. M., Dernini, S., Burlingame, B., Meybeck, A., & Conforti, P. (2015). Food security and sustainability: Can one exist without the other? *Public Health Nutrition, 18*(13), 2293–2302. https://doi.org/10.1017/S136898001500021X

Berry, R. (2016). Podcasting: Considering the evolution of the medium and its association with the word "radio." *Radio Journal: International Studies in Broadcast & Audio Media, 14*(1), 7–22. https://doi.org/10.1386/rjao.14.1.7_1

Biggi, C., Biasini, B., Ogrinc, N., Strojnik, L., Endrizzi, I., Menghi, L., ... & Menozzi, D. (2024). Drivers and barriers influencing adherence to the Mediterranean diet: A comparative study across five countries. *Nutrients, 16*(15), 2405. https://doi.org/10.3390/nu16152405

Bode, L., & Vraga, E. K. (2017). See something, say something: Correction of global health misinformation on social media. *Health Communication, 33*(9), 1131–1140. https://doi.org/10.1080/10410236.2017.1331312

Boland, M. J., Rae, A. N., Vereijken, J. M., Meuwissen, M. P. M., Fischer, A. R. H., van Boekel, M. A. J. S., ... & Hendriks, W. H. (2013). The future supply of animal-derived protein for human consumption. *Trends in Food Science & Technology, 29*(1), 62–73. https://doi.org/10.1016/j.tifs.2012.07.002

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2–16. https://doi.org/10.1177/0963662515607406

Borah, P., Xiao, X., & Lee, D. K. L. (2022). Narrative messages, information seeking, and COVID-19 vaccine intention: The moderating role of perceived behavioral control. *American Journal of Health Promotion, 36*(6), 923–933. https://doi.org/10.1177/08901171221075019

Boström, M., & Klintman, M. (2019). Can we rely on 'climate-friendly' consumption? *Journal of Consumer Culture, 19*(3), 359–378. https://doi.org/10.1177/1469540517717782

Bouis, H. E., & Saltzman, A. (2017). Improving nutrition through biofortification: A review of evidence from HarvestPlus, 2003 through 2016. *Global Food Security, 12*, 49–58. https://doi.org/10.1016/j.gfs.2017.01.009

Bouis, H. E., Chassy, B. M., & Ochanda, J. O. (2003). Genetically modified food crops and their contribution to human nutrition and food quality. *Trends in Food Science & Technology, 14*(5–8), 191–209. https://doi.org/10.1016/S0924-2244(03)00073-6

Boulos, M. N. K., Maramba, I., & Wheeler, S. (2006). Wikis, blogs and podcasts: A new generation of web-based tools for virtual collaborative clinical practice and education. *BMC Medical Education, 6*(1). https://doi.org/10.1186/1472-6920-6-41

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Breen, R. L. (2006). A practical guide to focus-group research. *Journal of Geography in Higher Education, 30*(3), 463–475. https://doi.org/10.1080/03098260600927575

Bryant, C. J., & Barnett, J. C. (2019). What's in a name? Consumer perceptions of in vitro meat under different names. *Appetite, 137*, 104–113. https://doi.org/10.1016/j.appet.2019.02.021

Business Wire. (2023). *U.S. plant-based meat-focused insights report, 2024–2029: Featuring Beyond Meat, Impossible Foods, Quorn, Tofurky, and Tyson Foods*. Retrieved January 1, 2025, from https://vegconomist.com/businesswire/us-plant-based-meat-focused-insights-report-2024-2029-featuring-beyond-meat-impossible-foods-quorn-tofurky-and-tyson-foods/

Caceres, M. M. F., Sosa, J. P., Lawrence, J. A., Sestacovschi, C., Tidd-Johnson, A., Rasool, M. H. U., ... & Fernandez, J. P. (2022). The impact of misinformation on the COVID-19 pandemic. *AIMS Public Health, 9*(2), 262. https://doi.org/10.3934/publichealth.2022018

Cao, Y., & Miao, L. (2023). Consumer perception of clean food labels. *British Food Journal, 125*(2), 433–448. https://doi.org/10.1108/BFJ-03-2021-0246

Centers for Disease Control and Prevention. (2024). *Coronavirus Disease 2019 (COVID-19)*. Retrieved January 1, 2025, from https://www.cdc.gov/covid/index.html

Chan-Olmsted, S., & Wang, R. (2020). Understanding podcast users: Consumption motives and behaviors. *New Media & Society, 24*(3), 146144482096377. https://doi.org/10.1177/1461444820963776

Chassy, B. M. (2007). The history and future of GMOs in food and agriculture. *Cereal Foods World, 52*(4), 169. https://doi.org/10.1094/CFW-52-4-0169

Chriki, S., & Ellies-Oury, M.-P. (2022). Is "cultured meat" a viable alternative to slaughtering animals and a good compromise between animal welfare and human expectations? *Animal Frontiers, 12*(1), 35–42. https://doi.org/10.1093/af/vfac002

Chriki, S., & Hocquette, J.-F. (2020). The myth of cultured meat: A review. *Frontiers in Nutrition, 7*(7), 7. https://doi.org/10.3389/fnut.2020.00007

Chun-Ting, P., Meng-Ju, L., Nen-Fu, H., Jhong-Ting, L., & Jia-Jung, S. (2020, January). Agriculture blockchain service platform for farm-to-fork traceability with IoT sensors. In *2020 International Conference on Information Networking (ICOIN)* (pp. 158–163). IEEE. https://doi.org/10.1109/ICOIN48656.2020.9016535

Cicatiello, C., De Rosa, B., Franco, S., & Lacetera, N. (2016). Consumer approach to insects as food: Barriers and potential for consumption in Italy. *British Food Journal, 118*(9), 2271–2286. https://doi.org/10.1108/bfj-01-2016-0015

Cinelli, M., Quattrociocchi, W., Galeazzi, A., Valensise, C. M., Brugnoli, E., Schmidt, A. L., ... & Scala, A. (2020). The COVID-19 social media infodemic. *Scientific Reports, 10*(1), 1–10. https://doi.org/10.1038/s41598-020-73510-5

Circus, V. E., & Robison, R. (2018). Exploring perceptions of sustainable proteins and meat attachment. *British Food Journal, 121*(5), 1235–1249. https://doi.org/10.1108/bfj-01-2018-0025

Clune, S., Crossin, E., & Verghese, K. (2017). Systematic review of greenhouse gas emissions for different fresh food categories. *Journal of Cleaner Production, 140*, 766–783. https://doi.org/10.1016/j.jclepro.2016.04.082

Codex Alimentarius Commission. (2020). *Guidelines for the regulation of cultured meat.* Retrieved January 1, 2025, from http://www.fao.org/fao-who-codexalimentarius

Collins, K., Shiffman, D., & Rock, J. (2016). How are scientists using social media in the workplace? *PLOS ONE, 11*(10), e0162680. https://doi.org/10.1371/journal.pone.0162680

Craig, W. J. (2009). Health effects of vegan diets. *The American Journal of Clinical Nutrition, 89*(5), 1627S–1633S. https://doi.org/10.3945/ajcn.2009.26736N

Dafni, M. F., & Likudis, Z. (2024). Consumer willingness to buy products with geographical origin (PGO) and protected designation of origin (PDO): A review. *Brazilian Journal of Science, 3*(10), 1–6. https://doi.org/10.14295/bjs.v3i10.620

Dagevos, H. (2021). Finding flexitarians: Current studies on meat eaters and meat reducers. *Trends in Food Science & Technology, 114*, 530–539. https://doi.org/10.1016/j.tifs.2021.06.021

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences, 111*(Supplement_4), 13614–13620. https://doi.org/10.1073/pnas.132064511

Dame Adjin-Tettey, T. (2022). Combating fake news, disinformation, and misinformation: Experimental evidence for media literacy education. *Cogent Arts & Humanities, 9*(1), 2037229. https://doi.org/10.1080/23311983.2022.2037229

Daughton, C. G. (2001). Emerging pollutants, and communicating the science of environmental chemistry and mass spectrometry: Pharmaceuticals in the environment. *Journal of the American Society for Mass Spectrometry, 12*(10), 1067–1076. https://doi.org/10.1016/s1044-0305(01)00287-2

Davies, S. R., & Hara, N. (2017). Public science in a wired world: How online media are shaping science communication. *Science Communication, 39*(5), 563–568. https://doi.org/10.1177/1075547017736892

Davis, C., Bryan, J., Hodgson, J., & Murphy, K. (2015). Definition of the Mediterranean diet: A literature review. *Nutrients, 7*(11), 9139–9153. https://doi.org/10.3390/nu7115459

de Boer, J., & Aiking, H. (2022). Considering how farm animal welfare concerns may contribute to more sustainable diets. *Appetite, 168*, 105786. https://doi.org/10.1016/j.appet.2022.105786

de Koning, W., Dean, D., Vriesekoop, F., Aguiar, L. K., Anderson, M., Mongondry, P., Oppong-Gyamfi, M., Urbano, B., Luciano, C. A. G., Jiang, B., Hao, W., Eastwick, E., Jiang, Z. (Virgil), & Boereboom, A. (2020). Drivers and inhibitors in the acceptance of meat alternatives: The case of plant- and insect-based proteins. *Foods, 9*(9), 1292. https://doi.org/10.3390/foods9091292

de Oliveira Padilha, L. G., & Malek, L. (2022). Consumers' attitudes towards lab-grown meat, conventionally raised meat, and plant-based protein alternatives. *Food Quality and Preference, 99*, 104573. https://doi.org/10.1016/j.foodqual.2022.104573

Delgado Calvo-Flores, L., Garino, C., Moreno, F. J., & Broll, H. (2022). Insects in food and their relevance regarding allergenicity assessment. *EFSA Journal, 20*, e200909. https://doi.org/10.2903/j.efsa.2022.e200909

Derbyshire, E. J. (2017). Flexitarian diets and health: A review of the evidence-based literature. *Frontiers in Nutrition, 3*, 231850. https://doi.org/10.3389/fnut.2016.00055

Dernini, S., & Berry, E. M. (2015). Mediterranean diet: From a healthy diet to a sustainable dietary pattern. *Frontiers in Nutrition, 2*, 15. https://doi.org/10.3389/fnut.2015.00015

Deroy, O., Reade, B., & Spence, C. (2015). The insectivore's dilemma, and how to take the West out of it. *Food Quality and Preference, 44*, 44–55. https://doi.org/10.1016/j.foodqual.2015.02.007

Devitt, I. (2024). Greenwashing in the meat and seafood industry. *University of South Australia Law Review, 6*, 21–31. https://doi.org/10.21913/USLRunisalr.v6.1689

Dias, C., & Mendes, L. (2018). Protected designation of origin (PDO), protected geographical indication (PGI) and traditional speciality guaranteed (TSG): A bibliometric analysis. *Food Research International, 103*, 492–508. https://doi.org/10.1016/j.foodres.2017.09.059

Dixon, K. A., Michelsen, M. K., & Carpenter, C. L. (2023). Modern diets and the health of our planet: An investigation into the environmental impacts of food choices. *Nutrients, 15*(3), 692. https://doi.org/10.3390/nu15030692

Donaldson, A. (2022). Digital from farm to fork: Infrastructures of quality and control in food supply chains. *Journal of Rural Studies, 91*, 228–235. https://doi.org/10.1016/j.jrurstud.2021.10.004

Drew, C. (2017). Educational podcasts: A genre analysis. *E-Learning and Digital Media, 14*(4), 201–211. https://doi.org/10.1177/2042753017736177

Drexler, D., Fiala, J., Havlíčková, A., Potůčková, A., & Souček, M. (2018). The effect of organic food labels on consumer attention. *Journal of Food Products Marketing, 24*(4), 441–455. https://doi.org/10.1080/10454446.2017.1311815

Duarte, P., & Teixeira, M. (2021). Healthy eating as a trend: Consumers' perceptions towards products with nutrition and health claims. *Revista Brasileira de Gestão de Negócios, 23*, 405–421. https://doi.org/10.7819/rbgn.v23i3.4113

Durant, J. R., Evans, G. A., & Thomas, G. P. (1989). The public understanding of science. *Nature, 340*(6228), 11–14. https://doi.org/10.1038/340011a0

Eftimov, T., Korošec, P., Potočnik, D., Ogrinc, N., Heath, D., & Seljak, B. K. (2017). How to perform proper statistical analysis on food data? An e-learning tool: Advanced statistics in natural sciences and technologies. In *Science within food: Up-to-date*

advances on research and educational ideas (pp. 144–151). Formatex Research Center.

Ekmekcioglu, C., Wallner, P., Kundi, M., Weisz, U., Haas, W., & Hutter, H.-P. (2017). Red meat, diseases, and healthy alternatives: A critical review. *Critical Reviews in Food Science and Nutrition, 58*(2), 247–261. https://doi.org/10.1080/10408398.2016.1158148

Estruch, R., Ros, E., Salas-Salvadó, J., Covas, M. I., Corella, D., Arós, F., ... & Martínez-González, M. A. (2018). Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. *New England Journal of Medicine, 378*(25), e34. https://doi.org/10.1056/NEJMoa1800389

European Commission. (2013). *Ethics for researchers: Facilitating research excellence in FP7*. Publications Office of the European Union. Retrieved January 15, 2022, from https://ec.europa.eu/research/participants/data/ref/fp7/89888/ethics-for-researchers_en.pdf

European Commission. (2020). *Horizon 2020: The EU framework programme for research and innovation*. Retrieved January 1, 2025, from https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020

European Commission. (2020). *Quality schemes explained*. Retrieved January 1, 2025, from https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/quality-schemes-explained_en

European Food Safety Authority (EFSA). (2018). *Regulation (EU) 2015/2283 on novel foods*. Retrieved January 1, 2025, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015R2283

Fan, B., Qian, J., Wu, X., Du, X., Li, W., Ji, Z., & Xin, X. (2019). Improving continuous traceability of foodstuff by using barcode-RFID bidirectional transformation equipment: Two field experiments. *Food Control, 98*, 449–456. https://doi.org/10.1016/j.foodcont.2018.12.002

Fang, T. E., Cao, H., Wang, Y. U. E., Gong, Y., & Wang, Z. (2023). Global scientific trends on healthy eating from 2002 to 2021: A bibliometric and visualized analysis. *Nutrients, 15*(6), 1461. https://doi.org/10.3390/nu15061461

FAO. (2009). *How to feed the world in 2050*. Food and Agriculture Organization. Retrieved January 1, 2025, from https://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

Farkas, J., & Mohácsi-Farkas, C. (2011). History and future of food irradiation. *Trends in Food Science & Technology, 22*(2–3), 121–126. https://doi.org/10.1016/j.tifs.2010.04.002

Ferri García, R., & Rueda García, M. D. M. (2020). Efficiency of propensity score adjustment and calibration on the estimation from non-probabilistic online surveys. https://doi.org/10.2436/20.8080.02.73

Fischer, E., & Guzel, G. T. (2023). The case for qualitative research. *Journal of Consumer Psychology, 33*(1), 259–272. https://doi.org/10.1002/jcpy.1300

Fischer, G., Shah, M. M., & Van Velthuizen, H. T. (2002). *Climate change and agricultural vulnerability*. Retrieved January 1, 2025, from https://pure.iiasa.ac.at/id/eprint/6670

Fischhoff, B., & Scheufele, D. A. (2013). The science of science communication. *Proceedings of the National Academy of Sciences, 110*(supplement_3), 14031–14032. https://doi.org/10.1073/pnas.1312080110

Fiske, S. T., & Dupree, C. (2014). Gaining trust as well as respect in communicating to motivated audiences about science topics. *Proceedings of the National Academy of*

Sciences, 111(Supplement_4), 13593–13597. https://doi.org/10.1073/pnas.1317505111

Fitton, N., Alexander, P., Arnell, N., Bajzelj, B., Calvin, K., Doelman, J., ... & Smith, P. (2019). The vulnerabilities of agricultural land and food production to future water scarcity. *Global Environmental Change, 58*, 101944. https://doi.org/10.1016/j.gloenvcha.2019.101944

Floura Southey. (2023). *'A great achievement for the Dutch government': First Member State approves pre-market tastings of cultivated meat.* FoodNavigator. Retrieved January 1, 2025, from https://www.foodnavigator.com/Article/2023/07/19/cultivated-meat-tastings-formally-approved-in-the-netherlands

Floura Southey. (2023). *France's 'veggie' burger ban escalates to the European Court of Justice.* FoodNavigator. Retrieved January 1, 2025, from https://www.foodnavigator.com/Article/2023/08/03/france-s-veggie-burger-ban-escalates-to-the-european-court-of-justice

FMI & NIQ. (2023). *Transparency trends 2023: Food shoppers increasingly prioritize information.* FMI. Retrieved January 1, 2025, from https://www.fmi.org/forms/store/ProductFormPublic/transparency-trends-2023?utm_source=chatgpt.com

Font-i-Furnols, M. (2023). Meat consumption, sustainability and alternatives: An overview of motives and barriers. *Foods, 12*(11), 2144. https://doi.org/10.3390/foods12112144

Food and Drug Administration (FDA). (2022). *Focus area: Novel foods and food ingredients.* Retrieved January 1, 2025, from https://www.fda.gov/science-research/focus-areas-regulatory-science-report/focus-area-novel-foods-and-food-ingredients

Food and Drug Administration (FDA). (n.d.). *Regulatory authority over food safety of Siluriformes (e.g., catfish).* Retrieved January 1, 2025, from https://www.fda.gov/media/184810/

Food Safety Commission of Japan (FSCJ). (n.d.). *Evaluation reports on new food materials and specified health use.* Retrieved January 1, 2025, from https://www.fsc.go.jp/english/evaluationreports/newfoods_sphealth_e1.html

Food Standards Agency (FSA). (2022). *Alternative proteins for human consumption.* Retrieved January 1, 2025, from https://www.food.gov.uk/research/novel-and-non-traditional-foods-additives-and-processes/alternative-proteins-for-human-consumption

Food Standards Agency (FSA). (2024). *Novel foods guidance.* Retrieved January 1, 2025, from https://www.food.gov.uk/business-guidance/regulated-products/novel-foods-guidance

Food Standards Australia New Zealand (FSANZ). (2022). *Novel foods.* Retrieved January 1, 2025, from https://www.foodstandards.gov.au/business/novel

Fresán, U., & Sabaté, J. (2019). Vegetarian diets: Planetary health and its alignment with human health. *Advances in Nutrition, 10*, S380–S388. https://doi.org/10.1093/advances/nmz019

Frewer, L., & Salter, B. (2002). Public attitudes, scientific advice and the politics of regulatory policy: The case of BSE. *Science and Public Policy, 29*(2), 137–145. https://doi.org/10.3152/147154302781781056

Garnett, T. (2009). Livestock-related greenhouse gas emissions: Impacts and options for policy makers. *Environmental Science & Policy, 12*(4), 491–503. https://doi.org/10.1016/j.envsci.2009.01.006

Gebbers, R., & Adamchuk, V. I. (2010). Precision agriculture and food security. *Science, 327*(5967), 828–831. https://doi.org/10.1126/science.1183899

Gere, A., Székely, G., Kovács, S., Kókai, Z., & Sipos, L. (2017). Readiness to adopt insects in Hungary: A case study. *Food Quality and Preference, 59*, 81–86. https://doi.org/10.1016/j.foodqual.2017.02.005

Ghvanidze, S., Velikova, N., Dodd, T. H., & Oldewage-Theron, W. (2016). Consumers' environmental and ethical consciousness and the use of related food products information: The role of perceived consumer effectiveness. *Appetite, 107*, 311–322. https://doi.org/10.1016/j.appet.2016.08.097

Gilbert, N. (2012). One-third of our greenhouse gas emissions come from agriculture. *Nature, 31*, 10–12. https://doi.org/10.1038/nature.2012.11708

Gillespie, S., & van den Bold, M. (2017). Agriculture, food systems, and nutrition: Meeting the challenge. *Global Challenges, 1*(3), 1600002. https://doi.org/10.1002/gch2.201600002

Glass-O'Shea, B. (2021). The history and future of genetically modified crops: Frankenfoods, superweeds, and the developing world. *Journal of Food Law & Policy, 7*(1). Retrieved January 1, 2025, from https://scholarworks.uark.edu/jflp/vol7/iss1/3

Glavič, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. *Journal of Cleaner Production, 15*(18), 1875–1885. https://doi.org/10.1016/j.jclepro.2006.12.006

Glogoveţan, A. I., Dabija, D. C., Fiore, M., & Pocol, C. B. (2022). Consumer perception and understanding of European Union quality schemes: A systematic literature review. *Sustainability, 14*(3), 1667. https://doi.org/10.3390/su14031667

Goel, A., & Gupta, L. (2020). Social media in the times of COVID-19. *Journal of Clinical Rheumatology, 26*(6), 220–223. https://doi.org/10.1097/RHU.0000000000001508

Good Food Institute APAC. (n.d.). *Novel food regulations around the world.* Retrieved January 1, 2025, from https://gfi-apac.org/novel-food-regulations-around-the-world/

Good Food Institute Europe. (2024). *UK Food Standards Agency to introduce initial regulated product reforms next year.* Retrieved January 1, 2025, from https://gfieurope.org/blog/uk-food-standards-agency-to-introduce-initial-regulated-product-reforms-next-year/

Good Food Institute. (2023). *State of global policy on alternative proteins 2023.* Retrieved January 1, 2025, from https://gfi.org/wp-content/uploads/2024/05/State-of-Global-Policy-on-Alternative-Proteins-2023.pdf

Grasso, A. C., Hung, Y., Olthof, M. R., Verbeke, W., & Brouwer, I. A. (2019). Older consumers' readiness to accept alternative, more sustainable protein sources in the European Union. *Nutrients, 11*(8), 1904. https://doi.org/10.3390/nu11081904

Green, J. M. (2009). Evolution of glyphosate-resistant crop technology. *Weed Science, 57*(1), 108–117. https://doi.org/10.1614/WS-08-030.1

Grubb, M., Koch, M., Thomson, K., Sullivan, F., & Munson, A. (1993). *The 'Earth Summit' agreements: A guide and assessment: An analysis of the Rio '92 UN Conference on Environment and Development* (1st ed.). Routledge. https://doi.org/10.4324/9780429273964

Grunert, K. G. (2005). Consumer behaviour with regard to food innovations: Quality perception and decision-making. In *Innovation in agri-food systems* (pp. 57–85). Wageningen Academic. https://doi.org/10.3920/9789086866663_004

Guasch-Ferré, M., & Willett, W. C. (2021). The Mediterranean diet and health: A comprehensive overview. *Journal of Internal Medicine, 290*(3), 549–566. https://doi.org/10.1111/joim.13333

Handley, A., & Chapman, C. C. (2012). *Content rules* (2nd ed., Vol. 13, p. 246). John Wiley & Sons. ISBN: 978-1118232606

Hantrais, L., Allin, P., Kritikos, M., Sogomonjan, M., Anand, P. B., Livingstone, S., ... & Innes, M. (2021). Covid-19 and the digital revolution. *Contemporary Social Science, 16*(2), 256–270. https://doi.org/10.1080/21582041.2020.1833234

Harris, J. M., & Shiptsova, R. (2007). Consumer demand for convenience foods: Demographics and expenditures. *Journal of Food Distribution Research, 38*(3), 22–36. https://doi.org/10.22004/ag.econ.46585

Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology, 61*, 11–25. https://doi.org/10.1016/j.tifs.2016.12.006

Hassoun, A., Boukid, F., Pasqualone, A., Bryant, C. J., García, G. G., Parra-López, C., ... & Barba, F. J. (2022). Emerging trends in the agri-food sector: Digitalisation and shift to plant-based diets. *Current Research in Food Science, 5*, 2261–2269. https://doi.org/10.1016/j.crfs.2022.11.010

He, J., Evans, N. M., Liu, H., & Shao, S. (2020). A review of research on plant-based meat alternatives: Driving forces, history, manufacturing, and consumer attitudes. *Comprehensive Reviews in Food Science and Food Safety, 19*(5), 2639–2656. https://doi.org/10.1111/1541-4337.12610

Health Canada. (2006). *Guidelines for the safety assessment of novel foods.* Retrieved January 1, 2025, from https://www.canada.ca/en/health-canada/services/food-nutrition/legislation-guidelines/guidance-documents/guidelines-safety-assessment-novel-foods-2006.html

Heath, D., Vehar, A., Kouřimská, L., Kulma, M., Škvorová, P., Salmonová, H. Š., ... & Ogrinc, N. (2024). Quality, safety and authenticity of insect protein-based food and feed: Insights from the INPROFF Project. *Exploration of Foods and Foodomics, 2*(4), 339–362. https://doi.org/10.37349/eff.2024.00041

Hénault-Ethier, L., Reid, B., Hotte, N., Paris, N., Quinche, M., Lachance, C., Fortin, A., Normandin, É., Laderriere, V., & Vandenberg, G. (2023). Growth trials on vegetables, herbs, and flowers using mealworm frass, chicken manure, and municipal compost. *ACS Agricultural Science & Technology, 3*(3), 249–259. https://doi.org/10.1021/acsagscitech.2c00217

Henchion, M., Hayes, M., Mullen, A. M., Fenelon, M., & Tiwari, B. (2017). Future protein supply and demand: Strategies and factors influencing a sustainable equilibrium. *Foods, 6*(7), 53. https://doi.org/10.3390/foods6070053

Henson, S., & Heasman, M. (1998). Food safety regulation and the firm: Understanding the compliance process. *Food Policy, 23*(1), 9–23. https://doi.org/10.1016/S0306-9192(98)00015-3

Hocquette, J.-F., Chriki, S., Fournier, D., & Ellies-Oury, M.-P. (2024). Will "cultured meat" transform our food system towards more sustainability? *Animal, 18*(2), 101145. https://doi.org/10.1016/j.animal.2024.101145

Hsu, J. L., Sung, C. C., & Tseng, J. T. (2023). Willingness-to-pay for ready-to-eat clean label food products at convenience stores. *Future Foods, 7*, 100237. https://doi.org/10.1016/j.fufo.2023.100237

Hung-Baesecke, C. J. F., Chen, Y. R. R., & Boyd, B. (2016). Corporate social responsibility, media source preference, trust, and public engagement: The informed public's perspective. *Public Relations Review, 42*(4), 591-599. https://doi.org/10.1016/j.pubrev.2016.03.015

Hwang, J., You, J., Moon, J., & Jeong, J. (2020). Factors affecting consumers' alternative meats buying intentions: Plant-based meat alternative and cultured meat. *Sustainability, 12*(14), 5662. https://doi.org/10.3390/su12145662

Impossible Foods. (n.d.). *What is soy leghemoglobin or heme?* Retrieved January 1, 2025, from https://faq.impossiblefoods.com/hc/en-us/articles/360019100553-What-is-soy-leghemoglobin-or-heme

IPIFF. (2020). *Edible insects on the European market.* Retrieved January 1, 2025, from https://ipiff.org/wp-content/uploads/2020/06/10-06-2020-IPIFF-edible-insects-market-factsheet.pdf

Jang, J., & Lee, D. W. (2024). Advancements in plant-based meat analogs enhancing sensory and nutritional attributes. *NPJ Science of Food, 8*(1), 50. https://doi.org/10.1038/s41538-024-00292-9

Janssen, M., & Hamm, U. (2012). Product labelling in the market for organic food: Consumer preferences and willingness-to-pay for different organic certification logos. *Food Quality and Preference, 25*(1), 9–22. https://doi.org/10.1016/j.foodqual.2011.12.004

Jarchlo, A. I., & King, L. (2022). *Survey of consumer perceptions of alternative, or novel, sources of protein.* Food Standards Agency. https://doi.org/10.46756/sci.fsa.ncn554 (accessed on 10 February 2022).

Jensen, E. A., & Gerber, A. (2020). Evidence-based science communication. *Frontiers in Communication, 4.* https://doi.org/10.3389/fcomm.2019.00078

Jiang, S., & Fang, W. (2019). Misinformation and disinformation in science: Examining the social diffusion of rumours about GMOs. *Cultures of Science, 2*(4), 327–340. https://doi.org/10.1177/209660831900200407

Johnson, A. W., & Earle, T. (2016). The Evolution of Human Societies: From Foraging Group to Agrarian State (an excerpt). *Journal of Economic Sociology*, *17*(5), 30-76. https://doi.org/10.17323/1726-3247-2016-5-30-76

Josephson, E. S. (1983). An historical review of food irradiation. *Journal of Food Safety, 5*(4), 161–189. https://doi.org/10.1111/j.1745-4565.1983.tb00469.x

Kanerva, N., Kaartinen, N. E., Schwab, U., Lahti-Koski, M., & Männistö, S. (2014). The Baltic Sea Diet Score: A tool for assessing healthy eating in Nordic countries. *Public Health Nutrition, 17*(8), 1697–1705. https://doi.org/10.1017/S1368980013002395

Kaufmann, A. (2011). The current role of high-resolution mass spectrometry in food analysis. *Analytical and Bioanalytical Chemistry, 403*(5), 1233–1249. https://doi.org/10.1007/s00216-011-5629-4

Kearney, J. (2010). Food consumption trends and drivers. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554), 2793–2807. https://doi.org/10.1098/rstb.2010.0149

Keller and Heckman LLP. (2024). *Singapore introduces new legislation regulating food, alternative proteins, and more.* Retrieved January 1, 2025, from https://www.khlaw.com/insights/singapore-introduces-new-legislation-regulating-food-alternative-proteins-and-more

Kleih, A. K., Lehberger, M., & Sparke, K. (2022). Using photographs in mixed methods research: An illustration integrating quantitative and qualitative analyses from consumer research. *Journal of Mixed Methods Research, 16*(4), 438–457. https://doi.org/10.1177/15586898211056748

Koch, C. H. (2020). Brands as activists: The Oatly case. *Journal of Brand Management, 27*(5), 593–606. https://doi.org/10.1057/s41262-020-00199-2

Kouper, I. (2010). Science blogs and public engagement with science: Practices, challenges, and opportunities. *Journal of Science Communication, 9*(1). https://doi.org/10.22323/2.09010202

Krznarić, Ž., Karas, I., Ljubas Kelečić, D., & Vranešić Bender, D. (2021). The Mediterranean and Nordic diet: A review of differences and similarities of two sustainable, health-promoting dietary patterns. *Frontiers in Nutrition, 8*, 683678. https://doi.org/10.3389/fnut.2021.683678

Kumar, S., Palve, A., Joshi, C., & Srivastava, R. K. (2019). Crop biofortification for iron (Fe), zinc (Zn), and vitamin A with transgenic approaches. *Heliyon, 5*(6), e01914. https://doi.org/10.1016/j.heliyon.2019.e01914

Kuokkanen, H., & Sun, W. (2020). Companies, meet ethical consumers: Strategic CSR management to impact consumer choice. *Journal of Business Ethics, 166*(2), 403–423. https://doi.org/10.1007/s10551-019-04145-4

Lam, T., Heales, J., & Hartley, N. (2024). The impacts of traceability systems on consumer trust. *Journal of Computer Information Systems*, 1–15. https://doi.org/10.1080/08874417.2024.2316651

Lee, Y., & Li, J. Y. Q. (2021). The role of communication transparency and organisational trust in publics' perceptions, attitudes, and social distancing behaviour: A case study of the COVID-19 outbreak. *Journal of Contingencies and Crisis Management, 29*(4), 368–384. https://doi.org/10.1111/1468-5973.12354

Leer, J. (2016). The rise and fall of the New Nordic Cuisine. *Journal of Aesthetics & Culture, 8*(1), 33494. https://doi.org/10.3402/jac.v8.33494

Linnemann, A. R., Benner, M., Verkerk, R., & van Boekel, M. A. (2006). Consumer-driven food product development. *Trends in Food Science & Technology, 17*(4), 184–190. https://doi.org/10.1016/j.tifs.2005.11.015

Lippi, G., Mattiuzzi, C., & Sanchis-Gomar, F. (2015). Red meat consumption and ischemic heart disease: A systematic literature review. *Meat Science, 108*, 32–36. https://doi.org/10.1016/j.meatsci.2015.05.019

Loomba, S., De Figueiredo, A., Piatek, S. J., De Graaf, K., & Larson, H. J. (2021). Measuring the impact of COVID-19 vaccine misinformation on vaccination intent in the UK and USA. *Nature Human Behaviour, 5*(3), 337–348. https://doi.org/10.1038/s41562-021-01056-1

Lusk, J. L. (2019). Consumer beliefs about healthy foods and diets. *PLOS ONE, 14*(10), e0223098. https://doi.org/10.1371/journal.pone.0223098

Lusk, J. L., & McCluskey, J. (2018). Understanding the impacts of food consumer choice and food policy outcomes. *Applied Economic Perspectives and Policy, 40*(1), 5–21. https://doi.org/10.1093/aepp/ppx054

Lusk, J. L., Roosen, J., & Bieberstein, A. (2014). Consumer acceptance of new food technologies: Causes and roots of controversies. *Annual Review of Resource Economics, 6*(1), 381–405. https://doi.org/10.1146/annurev-resource-100913-012735

Lyon, F. (2014). *IARC monographs on the evaluation of carcinogenic risks to humans.* World Health Organization, International Agency for Research on Cancer. Retrieved January 1, 2025, from https://monographs.iarc.who.int/wp-content/uploads/2018/08/14-002.pdf

MacKenzie, L. E. (2019). Science podcasts: Analysis of global production and output from 2004 to 2018. *Royal Society Open Science, 6*(1), 180932. https://doi.org/10.1098/rsos.180932

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of*

Teaching and Learning in Higher Education, 9(3). http://ojs.aishe.org/index.php/aishe-j/article/view/335

Malina, M. A., Nørreklit, H. S., & Selto, F. H. (2011). Lessons learned: Advantages and disadvantages of mixed-method research. *Qualitative Research in Accounting & Management, 8*(1), 59–71. https://doi.org/10.1108/11766091111124702

Martínez-González, M. A., Salas-Salvadó, J., Estruch, R., Corella, D., Fitó, M., Ros, E., & Predimed Investigators. (2015). Benefits of the Mediterranean diet: Insights from the PREDIMED study. *Progress in Cardiovascular Diseases, 58*(1), 50–60. https://doi.org/10.1016/j.pcad.2015.04.003

Maruyama, S., Streletskaya, N. A., & Lim, J. (2021). Clean label: Why this ingredient but not that one? *Food Quality and Preference, 87*, 104062. https://doi.org/10.1016/j.foodqual.2020.104062

McAfee, A. J., McSorley, E. M., Cuskelly, G. J., Moss, B. W., Wallace, J. M., Bonham, M. P., & Fearon, A. M. (2010). Red meat consumption: An overview of the risks and benefits. *Meat Science, 84*(1), 1–13. https://doi.org/10.1016/j.meatsci.2009.08.029

McCarthy, U., Uysal, I., Badia-Melis, R., Mercier, S., O'Donnell, C., & Ktenioudaki, A. (2018). Global food security: Issues, challenges, and technological solutions. *Trends in Food Science & Technology, 77*, 11–20. https://doi.org/10.1016/j.tifs.2018.05.002

McClung, S., & Johnson, K. (2010). Examining the motives of podcast users. *Journal of Radio & Audio Media, 17*(1), 82–95. https://doi.org/10.1080/19376521003719391

McCluskey, J. J. (2015, July). Changing food demand and consumer preferences. In *Agricultural Symposium, Federal Reserve Bank of Kansas City* (pp. 14–15). Retrieved January 1, 2025, from https://www.kansascityfed.org/Agriculture/documents/7025/mccluskey-paper.pdf

McDonald's. (n.d.). *McPlant.* Retrieved January 1, 2025, from https://www.mcdonalds.com/gb/en-gb/latest-updates/mcplant.html

McHugh, S. (2016). How podcasting is changing the audio storytelling genre. *Radio Journal: International Studies in Broadcast & Audio Media, 14*(1), 65–82. https://doi.org/10.1386/rjao.14.1.65_1

Meltzer, H. M., Brantsæter, A. L., Trolle, E., Eneroth, H., Fogelholm, M., Ydersbond, T. A., & Birgisdottir, B. E. (2019). Environmental sustainability perspectives of the Nordic diet. *Nutrients, 11*(9), 2248. https://doi.org/10.3390/nu11092248

Mensah, J. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences, 5*(1), 1653531. https://doi.org/10.1080/23311886.2019.1653531

Micheelsen, A., Holm, L., & Jensen, K. O. D. (2013). Consumer acceptance of the New Nordic Diet: An exploratory study. *Appetite, 70*, 14–21. https://doi.org/10.1016/j.appet.2013.06.081

Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions, and acceptance of meat and plant-based meat alternatives. *Food Quality and Preference, 87*, 104063. https://doi.org/10.1016/j.foodqual.2020.104063

Ministry of Food and Drug Safety (MFDS). (2022). *Novel food guidelines.* Retrieved January 1, 2025, from https://www.mfds.go.kr/eng/brd/m_15/view.do?seq=72437

Mithril, C., Dragsted, L. O., Meyer, C., Blauert, E., Holt, M. K., & Astrup, A. (2012). Guidelines for the New Nordic Diet. *Public Health Nutrition, 15*(10), 1941–1947. https://doi.org/10.1017/S136898001100351X

Mithril, C., Dragsted, L. O., Meyer, C., Tetens, I., Biltoft-Jensen, A., & Astrup, A. (2013). Dietary composition and nutrient content of the New Nordic Diet. *Public Health Nutrition, 16*(5), 777–785. https://doi.org/10.1017/S1368980012004521

Moore, D. M., Burton, J. K., & Myers, R. J. (1996). Multiple-channel communication: The theoretical and research foundations of multimedia. In *Handbook of research for educational communications and technology* (pp. 851–875). Retrieved January 1, 2025, from https://www.researchgate.net/publication/237636912

Mrabet, R. (2023). Sustainable agriculture for food and nutritional security. In *Sustainable agriculture and the environment* (pp. 25–90). Academic Press. https://doi.org/10.1016/B978-0-323-90500-8.00013-0

National Health Service. (n.d.). *COVID-19 symptoms and what to do.* Retrieved January 1, 2025, from https://www.nhs.uk/conditions/covid-19/covid-19-symptoms-and-what-to-do/

National People's Congress of the People's Republic of China. (2011). *Food safety law.* Retrieved January 1, 2025, from http://www.npc.gov.cn/zgrdw/englishnpc/Law/2011-02/15/content_1620635.htm

Nyika, J., Mackolil, J., Workie, E., Adhav, C., & Ramadas, S. (2021). Cellular agriculture research progress and prospects: Insights from bibliometric analysis. *Current Research in Biotechnology, 3*, 215–224. https://doi.org/10.1016/j.crbiot.2021.07.001

Ogrinc, N., Fontolan, G., Faganeli, J., & Covelli, S. (2005). Carbon and nitrogen isotope compositions of organic matter in coastal marine sediments (the Gulf of Trieste, N Adriatic Sea): Indicators of sources and preservation. *Marine Chemistry, 95*(3-4), 163–181. https://doi.org/10.1016/j.marchem.2004.09.003

Onwezen, M. C., Bouwman, E. P., Reinders, M. J., & Dagevos, H. (2021). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. *Appetite, 159*, 105058. https://doi.org/10.1016/j.appet.2020.105058

Oonincx, D. G. A. B., van Broekhoven, S., van Huis, A., & van Loon, J. J. A. (2019). Correction: Feed conversion, survival and development, and composition of four insect species on diets composed of food by-products. *PLOS ONE, 14*(10), e0222043. https://doi.org/10.1371/journal.pone.0222043

Orsi, L., Voege, L. L., & Stranieri, S. (2019). Eating edible insects as sustainable food? Exploring the determinants of consumer acceptance in Germany. *Food Research International, 125*, 108573. https://doi.org/10.1016/j.foodres.2019.108573

Osterrieder, A. (2013). The value and use of social media as a communication tool in the plant sciences. *Plant Methods, 9*(1), 26. https://doi.org/10.1186/1746-4811-9-26

Owusu-Apenten, R., & Vieira, E. (2023). Thermal processing and canning. In *Elementary food science* (pp. 230–254). Springer. https://doi.org/10.1007/978-3-030-65433-7_12

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research, 42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Pan, A., Sun, Q., Bernstein, A. M., Schulze, M. B., Manson, J. E., Stampfer, M. J., ... & Hu, F. B. (2012). Red meat consumption and mortality: Results from 2 prospective cohort studies. *Archives of Internal Medicine, 172*(7), 555–563. https://doi.org/10.1001/archinternmed.2011.2287

Pan, A., Sun, Q., Bernstein, A., Schulze, M., Manson, J., Stampfer, M., Willett, W., & Hu, F. (2012). Red meat consumption and mortality. *Archives of Internal Medicine, 172*(7), 555. https://doi.org/10.1001/archinternmed.2011.2287

Payne, C. R., & Wansink, B. (2011). Quantitative approaches to consumer field research. *Journal of Marketing Theory and Practice, 19*(4), 377–390. https://doi.org/10.2753/MTP1069-6679190402

Peiró-Signes, A., Miret-Pastor, L., Galati, A., & Segarra-Oña, M. (2022). Consumer demand for environmental, social, and ethical information in fishery and aquaculture product labels. *Frontiers in Marine Science, 9*, 948437. https://doi.org/10.3389/fmars.2022.948437

Picardi, I., & Regina, S. (2008). Science via podcast. *JCOM, 7*(02), C05. https://doi.org/10.22323/2.07020305

Piha, S., Pohjanheimo, T., Lähteenmäki-Uutela, A., Křečková, Z., & Otterbring, T. (2018). The effects of consumer knowledge on the willingness to buy insect food: An exploratory cross-regional study in Northern and Central Europe. *Food Quality and Preference, 70*, 1–10. https://doi.org/10.1016/j.foodqual.2016.12.006

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science, 360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Post, M. J. (2012). Cultured meat from stem cells: Challenges and prospects. *Meat Science, 92*(3), 297–301. https://doi.org/10.1016/j.meatsci.2012.04.008

Premanandh, J. (2011). Factors affecting food security and contribution of modern technologies in food sustainability. *Journal of the Science of Food and Agriculture, 91*(15), 2707–2714. https://doi.org/10.1002/jsfa.4666

Pretty, J. (2018). Intensification for redesigned and sustainable agricultural systems. *Science, 362*(6417), eaav0294. https://doi.org/10.1126/science.aav0294

ProVeg International. (n.d.). *The rise and rise of plant-based milk.* Retrieved January 1, 2025, from https://proveg.org/news/rise-and-rise-of-plant-based-milk/

Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research, 7*, 100265. https://doi.org/10.1016/j.jafr.2021.100265

Quorn. (n.d.). *How is Quorn made?* Retrieved January 1, 2025, from https://www.quorn.co.uk/news/how-is-quorn-made

Raheem, D., Carrascosa, C., Oluwole, O. B., Nieuwland, M., Saraiva, A., Millán, R., & Raposo, A. (2018). Traditional consumption of and rearing edible insects in Africa, Asia, and Europe. *Critical Reviews in Food Science and Nutrition, 59*(14), 2169–2188. https://doi.org/10.1080/10408398.2018.1440191

Rahman, M. S. (2020). Food preservation: An overview. In M. S. Rahman (Ed.), *Handbook of food preservation* (3rd ed., pp. 7–18). CRC Press. https://doi.org/10.1201/9780429091483

Regulation (EU) 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. *Official Journal of the European Union, L304*, 29–56. Retrieved January 1, 2025, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011R1169

Rehman, N., Edkins, V., & Ogrinc, N. (2024). Is sustainable consumption a sufficient motivator for consumers to adopt meat alternatives? A consumer perspective on plant-based, cell-culture-derived, and insect-based alternatives. *Foods, 13*(11), 1627. https://doi.org/10.3390/foods13111627

Rehman, N., Edkins, V., & Ogrinc, N. (2024). Using podcasts to bridge the gap between science communication and specialized scientific fields: A case study of mass spectrometry. *Frontiers in Communication, 9*, 1384389. https://doi.org/10.3389/fcomm.2024.1384389

Reisch, L., Eberle, U., & Lorek, S. (2013). Sustainable food consumption: An overview of contemporary issues and policies. *Sustainability: Science, Practice and Policy, 9*(2), 7–25. https://doi.org/10.1080/15487733.2013.11908111

Ribeiro, J. C., Gonçalves, A. T. S., Moura, A. P., Varela, P., & Cunha, L. M. (2022). Insects as food and feed in Portugal and Norway: Cross-cultural comparison of determinants of acceptance. *Food Quality and Preference, 102*, 104650. https://doi.org/10.1016/j.foodqual.2022.104650

Riesch, H. (2014). Why did the proton cross the road? Humour and science communication. *Public Understanding of Science, 24*(7), 768–775. https://doi.org/10.1177/0963662514546299

Ringsberg, H. (2014). Perspectives on food traceability: A systematic literature review. *Supply Chain Management: An International Journal, 19*(5/6), 558–576. https://doi.org/10.1108/SCM-01-2014-0026

Ritala, A., Häkkinen, S. T., Toivari, M., & Wiebe, M. G. (2017). Single-cell protein—State-of-the-art, industrial landscape and patents 2001–2016. *Frontiers in Microbiology, 8*, 2009. https://doi.org/10.3389/fmicb.2017.02009

Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., ... & Smith, J. (2017). Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio, 46*, 4–17. https://doi.org/10.1007/s13280-016-0793-6

Rodríguez Escobar, M. I., Cadena, E., Nhu, T. T., Cooreman-Algoed, M., De Smet, S., & Dewulf, J. (2021). Analysis of the cultured meat production system in function of its environmental footprint: Current status, gaps and recommendations. *Foods, 10*(12), 2941. https://doi.org/10.3390/foods10122941

Ronald, P. (2011). Plant genetics, sustainable agriculture and global food security. *Genetics, 188*(1), 11–20. https://doi.org/10.1534/genetics.111.128553

Saitone, T. L., & Sexton, R. J. (2017). Agri-food supply chain: Evolution and performance with conflicting consumer and societal demands. *European Review of Agricultural Economics, 44*(4), 634–657. https://doi.org/10.1093/erae/jbx003

Satija, A., & Hu, F. B. (2018). Plant-based diets and cardiovascular health. *Trends in Cardiovascular Medicine, 28*(7), 437–441. https://doi.org/10.1016/j.tcm.2018.02.004

Saudi Food and Drug Authority (SFDA). (2021). *Novel food general requirements.* Retrieved January 1, 2025, from https://www.sfda.gov.sa/sites/default/files/2021-10/NovelFoodGeneralRequirements.pdf

Scheufele, D. A., & Krause, N. M. (2019). Science audiences, misinformation, and fake news. *Proceedings of the National Academy of Sciences, 116*(16), 7662–7669. https://doi.org/10.1073/pnas.180587111

Scholliers, P. (2015). Convenience foods: What, why, and when. *Appetite, 94*, 2–6. https://doi.org/10.1016/j.appet.2015.02.017

Schönleben, A. M., Yin, S., Strak, E., Johnson, A., Belova, L., Bamai, Y. A., ... & Covaci, A. (2024). Stable isotope ratios and current-use pesticide levels in edible insects: Implications on chemical food safety. *Food Research International, 179*, 114020. https://doi.org/10.1016/j.foodres.2023.114020

Science, Research and Evidence Directorate. (2022). *Consultation on transitional arrangements for edible insects in Great Britain: Summary of stakeholder responses.* Food Standards Agency. Retrieved January 1, 2025, from https://www.food.gov.uk/print/pdf/node/12076

Sedlacko, M., Reisch, L., & Scholl, G. (2013). Sustainable food consumption: When evidence-based policymaking meets policy-minded research—Introduction to the special issue. *Sustainability: Science, Practice and Policy, 9*(2), 1–6. https://doi.org/10.1080/15487733.2013.11908110

Shafi, U., Mumtaz, R., García-Nieto, J., Hassan, S. A., Zaidi, S. A. R., & Iqbal, N. (2019). Precision agriculture techniques and practices: From considerations to applications. *Sensors, 19*(17), 3796. https://doi.org/10.3390/s19173796

Shahzad, Z., Rouached, H., & Rakha, A. (2014). Combating mineral malnutrition through iron and zinc biofortification of cereals. *Comprehensive Reviews in Food Science and Food Safety, 13*(3), 329–346. https://doi.org/10.1111/1541-4337.12063

Shanahan, E. A., DeLeo, R. A., Albright, E. A., Li, M., Koebele, E. A., Taylor, K., Crow, D. A., Dickinson, K. L., Minkowitz, H., Birkland, T. A., & Zhang, M. (2023). Visual policy narrative messaging improves COVID-19 vaccine uptake. *PNAS Nexus, 2*(4), pgad080. https://doi.org/10.1093/pnasnexus/pgad080

Shanmugam, K., Bryngelsson, S., Östergren, K., & Hallström, E. (2023). Climate impact of plant-based meat analogues: A review of life cycle assessments. *Sustainable Production and Consumption, 36*, 328–337. https://doi.org/10.1016/j.spc.2023.01.014

Shi, W., Huang, X., Schooling, C. M., & Zhao, J. V. (2023). Red meat consumption, cardiovascular diseases, and diabetes: A systematic review and meta-analysis. *European Heart Journal, 44*(28), 2626–2635. https://doi.org/10.1093/eurheartj/ehad336

Shukla, S. (2011). Freeze-drying process: A review. *International Journal of Pharmaceutical Sciences and Research, 2*(12), 3061–3068. https://doi.org/10.13040/IJPSR.0975-8232.2(12).3061-68

Siddiqui, S. A., Khan, S., Farooqi, M. Q. U., Singh, P., Fernando, I., & Nagdalian, A. (2022). Consumer behavior towards cultured meat: A review since 2014. *Appetite, 179*, 106314. https://doi.org/10.1016/j.appet.2022.106314

Siegrist, M., Sütterlin, B., & Hartmann, C. (2018). Perceived naturalness and evoked disgust influence acceptance of cultured meat. *Meat Science, 139*, 213–219. https://doi.org/10.1016/j.meatsci.2018.02.007

Singapore Food Agency (SFA). (2024). *Guidelines on novel food.* Retrieved January 1, 2025, from https://www.sfa.gov.sg/regulatory-standards-frameworks-guidelines/novel-food-framework/guidelines-on-novel-food

Sinke, P., Swartz, E., Sanctorum, H., van der Giesen, C., & Odegard, I. (2023). Ex-ante life cycle assessment of commercial-scale cultivated meat production in 2030. *The International Journal of Life Cycle Assessment, 28*(3), 234–254. https://doi.org/10.1007/s11367-022-02128-8

Smetana, S. (2023). Circularity and environmental impact of edible insects. *Journal of Insects as Food and Feed, 9*(9), 1111–1114. https://doi.org/10.3920/jiff2023.x004

Social Research Association. (2021). *Research ethics guidance.* The SRA. Retrieved February 10, 2022, from https://the-sra.org.uk/SRA/SRA/Ethics/Research-Ethics-Guidance.aspx

Sofi, F., Macchi, C., Abbate, R., Gensini, G. F., & Casini, A. (2013). Mediterranean diet and health. *BioFactors, 39*(4), 335–342. https://doi.org/10.1002/biof.1096

Spiggle, S. (1994). Analysis and interpretation of qualitative data in consumer research. *Journal of Consumer Research, 21*(3), 491–503. https://doi.org/10.1086/209413

Stazio, M. (2021). Verace Glocal Pizza: Localized globalism and globalized localism in the Neapolitan artisan pizza. *Food, Culture & Society, 24*(3), 406–430. https://doi.org/10.1080/15528014.2021.1884400

Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., & Sexton, A. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. *Trends in Food Science & Technology, 78*, 155–166. https://doi.org/10.1016/j.tifs.2018.04.010

Stoner, M. C., Tweedy, D., Comello, M. G. L., Toval, C., Pettifor, A. E., Larsen, M. A., ... & Hightow-Weidman, L. B. (2022). Using narratives to inform the development of a digital health intervention related to COVID-19 vaccination in Black young adults

in Georgia, North Carolina, and Alabama. *Vaccine, 40*(48), 6908–6916. https://doi.org/10.1016/j.vaccine.2022.10.027

Su, L. Y. F., Scheufele, D. A., Bell, L., Brossard, D., & Xenos, M. A. (2017). Information-sharing and community-building: Exploring the use of Twitter in science public relations. *Science Communication, 39*(5), 569–597. https://doi.org/10.1177/1075547017734226

Sun, S., & Wang, X. (2019). Promoting traceability for food supply chain with certification. *Journal of Cleaner Production, 217*, 658–665. https://doi.org/10.1016/j.jclepro.2019.01.296

Swales, J. G., Hamm, G., Clench, M. R., & Goodwin, R. J. A. (2019). Mass spectrometry imaging and its application in pharmaceutical research and development: A concise review. *International Journal of Mass Spectrometry, 437*, 99–112. https://doi.org/10.1016/j.ijms.2018.02.007

Tan, H. S. G., Verbaan, Y. T., & Stieger, M. (2017). How will better products improve the sensory-liking and willingness to buy insect-based foods? *Food Research International, 92*, 95–105. https://doi.org/10.1016/j.foodres.2016.12.021

Taneja, H., Webster, J. G., Malthouse, E. C., & Ksiazek, T. B. (2012). Media consumption across platforms: Identifying user-defined repertoires. *New Media & Society, 14*(6), 951–968. https://doi.org/10.1177/1461444811436146

The Guardian. (2019, April 2). *Burger King unveils vegan Whopper made with meat-free Impossible Burger.* Retrieved January 1, 2025, from https://www.theguardian.com/business/2019/apr/02/burger-king-vegan-whopper-meat-free-impossible-launch

Tian, J., Bryksa, B. C., & Yada, R. Y. (2016). Feeding the world into the future: Food and nutrition security: The role of food science and technology. *Frontiers in Life Science, 9*(3), 155–166. https://doi.org/10.1080/21553769.2016.1174958

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature, 515*(7528), 518–522. https://doi.org/10.1038/nature13959

Treen, K. M. D. I., Williams, H. T., & O'Neill, S. J. (2020). Online misinformation about climate change. Wiley Interdisciplinary Reviews: Climate Change, 11(5), e665. https://doi.org/10.1002/wcc.665

Treich, N. (2021). Cultured meat: Promises and challenges. *Environmental and Resource Economics, 79*(1), 33–61. https://doi.org/10.1007/s10640-021-00551-3

Tso, R., Lim, A. J., & Forde, C. G. (2020). A critical appraisal of the evidence supporting consumer motivations for alternative proteins. *Foods, 10*(1), 24. https://doi.org/10.3390/foods10010024

Tsofliou, F., Vlachos, D., Hughes, C., & Appleton, K. M. (2022). Barriers and facilitators associated with the adoption of and adherence to a Mediterranean-style diet in adults: A systematic review of published observational and qualitative studies. *Nutrients, 14*(20), 4314. https://doi.org/10.3390/nu14204314

Tuomisto, H. L., & Teixeira de Mattos, M. J. (2011). Environmental impacts of cultured meat production. *Environmental Science & Technology, 45*(14), 6117–6123. https://doi.org/10.1021/es200130u

Turesky, R. J. (2018). Mechanistic evidence for red meat and processed meat intake and cancer risk: A follow-up on the international agency for research on cancer evaluation of 2015. *Chimia, 72*(10), 718. https://doi.org/10.2533/chimia.2018.718

UK Government. (2023). *Industry leaders welcome landmark plan for UK advanced manufacturing.* Retrieved January 1, 2025, from https://www.gov.uk/government/news/industry-leaders-welcome-landmark-plan-for-uk-advanced-manufacturing

UK Government. (n.d.). *Scottish farmed salmon.* Protected food name scheme. Retrieved January 1, 2025, from https://www.gov.uk/protected-food-drink-names/scottish-farmed-salmon

Van der Weele, C., Feindt, P., van der Goot, A. J., van Mierlo, B., & van Boekel, M. (2019). Meat alternatives: An integrative comparison. *Trends in Food Science & Technology, 88*, 505–512. https://doi.org/10.1016/j.tifs.2019.04.018

van Huis, A. (2013). Potential of insects as food and feed in assuring food security. *Annual Review of Entomology, 58*, 563–583. https://doi.org/10.1146/annurev-ento-120811-153704

Van Loo, E. J., Caputo, V., & Lusk, J. L. (2020). Consumer preferences for farm-raised meat, lab-grown meat, and plant-based meat alternatives: Does information or brand matter? *Food Policy, 95*(1), 101931. https://doi.org/10.1016/j.foodpol.2020.101931

Vegconomist. (2023). *Labelling plant-based foods in China.* Retrieved January 1, 2025, from https://vegconomist.com/politics-law/labelling-plant-based-foods-in-china/

Verbeke, W. (2015). Consumer acceptance of insects as food: A review. *Food Quality and Preference, 49*, 17–25. https://doi.org/10.1016/j.foodqual.2014.11.005

Vicsek, L. (2010). Issues in the analysis of focus groups: Generalisability, quantifiability, treatment of context and quotations. *The Qualitative Report, 15*(1), 122–141. https://doi.org/10.46743/2160-3715/2010.1143

Vogtschmidt, Y. D., Raben, A., Faber, I., de Wilde, C., Lovegrove, J. A., Givens, D. I., ... & Soedamah-Muthu, S. S. (2021). Is protein the forgotten ingredient? Effects of higher compared to lower protein diets on cardiometabolic risk factors: A systematic review and meta-analysis of randomised controlled trials. *Atherosclerosis, 328*, 124–135. https://doi.org/10.1016/j.atherosclerosis.2021.05.011

Weingart, P. (2023). Trust and distrust of scientific experts and the challenges of the democratization of science. In G. Eyal & T. Medvetz (Eds.), *The Oxford Handbook of Expertise and Democratic Politics* (pp. 29–51). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190865565.013.3

Weingart, P., & Guenther, L. (2016). Science communication and the issue of trust. *Journal of Science Communication, 15*(5), C01. https://doi.org/10.22323/2.15050301

Weingart, P., Joubert, M., & Connoway, K. (2021). Public engagement with science—Origins, motives, and impact in academic literature and science policy. *PLOS ONE, 16*(7), e0254201. https://doi.org/10.1371/journal.pone.0254201

Wendin, K. M., & Nyberg, M. E. (2021). Factors influencing consumer perception and acceptability of insect-based foods. *Current Opinion in Food Science, 40*, 67–71. https://doi.org/10.1016/j.cofs.2021.01.007

West, J. D., & Bergstrom, C. T. (2021). Misinformation in and about science. *Proceedings of the National Academy of Sciences, 118*(15), e1912444117. https://doi.org/10.1073/pnas.1912444117

Wild, F., Czerny, M., Janssen, A. M., Kole, A. P. W., Zunabovic, M., & Domig, K. J. (2014). The evolution of a plant-based alternative to meat: From niche markets to widely accepted meat alternatives. *Agro Food Industry Hi-Tech, 25*(1), 45–49. Retrieved January 1, 2025, from https://edepot.wur.nl/372217

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., & Jonell, M. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet, 393*(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

World Health Organization. (2020). *Responding to community spread of COVID-19: Interim guidance, 7 March 2020 (No. WHO/COVID-19/Community_Transmission/2020.1).* Retrieved January 1, 2025, from

https://apps.who.int/iris/bitstream/handle/10665/331421/WHO-COVID-19-Community_Transmission-2020.1-eng.pdf

World Health Organization. (2021). *Fighting misinformation in the time of COVID-19, one click at a time.* Retrieved January 1, 2025, from https://www.who.int/news-room/feature-stories/detail/fighting-misinformation-in-the-time-of-covid-19-one-click-at-a-time

Yang, S., Brossard, D., Scheufele, D. A., & Xenos, M. A. (2022). The science of YouTube: What factors influence user engagement with online science videos? *PLOS ONE, 17*(5), e0267697. https://doi.org/10.1371/journal.pone.0267697

Zhang, A., Mankad, A., & Ariyawardana, A. (2020). Establishing confidence in food safety: Is traceability a solution in consumers' eyes? *Journal of Consumer Protection and Food Safety, 15*(2), 99–107. https://doi.org/10.1007/s00003-020-01277-y

Zhong, C. B., & DeVoe, S. E. (2010). You are how you eat: Fast food and impatience. *Psychological Science, 21*(5), 619–622. https://doi.org/10.1177/0956797610366090

Ziman, J. (1991). Public understanding of science. *Science, Technology, & Human Values, 16*(1), 99–105. https://doi.org/10.1177/016224399101600106

Zmuni. (2022). Guidance on the application of novel food ingredients in China. Retrieved January 1, 2025, from https://www.zmuni.com/en/news/guidance-on-the-application-of-novel-food-ingredients-in-china/

Bibliography

Publications Related to the Thesis

Journal Articles

Rehman, N., Tuck, C., & Ogrinc, N. (2025). Drivers and barriers of seafood consumption: A comparative analysis across Denmark, Italy, and Slovenia. *Manuscript in preparation.*

Rehman, N., & Ogrinc, N. (2024). Consumer perceptions and acceptance of edible insects in Slovenia. *Foods, 13*(16), Article 2629. https://doi.org/10.3390/foods13162629

Rehman, N., Edkins, V., & Ogrinc, N. (2024). Using podcasts to bridge the gap between science communication and specialized scientific fields: A case study of mass spectrometry. *Frontiers in Communication, 9*, Article 1384389. https://doi.org/10.3389/fcomm.2024.1384389

Biggi, C., Biasini, B., Ogrinc, N., Strojnik, L., Endrizzi, I., Menghi, L., Khémiri, I., Mankai, A., Ben Slama, F., Jamoussi, H., Riviou, K., Elfazazi, K., Rehman, N., Scazzina, F., & Menozzi, D. (2024). Drivers and barriers influencing adherence to the Mediterranean diet: A comparative study across five countries. *Nutrients, 16*(15), Article 2405. https://doi.org/10.3390/nu16152405

Heath, D., Vehar, A., Kouřimská, L., Kulma, M., Škvorová, P., Šubrtová Salmonová, H., Lampová, B., Rehman, N., Jamnik, P., Jeršek, B., Červek, M., Poklar Ulrih, N., & Ogrinc, N. (2024). Quality, safety, and authenticity of insect protein-based food and feed: Insights from the INPROFF project. *Exploration of Foods and Foodomics*, Article 00041. https://doi.org/10.37349/eff.2024.00041

Rehman, N., Edkins, V., & Ogrinc, N. (2024). Is sustainable consumption a sufficient motivator for consumers to adopt meat alternatives? A consumer perspective on plant-based, cell-culture-derived, and insect-based alternatives. *Foods, 13*(11), Article 1627. https://doi.org/10.3390/foods13111627

Scientific Conference Contributions

Rehman, N., Tuck, C., & Ogrinc, N. (2024). Understanding consumer perceptions and strategies for increasing acceptance of new alternative protein foods. In *Proceedings of FoodTraNet Conference 2024.* Jožef Stefan Institute. [Oral presentation].

FoodTraNet Conference. (2024). *Book of abstracts: FoodTraNet Conference.* Ljubljana, Slovenia: Jožef Stefan Institute. ISBN: 978-961-264-296-9.

Rehman, N., Tuck, C., & Ogrinc, N. (2024). Beyond sustainable consumption: Investigating barriers to increase consumer acceptance of alternative protein foods. In *Proceedings of IUFoST 2024.* International Union of Food Science and Technology. [Oral presentation].

Jožef Stefan International Postgraduate School. (2023). *Book of abstracts: 2nd ISO-FOOD Symposium: ISO-FOOD from food sources to health*. Portorož, Slovenia: Jožef Stefan International Postgraduate School, Jožef Stefan Institute. ISBN: 978-961-264-268-6.

Rehman, N., Edkins, V., & Ogrinc, N. (2023). Motivation and barriers to the adoption of new alternative foods among European consumers. In *Proceedings of the 2nd ISO-FOOD Symposium: ISO-FOOD from food sources to health*. Jožef Stefan International Postgraduate School, Portorož, Slovenia. [Poster presentation].

Jožef Stefan International Postgraduate School. (2022). *Book of abstracts: 14th Jožef Stefan International Postgraduate School Students' Conference*. Kamnik, Slovenia: Jožef Stefan International Postgraduate School, Jožef Stefan Institute.

Rehman, N., Edkins, V., & Ogrinc, N. (2022). Science communication: Using podcasts for communicating mass spectrometry applications. In *Proceedings of the 14th Jožef Stefan International Postgraduate School Students' Conference*. Jožef Stefan International Postgraduate School, Kamnik, Slovenia. [Oral and poster presentation].

Rehman, N., Edkins, V., & Ogrinc, N. (2022). Using podcasts for science communication: An example of public perception to mass spectrometry applications. In *Proceedings of the 24th International Mass Spectrometry Conference*. International Mass Spectrometry Society, Maastricht, Netherlands. [Poster presentation].

Other Publications

Macan Schönleben, A., den Ouden, F., Yin, S., Fransen, E., Bosschaerts, S., Andjelkovic, M., Rehman, N., van Nuijs, A., Covaci, A., & Poma, G. (2025). Organophosphorus flame retardant, phthalate, and alternative plasticizer contamination in novel plant-based food: A food safety investigation. *Environmental Science & Technology, 59*(18), 9209–9220. https://doi.org/10.1021/acs.est.4c11805

Biography

Nayyer Rehman was born on 26 February 1992 in Karachi, Pakistan. She attended the Beaconhouse School System, where she received scholarships for her academic performance in O-Levels and A-Levels. Her interest in food science and technology led her to pursue a bachelor's degree in Food Engineering at NED University of Engineering and Technology, where she graduated as a silver medallist. For her final-year project, she worked with Dalda Foods on automating its oil-blending process.

In 2017, she moved to Germany to study International Food Business and Consumer Studies at the University of Kassel and Hochschule Fulda. She was awarded the prestigious Deutschlandstipendium and STIBET-Abschlusstipendium scholarships in recognition of her academic performance. Her master's thesis, conducted at Fit Ingredients, focused on supplier and product qualification for consumer health and safety, with findings successfully embedded into the company's ERP system.

In 2021, Nayyer joined the Marie Skłodowska-Curie ITN FoodTraNet project as one of 15 Early-Stage Researchers. She is currently pursuing her PhD at the Jožef Stefan International Postgraduate School while being hosted at WRG Europe Ltd. in the UK, in collaboration with the Jožef Stefan Institute in Slovenia. Her research focuses on consumer awareness and acceptance of food technologies, using quantitative methodologies such as surveys and qualitative approaches like interviews and focus groups across multiple European countries.

She has remained actively engaged in both academic and industry settings to gain hands-on experience. As a Research and Technical Assistant at her master's universities, she supported professors in modules on innovative product development, consumer sciences, and sustainability while mentoring students on product development and consumer marketing projects. She also gained industrial experience at Döhler, initially in research and development and later in global marketing, where she worked on client portfolio presentations and large-scale consumer surveys.

Beyond academia and industry, Nayyer is committed to making science more accessible to the public. She developed two podcast series featuring researchers and industry experts, aimed at bridging the gap between scientists and the general public. She also designed a survey to educate children on food traceability and authenticity.

She has presented her research in six papers and at eight international conferences. She also took part in organising the 14th Jožef Stefan International Postgraduate School Students' Conference and moderated sessions on consumer research at the International Union of Food Science and Technology (IUFoST) to facilitate dialogues on improving consumer engagement with food research.

Nayyer's work explores how consumers interact with food science, focusing on informed choices, sustainability, and public engagement. Her PhD research provides a framework to help researchers, industry, and policymakers understand consumer perspectives. Looking ahead, she aims to promote participatory research initiatives and interdisciplinary discussions on integrating citizen science into food research and sustainable consumption.