Consumer responses to protein alternatives: *The impact of information sharing and sensory experience on liking, emotion and choice*

Yuchen Zhang

20314723

School of Biosciences

University of Nottingham, United Kingdom

Thesis submitted for the degree of

Doctor of Philosophy

May 2026

Contents

Acknowledgements 6

Abstract 8

Chapter 1. 11

1.1 General Introduction 11

1.2 Environmental impacts of food production and consumption 13

1.3 Definition of protein alternatives 16

1.3.1 Plant-based meat 17

1.3.2 Edible insect 19

1.3.3 Lab-grown (cultured) meat 21

1.3.4 Hybrid meat 24

1.4 Beef and protein alternatives costs and scalability challenges 26

1.5 Consumer acceptance and motivations for protein alternatives 30

1.6 Communicating product information to consumers 33

1.7 Consumer Research Method 35

1.7.1 Survey 36

1.7.2 Conjoint analysis 38

1.7.3 Sensory evaluation 40

1.7.4 Real-world food choice 41

1.8 Consumer response measurement 43

1.8.1 Hedonic responses 43

1.8.2 Purchase intention & Ordering intention 45

1.8.3 Emotional responses 47

1.8.4 Measure food choice in real-world context 50

1.9 Research objectives and knowledge gaps 51

1.9.1 Knowledge gaps 51

1.9.2 The overall objective of this research: 52

Chapter 2. 54

Abstract 55

2.1 Introduction 56

2.2 Materials and Methods 60

2.2.1 Participant and survey structure 60

2.2.2 Food-related environmental impact video and sharing conditions 62

2.2.3 Shopping Scenario & Products 64
2.2.4 Demographics and personal traits 68
2.2.5 Data analysis 69
2.3 Results 70
2.3.1 Overall liking, purchase intention and emotional responses 70
2.3.2 The impact of sharing information on consumer responses to protein sources 76
2.3.3 Personal traits clusters 77
2.3.4 The impact of personal trait cluster on consumer responses 80
2.4 Discussion 85
2.4.1 Overall expected liking and emotional responses for the four different protein sources 86
2.4.2 Impact of information on expected liking 92
2.4.3 Impact of personal trait cluster on overall liking 92
2.5 Conclusion 97
Chapter 3. 99
Abstract 100
3.1 Introduction 101
3.1.1 Acceptance and information impact 103
3.2 Materials and Methods 105
3.2.1 Overview of the experimental approach 105
3.2.2 Participants 106
3.2.3 Written Scenario & Products Description 106
3.2.4 Rating-based conjoint task 110
3.2.5 Emotional responses task 111
3.2.6 Data analysis 111
3.3 Results 112
3.3.1 Ordering intention and emotional response for each product 112
3.3.2 Impact of information on ordering intention 114
3.4 Discussion 124
3.4.1 Overall ordering intention and emotional responses towards three protein alternatives 124
3.4.2 The impact of sensory, nutritional, and environmental information on consumers' ordering intention for protein alternatives 127
3.4.3 Methodology considerations 132

3.5 Future research and practical implications 133
3.6 Conclusions 134
Chapter 4. 136
Abstract 137
4.1 Introduction 138
4.1.1 Measuring consumer responses and food choice 141
4.2 Materials & Methods 143
4.2.1 Experimental design 143
4.2.2 Participants 144
4.2.3 Sample preparation and information presented 145
4.2.4 Sensory attributes and emotion responses across the eating episode 147
4.2.5 Data analysis 148
4.3 Results 149
4.3.1 Consumer food choice across three weeks 149
4.3.2 Liking across three weeks 150
4.3.3 Emotional responses across three weeks 153
4.3.4 Sensory responses across three weeks 154
4.3.5 Understanding consumer responses across the full eating journey: Before, Early and Post-Consumption 157
4.4 Discussion 162
4.4.1 Measuring consumer food choice in a real environment 162
4.4.2 Consumer food choice, liking, emotions, and sensory properties across three weeks 163
4.4.3 Impact of environmental information on the choice of hybrid burger 167
4.4.4 Consumer responses across the full eating journey: Before, Early Consumption, and Post-Consumption 169
4.4.5 Limitations and Future Directions 171
4.5 Conclusion 172
Chapter 5. 174
5.1 Summary of Key findings and contributions 174
5.1.1 Comparing products across chapters 182
5.2 Implication 184
5.2.1 Implications for information as intervention tools 184
5.2.2 Implications for personal traits 186

5.2.3 Implications for sensory optimisation 187
5.2.4 Implications for emotional responses 188
5.3 Limitations and future research opportunities 190
5.4 Beyond this thesis: Consumer behaviour towards future protein alternatives 196
Chapter 6. 198
6.1 Appendix A Chapter 2 Video Transcript 198
6.2 Appendix B: Chapter 2 Supplementary materials 201
6.3 Appendix C Chapter 3 Summary of the Conjoint Study Demographics 203
6.4 Appendix D: Chapter 3 Average citation proportions of emotional terms towards plant-based burgers across the eight concepts 204
6.5 Appendix E: Chapter 3 Average citation proportions of emotional terms towards hybrid burgers across the eight concepts 207
6.6 Appendix F: Chapter 3 Average citation proportions of emotional terms towards edible insect burgers across the eight concepts 209
6.7 Appendix G Chapter 4 The sensory attribute and definition 210
6.8 Appendix H Chapter 4 Differences in the proportion of emotional responses towards the product 211
6.9 Appendix I Chapter 4 Differences in the proportion of sensory attributes towards the product 212
6.10 Appendix J Chapter 4 Two-way ANOVA for the liking of two burgers across the expected, two-bite, and finished stages in Week 1 213
6.11 Appendix K Chapter 4 Two-way ANOVA for the liking of three burgers across the expected, two-bite, and finished stages in Week 3 214
Conferences 215
Award 216
Chapter 7. Reference 217

Acknowledgements

My four-year PhD journey has passed in the blink of an eye. During this time, I have been fully engaged in completing three research projects. As an international student, I have faced many challenges along the way, but I have also been fortunate to receive help from many friends and important people. I would like to express my sincere gratitude to all of them.

First and foremost, I would like to thank my parents. As a self-funded student, your support has been unparalleled. Every time I returned home, you encouraged me to stay relaxed and take my studies one step at a time.

I am especially grateful to my supervisor, Dr. Qian Yang, and Dr. Rebecca Ford. Thank you for your academic guidance, particularly in writing and data analysis. Your advice has been invaluable, especially during times of uncertainty, helping me to keep moving forward.

I would also like to thank Dr. Margaret Thibodeau. In every meeting and discussion, whether about research objectives or data analysis, and even in daily life, your constructive suggestions have been extremely helpful.

I am grateful to my friends who assisted me with my research projects during my PhD. Dr Hannah Ford, although we did not meet often in person, I learned a lot from you, from my Master's to my PhD periods, all the knowledge significantly contributed to my work. Thanks to the University of Nottingham food catering team, including Jade, Robert, and other members, for assisting me with my final products. I would especially like to thank

Rhedd, Tobias, Tobias, and Alison for their help in my final project. Thanks, Anne, for your support on the data analysis for my conjoint study.

I want to thank my girlfriend, Lin Zhang, who has been by my side for ten years. From when we first met in Henan, China, to our move to Reading start our undergraduate degree, and later to Nottingham to start my Master's, and finally to the PhD. Thank you for your love and support, which have been truly invaluable.

I am deeply grateful for all the friends I have met along the way, and for the knowledge, experiences, and guidance I have received. These will have a profound impact on my future life.

Abstract

Shifting to more sustainable protein sources is widely regarded as a key strategy to improve the environmental sustainability of current food systems. However, this transition depends on consumer acceptance, which is shaped by consumer expectations, information cues, and consumer experiences. Given the complexity of food choice behaviour, a more integrated understanding of how consumers respond to protein alternatives across different decision-making contexts is needed.

This thesis investigates UK consumers' responses to a range of protein alternatives, including plant-based, hybrid, edible insect, and lab-grown products. It examines how different types of protein alternatives, sharing information, and tasting exposure influence consumer liking, emotional response, and consumer choices. A mixed-methods approach was employed, combining online surveys to study consumer responses to protein alternatives using a written supermarket shopping scenario (Chapter 2), trade-offs between different information using conjoint analysis with a written restaurant scenario (Chapter 3), and a real-world choice experiment in a university cafeteria (Chapter 4).

Across studies, conventional beef consistently elicited the highest expected liking and positive emotions, suggesting that beef functions as a strong hedonic and emotional association in consumers' minds. This highlights a fundamental challenge for meat reduction strategies. Among protein alternatives, hybrid and plant-based products were generally liked more than edible insects and lab-grown beef. Liking for plant-based burgers remained

relatively stable at neutral levels with emotional responses mainly associated with *neutral* and *bored* in Chapters 2 and 3, but more negative emotions in Chapter 4. Hybrid burgers showed high expected liking and ordering intention, with emotional responses more strongly associated with positive emotions in Chapters 3 and 4. Lab-grown beef evoked mixed emotional responses, indicating a cognitive conflict where benefits are recognised but emotions remain *uncertain*. The edible insect reminder evoked negative emotions, indicating strong consumer rejection driven by a *disgust* barrier.

Across information conditions, sensory information emerged as the most influential factor in shaping consumer responses, followed by environmental and nutritional information. This suggests that expectations of taste and eating experience play a central role in the acceptance of protein alternatives. In the real-world food-choice study, sensory experience combined with environmental information significantly impacts plant-based and hybrid burger choices, as well as liking and emotional responses. Therefore, it suggests that consumer choices are dynamic and can extend beyond initial sensory expectations, highlighting the importance of positive repeated sensory experiences in shaping food choices over time.

Overall, this research demonstrates that consumer acceptance of protein alternatives is driven not only by environmental or nutritional information, but more strongly by sensory expectations and emotional responses. The findings suggest that information-based intervention alone is insufficient to overcome the strong emotional attachment to conventional meat. Instead, strategies to support protein transition should prioritise developing products

that meet or exceed consumers' sensory expectations, alongside repeated positive consumption experiences to build familiarity and a positive emotional attachment over time. Collectively, these findings highlight the importance of integrating sensory optimisation and targeted information strategies to facilitate meaningful and sustained shifts towards more protein alternative consumptions.

Chapter 1.
Introduction

1.1 General Introduction

Due to population growth, water scarcity, public health, food security, and climate change, the United Nations has identified 17 sustainable development global challenges that require urgent attention (United Nations, 2015). Food systems sustainability has emerged as one of the most critical global challenges addressed by the United Nations. With the global population projected to reach 9.1 billion by 2050 and to rise further to 11.2 billion by 2100 (United Nations, 2017), food demand is significantly increasing. Global food production is expected to increase by approximately 70% by 2050 in order to meet future demand. However, food systems are becoming increasingly vulnerable as a result of climate change, water scarcity, and a range of environmental and socio-economic pressures. Although significant advances in agricultural productivity have been made, global hunger remains a persistent issue, while obesity rates continue to increase worldwide. In addition, global agricultural and food systems account for more than 25% of total greenhouse gas (GHG) emissions (Poore and Nemecek, 2018). Collectively, these challenges underscore the urgent need to adopt more sustainable food production practices and to encourage healthier, more sustainable dietary choices. Animal-based protein production is increasingly recognised as environmentally unsustainable due to its substantial contribution to greenhouse gas emissions, land degradation and

water usage (Lumsden *et al.*, 2024). With population growth, global demand for protein is increasing; the environmental burden associated with conventional animal protein is expected to pose greater challenges to our food system. In response to these challenges, alternative proteins, including plant-based, fermentation-derived, cultivated, and edible insect-based, have gained growing attention as one of the solutions to reduce the environmental impact of food production while supporting the increasing global demand for protein. Despite product development and increased market availability, the sustainability benefits of alternative proteins can only be demonstrated if they are widely accepted and adopted by consumers. Consumer acceptance remains one of the most critical barriers to transitioning to more sustainable protein sources. In addition, how information about these products is communicated also plays a critical role in shaping acceptance. While existing research has examined consumer attitudes towards alternative proteins, there remains a limited understanding of how different types of information and the trade-offs among them influence consumer perceptions of these products. Therefore, the overall aim of this thesis is to examine consumer responses to alternative proteins and to investigate how information sharing can promote greater adoption of these alternatives, using a range of methodological approaches. This study aims to provide evidence-based insights to inform product development, communication strategies, and policy interventions, ultimately supporting the transition towards a more sustainable food system.

1.2 Environmental impacts of food production and consumption

The urgency of addressing global warming underscores the influence of human activities on our planet's climate system. According to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6), published in 2021, anthropogenic activities have increased global average surface temperatures by approximately 1.07 °C above pre-industrial levels. The report further concludes that most of the warming observed since the mid-20th century can be attributed to human activities, particularly the burning of fuels, land-use, and agricultural practices (Lee *et al.*, 2023).

Mitigating climate change requires substantial reductions in greenhouse gas emissions (GHG) across all sectors, including agriculture, which plays a major role in global environmental issues (Shukla *et al.*, 2019). Agriculture activities are responsible for 25% of global GHG emissions, particularly in the form of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Ritchie, Rosado and Roser, 2022). These emissions arise from various sources, such as land-use change, fertiliser application, and livestock production. Livestock production is estimated to contribute to 12% to 18% of total global GHG emissions, which is more than 50% of total global agricultural and food activities (González *et al.*, 2020). Methane emissions from enteric fermentation in ruminant animals and feed production are major drivers of livestock-related emissions. Beyond climate impact, livestock production also adds additional pressure on natural resources, contributing to high water footprint, water pollution, deforestation, biodiversity loss, and

water scarcity (Farvid *et al.*, 2018). These environmental burdens highlight the importance of identifying effective strategies to reduce excessive meat consumption as part of broader climate change mitigation efforts.

The environmental impact of food products and consumption varies substantially depending on the type of food. As detailed in Figure 1-1, ruminant meats such as beef and lamb have exceptionally high climate footprints, generating approximately 99.5 kg (beef herd), 33.3 kg (dairy herd beef) and 39 kg CO_2 equivalents per kilogram of product, respectively. These high emissions are largely attributed to methane released during enteric fermentation, as well as emissions associated with feed production and land-use change (Poore and Nemecek, 2018; Davison, Black and Moss, 2020). Therefore, the majority of the research has focused on reducing meat consumption, focusing on beef and lamb. In contrast, plant-based protein sources such as legumes (lentils, beans), nuts and grains have substantially lower environmental impact (between 0.4 kg and 5 kg CO_2 per kilogram of food). This data highlights the significant potential to reduce current meat consumption and increase intake of plant-based protein to lower GHG emissions and reduce environmental pressures. Consequently, changes in food production systems and motivating consumers to choose more sustainable dietary options are increasingly recognised as critical components of sustainable development and climate change mitigation

strategies.

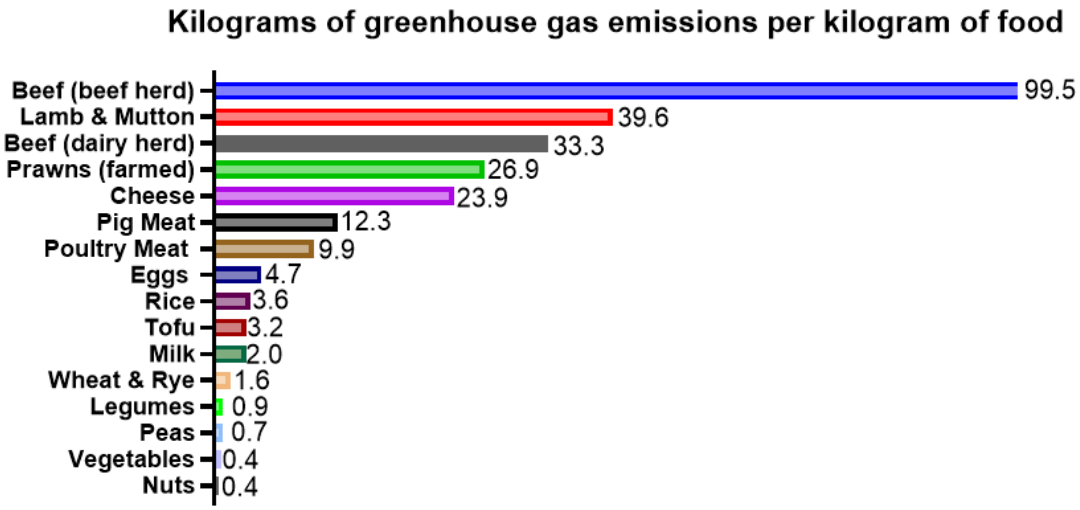


Figure 1-1 Greenhouse gas emissions per kilogram of food product (Poore and Nemecek, 2018)

The United Kingdom has experienced an increase in overall meat consumption over the past decade (2013-2023). Total meat consumption increased from 4.42 million tonnes in 2013 to 5.09 million tonnes in 2023, reflecting a 13.16% rise (data were calculated by multiplying the population by Figure 1-2 per capita consumption in each year). This growth is also evident in per capita meat consumption, which rose from 78.17 kg in 2013 to 82.25 kg in 2023. According to Figure 1-2, UK consumers show distinct preferences for different types of meat. Poultry consumption has increased over the past decade, with poultry emerging as the most consumed meat per capita in the UK, followed by pork. Specifically, per capita chicken consumption rose substantially from 29.72 kg in 2013 to 38.18 kg in 2023, the largest growth among all meat categories. Pork consumption also showed no significant change (Figure 1-2). In contrast, beef consumption declined significantly. Per capita beef consumption decreased from 18.05 kg

in 2012 to 16.85 kg in 2022. As illustrated in Figure 1-2, beef consumption peaked around 2020 at approximately 20 kg per capita, after which a slight decline was observed, reaching a lower level in 2023. These changes in meat consumption indicate the early stages of a dietary transition away from red meat. However, this change should be interpreted with caution, as the decline is modest. Beef production is associated with higher greenhouse gas emissions. As a result, even a small reduction in beef intake can yield larger environmental benefits. Therefore, more tailored intervention strategies are needed to improve the availability and acceptability of alternative protein sources to support dietary changes toward more sustainable consumption.

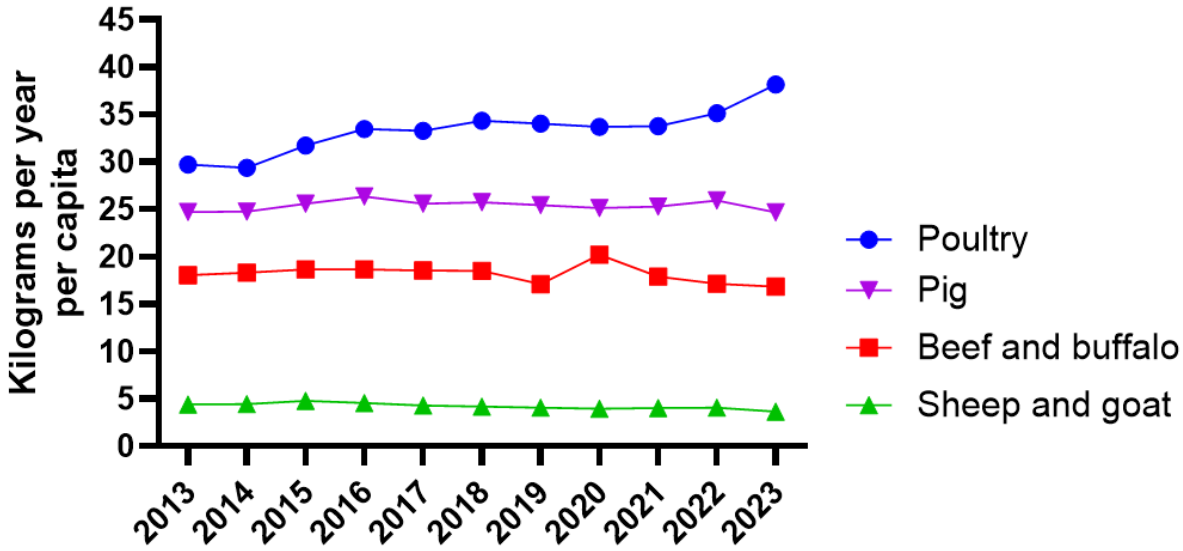


Figure 1-2 United Kingdom per capita meat (poultry, beef, sheep and pig) from 2013 to 2023. The data source from (FAO, 2024).

1.3 Definition of protein alternatives

As discussed in the previous section, ruminant-derived proteins contribute significantly to GHG emissions, land use, and water consumption. Replacing or partially substituting these proteins with lower-impact protein alternatives

represents one of the most effective strategies to mitigate climate change while simultaneously addressing global public health challenges. The protein alternatives were broadly defined as ‘food products that can replace animal proteins’, which could include meat substitutes, plant-based proteins, cultivated meats, mycoproteins, algae, insects, and hybrid meats that substitute or extend traditional ‘meat’ products (Nguyen *et al.*, 2022).

1.3.1 Plant-based meat

Facing the dual challenges of climate change and diet-related public health concerns associated with excessive meat consumption. Scientific research and commercial innovation have increasingly focused on consumer behaviour towards plant-based meat alternatives. This growing interest is reflected in the rapid expansion of academic research, with the cumulative number of studies identified in Scopus increasing from approximately 419 in 2015 to 2660 by 2025, the search based on the Onwezen *et al.* (2021) keywords[1]. This trend highlights the accelerating interest in alternative protein development. Since 2010, the market for plant-based protein has expanded rapidly, with significant growth from the mid-2010s to 2022 (Aschemann-Witzel *et al.*, 2021; Appiani, Cattaneo and Laureati, 2023). In the United States, the plant-based food retail market totalled $8.1 billion in 2024. However, recent reports suggest that market growth has slowed since 2022 (GFI, 2024b). Early plant-based products, often referred to as first-generation alternatives, were primarily derived from processed plant

[1] ALL(consumption*) AND TITLE-ABS-KEY (food* AND consumer* AND (accept* OR preference* OR willing* OR buy* OR purchas* OR choice* OR behavio* OR adopt* OR perception*) AND (“cultured meat*” OR “in vitro meat*” OR “synthetic meat*” OR seaweed* OR alga* OR insect* OR lupin* OR pulse* OR legume* OR *bean* OR “dry pea*” OR chickpea* OR “cow pea*” OR “pigeon pea*” OR lentil* OR “meat alternative*” OR “meat substitute*” OR “plant-based meat*” OR “meat analogue*”))

ingredients such as soybeans, wheat gluten, and pulses. These products, such as tofu, were not originally designed to closely replicate the sensory attributes of meat, as they were considered a separate product category.

Advances in food science and biotechnology, combined with consumer demand for more vegetarian or sustainable options, led to the development of second-generation plant-based meat alternatives (He *et al.*, 2020). While plant-based, these products incorporate more intensive processing technologies, such as thermal extrusion, fermentation, and protein cross-linking, as well as more flavourings, with the aim of more closely mimicking the texture and flavour of conventional meat (Wood and Tavan, 2022). The main objective of second-generation plant-based meat alternatives is to closely resemble traditional meat in appearance, nutritional value, texture, and flavour (He *et al.*, 2020; Andreani *et al.*, 2023). Leading companies such as Beyond Meat™, Moving Mountain™, and Impossible Foods™ utilised the second-generation approach, producing a range of product categories that offer substantial environmental benefits. For instance, Beyond Meat™ generates approximately 0.43 kg of equivalents per patty (Graça, Calheiros and Oliveira, 2015; Dominguez-Lacueva, Beriain and Aldaya, 2025). Although second-generation plant-based foods require multiple processing steps that contribute to GHG emissions, the overall GHG emissions are still reported as significantly lower than those of beef or lamb.

Although substantial development work has been undertaken to improve the nutritional composition of plant-based meat, in an effort to match the nutritional profile of their animal-based counterparts. Plant-based foods are

generally rich in dietary fibre, lower saturated fat; however, they may also present potential nutritional limitations, including lower iron bioavailability and reduced protein quality, as some plant-based proteins lack certain essential amino acids (He *et al.*, 2020). With regards to sensory properties, a range of technologies and ingredients have been employed to optimise the texture and flavour of plant-based meat products (Andreani *et al.*, 2023).

The plant-based meat currently represents the largest and most commercially established segment of the UK alternative protein market. Andreani *et al.* (2023) indicated that the UK is one of the leading European markets for plant-based meat product launches. Plant-based meat, the second-largest category by sales value, declined steadily from £392 million in the year to January 2023 to £333 million in the year to January 2025, with sales volume falling by 22.1% over the same period (GFI, 2025). These declines reflect the combined pressure of the cost-of-living crisis and growing consumer concerns around product quality and price, consistent with the barriers identified by Andreani *et al.* (2023) and Aschemann-Witzel *et al.* (2021).

1.3.2 Edible insect

Edible insects have been part of human diets throughout history, and insect consumption remains common in some regions worldwide (Moruzzo, Mancini and Guidi, 2021). It is estimated that more than two billion people regularly consume insects as part of their traditional diets (Raihan, 2023). Previous studies have shown that edible insects are a highly nutritious and healthy food source, rich in fat, protein, vitamins, and fibre (Lange and Nakamura,

2021). The protein content of edible insects varies by species, diet, and development stage, typically ranging from 35% in termites to 61% in crickets, grasshoppers, and locusts, reaching up to 77% on a dry-weight basis (Rumpold and Schlüter, 2013a), which is similar to beef (Lange and Nakamura, 2021).

From an environmental perspective, insect farming is associated with relatively low GHG emissions, estimated at 11.8 kg of CO_2 equivalents per kilogram of product, which is substantially lower than emissions from beef production (Smetana *et al.*, 2015). In addition, edible insects are often reared using waste streams such as food waste, brewers' spent grains, thereby converting low-value waste into high-quality protein, which supports the circular food system and economy (Biteau *et al.*, 2024). Although commercial adoption remains limited, there is an increasing trend to incorporate edible insects into processed forms such as powder, flours, protein bars, and baked goods (Lumanlan, Williams and Jayasena, 2022).

The edible insect is high in protein, with a well-balanced essential amino acid profile, and is also a good source of minerals (phosphorus, iron and zinc) and vitamins, including riboflavin and folic acid (Tang *et al.*, 2019; Ribeiro, Pintado and Cunha, 2024). In addition, insects contain considerable amounts of lipid, ranging from 8 to 70% of dry weight, depending on species. Their fatty acid profiles are dominated by saturated and monounsaturated fatty acids (>80%), while mature insects also provide appreciable levels of polyunsaturated fatty acids, particularly linoleic and α-linolenic acids, which are essential for human health (Tang *et al.*, 2019).

Sensory quality varies by species and processing, but is frequently negatively perceived in Western contexts (Ribeiro, Pintado and Cunha, 2024). Key sensory issues include odour and flavour linked to spoiled food, attributed to lipid peroxidation in insect fat fractions. Whole insects and insect flours often receive lower ratings in hedonic tests compared to conventional products, mainly due to darker appearance and grainy, dry textures (Lange and Nakamura, 2021).

Globally, the edible insects market was valued at USD 1.73 billion in 2025 and is projected to reach USD 13.23 billion by 2034 (Fortune Business Insights, 2025). However, the growth is driven primarily by animal feed and ingredients application rather than direct human consumption. Consumer growing awareness of environmental sustainability, food security, and resource efficiency has positioned insects as an attractive protein source, given their lower land use, water requirements, and greenhouse gas emissions compared to conventional livestock (Ardoin and Prinyawiwatkul, 2021). However, despite strong growth potential, consumer acceptance remains a major barrier. Cultural perceptions, food neophobia, and concerns about safety and processing continue to limit widespread adoption, with a significant proportion of consumers still reluctant to consume insect-based foods (Castro and Chambers, 2019).

1.3.3 Lab-grown (cultured) meat

Lab-grown meat, also referred to as cultured, cultivated or cell-based meat, is produced by cultivating animal cells outside the animal's body. A small number of cells are collected from a living animal through biopsy and then

grown in a bioreactor, where they are supplied with nutrients to form muscle tissue that resembles conventional meat (Bryant and Barnett, 2020).

A major milestone in the sector occurred in 2020, when Singapore became the first country to approve the commercial sale of cultivated meat, enabling the sale of cultivated chicken nuggets in restaurants. There is an increasing number of companies focused on developing cultivated products such as burger patties, pork sausages, poultry-based (chicken nugget) products, and seafood-based products.

Early life-cycle assessments suggest that cultivated meat could reduce energy use by 7-45%, greenhouse gas emissions by 78-96%, and water consumption by 82-96% compared with conventional meat production (Tuomisto and Teixeira de Mattos, 2011). However, these estimates are based on hypothetical large-scale production scenarios, as comprehensive life-cycle data from fully operational facilities are not yet available. Further research is required to assess the true environmental performance of cultivated meat at scale.

Nutritionally, lab-grown meat shows variability: protein content 4–20%, the differences can be attributed to the different scaffolds used and the efficiency of protein synthesis pathways in the cells (lower than beef, 22%-26%) (Agostinis Ferreira, Poniewas and de Macedo, 2026). Essential amino acids like isoleucine and lysine are often deficient. Collagen levels (1.59–7 mg/g) also fall short of conventional meat's 12–54 mg/g (Agostinis Ferreira, Poniewas and de Macedo, 2026).

Sensory evaluation of lab-grown meat remains limited (Agostinis Ferreira, Poniewas and de Macedo, 2026). However, several instrumental studies have examined its sensory properties compared with conventional beef. Instrumental analyses using electronic tongue systems have identified measurable differences in taste-related attributes between cultivated and conventional meat, particularly with respect to umami, bitterness, sourness, and astringency (Joo *et al.*, 2022). Lower umami and bitterness intensities observed in cultivated meat have been associated with reduced concentrations of glutamic acid, aspartic acid, and inosine monophosphate (Agostinis Ferreira, Poniewas and de Macedo, 2026).

Within the protein alternatives landscape, cultivated meat (lab-grown meat) represents an innovative but early-stage segment, transitioning from laboratory development to initial commercialisation. Recent market research shows that cultivated meat is gradually moving from small-scale tastings to limited retail sales (da Silva and Conte-Junior, 2024). The number of companies in the sector has grown rapidly, from 12 in 2013 to over 150 by 2022, reflecting rising global investment and industry interest (Tsvakirai, Nalley and Tshehla, 2024). In terms of market size, cultivated meat was valued at approximately $1.64 million in 2021 and is projected to grow to $206.6 million by 2025 and $2.79 billion by 2030, indicating strong future growth potential. Although products are already available in markets such as Singapore, they remain positioned as high-end, suggesting that affordability and consumer accessibility remain key challenges. Production costs have decreased significantly, from around $325,000 per product in 2013 to approximately $4–11 per 100g serving by 2021. The cultivated meat remains

considerably more expensive than conventional beef, which retails at approximately £21.00 per kilogram in the UK, underscoring that cost parity remains a key barrier to mainstream consumer adoption (Tsvakirai, Nalley and Tshehla, 2024). Overall, the cultured meat (lab-grown meat) is characterised by strong innovation and sustainability-driven demand, but remains in a developmental phase, where overcoming cost and consumer perception barriers is essential for future growth.

1.3.4 Hybrid meat

Hybrid meat products combine conventional animal meat with plant-based ingredients. It has gained increasing attention as a solution for transitional proteins. Although no universally accepted definition exists, hybrid meat is defined as a blend of animal and plant proteins in varying ratios. The hybrid meat design aimed to reduce overall meat content while maintaining similar sensory properties of a conventional meat product. Given the high proportion of meat eaters globally and in the UK, hybrid meat products may appeal to consumers who are unwilling to fully replace meat but are open to reducing their intake. From an environmental point of view, substituting a portion of meat with plant ingredients can lead to meaningful reductions in GHG emissions. For example, a hybrid meat product containing 50% plant-based ingredients can reduce GHG emissions by at least 32% compared with conventional beef products (Dominguez-Lacueva, Beriain and Aldaya, 2025). Between 2016 and 2020, 38 hybrid meat products were launched in the UK by retailers such as Aldi, Tesco, and Waitrose, and by private labels, with 12 of these products still available today, and sausages being the most

launched product type (Grasso and Jaworska, 2020). Overall, the nutritional and sensory quality of hybrid meat largely depends on the blending ratio of plant-based ingredients and conventional meat. From a nutritional perspective, partial substitution of beef with plant protein ingredients generally reduces fat and cholesterol content, while increasing dietary fibre (Baune *et al.*, 2023).

Previous studies suggested that hybrid meats with moderate plant-based substitution (around 10–30%) can achieve sensory acceptance comparable to conventional meat, whereas higher plant-based substitution levels often lead to reduced consumer acceptance, likely due to taste and texture issues (Baune *et al.*, 2023; Grasso and Goksen, 2023). Importantly, acceptance strongly depends on the type of plant protein and processing technology (Grasso, 2024).

Recent market research indicates that hybrid meat products (i.e., products combining meat with plant-derived ingredients) remain a relatively niche and unstable category within retail environments (Grasso, 2024). In previous years, these products have primarily been introduced in familiar formats such as mince, sausages, and meatballs, rather than in burger patties, suggesting a limited and cautious product development strategy by manufacturers. For example, hybrid minced meat products such as Tesco’s Meat and Vegetable Beef Mince were previously available in the UK market; however, this product has since been discontinued(Grasso, 2024). Overall, hybrid meat products appear to struggle to establish a stable retail presence, potentially

due to unclear positioning between conventional meat and plant-based alternatives.

1.4 Beef and protein alternatives costs and scalability challenges

In the context of food production, production costs and scalability are key economic factors that affect whether traditional meat and alternative protein sources can succeed in the market. Production costs refer to the total economic inputs required to produce, process, and deliver food products, including agricultural inputs, resource use, labour, processing, technology, and regulatory compliance.

Beef is the most resource-intensive and costly protein source among conventional and alternative proteins. Production costs are extremely high because feed alone represents 60% or more of total costs, and the cow-calf breeding phase contributes a further 60–70% of costs until slaughter (Greenwood, 2021). Beef production also requires long growth cycles, extensive grazing land, and large volumes of water, while methane emissions and strict environmental regulations add significant indirect costs. For beef, standardised production costs from 2009 are $8.02 per kg at the farm level. Although this production cost is dated (17 years old), it remains a useful benchmark for comparing relative cost structures. UK retail beef prices (around £20.00 per kg) further confirm that beef is among the most expensive protein sources, supporting the idea that production costs have remained consistently high over time (Lusk and Norwood, 2009). Beef is the most resource-intensive and costly protein source overall. From a scalability

perspective, beef production is severely constrained. It depends on vast rangeland and pasture areas, and its efficiency is highly vulnerable to climate variability, drought, and seasonal feed shortages (Greenwood, 2021). Although feedlot systems can improve productivity, they require heavy capital investment, grain supplies, and processing infrastructure.

Plant-based meat products typically have lower long-term production costs due to the high efficiency of crop cultivation. Key raw materials such as soy, pea, and wheat protein are significantly cheaper than animal proteins. At the farm level, soybeans cost $0.031 per gram of protein and wheat costs $0.031 per gram of protein, whereas beef costs $0.321 per gram of protein, around 10 times higher for the same amount of protein (Lusk and Norwood, 2009). Despite these low-cost agricultural inputs, the overall production costs of plant-based meat are still relatively high, as reflected in retail prices such as £16.95 per kg for a soy-based alternative. This is due to high processing costs and additional expenses such as plant-based fats, flavours, and colour additives, which further increase production costs. The scalability challenges for plant-based meat differ significantly from conventional beef. Unlike beef production, which is limited by land, feed, and livestock rearing, the main constraints for plant-based meat are processing technologies and standardisation rather than primary agricultural production (Gulzar *et al.*, 2025). The core challenge arises from the need to use specialised processes such as high-moisture extrusion to create a fibrous, meat-like texture (He *et al.*, 2020). These processes require strict control over temperature, pressure, and flow to replicate the chewiness and structure of animal muscle. Without precise manufacturing, texture consistency cannot be maintained at scale.

Flavour standardisation presents another major challenge, as plant proteins often have natural off-notes that require consistent masking and balancing during large-scale production (Andreani *et al.*, 2023). Taken together, scalable production of plant-based meat depends heavily on standardised equipment, uniform processing protocols, and stable formulation. Only with fully industrialised and repeatable systems can manufacturers achieve reliable texture, flavour, and cost efficiency during mass production.

In practice, insect protein production in the UK carries high costs compared with conventional meat, driven by regulatory constraints, labour intensity, and inefficient systems (Yang and Cooke, 2021). Strict EU and UK rules limit insect feed to certified human-grade plant materials, banning low-cost food waste and animal by-products that could reduce expenses, which further cause edible insect feed alone to account for 60–70% of total production costs (Becker, 2008). Without automation and affordable feed streams, insect protein cannot achieve the cost competitiveness its biological efficiency theoretically promises. Currently, several manufacturers in the UK produce insect-based crackers. For example, buffalo insect crackers cost as much as £132 per kilogram, which directly reflects the edible insect sector's extremely high production costs. Scaling edible insect production in the UK faces five main barriers that block industrial-level expansion. A lack of automated equipment and standardised farming systems keeps operations small-scale and labour-dependent, while inconsistent rearing knowledge and limited technical expertise lead to unstable yields (Rumpold and Schlüter, 2013b).

Lab-grown meat (cultivated meat) currently has the highest production costs among alternative proteins. Lab-grown meat requires technology consistent with pharmaceutical production plants. The production process requires specialised bioreactors, which are large, sealed tanks used to grow cells under controlled conditions, making the process both expensive and energy-intensive (Garrison, Biermacher and Brorsen, 2022). According to Garrison, Biermacher and Brorsen (2022), producing 1 kilogram of lab-grown meat costs around $63 in a commercial-scale facility, with the main costs coming from growth media, bioreactor equipment, and highly skilled labour. Scalability is therefore a major challenge, as current systems are not economically suitable for mass-market production. Even in large-scale facilities costing up to $60 million, production costs remain far higher than those of conventional meat. This is because animal cells grow slowly, require expensive nutrients, and must be maintained under strict sterile conditions (Humbird, 2021). As a result, achieving large-scale production in the short term is difficult, as increasing output does not significantly reduce the unit cost. However, in the long term, lab-grown meat has strong scalability potential. Unlike traditional livestock farming, it does not require large areas of land, long growth periods, or large quantities of feed. With further technological development, production could take place in urban factories and expand without being limited by animal breeding cycles or natural resource constraints (Humbird, 2021). If these challenges are addressed in the future, large-scale production could eventually reduce production costs.

1.5 Consumer acceptance and motivations for protein alternatives

While protein alternatives are often promoted for their environmental benefits, consumer acceptance and willingness to adopt are critical determinants of the product's market success. Despite increasing availability and public encouragement to promote protein alternatives, only a small percentage of consumers demonstrated regular purchase of protein alternatives, which are dominated by vegans and vegetarians (Michel, Hartmann and Siegrist, 2021). In the UK, approximately 4.5% of people are vegans and vegetarians, and there is an increasing number of flexitarians who are trying to reduce but not completely remove meat from their diet (Bechtold *et al.*, 2021; Stewart *et al.*, 2021)

A growing body of literature consistently shows that acceptance of protein alternatives remains limited compared to conventional meat products. Consumers typically prefer and feel more attached to conventional meat products, whereas protein alternatives often face hesitation and scepticism (de Koning *et al.*, 2020; Dupont and Fiebelkorn, 2020; Lang, 2020; Grasso, Asioli and Smith, 2022; Coucke, Slabbinck and Vermeir, 2023). In addition, consumer acceptance of protein alternatives is influenced by a complex interplay of factors that can be broadly grouped as product-related factors (intrinsic and extrinsic factors), psychological factors (e.g., food neophobia and disgust sensitivity), and environmental factors (e.g., social and cultural).

Among the different categories of protein alternatives, plant-based alternatives are generally the most widely accepted. Their higher acceptance

is largely attributed to perceived familiarity and compatibility with existing dietary habits (Onwezen *et al.*, 2021). Motivations for consuming plant-based meat alternatives extend beyond animal welfare and also include convenience and food safety (Graça, Calheiros and Oliveira, 2015; Onwezen *et al.*, 2021; Ford *et al.*, 2024b). Sensory quality further contributes to consumer interest; however, the technological processing required to replicate meat-like characteristics often leads to perceptions of overprocessing, which in turn raises concerns regarding product naturalness, healthiness, and safety (Ford *et al.*, 2023a). Environmental friendliness and health benefits are often highlighted as reasons for plant-based meat to replace conventional meat, but not all consumers accept these claims (Hartmann, Furtwaengler and Siegrist, 2022).

Hybrid meat products showed a similar acceptance pattern to plant-based products, which may be due to these products retaining a familiar meat component while reducing the proportion of animal ingredients (Grasso and Goksen, 2023). Motivations for consuming hybrid meat products seem similar to those for plant-based meat alternatives. Consumers are often motivated to choose hybrid meat products for their perceived environmental and health benefits, as these products reduce the overall proportion of animal-derived ingredients while retaining familiar meat components (Van Dijk *et al.*, 2023). Sensory appeal is a particularly strong factor influencing acceptance, since hybrid meat is often seen as more tasty and flavourful than fully plant-based alternatives (Grasso and Goksen, 2023). Furthermore, the convenience, simplicity of preparation, and ethical concerns can increase consumer interest in hybrid meat (Van Dijk *et al.*, 2023; Grasso, 2024).

In contrast, edible insects are consistently identified as the least accepted protein sources in a wide range of literature. A strong disgust emotion is often associated with edible insects (Broeckhoven *et al.*, 2021), which aligns with findings from Ford *et al.* (2024b), who found 25.3% of UK consumers unwilling to adopt edible insects. Consumers generally accept lab-grown meat, but acceptance levels remain lower than those of plant-based alternatives and much higher than for edible insects (Bryant and Barnett, 2020; Onwezen *et al.*, 2021). This reflects ongoing uncertainty for the product categories. Also, as lab-grown products are not yet available on the market, almost all studies investigating lab-grown meat have used an online survey approach without tasting, assuming that lab-grown meat would mimic the sensory properties of its meat counterpart. Edible insects and cultured meat show similar motivations and barriers. Perceived environmental advantages and potential health benefits can encourage openness towards these alternatives, whereas food neophobia remains a significant barrier to acceptance (Onwezen *et al.*, 2021). Disgust remains one of the main psychological barriers to eating edible insects (Tang et al., 2019; Russell and Knott, 2021). For cultured meat, resistance mainly stems from worries about unnaturalness and high costs, which further reduce consumer willingness to try these products (Bryant and Barnett, 2020; Pakseresht, Ahmadi Kaliji and Canavari, 2022; Van Dijk *et al.*, 2023).

In addition to psychological factors influencing consumer acceptance of protein alternatives, food neophobia and disgust-related emotions are significant psychological barriers, especially for novel alternative proteins. Food neophobia, which is the reluctance to try unfamiliar foods (Pliner and

Hobden, 1992), has been commonly linked to lower acceptance of insects (Sogari, Bogueva and Marinova, 2019), cultured meat (Hamlin, McNeill and Sim, 2022), hybrid meat (Van Dijk *et al.*, 2023), and plant-based meat substitutes (Bryant *et al.*, 2019). Closely related emotional reactions, such as general disgust sensitivity and fear, further decrease acceptance, particularly for insect-based and cultured meat products (Poortvliet *et al.*, 2019; Russell and Knott, 2021).

1.6 Communicating product information to consumers

One of the strategies or interventions to promote consumer choice towards protein alternatives was providing effective information that can shape consumers' knowledge, emotional responses and attitudes, thereby increasing openness and willingness to adopt protein alternatives and support consumer food choice decision making (Jaeger, Hedderley and Prescott, 2023; Beyer *et al.*, 2024; Chung *et al.*, 2024).

According to Onwezen *et al.* (2021), only 24 studies investigated sharing information as an intervention strategy prior to June 2020, indicating the area of research was relatively underdeveloped at that time. However, since 2020, interest in this topic has increased, with approximately 29 studies published between 2020 and 2025, investigating how information influences consumer acceptance or purchase intention regarding protein alternatives. Overall, information-based interventions are considered a relatively cost-effective tool for influencing consumer perceptions. However, the effectiveness of

information is strongly influenced by message frames, type, and the format of the information provided.

Most studies examined the impact of different types of information on protein alternatives, particularly plant-based products (Isabel Sonntag *et al.*, 2023; Sicilia, López and Palazón, 2023; Chung *et al.*, 2024). The environmental claims are frequently reported as a significant driver of acceptance, especially for plant-based meat alternatives (Broeckhoven *et al.*, 2021; Carlsson *et al.*, 2021; Edenbrandt and Lagerkvist, 2021; Katare *et al.*, 2022; Piochi, Micheloni and Torri, 2022; Bazoche *et al.*, 2023; Holenweger, Stöckli and Brügger, 2023; Isabel Sonntag *et al.*, 2023; Segovia, Yu and Van Loo, 2023; Williams, Flannery and Patel, 2023; Beyer *et al.*, 2024). For edible insect and lab-grown meat, both environmental and nutritional information have been shown to influence acceptance and willingness to try these products (Mancini and Antonioli, 2020; Van Loo, Caputo and Lusk, 2020; Erhard, Jahn and Boztug, 2024).

Despite this research showing positive effects, some studies suggest that the information has only a small impact on consumer acceptance of protein alternatives (Bryant *et al.*, 2019; Onwezen and Dagevos, 2024). Other information, such as price, naturalness of ingredients, also plays a role in shaping acceptance (Mancini and Antonioli, 2020; Grasso *et al.*, 2022; Piochi, Micheloni and Torri, 2022). They are also increasing evidence that suggests that the sensory properties of the product and tasting experiences are more influential (Ford *et al.*, 2024a). Grasso, Asioli and Smith (2022) indicate that when consumers have the opportunity to taste the product,

sensory appeal becomes more important than ingredient information. If the sensory properties of plant-based meat do not meet expectations, consumers' purchase intention decreases.

In addition to information content, the formats through which information is delivered vary widely across studies. Common approaches include written information (Mancini and Antonioli, 2020), on-pack claims (Carlsson *et al.*, 2021; Katare *et al.*, 2022; Bazoche *et al.*, 2023; Jaeger *et al.*, 2023; Segovia, Yu and Van Loo, 2023), visual and labels (Sicilia, López and Palazón, 2023; Williams, Flannery and Patel, 2023; Beyer *et al.*, 2024), and video (Ford *et al.*, 2024a). These formats are often used to convey information about ingredients, production processes, environmental information, nutritional information, and production technology (Mancini and Antonioli, 2020; Van Loo, Caputo and Lusk, 2020). The aim of examining the effects of different levels of information provided about protein alternatives is to identify which information most effectively supports consumers in making sustainable food choices. The findings can be used to develop a simplified communication system that enables rapid and intuitive decision-making in real-world purchasing contexts. For example, the traffic light system for nutrition content on the pack system is a successful development to support consumer rapid decision making based on the nutritional composition of the products (Sicilia, López and Palazón, 2023).

1.7 Consumer Research Method

Consumer behaviour is commonly defined as 'the study of the processes involved when individuals select, purchase, use, or dispose of products,

services, ideas, or experiences to satisfy needs and desires' (Solomon and Russell, 2024). Within the broad field, sensory and consumer science provides a systematic framework for understanding how consumers perceive, evaluate, and respond to food products. According to Beckley, Paredes and Vahalik (2025), the sensory science definition is an interdisciplinary field that includes facets of fundamental sensory science (psychophysics and stimulus response measurements) with applied product analysis, including emotions, feelings/mood, choices, needs, and wants. Understanding consumer acceptance and behaviour towards protein alternatives is complex, as it involves expectations, sensory experiences, cognitive trade-offs, actual purchasing and eating behaviour; therefore, to better understand consumer responses, multiple consumer methods are required.

1.7.1 Survey

Survey/Questionnaires have long been a foundational tool in consumer research, with formats tailored to diverse research objectives. Traditionally, surveys were conducted in person using paper copies or through email circulations. In recent years, as technology advances and an increased consumer questionnaire platform with a diverse consumer database, online questionnaires have emerged rapidly (Jaeger and Cardello, 2022). This shift has made online questionnaires particularly prevalent in studies focusing on exploring consumer attitudes towards protein alternatives (Fehér *et al.*, 2020; Onwezen *et al.*, 2021; Onwezen and Dagevos, 2024). A survey systematically collects data from participants using a structured set of

questions and is widely used in social science, consumer research, and psychology to measure attitudes, perceptions, beliefs, and self-reported behaviours. It can capture both closed-ended questions (e.g., multiple choice and Likert Scales) and open-ended questions, allowing both quantitative and qualitative data collection. It is generally considered a cost-effective and time-efficient research method.

Despite the widespread use of survey-based methods in consumer and food research, these approaches have important limitations, particularly in capturing hypothetical choice behaviour and measuring behavioural intentions. A key limitation is that responses are typically based on product images, descriptions, or labels rather than actual sensory experiences, such as taste, aroma, texture, or mouthfeel. The absence of a real consumption context may lead to biased or incomplete evaluations, as consumers are unable to assess critical sensory attributes that also strongly influence real-world food choices. Furthermore, survey-based measures are subject to the well-known intention–behaviour gap, where consumers stated willingness to try or purchase products in hypothetical settings does not always reflect their actual behaviour. This gap occurs because real purchasing decisions are influenced by practical factors such as price, brand familiarity, convenience, and the availability of alternative options. For example, a participant may express a strong intention to purchase a novel plant-based product in an online survey, but in a real retail setting, they may choose a more familiar or lower-cost option instead. In addition, social desirability bias may further distort survey responses, particularly in online settings, where respondents may overreport socially acceptable or health-oriented choices rather than

reflect their true preferences (Zhu, Greene and Dolnicar, 2024). Taken together, these limitations may reduce the predictive validity and external validity of survey-based findings, and should therefore be carefully considered when interpreting the results.

Nevertheless, survey-based approaches remain widely used in the study of novel protein alternatives. This is largely because these products, such as lab-grown meat and edible insects, are not yet widely available on the market, making it difficult to observe actual consumer behaviour in real purchase contexts. As a result, surveys can be used to gather consumer perceptions, expectations, motivations, and barriers to these novel protein alternatives (Sogari, Bogueva and Marinova, 2019; Dupont and Fiebelkorn, 2020; Heijnk, Espey and Schuenemann, 2023). In addition, survey methods enable researchers to reach diverse samples, offering valuable insights into potential market acceptance across different consumer groups. The survey results play an important role in understanding consumer responses during the early stages of product development.

1.7.2 Conjoint analysis

Conjoint analysis originated in marketing (Green and Srinivasan, 1990) and is now widely used in both academic research and the industry within the food sector (Asioli *et al.*, 2016; Jaeger, Chheang and Ares, 2023). Consumers make trade-offs between factors (e.g., taste, price, sustainability, nutritional content, etc.). Conjoint analysis estimates the relative importance of factors by asking how individuals evaluate products with multiple factors and quantifying the trade-offs. Instead of presenting each factor in isolation,

conjoint analysis presents products as a set of factors (e.g., in a full experimental design of the number of factors selected), reflecting the way real-world purchasing decisions are made. For example, the typical 2 × 2 rating-based conjoint design can be constructed based on two factors, each with two levels. In the typical conjoint study, the first factor could be product types, with levels plant-based and beef product. The second factor is price, with levels of low price and high price. Therefore, combining these factors results in four product concepts, and participants need to rate all the product concepts individually for willingness to purchase or ordering:

1) plant-based product at a low price
2) plant-based product at a high price
3) beef product at a low price
4) beef product at a high price

Choice-based conjoint analysis presents individuals with a set of product concepts and asks them to select the option they would most likely choose (Næs, Brockhoff and Tomic, 2011; Asioli *et al.*, 2016). This is particularly helpful to capture decision-making under competitive choice conditions; however, rating-based conjoint analysis models present results directly in the same units as the rating scores, while for the choice-based conjoint, the size of the coefficients can only be considered relative to each other (Asioli *et al.*, 2016). Rating-based conjoint analysis enables consumers to evaluate each product concept independently, typically rating on a liking or purchase intention. These ratings can then be used to analyse the relative contribution of each attribute. In the context of alternative protein, rating-based conjoint

analysis can provide insight into how individual attributes (e.g. environmental, sensory or nutritional information) contribute to overall liking or purchase intention.

However, conjoint analysis has limitations, particularly in terms of cognitive burden and the difficulty of interpreting complex choice sets. Cognitive burden is especially serious in choice-based conjoint analysis, because respondents must compare several product attributes at the same time and make trade-offs between different attributes. This high cognitive burden can lead to decision fatigue, especially when the number of attributes is large (Kulshreshtha, Sharma and Bajpai, 2021). Although rating-based conjoint reduces this burden by allowing participants to evaluate each product individually, it can still experience information overload when too many attributes are included. In addition, interpretation difficulty is another limitation caused by complex choice sets in the conjoint analysis. When attributes are technical or unfamiliar, respondents may not understand the product profiles in the same way. They may become confused about what each option represents. This can lead to inconsistent responses and may reduce the reliability of the results. Unlike cognitive burden, interpretation difficulty can affect both choice-based and rating-based conjoint, as it comes from the complexity of attributes rather than the task format.

1.7.3 Sensory evaluation

Sensory evaluation is often described as using the definition of the Institute of Food Technology: ‘a scientific method used to evoke, measure, analyse and interpret those responses to products as perceived through the senses

of sight, smell, touch, taste and hearing' (Kemp, Hollowood and Hort, 2009; Lawless and Heymann, 2010). Sensory properties are key drivers of consumer acceptance; therefore, sensory evaluation captures direct product experiences and is commonly used during the product development stage to predict the likelihood of market success.

Due to sensory evaluation typically requires participants to consume the products, which raises ethical concerns and product availability for some novel protein alternatives. For example, lab-grown meat has not yet been approved by the UK Food Standards Agency (FSA); therefore, it's not legally available for consumer testing. As a result, direct sensory evaluation involving lab-grown meat is currently not feasible. Although edible insects (e.g., yellow mealworm, house cricket, banded cricket, black soldier fly) have received approval from the FSA for a novel food taste trial, market availability remains limited; therefore, they are difficult to source.

Not surprisingly, existing sensory studies have focused on commercially available protein alternatives, mainly plant-based products (Elzerman *et al.*, 2011; Caputo, Sogari and Van Loo, 2023; Gonzalez-Estanol *et al.*, 2023; Orr *et al.*, 2023; Petrat-Melin and Dam, 2023; Giezenaar *et al.*, 2024; Sogari *et al.*, 2024), and hybrid meat products (Grasso, Asioli and Smith, 2022; Petrat-Melin and Dam, 2023; Chin *et al.*, 2024).

1.7.4 Real-world food choice

Real-world food choice refers to the decisions consumers make in their everyday environments, such as selecting meals in a restaurant or purchasing products in a supermarket. Unlike laboratory-based sensory

evaluations, where participants taste multiple samples in a controlled order and environment, and provide ratings on perceived sensory properties or liking (Stelick and Dando, 2018). Real-world choices involve selecting and consuming a single product influenced by contextual factors, including price, convenience, branding, prior experience, and immediate emotional responses (Ballco and Gracia, 2020). While controlled sensory studies provide valuable insights into consumer preferences, they often fail to capture the complexity of decision-making in naturalistic settings, including the dynamic interplay between cognition, emotion, and behaviour (King *et al.*, 2004; Van Loo, Caputo and Lusk, 2020; Caputo, Sogari and Van Loo, 2023).

Food decision-making is dynamic, shaped by both past experiences and real-time experience. Consumers form initial expectations before consumption that guide their choices, and these expectations are subsequently confirmed or updated through sensory experiences such as taste, texture, and aroma (Sobal and Bisogni, 2009). For protein alternatives, consumers often rely on limited information, such as ingredient descriptions or external recommendations, to develop initial expectations, particularly when comparing these products to conventional beef (Meyer and Simons, 2021). Most previous studies have focused on measuring these expectations through online questionnaires, but the gap between initial expectations and actual consumption experience can strongly influence long-term acceptance and repurchase intentions (Castellini and Graffigna, 2022; Fernqvist, Spendrup and Tellström, 2024). Observing such dynamic decision-making in real-world contexts is therefore essential, as it captures the natural processes by which consumers evaluate and adapt their preferences,

something that controlled laboratory studies cannot fully replicate (Galiñanes Plaza, Delarue and Saulais, 2019).

Previous research has examined food choices in real-life contexts, such as restaurants and supermarkets, by observing actual consumption or purchase behaviour. For example, Carroll and Samek (2018) investigated hedonic responses and food selections in cafeteria settings, while Varela and Ares (2018) studied consumer choices during supermarket tasting sessions. These studies suggest that consumers' real-world decisions are shaped not only by product attributes but also by repeated interactions, contextual cues, and emotional responses, which are often overlooked in traditional sensory evaluations.

However, there is currently a lack of research exploring how consumers choose protein alternatives in real-world settings. As a result, it remains unclear whether preferences measured in laboratory sensory evaluations accurately predict actual selection and consumption behaviour. Integrating insights from recent advances in real-world consumer measurement. For example, combining behavioural observation with emotional and cognitive indicators could provide a more accurate understanding of consumer decision-making for protein alternatives and improve predictions of market success.

1.8 Consumer response measurement

1.8.1 Hedonic responses

Hedonic measurement is a fundamental method in sensory and consumer research, widely used to assess consumer acceptance and preference for

products across a wide range of categories such as food, beverages, and non-food areas (e.g. cosmetics) (Stone, Bleibaum and Thomas, 2021). Hedonic data has been the industry standard for quantifying product acceptability and supporting decision-making during the product development stage. Hedonic response is commonly used as a predictor of the likelihood of product success on the market. Various scales have been developed for capturing liking data. One of the most commonly used approaches is the 9-point scale, originally developed by Peryam and Pilgrim (1957). It is a simple categorical scale that captures like and dislike responses. As suggested by its name, it consists of nine distinct points from ‘Dislike extremely’ to ‘Like extremely’, with neither like nor dislike in the middle. The scale is highly intuitive and accessible, allowing naive consumers to quickly understand and use the scale with minimal training. However, the scale was critiqued with a ceiling effect, which might limit its effectiveness in discriminating between well-liked food products. The category liking scale also has many other variations, including 5-point and 7-point scales. The 5-point visual scale is often used for children's research due to its simplicity.

Another alternative to the 9-point hedonic scale is called Labelled Affective Magnitude (LAM) scale Schutz and Cardello (2001). The LAM scale was specifically designed to assess liking/disliking of foods on a line scale, which has been shown to have a greater discrimination power for distinguishing between well-liked samples compared to the 9-point hedonic scale (Lawless, Popper and Kroll, 2010). The scale includes a line with anchor terms that are logarithmically spaced, ranging from ‘dislike extremely’ to ‘like extremely’,

which are the same as the 9-point hedonic scale. With two additional labels representing ‘greatest imaginable dislike’ and ‘greatest imaginable like’. The additional labels remove the ceiling effect from the 9-point hedonic scale. Due to this, this thesis examined protein alternatives, which were unlikely to fall into the category of highly liked products, to keep simplicity for consumers and enable easy-to-use, 9-point hedonic responses were mainly used.

1.8.2 Purchase intention & Ordering intention

When consumers make food-related decisions, behavioural willingness typically occurs in two typical consumption contexts: purchasing food products in retail settings (e.g., supermarkets) and ordering food in food-service settings (e.g., restaurants). Therefore, consumer behavioural intention is often represented by two related but context-specific constructs: purchase intention (in retail settings) and ordering intention (in food-serving settings).

Purchase intention refers to a consumer’s willingness to buy a specific product in a retail context. It is considered a goal-oriented behavioural expectation, distinct from mere hedonic liking. Whereas liking reflects affective preference, purchase intention links attributes and evaluation to prospective behaviour, making it a stronger predictor of actual food choice (Teixeira, Kallas and Dias, 2024). In contrast, order intention captures consumers’ willingness of a food item in a restaurant context, reflecting behavioural intention under food-service conditions rather than retail purchase situations (Jaeger, Chheang and Ares, 2023).

Both purchase intention and ordering intention can be measured using a self-report survey. Instead of asking how much consumers like a product, these measures directly examine consumers' behavioural willingness, such as 'How willing are you to purchase this product?' (purchase intention) or 'How interested are you in ordering this product?' (ordering intention). Likert scales with clearly defined anchors are commonly used, such as ranging from 'extremely unwilling to buy' to 'extremely willing to buy' (Ford *et al.*, 2024b) or from 'not at all interested in ordering' to 'extremely interested in ordering' (Jaeger, Chheang and Ares, 2023).

To measure consumer purchase and ordering intentions, the number of Likert scale points may vary (e.g., 5-, 7-, or 9-point scales), and in some cases, continuous line scales can also be used depending on the research context. In addition, established multi-item questionnaires may be employed to measure consumer purchase intention, for example Ren, Yang and Gu (2023) examine consumer purchase intention for edible insect by using two statements (e.g., 'Instead of conventional foods, I will spend more money on insect alternative foods'; 'Due to the positive impact on the environment, I intend to purchase insect alternative foods in the future'). Although both purchase intention and ordering intention demonstrate relatively high external validity by explicitly targeting behavioural willingness, they are commonly assessed in hypothetical settings. As a result, a limitation remains the potential gap between stated intention and actual purchasing or ordering behaviour.

1.8.3 Emotional responses

Emotion plays a critical role in food evaluation and decision-making. Emotion can be defined as a short-term process involving coordinated changes across multiple components, including elicitation, expression, subjective feelings, autonomic, physiology, and action tendencies (Delplanque and Sander, 2021). Emotion is different from mood, which refers to a longer-lasting state of psychological arousal (Gibson, 2006). Emotions are deeply embedded in sensory perception and food choice. Through evolution, one of the basic emotions – fear is defined as enhanced sensory perception in order to efficiently respond to unforeseen events (Susskind *et al.*, 2008).

Previous studies agreed that emotional measurement provides additional data compared with hedonic liking alone (Gibson, 2006; Meiselman, 2021; Low *et al.*, 2022). For example, two food products may have similar liking scores but evoke different emotional responses, and recognising these emotional differences is essential for product development and cross-cultural research (Ng, Chaya and Hort, 2013; Cardello and Jaeger, 2016; Yang *et al.*, 2020). Measuring emotional responses is increasingly recognised as essential in food-related research, as it is shown to provide much more product discrimination than liking alone and can help researchers to better understand consumer food choice (Thomson, Crocker and Marketo, 2010; Dalenberg *et al.*, 2014). While hedonic measurement primarily captures a single like-to-dislike dimension, consumer responses to food are multidimensional and have emotional, experiential aspects that extend beyond liking alone (Thomson, Crocker and Marketo, 2010).

A wide variety of methods, both implicit and explicit, have been proposed for measuring emotional responses. Generally, these methods can be classified into four categories: physiological measurement (e.g. heart-rate and brain responses), facial recognition (e.g. facial expression), behavioural tasks (e.g. Affective Priming Paradigm) and self-reported questionnaire (Lagast *et al.*, 2017). While implicit methods have gained interest, but its data is often difficult to interpret and not as discriminative as self-reported questionnaires (Beyts *et al.*, 2017). Although the self-reported questionnaire has been criticised for potential cognitive bias and high cognitive effort required to accurately report the emotions evoked by the product, due to the emotions being short-term. However, self-report emotion lexicons have been the most commonly used due to their accessibility, low cost and ease of data collection and analysis (Meiselman, 2021; Low *et al.*, 2022).

There are various methods for capturing self-reported emotional responses, such as using a generic emotion lexicon, a product-specific lexicon defined by consumers, visual cues like emojis, and PrEmo (Low *et al.*, 2022).

Among pre-defined emotion lexicons, EsSense Profile (King and Meiselman, 2010) and EsSense 25 (Nestrud *et al.*, 2016) are the most widely used. EsSense Profile and EsSense 25 have been used to capture emotional responses across a wide range of products, including beer (Luz *et al.*, 2024), coffee (Kanjanakorn and Lee, 2017), iced tea (Yang *et al.*, 2019) etc. EsSense profile has been criticised for largely consisting of positive emotions, and some emotion terms might not be relevant to specific product categories. Therefore, consumer-defined product-specific lexicons have

been suggested and developed to address such a challenge. Consumer-defined emotion lexicons have high ecological validity because they are tailored to specific food categories, resulting in much greater accuracy compared to pre-defined emotion lexicons (Panagiotou and Gkatzionis, 2022). However, the development of consumer-defined lexicons can be time-consuming and resource heavy (Panagiotou and Gkatzionis, 2022).

A specialised consumer-defined emotion lexicon was developed for meat and plant-based burger patties, capturing consumer emotional responses to these products (Orr *et al.*, 2023). It includes both generic food-related emotions and specific emotions linked to plant-based and beef patties, such as novelty, uncertainty, and deception. This consumer-defined emotion lexicon has 24 emotion terms, which have 11 positive emotions, 11 negative, and 2 unclassified emotions (See Table 1-1). In the current three chapters, all these emotion lexicons were used to measure product emotional responses.

Table 1-1 Consumer-defined emotion lexicon for meat and plant-based foods according to Orr et al. (2023)

Positive	Negative	Unclassified
Calm	Unhappy/ Sad	Curious
Adventurous	Dissatisfied	Neutral
Energetic	Angry	
Pleasant/ Grateful	Anxious	
Loving	Afraid	
Amazed	Suspicious	
Hopeful	Bored	
Happy	Disappointed	
Hungry	Deceived	
Nostalgic	Disgusted	
Satisfied	Uncertain	

1.8.4 Measure food choice in real-world context

Previous research has examined food choices in real-life contexts, such as restaurants and supermarkets, by observing actual consumption or purchase behaviour. For example, Carroll and Samek (2018) investigated hedonic responses and food selections in cafeteria settings, while Varela and Ares (2018) studied consumer choices during supermarket tasting sessions. These studies suggest that consumers' real-world decisions are shaped not only by product attributes but also by repeated interactions, contextual cues, and emotional responses, which are often overlooked in traditional sensory evaluations.

However, there is currently a lack of research exploring how consumers choose protein alternatives in real-world settings. As a result, it remains unclear whether preferences measured in laboratory sensory evaluations accurately predict actual selection and consumption behaviour. Integrating insights from recent advances in real-world consumer measurement, such as

combining behavioural observation with emotional and cognitive indicators, could provide a more accurate understanding of consumer decision-making for protein alternatives and improve predictions of market success.

1.9 Research objectives and knowledge gaps

The growth of research on consumers' protein alternatives underscores the importance of this topic. It also suggests a sense of urgency to bring about behavioural change in order to address the climate crisis. Therefore, any knowledge that contributes to this field is important, especially in an aimed to achieve the sustainable food goals. Nevertheless, certain research gaps have emerged that relate to the topics discussed and are highlighted below.

1.9.1 Knowledge gaps

- Liking can provide basic insights into consumer acceptance of protein alternatives. However, emotional responses can offer additional insights into consumer attitudes and preferences. Yet few studies have examined differences in emotional responses across protein alternatives (Schouteten *et al.*, 2016; Sogari *et al.*, 2024). This knowledge gap is discussed in Chapters 2, 3, and 4.
- Few studies evaluate the plant-based and hybrid burger sensory characteristics (Grasso *et al.*, 2022; Caputo, Sogari and Van Loo, 2023; Sogari *et al.*, 2024). However, no previous studies have investigated consumers' real food choices among plant-based, hybrid, and beef products in real-world settings. This research gap is addressed in Chapter 4.

- Few studies have explored consumer choice, liking and emotional responses and sensory perception in the real-world setting (Beyer *et al.*, 2024; Cobo *et al.*, 2025). However, no studies have explored how traditional sensory evaluation translates to real-world choice. This knowledge gap is addressed in Chapter 4.
- While food choice is dynamic, shaped by liking, expectations, prior experience that may evolve post-tasting or information exposure, no previous studies have examined repeated food choices of protein alternatives in real-world settings while capturing these dynamic changes. This knowledge gap is addressed in Chapter 4.

1.9.2 The overall objective of this research:

The overall aim of this thesis is to investigate consumer acceptance of diverse protein alternatives compared with the conventional beef burger, and how sensory experience, information sharing, and individual traits shape consumer choices, responses, interest in ordering, and perceptions. Three chapters have different objectives that are listed in each chapter. This thesis is structured into three empirical chapters, each addressing a different aspect of the overall research aim.

- Chapter 2 focuses on consumer perceptions, expected liking, and emotional responses toward different protein alternatives, including plant-based, edible insect, and lab-grown beef burgers. This chapter also examines the influence of individual traits, such as food neophobia and food disgust sensitivity, on consumer responses to these protein alternatives.

- Chapter 3 investigates the impact of multi-dimensional information: sensory, nutritional, and environmental, on consumers' interest in ordering and emotional responses toward protein alternative burgers, including plant-based, edible insect, and hybrid burgers.
- Chapter 4 examines consumer choices among conventional beef, hybrid, and plant-based burgers in a real food service context. In particular, this chapter assesses how tasting experiences and environmental information are associated with changes in burger selection across repeated visits.

The end goal is to establish a comprehensive foundation for designing targeted information interventions that promote sustainable protein alternatives by incorporating insights into consumer responses, the effects of information, and individual differences.

Chapter 2.

Investigate the environmental information sharing impact on consumers' responses to protein alternatives

Yuchen Zhang[a], Margaret Thibodeau[a], Rebecca Ford[a], Qian Yang[a]

[a] Sensory Science Centre, Division of Food, Nutrition & Dietetics, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough LE12 5RD, UK

Highlights:

- Consumers moderately liked the plant-based burger patty, which evoked neutral emotions.
- The lab-grown beef burger patty evoked bipolar emotions with moderate overall liking.
- *Food explorers* accept all protein sources with high openness.
- *Novel/disgust fearers* reduced their expected liking towards the edible insect burger patty more than *food explorers*.
- *Food tech fearers* significantly dislike the lab-grown beef burger patty compared with f*ood explorers.*
- *Everything fearers* liked lab-grown beef and edible insect burger patties the least compared with other consumers.

Abstract

Adopting more sustainable protein sources could be a key solution for making our current food systems more sustainable. This study aimed to investigate UK consumers' expected liking and emotional responses towards plant-based, edible insect, and lab-grown beef and conventional beef burger patties. Additionally, this study also explored the impact of sharing environmental information and how personal traits such as Food Neophobia (FN), Food Technology Neophobia (FTN), and Food Disgust (FD) influence their responses toward protein sources. In total, 574 UK meat-eating consumers conducted an online survey presented with a simulated shopping scenario. Participants were asked to imagine picking up each option from the shelf and imagining how much they would expect to like it and how it would make them feel. As expected, consumers gave the highest expected liking for conventional beef, which was associated with positive emotions. Plant-based and lab-grown beef burger patties were also generally liked, but their emotional profiles were quite different. Plant-based burger patty evoked expected neutral emotions (e.g., *Bored* and *Neutral*), whereas lab-grown beef burger patty evoked bipolar emotions (e.g., *Amazed*, *Hopeful*, *Deceived*, *Uncertain*). The edible insect burger patty was the least liked and evoked negative emotions (e.g., *Disgust*). A significant but small effect was found from sharing environmental information about any of the protein sources.

Further cluster analysis of mean scores for FNS, FTNS, and FD identified four consumer segments: *food Explorers*, *everything fearers*, *novel/disgust fearers,* and *food tech fearers*. *Food explorers* who exhibit high expected liking across all protein sources. *Novel/disgust fearers* and *food tech fearers,* who reduced the expected

liking for protein alternatives for edible insect and lab-grown beef burger compared with *food explorers*. These findings highlight the importance of understanding consumer emotions and tailoring strategies to promote acceptance of sustainable protein sources in the UK.

2.1 Introduction

With the global challenges of population growth, ageing, and climate change, there is a growing global demand for a sustainable food system transition. The current global food systems and consumer consumption patterns are unsustainable for human and planetary health (Alae-Carew *et al.*, 2022). The United Nations (UN) emphasised that '*Unless we act now, the 2030 Agenda will become an epitaph for a world that might have been*' (United Nations, 2015). One of the options to achieve environmentally friendly development goals is to consume more sources of sustainable food products. Reducing red meat consumption and increasing the intake of sustainable protein alternatives represent potential strategies to facilitate the transition toward a sustainable food system (Jarmul *et al.*, 2020).

Protein sources have been the target product categories to deliver a more sustainable food, as it is well-known that red meat is generally known to generate much higher greenhouse gas emissions, for example, beef produced from cattle herds has emissions of approximately 99.48 kg CO_2 equivalents per kilogram of herd beef, which is significantly higher than plant-based protein (0.48 kg of CO_2 equivalents) (Heller and Keoleian, 2018; Poore and Nemecek, 2018). With the increasing global demand for protein, there is a need for a wide range of protein sources that are accessible and accepted by consumers. The main categories of protein alternatives include meat substitutes, plant-based protein, cultivated meats,

mycoproteins, algae, insects, and hybrid meats (Nguyen *et al.*, 2022). Plant-based proteins are derived from plant sources, and the most commonly used is soya-based (He *et al.*, 2020).

Lab-grown meat, also known as cultured meat or cultivated meat, is produced from animal cells taken from living animals and then grown in a nutrient-rich medium in a controlled environment (Bryant and Barnett, 2020). In December 2020, the California startup 'Eat Just™' received regulatory approval in Singapore for the world's first cell-cultured meat product, deemed safe for consumption and commercial sale. This first cell-cultured meat product is composed of 70% cultured chicken cells and plant protein (Waltz, 2021). The UK has emerged as an active investor in the development of lab-grown (cultivated) meat technologies. While lab-grown meat has not yet been approved for human consumption, a significant regulatory milestone was reached in 2024. Lab-grown meat was approved for use in pet food in 2024, with a company called 'Meatly™' having launched a limited release of chicken dog treats made with plant protein and 4% cultivated chicken, marking the first commercial application of cultivated meat in the UK market (Meatly, 2025). This early-stage approval signals both regulatory openness and growing commercial momentum, suggesting that human food applications may follow in the foreseeable future. As public and private investment in the lab-grown meat sector continues to grow, understanding consumer expectations becomes increasingly important.

Edible insects have been consumed historically across many cultures, including African and Asian; however, they are generally considered a novel protein source for Western consumers (Ardoin and Prinyawiwatkul, 2021). In the UK, several edible insect species (e.g., yellow mealworm, house cricket, branded cricket, black soldier

fly) have been approved for human consumption by the Food Standards Agency (FSA, 2025). Therefore, compared to lab-grown meat, edible insects are at a more advanced stage of regulatory approval and commercial readiness. Despite the regulatory approval, the market for edible insect products in the UK remains limited. Consumer acceptance of edible insects is shaped by cultural norms, food neophobia, and disgust sensitivity; these psychological barriers can limit consumer willingness to try or consume edible insect food products. Therefore, studying personal traits could provide additional insights towards these novel protein alternatives (Moher *et al.*, 2009; Li *et al.*, 2022). The most popular personal traits have been studied, including Food Neophobia (FN), Food Technology Neophobia (FTN), and Food Disgust (FD).

FN is defined as an aversion to trying new or novel foods, which can be measured using the Food Neophobia Scale (Pliner and Hobden, 1992; Rabadán and Bernabéu, 2021). High food neophobia consumers have shown to have lower acceptability of a range of protein alternatives, such as plant-based protein, lab-grown meat, and edible insect (Siegrist and Hartmann, 2019; Wilks *et al.*, 2019; Maria Valentina *et al.*, 2023). FD serves as an emotion that prompts the rejection of food, primarily aimed at averting the consumption of substances that may be harmful or contaminated with pathogens (Hartmann and Siegrist, 2018; Thibodeau *et al.*, 2021). A person's sensitivity to food disgust can be measured using the Food Disgust Scale (Hartmann and Siegrist, 2018; Thibodeau *et al.*, 2021). Hartmann and Siegrist (2018) found that food disgust sensitivity significantly affects consumer edible insect acceptability. FTN was developed by Cox and Evans (2008) to measure reluctance towards new food technologies. Recent research found that individuals

with high food technology neophobia are less willing to try new foods produced by novel technologies, especially lab-grown meat (Krings, Dhont and Hodson, 2022; Wendt and Weinrich, 2023). Although these personal traits have been explored in different studies, the interrelationships among these three traits and their impact on protein alternative acceptability have not been fully examined.

Sharing information as an intervention strategy to enhance consumer acceptance of protein alternatives has always been a focus of research (Schouteten *et al.*, 2016; Broeckhoven *et al.*, 2021; Onwezen *et al.*, 2021; Grasso *et al.*, 2022; Greene, Yuheng Zhu and Dolnicar, 2023; Segovia, Yu and Van Loo, 2023). It has been shown that information presented on the front of food packaging, incorporating text and imagery (Schouteten *et al.*, 2016; Grasso *et al.*, 2022; Segovia, Yu and Van Loo, 2023), utilising food-labelling strategies (Broeckhoven *et al.*, 2021), have significantly increased consumer liking towards protein alternatives. In addition, the health and environmental benefits of concise texts and carbon labelling have been shown to positively impact consumer acceptance in overall liking and purchase intention (Van Loo, Caputo and Lusk, 2020; Yang *et al.*, 2020; Broeckhoven *et al.*, 2021). However, studies also suggest that the impact of sharing information is limited. Grasso *et al.* (2022) indicated that food ingredient information did not significantly impact the overall liking of the hybrid burger (60% beef and 40% vegetables) and Laureati *et al.* (2016) found a marginal but positive impact of environmental and nutritional information on the acceptance of edible insects.

Therefore, studying consumer expectations and responses to novel protein sources such as lab-grown meat and edible insects, as well as more market available products such as plant-based, can help researchers to understand consumer

expectations towards different protein alternatives and how specific information can influence their responses. Such insights are critical for informing product design and communication strategies. More specifically, this study aimed to 1) Explore UK consumers' liking/ purchase intention and emotional responses towards plant-based, edible insect, lab-grown and conventional beef burgers; 2) Investigate how sharing environmental information influences consumer response to the four protein sources; 3) Understand how personal traits (Food Neophobia, Food Technology Neophobia and Food Disgust) influence consumer responses to the four protein sources and the interrelationship between the three personal traits.

2.2 Materials and Methods

2.2.1 Participant and survey structure

A convenience sample of participants was recruited (1) via email and poster advertisement across the University of Nottingham's campus and (2) via Prolific (www.prolific.com). Following the completion of the study, participants were offered the opportunity to enter a voluntary prize draw (university participants) or paid a nominal fee (Prolific). Participants were eligible for the study if they were 18 years old or older, had lived in the UK for at least 3 months and self-reported as meat eaters (omnivores and flexitarians). As this study was collecting responses to conventional beef products, non-meat eaters (vegetarians, vegans, and pescatarians) were excluded from the study. The study was reviewed by the University of Nottingham's School of Bioscience Research Ethics Committee and was granted a favourable ethical opinion (SBREC202223026FEO).

A total of 933 participants consented to take part in the study. However, 332 participants (35.8%) were excluded for not completing all questions in the survey.

Participants (n=27) were also excluded for completing the questionnaire too quickly if their completion time was less than 60% of the median response time within their respective video exposure condition, which was 11 minutes for participants who watched the video and 7 minutes for those who did not (Jaeger and Cardello, 2022). Thus, a convenience sample of 574 participants (33 ± 12 years, 408 female and 166 male) was retained for the analysis. The study was divided into three sections, which are summarised in Figure 2-1. Further details of each section are also provided in the order completed by the participants below.

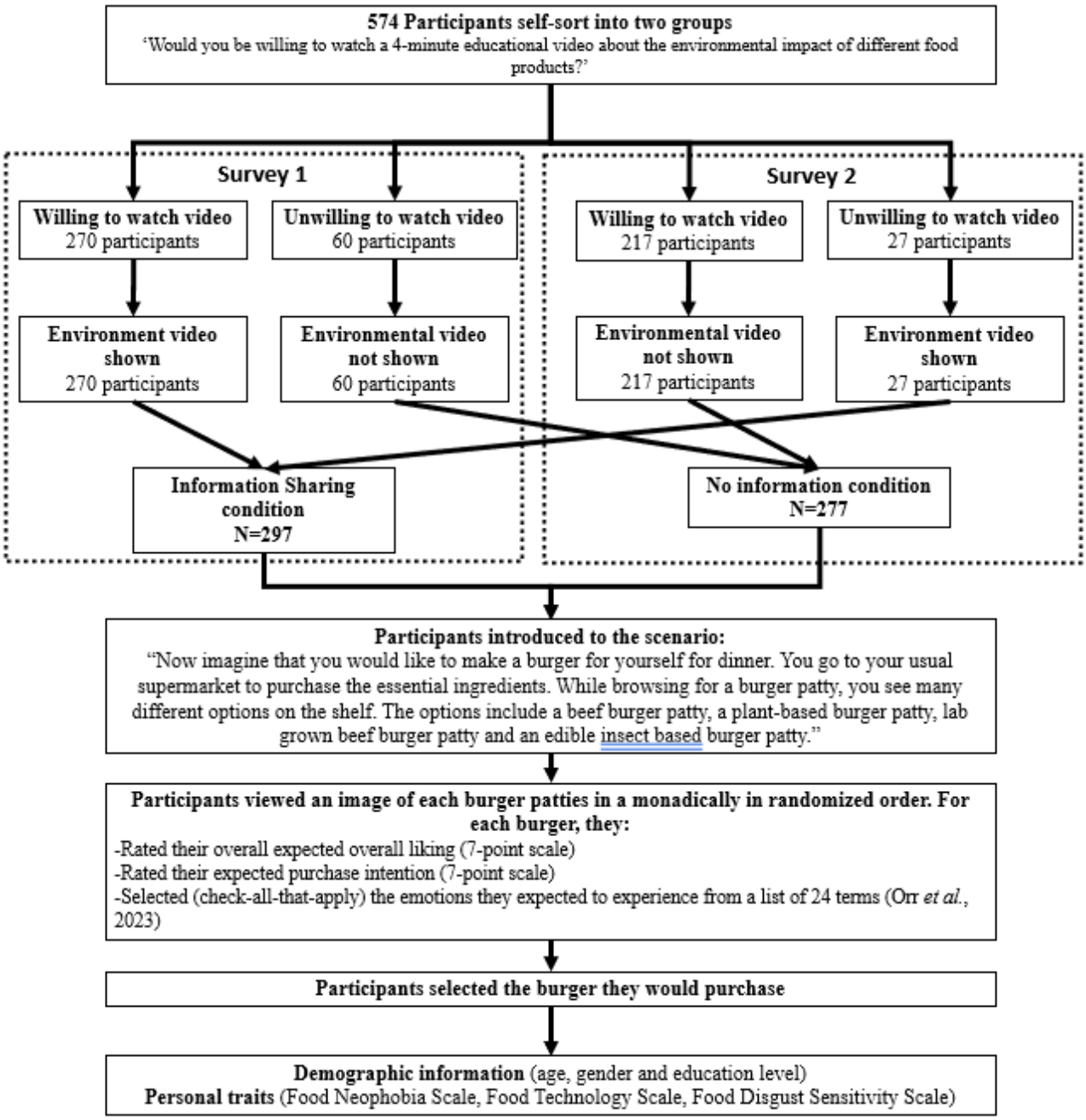


Figure 2-1 Survey structure flowchart showing only included participants (n = 574).

2.2.2 Food-related environmental impact video and sharing conditions.

To explore the effect of providing information on food's environmental impact to consumers, a 5-minute video was developed focusing on the greenhouse gas

emissions of different food groups (Ford *et al.* (2024a); https://mediaspace.nottingham.ac.uk/media/t/1_ekt5gwdh). It explained that food production accounts for about 26% of global human-related greenhouse gas emissions, with about half of those coming from meat. For example, producing 1 kilogram of beef burgers emits roughly 54 kg of CO_2 equivalents, which is comparable to a short-haul flight. In contrast, many plant-based foods have much lower emissions, often under 2 kg of CO_2 equivalents. The video also introduced lab-grown meat as a potential low-emission protein alternative with 87% lower emissions compared to conventional beef. The video briefly explained the production method of lab-grown meat, whereby animal cells are cultivated in fermentation tanks to form muscle tissue. The video also talked about edible insects, such as mealworms, which emit about 50 times less emissions than conventional beef. A full transcript of the video is available in Appendix A.

Online questionnaires were administered using Compusense Cloud (Compusense, Canada). Two separate but structurally identical 15-minute online questionnaires were used as described in Figure 2-1. The only difference between the two surveys was the strategy used to expose participants to the environmental video. In Survey 1, participants were asked if they were willing to watch the video. Those who agreed were shown the video, whereas those who declined were not. This approach resulted in an unbalanced sample, with 81.1% of participants opting to watch the video. To address this imbalance, the allocation strategy was reversed in Survey 2. Participants who were unwilling to watch the video were shown the video (88.9%), while those who were willing were not. This counterbalancing approach aimed to improve the distribution of participants between the two video exposure conditions.

Across both surveys, only 15.2% of participants were initially unwilling to watch the video. Therefore, data from both surveys were pooled and analysed solely based on whether participants watched the video (information-sharing condition, n = 297, 51.7%) or did not (no-information condition, n = 277, 48.3%). This allowed for a more balanced and robust assessment of the video's impact on emotional responses to the protein sources. Although the software could not confirm whether participants in the information-sharing condition watched the video, a 5-minute timer prevented them from accessing the next page of the questionnaire, limiting their ability to skip the video.

2.2.3 Shopping Scenario & Products

To explore the impact of burger patty type on consumer responses, a written scenario was used to simulate the context, as follows: 'Now imagine that you would like to make a burger for yourself for dinner. You go to your usual supermarket to purchase the essential ingredients. While browsing for a burger patty, you see many different options on the shelf. The options include a beef burger patty, a plant-based burger patty, a lab-grown beef burger patty and an edible insect-based patty.' Below the written scenario, participants were also able to see an image of all four burger packages (Table 2-1).

The packaging was designed to simulate a supermarket environment and to convince participants that alternative products were meat-like, with similar sensory qualities to a conventional burger. A background image of a person holding a tray with two burger patties at a supermarket was downloaded from Shutterstock. The packaging format and design were kept largely consistent for all four products.

However, the top portion of the label was customised for each burger patty type by changing the name and adding an image of the main protein source. Raw beef patties were selected for the top of the label of both beef products (conventional beef and lab-grown patties).

For the lab-grown beef patty, an image of raw beef patties identical to that of conventional beef was used, rather than visuals of cell cultures or laboratory cultivation scenes. This decision was based on two key reasons. First, commercially available lab-grown meat products do not exist on the market and are expected to mimic the visual appearance and texture of conventional beef. Second, using laboratory-associated imagery would likely evoke perceptions of ‘artificiality’ and unnaturalness, potentially leading to mixed consumer responses independent of sensory characteristics. To ensure our experiment focused on perceived sensory similarity, the lab-grown beef burger picture was consistent with conventional beef.

For the edible insect burger, an image of whole buffalo worms was used to clearly identify the primary protein source. This approach is justified by the need to maintain consistent labelling within the four products, ensuring that participants accurately recognise the key ingredient. Visual presentation is known to strongly shape consumer responses to insect-based foods: exposure to whole insects may evoke disgust, food neophobia, or negative emotional reactions, whereas images of processed, invisible insect materials could reduce aversion and improve acceptance. The plant-based burger patty, an image of peas, was displayed.

258 *Table 2-1 Summary of names, images, and descriptions of the four burger patty*
259 *types*

Burger Patty Type	Image	Description
Conventional beef burger patty		This beef burger patty is made from meat from cows that were raised by conventional methods on a farm.
Plant-based burger patty		This plant-based patty is made with peas, with no animal products
Lab-grown beef burger patty		This lab-grown beef patty is produced using animal cells that are taken from living cows. The cells are fed animal-free nutrients and transferred to fermentation tanks which allow them to grow into muscle strands before being formed into a burger.
Edible insect burger patty		This edible insect burger patty is made from buffalo worms, blended with plant-based ingredients.

After reviewing the context, participants evaluated each of the burger patties monadically in randomised order. Participants were asked to imagine picking up each product from the shelf based on the image provided, with a short written description (Table 2-1). Next, the participants rated their expected overall liking (7-point hedonic scale) and expected purchase intention (7-point scale).

A 7-point hedonic scale was used in this online survey instead of the traditional 9-point scale to improve participant experience and data quality (Lewis and Erdinç, 2017). The 9-point scale offers greater sensitivity in capturing subtle differences in consumer preferences. It may impose a higher cognitive burden on respondents, particularly in unmoderated online settings (Lewis and Erdinç, 2017).

In contrast, the 7-point scale simplifies the evaluation process, making it more suitable for online surveys by reducing cognitive load and improving response consistency. While this reduction in scale points may slightly limit the sensitivity to detect small differences in liking, it can enhance overall data reliability by minimising random error and inconsistent responses (Lewis and Erdinç, 2017). Taken together, the use of a 7-point scale represents a trade-off between sensitivity and data quality, with greater emphasis placed on obtaining reliable and interpretable data in an online research context.

Participants then rated emotional responses for each product by using the plant-based specific emotion lexicons using ‘check all that apply (CATA)’ (Orr *et al.*, 2023). The emotion terms were presented in a balanced randomised order across participants but kept consistent for each participant. Capturing consumer emotional responses to different protein alternatives could provide valuable information, as emotional response has been shown to offer additional data than hedonic liking

alone (Ng, Chaya and Hort, 2013; Yang *et al.*, 2020). This study used a product-specific emotional lexicon developed by Orr *et al.* (2023). After participants had evaluated all products, they were asked to indicate ‘Which burger patty do you think you would like to purchase and take home?’.

2.2.4 Demographics and personal traits

Participants were asked to answer a range of demographic questions (e.g., age, gender and education level). Next, participants completed the Food Neophobia Scale (FNS, 10-items, score range 10-70, (Pliner and Hobden, 1992)), and the Food Technology Neophobia Scale (FTNS, 13-items, score range 13-91, (Cox and Evans, 2008)), and a modified version of the short Food Disgust Sensitivity Scale (FDS, all items except LCON1, 7 items, score range 7-42), by using a 6-point scale from ‘Not Disgusted (grossed out) at all’ to ‘Extremely disgusted (grossed out)’ (Hartmann and Siegrist, 2018; Thibodeau *et al.*, 2021). Responses were summed to obtain three scores for each participant, one for each of the personal trait’s scales. All three personal traits had acceptable internal consistency based on Cronbach’s Alpha (Tavakol and Dennick, 2011), FNS (Cronbach's alpha = 0.70), FTNS (Cronbach's alpha = 0.80) and FDS (Cronbach's alpha = 0.70).

To better interpret and compare differences across the three personal traits, scores were z-score normalised to centre the data around the mean and standard deviation for easier comparison across scales (Thibodeau *et al.*, 2021). Because the scales have different score ranges, this makes it easier to visually identify which segments scored higher or lower than average across the three traits.

2.2.5 Data analysis

To address the study objectives, a series of statistical analyses was conducted. All data were analysed using XLSTAT (Addinsoft, 2019). A significant value of $p<0.05$ was adopted for all hypothesis tests. Tukey's HSD and partial eta^2 (η_p^2) were used as the post-hoc test and measure of effect size for all ANOVAs. The Sheskin procedure was selected as the post-hoc test for Cochran's Q. The partial eta2 (ηp^2) guideline is $\eta^2 < 0.01$ is 'negligible', $0.01 \leq \eta^2 < 0.06$ is 'small', $0.06 \leq \eta^2 < 0.14$ is 'medium' and $\eta^2 \geq 0.14$ is 'large' (Cohen, 2013; Jaeger, Chheang and Ares, 2025).

To examine product differences, one-way ANOVAs were performed to test for significant differences in liking and purchase intention between the four products. Pearson's correlation was used to examine the correlation between liking and purchase intention. Correspondence analysis and Cochran's Q tests were used to test if differences between the four products existed for the citation proportion of the emotion terms. A two-way ANOVA was performed to test the impact of information sharing and product type, as well as information × product interactions for liking and purchase intention.

To further explore cluster patterns for the three personal traits (FNS, FTNS, and FDS), Agglomerative Hierarchical Clustering (AHC) using Ward's method with Euclidean distance (centre and reduce) was performed based on participants' average FNS, FTNS, and FDS scores. Four clusters were generated. To better understand the clusters, z-score standardisation was performed on FNS, FTNS and FDS scores, making it easier to identify which segments scored higher or lower than average for each of the three personal traits. One-way ANOVA was conducted to examine the differences between clusters on the FNS, FTNS, and FDS scores.

Similarly, ANOVA was used to test for differences in mean age between the clusters. Finally, differences between the clusters based on gender, education, diet, and willingness to watch the video were tested using the Chi-square test.

A two-way ANOVA was used to test for differences among the personal trait clusters in liking for the burger patties. Samples (four products), consumer cluster, and their interaction term (cluster × sample) were treated as fixed effects. Similarly, to explore differences in emotional responses, two-way ANOVAs were conducted using the raw CATA emotion count data as the dependent variable, following the procedure outlined in Meyners and Hasted (2021). The purpose of this step was to identify statistically significant interaction effects between personal trait clusters and burger patty type. For those emotion attributes with significant interactions ($p < 0.05$), further multivariate analysis was performed. To account for unequal cluster sizes, emotion counts were converted to selection percentages by dividing the number of selections for each emotion by the total number of respondents within each cluster multiplied by 100. These percentage values were then subjected to Principal Component Analysis (PCA) to visualise the underlying structure of emotional profiles and to further interpret the nature of the interaction effects observed in the ANOVA.

2.3 Results

2.3.1 Overall liking, purchase intention and emotional responses

One-way ANOVA indicated a significant difference among the four burger patties (Figure 2-2). A ($F(3, 2292) = 402$, $p<0.001$, $\eta^2 = 0.39$). Post-hoc tests revealed that all four products had significantly different liking scores from each other. Overall, the conventional beef burger patty was most liked, with a mean liking around ‘liked moderately’ (M = 6.24). On average, the plant-based burger patty was ‘slightly liked’

354 (M = 4.83), while the lab-grown beef burger patty (M = 4.32) was closer to ‘neither
355 liked nor disliked’. The edible insect burger patty had the lowest mean liking score (M
356 = 2.65), which was between ‘dislike slightly’ and ‘dislike moderately’.

357

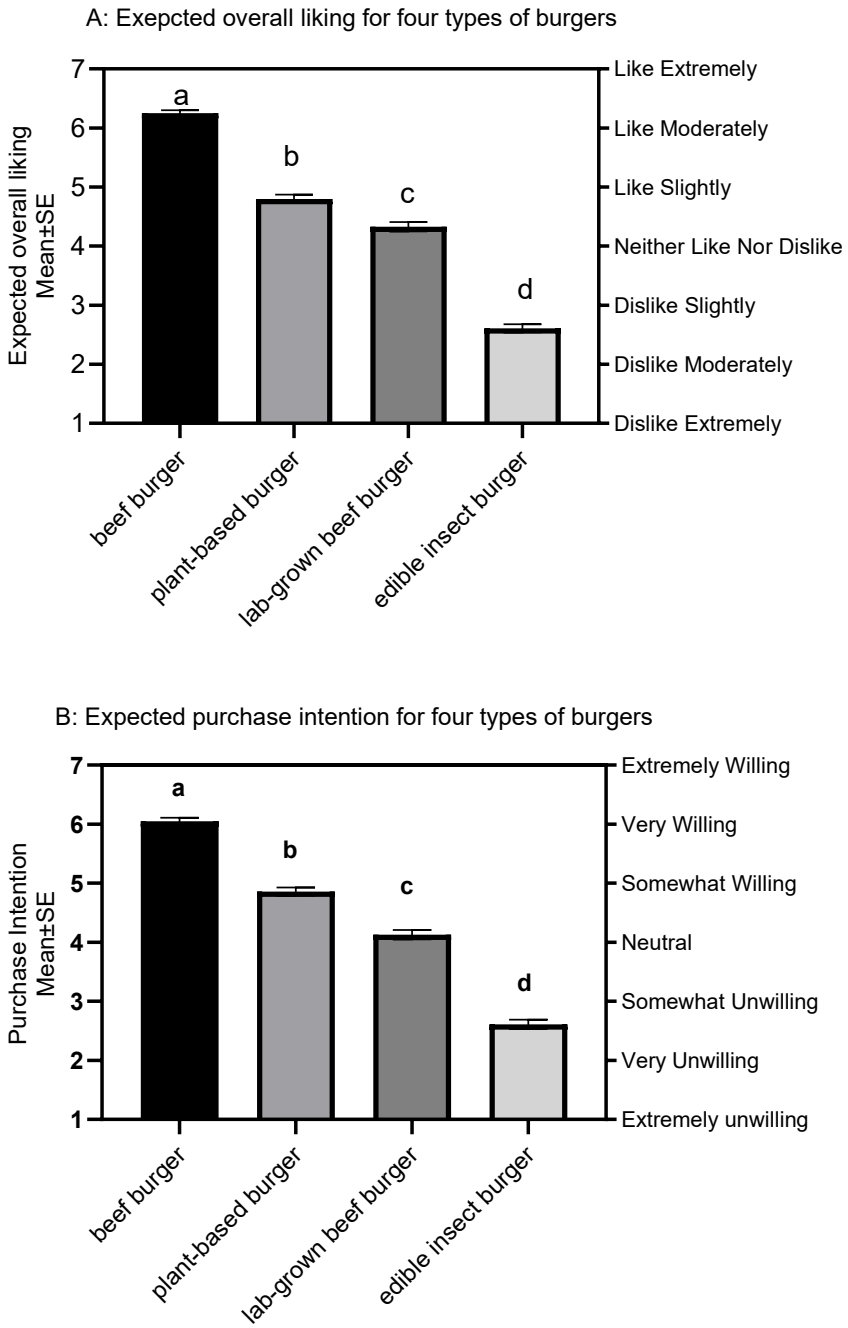


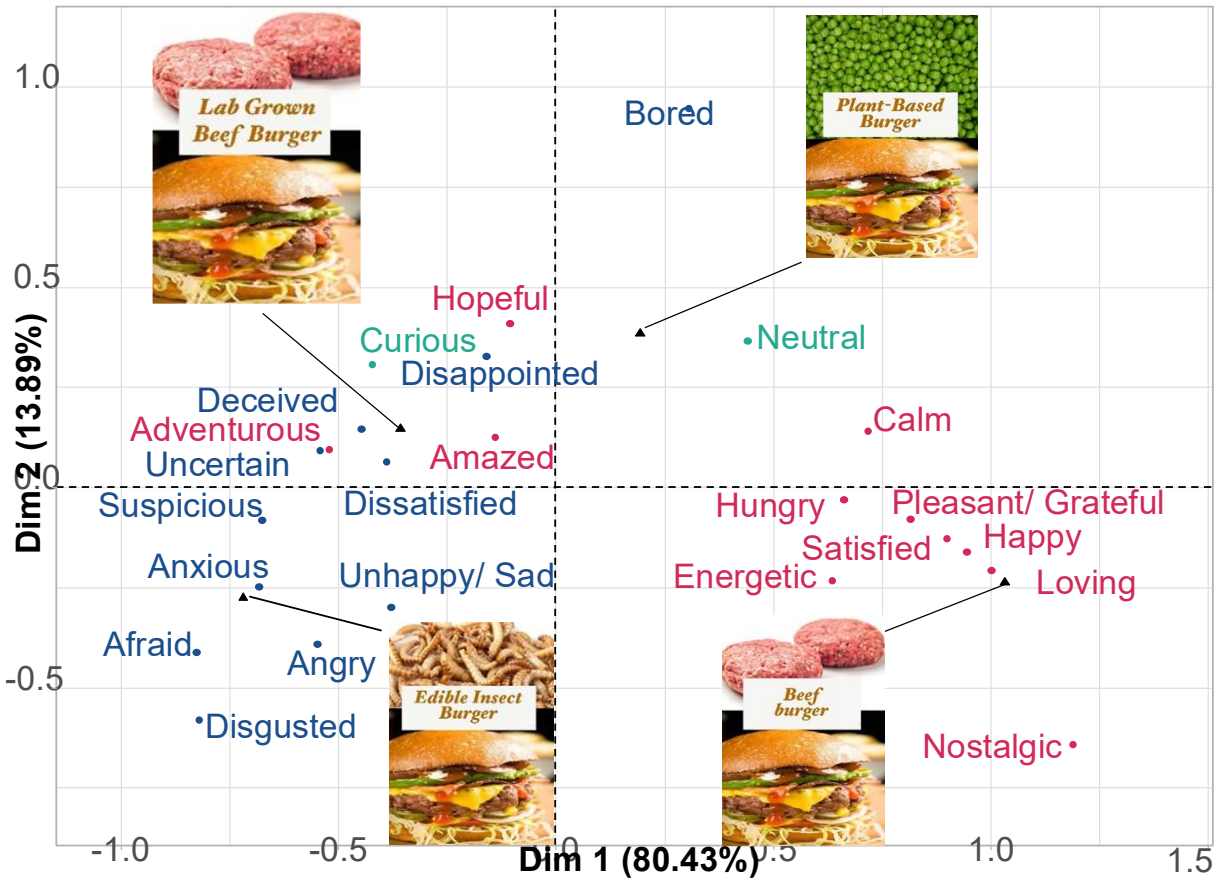
Figure 2-2 Mean with standard error (SE) expected overall liking (A) and purchase intention (B) of the four burger patty types (conventional beef, plant-based, lab-grown and edible insect burger patties. Products that differ significantly in liking are indicated with different letters ($p<0.05$, One-way ANOVA, Tukey's HSD)

Participant's purchase intention for the burger patties was consistent with liking (Figure 2-2B) as participants were more willing to consume the burgers that they expected to like. One-way ANOVA confirmed that purchase intention for all the products was significantly different ($F(3,2292) = 402$, $p<0.001$, $\eta^2=0.34$). As overall liking and overall purchase intention were highly correlated ($r(3) = 0.871$, $p<0.001$), no further analysis of the purchased intention data was performed.

Significant differences in the citation proportions were found between the burger patties for all the emotion terms (Cochran's Q, $p<0.05$, Appendix B Table S 6-1). Thus, correspondence analysis was performed on the full lexicon (Figure 2-3). A clear separation between the four burger patty types can be seen, indicating each product evoked a different emotional response. Dimension 1 explained 80.5% of the variation and Dimension 2 explained 13.9% of the variance. Dimension 1 separated mainly from positive emotions to negative emotions. The positive emotions (*satisfied*, *happy*, *pleasant/ grateful*, *hungry*) and the unclassified emotion *neutral* were largely selected for the products that are currently available in the UK market, namely the conventional beef and plant-based burger patties. While for the positive emotions the citation proportion was higher for the conventional beef burger patty than the plant-based burger patty, the opposite trend was observed for neutral.

The negative emotions were generally associated with the products not currently available at UK supermarkets, namely the lab-grown beef and edible insect burger patties. Some of these emotions were cited equally for both products (*uncertain*, *suspicious*, *adventurous*), while others were cited more frequently for the edible insect burger patty (*disgusted*, *anxious*, *afraid*).

Lab-grown burger patty also evoked negative emotions of *deceived* and *uncertain* emotions, and positive emotions *hopeful* and *amazed*. This suggests that the lab-grown burger evoked bipolar emotions. Similarly, participants were more likely to select *hopeful* for the plant-based burger patty than for the conventional beef burger patty. Moreover, a significantly higher proportion of participants expected to be *dissatisfied* and *disappointed* by the edible insect and plant-based burger patties compared to the products made with beef. Finally, *curiosity,* an unclassified emotion*,* was selected most frequently for the lab-grown beef burger patty. *Curious* was also selected to a lesser extent, for the edible insect and plant-based burger patties but was generally not selected by participants in responses to the conventional beef burger patty.



399

400 *Figure 2-3 Overall emotional response evoked by the four burger patty types*
401 *(conventional beef, plant-based, lab-grown beef and edible insect). Emotions are*
402 *classified into positive (n = 11, red), negative (n = 11, blue) and unclassified (n = 2,*
403 *green) groups based on Orr et al. (2023).*

404 After evaluating the products monadically, participants were asked to select the
405 burger patty type they would hypothetically purchase. Most participants (63.2%)
406 selected the conventional beef burger patty, which is consistent with the fact that it
407 scored highest for liking and was most closely associated with the positive emotions.
408 Also consistent with liking scores, the plant-based burger patty (19.4%) was next
409 most selected, followed by the lab-grown beef burger patty (14.9%) and the edible
410 insect burger patty (2.5%).

2.3.2 The impact of sharing information on consumer responses to protein sources

Two-way ANOVA found a significant information impact for expected liking, that the 'information sharing' group had higher expected liking scores for the burger patties than the 'no information' group (F (1, 2288) = 5.1, p = 0.02, effect size (η^2) = 0.001). A significant interaction between burger patty and information sharing group (F (3, 2288) = 497.8, p < .0001, effect size (η^2) = 0.40) was also found. No significant information sharing impact was found for conventional beef, plant-based and edible insect burger patties, sharing information significantly increased expected liking for the lab-grown beef burger patty. Consistent with the 1-way ANOVA results, there was a significant main effect of burger patty type, (F (3, 2288) = 4.4, p = 0.005, effect size (η^2) = 0.006, which is considered a negligible effect. As the other effect sizes in the model are considered small, it can be concluded that participants had clear preferences among the four burger options, but that the environmental video only had a limited influence on participants' burger patty preferences (Figure 2-4).

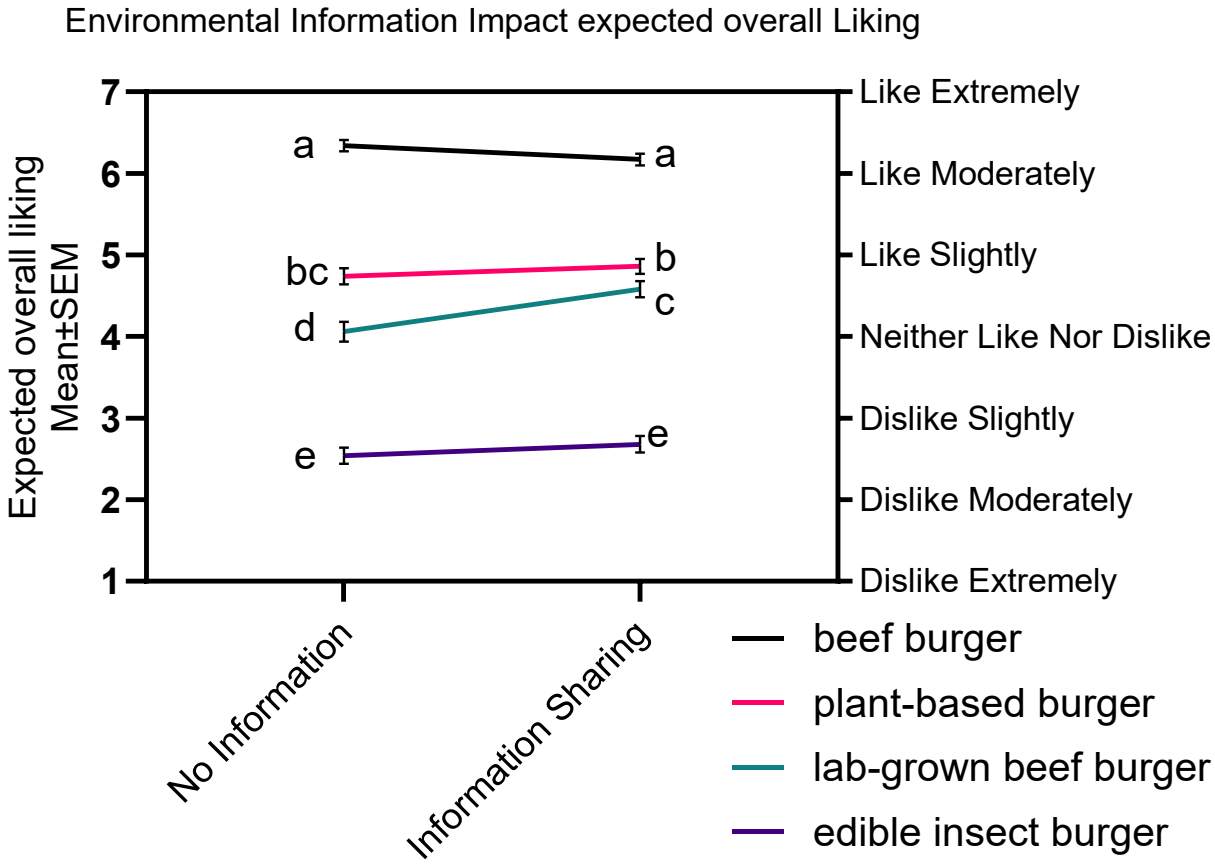


Figure 2-4 Interaction plot comparing the mean liking scores of participants in the 'no information' and 'information sharing' groups across the four burger patty types (conventional beef burger, plant-based burger, lab-grown beef burger and edible insect burger). Products that differ significantly in liking are indicated with different letters ($p<0.05$, 2-way ANOVA interaction, Tukey's HSD).

2.3.3 Personal traits clusters

Cluster analysis of FNS, FTNS and FDS z-score led to the identification of four consumer clusters, each with a distinct combination of personal traits. Figure 2-5 presents the mean standardised z-scores for each of the scales by consumer clusters. Mean z-scores above zero indicated that participants exhibited higher levels of these traits compared to the overall mean score with the whole study population,

whereas a score below zero reflects lower levels. One-way ANOVAs confirmed that significant differences in FNS, FTNS and FDS scores were found between the clusters. The differences between the clusters are summarised below, with full details available in Appendix B Table S 6-2.

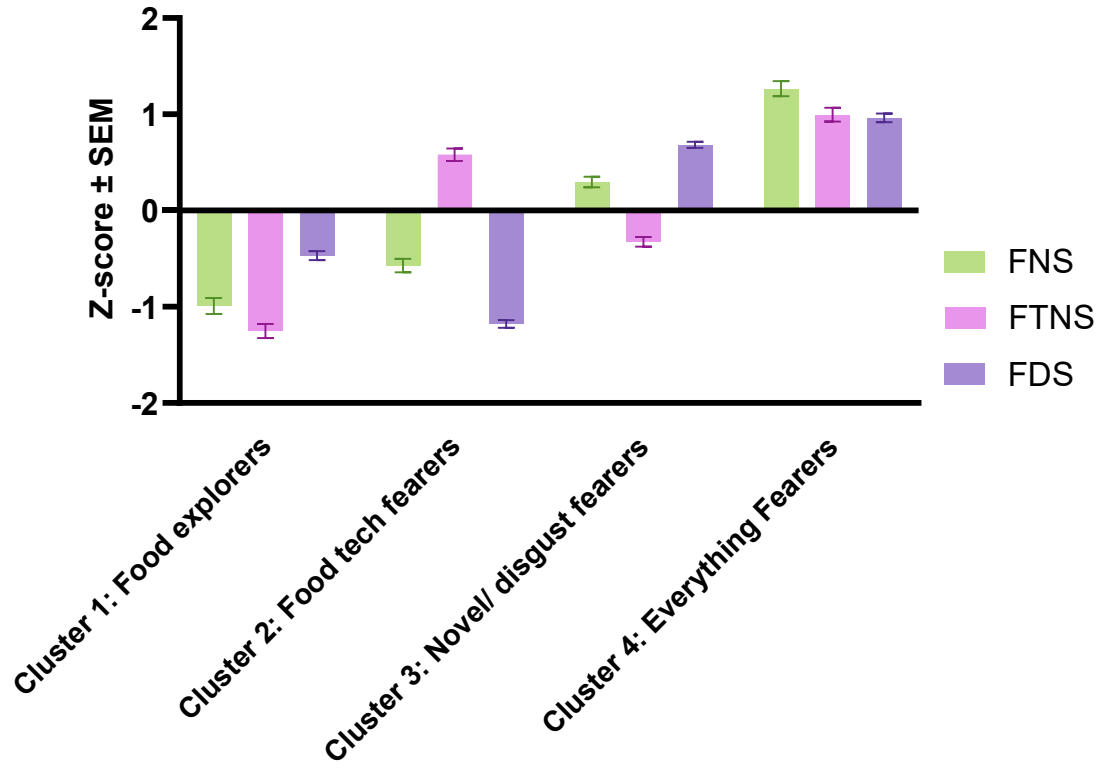


Figure 2-5 Mean (±SEM) scores for the food neophobia scale (FNS), the food technology neophobia scale (FTNS) and the food disgust sensitivity scale (FDS) for each of the consumer clusters (food explorers (n = 122, 21%), everything fearers (n = 128, 22%), novel/disgust fearers (n = 182, 32%), food tech fearers (n = 142, 25%)).

Cluster 1 (21%) had the lowest mean FNS and FTNS, with z-scores approximately one standard deviation below the mean. Thus, Cluster 1 has the lowest general and food technology neophobia and disgust traits and can be considered as the most open to trying new and unfamiliar foods, even if these foods are made with novel technologies. Furthermore, Cluster 1 also had the second lowest mean FDS scores, indicating that participants in Cluster 1 experienced relatively low levels of disgust in

456 food and food-related situations. Therefore, Cluster 1 was named *food explorers*. In
457 contrast, Cluster 4 (22%) had the highest mean score on FNS, FTNS, and FDS, with
458 scores all one standard deviation above the mean. Thus, compared to the other
459 clusters, Cluster 4 experiences the most neophobia and food-related disgust,
460 suggesting that they are likely more cautious or hesitant about all types of foods. As
461 a result, Cluster 4 was named as *everything fearers*.

462 The remaining clusters displayed a combination of high and low responses,
463 indicating a more varied pattern across the personal traits. Cluster 2 (25%) had the
464 second highest FTNS scores, but their mean FNS (second lowest) and FDS (lowest)
465 scores were below average. Taken together, these results suggest that for Cluster 2,
466 consumers who are afraid of novel food technology are the personal trait that is most
467 likely to impact food-related behaviour. Thus, Cluster 2 was named *food tech fearers*.

468 Cluster 3 was the largest cluster (32%), and when compared to Cluster 2, showed
469 the opposite trend. Mean scores for Cluster 3 were above average for FNS and FDS
470 (both second highest) but were lower for FTNS (second lowest). Thus, this suggests
471 that for Cluster 3, the inherent characteristics of foods themselves (e.g., novelty or
472 ability to elicit disgust) rather than the processes used to produce them are more
473 likely to impact their behaviour. Thus, they were named *novel/disgust fearers*.

474 Chi-square revealed a significant association between personal trait cluster and
475 dietary preference and willingness to watch the environmental video ($p<0.05$).
476 N*ovel/disgust fearers* (Cluster 3) were more likely to identify as flexitarian (12.6%)
477 and less likely to identify as omnivores (87.4%) than other clusters (flexitarians (3.9-
478 4.9%) and omnivores (95.1-96.1%) (Table S 6-2).

For willingness to watch video, fewer *everything fearers (78.12%)* were willing to watch the environmental video, while the opposite was true for *food explorers* (91.80%). No significant differences between the clusters were found based on age (ANOVA, $p = 0.31$), gender (Chi-square, $p = 0.21$), or education level ($p = 0.2$) show in Table S 6-2.

2.3.4 The impact of personal trait cluster on consumer responses

Two-way ANOVA revealed a significant main effect for personal trait cluster ($F(3, 2280) = 62.9$, $p<0.0001$, effect size (η^2) = 0.076, Figure 2-6). *Food explorers* reported the highest overall liking scores, and *everything fearers* have the lowest liking scores. *Food tech fearers* and *novel/disgust fearers* are between the above two clusters and did not differ from one another. A significant interaction between burger patty type and cluster was also found ($F(9, 2280) = 9.27$, $p<0.0001$, effect size (η^2) = 0.035). While the expected liking of the conventional beef burger patty did not differ between the clusters, significant differences were found for the plant-based, lab-grown beef and edible insect burger patties. The *food explorers* had significantly higher liking scores for the three burgers than the *everything fearers*. The most pronounced difference was found in the lab-grown beef burger patty, with *food explorers* expecting to moderately like it and *everything fearers* expecting to dislike it slightly. While significant differences were found for the plant-based and edible insect burger patties between clusters, the difference was not as wide as that of lab-grown beef.

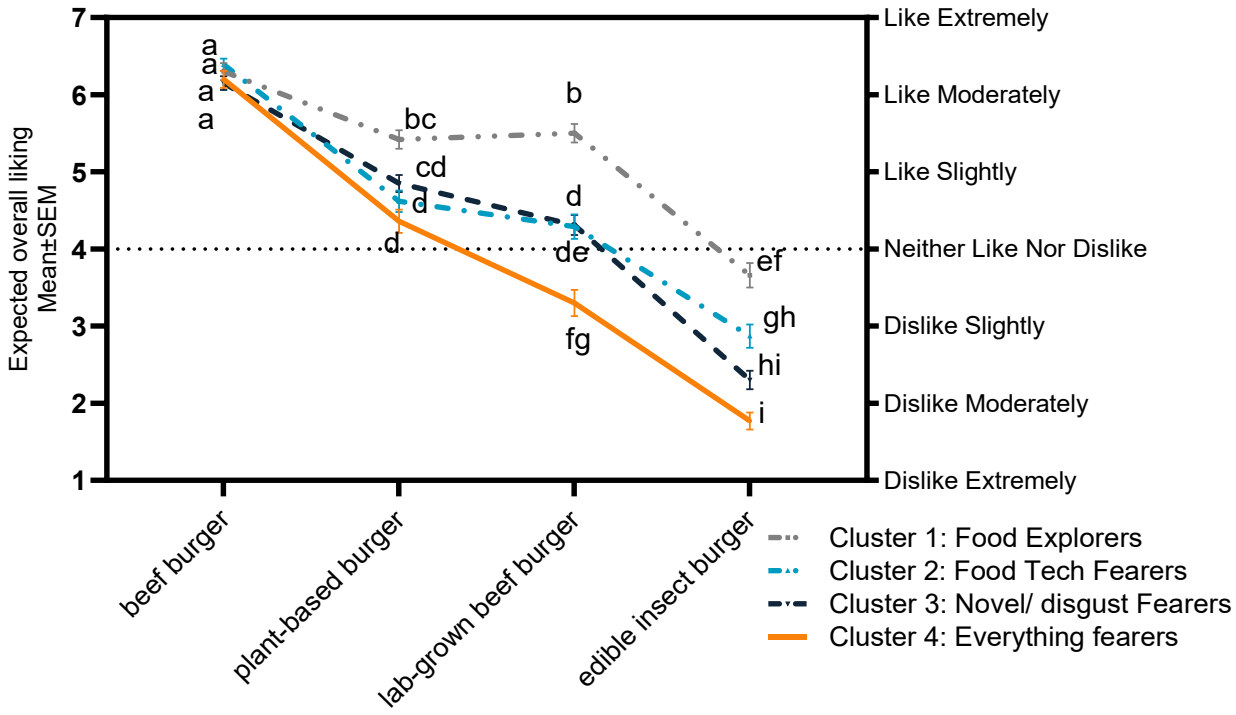


Figure 2-6 Two-way ANOVA for clusters of participants overall liking towards four burger patty types (conventional beef burger, plant-based burger, lab-grown beef burger and edible insect burger).

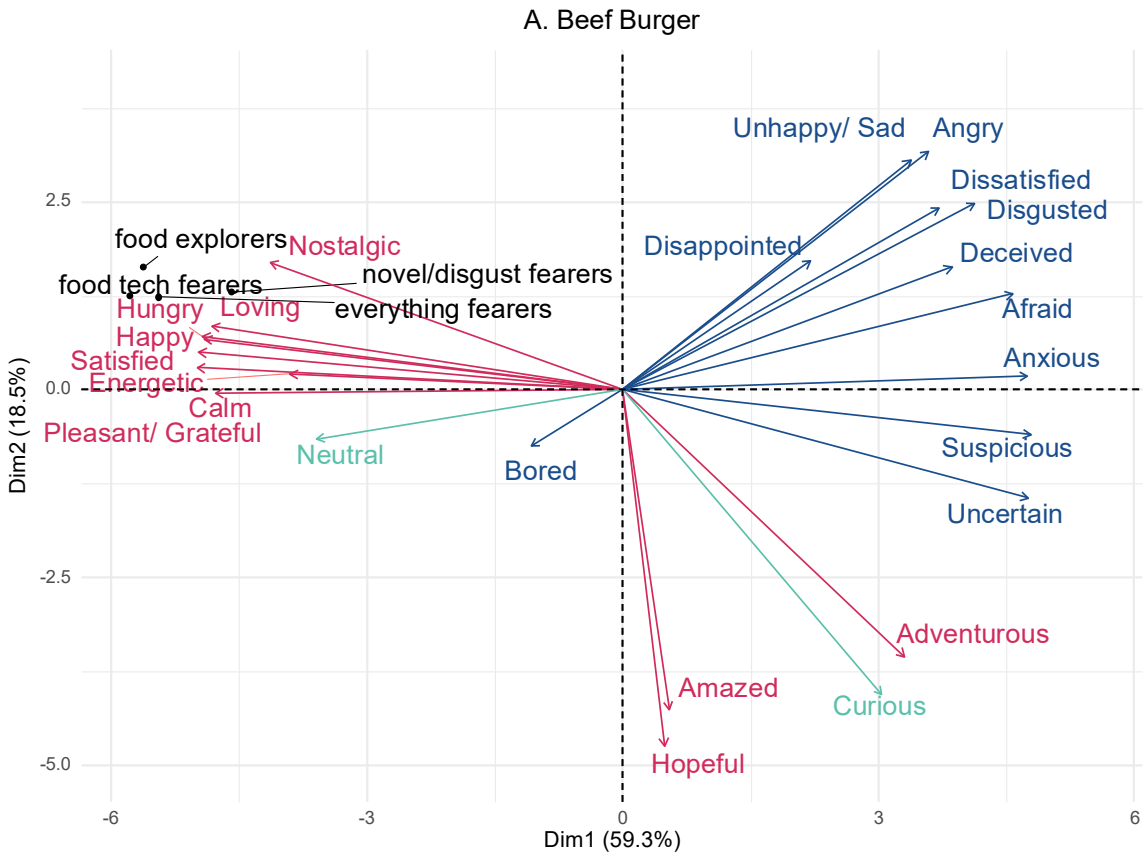
Emotional responses were found to vary by personal trait clusters across burger patty types based on the results in PCA, with 77.81% of the total variance explained. Dimension 1 accounts for 59.32%, primarily representing the emotional valence axis (ranging from negative to positive emotions). Dimension 2 accounted for an additional 18.49%, and was mainly defined by the emotions *amazed*, *hopeful*, *curious,* and *adventurous* (Figure 2-7).

For the beef burger patty, emotional responses were largely consistent across all clusters, with participants stably expressing positive emotions. This pattern suggests that conventional meat remain positive emotionally acceptable for different consumer segments (Figure 2-7A).

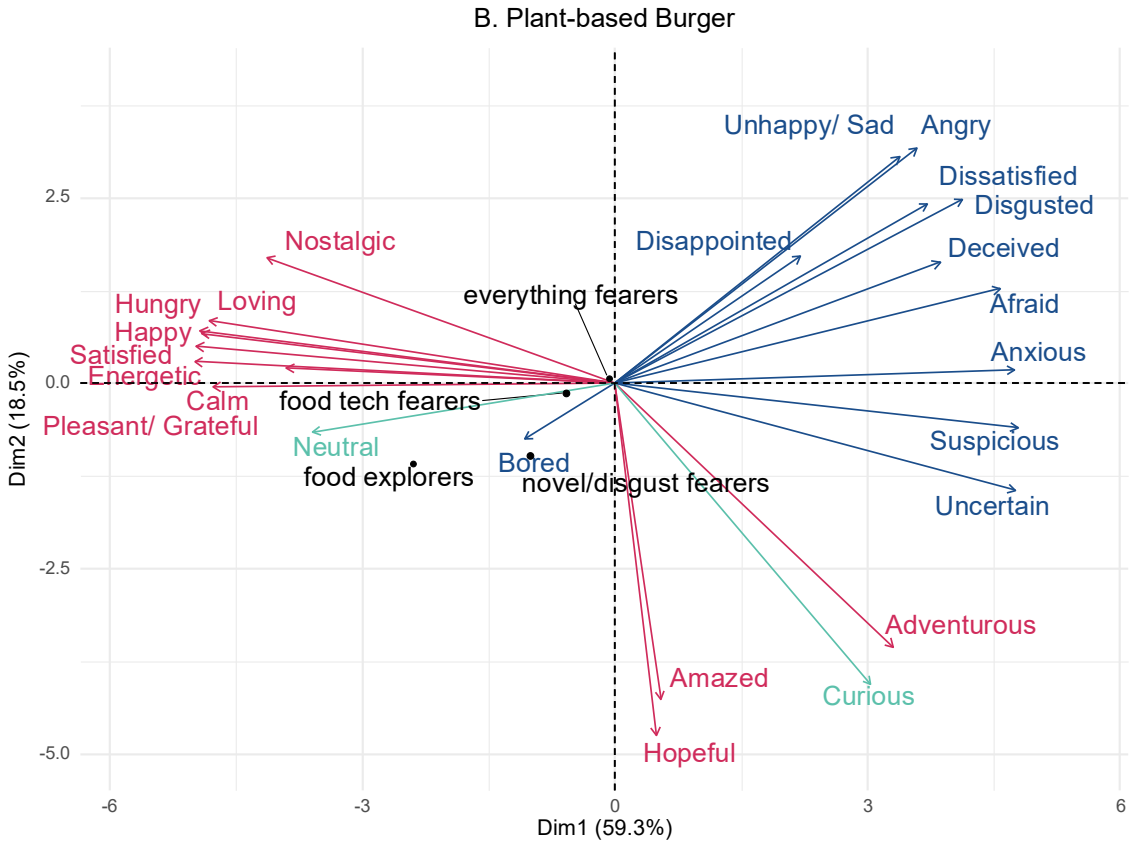
The emotional responses to the plant-based burger patty showed minimal variation across the four identified consumer clusters (Figure 2-7B). In the PCA biplot, the emotional positioning of all clusters was located close to each other and in the middle, suggesting very little emotion was evoked, and it mainly generated a *neutral* emotional reaction.

In contrast, emotional responses to the lab-grown beef and edible insect burger patties varied between clusters. Compared to *everything fearers*, *food explorers* experienced significantly stronger positive emotions towards the lab-grown beef burger patty, which include *adventurous*, *pleasant/grateful*, *amazed*, *hopeful*, *happy*, *satisfied*, and *curious* (Figure 2-7C). However, *food tech fearers* and *novel/disgust fearers* clustered closer together for the lab-grown beef burger patty, reflecting *suspicious* and *uncertain* emotions. Furthermore, based on the ANOVA results compared to *food explorers*, *everything fearers* expressed the highest levels of negative emotions in response to the lab-grown beef burger patty, including *dissatisfied*, *suspicious*, *disappointed*, *deceived*, and *disgusted*.

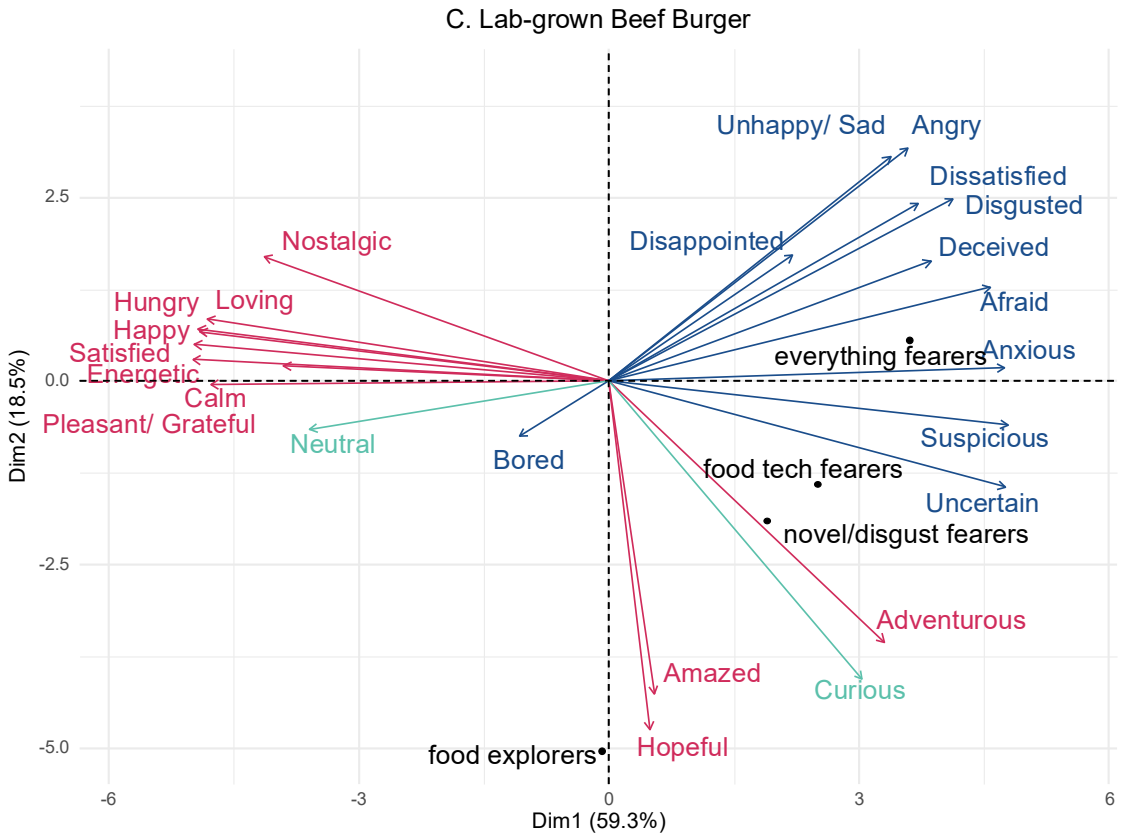
Regarding the edible insect burger patty, all clusters were positioned within the negative emotional responses, but the specific emotional profiles were different (Figure 2-7D). *Food explorers* reported significantly higher levels of a range of positive emotions, such as *adventurous*, *amazed*, *hopeful*, and *curious*, compared to everything fearers. *Everything fearers* experienced stronger negative emotional responses toward the edible insect burger patty, including emotion include *dissatisfied*, *angry*, and *disgusted*, compared with *food explorers*. *Food tech fearers* and *novel/disgust fearers* have stronger negative emotions, particularly *anxious*.


A. Beef Burger
Unhappy/ Sad
Angry
Dissatisfied
Disgusted
Disappointed
Deceived
Afraid
Anxious
food explorers
Nostalgic
food tech fearers
novel/disgust fearers
Hungry
Loving
everything fearers
Happy
Satisfied
Energetic
Calm
Pleasant/ Grateful
Neutral
Bored
Suspicious
Uncertain
Adventurous
Amazed
Curious
Hopeful
2.5
0.0
-2.5
-5.0
-6
-3
0
3
6
Dim2 (18.5%)
Dim1 (59.3%)

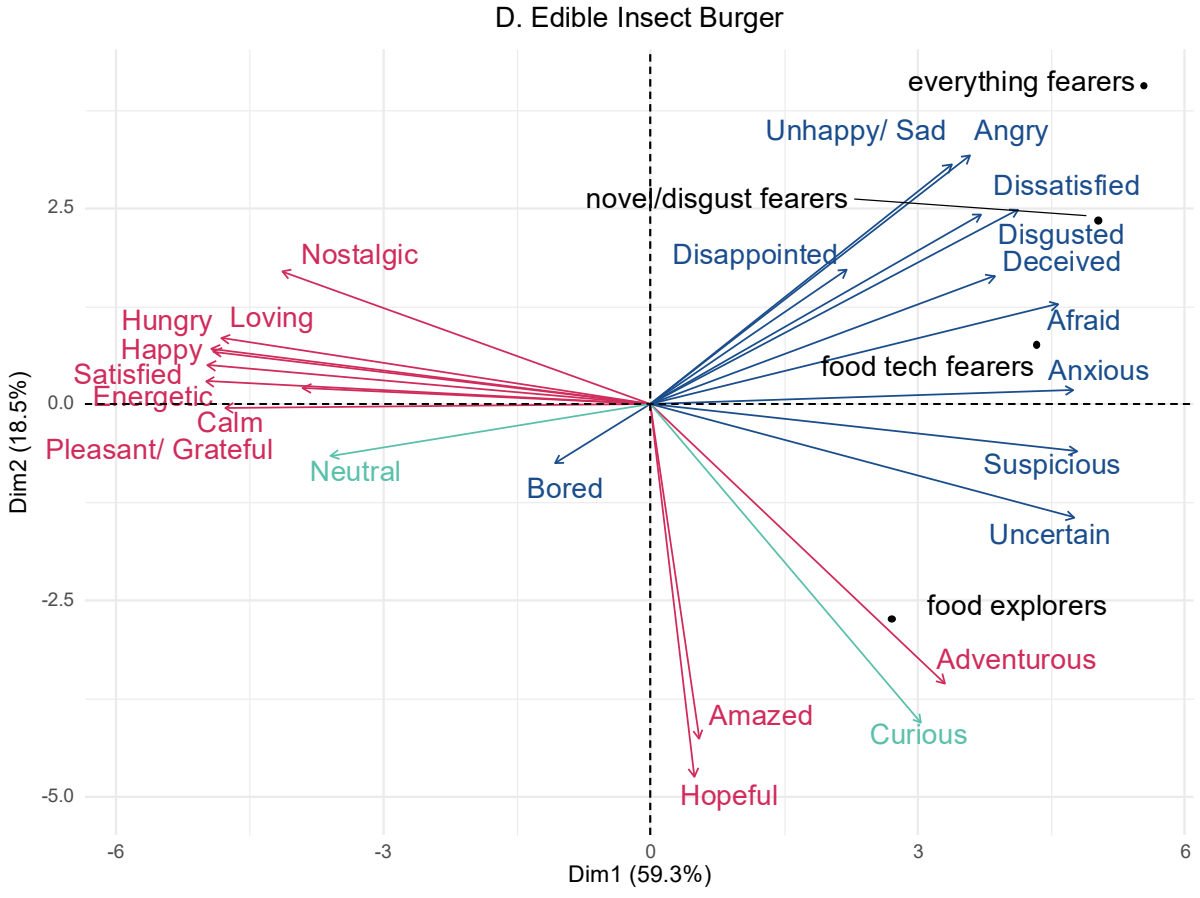
539


B. Plant-based Burger
Unhappy/ Sad
Angry
Dissatisfied
Disgusted
Nostalgic
Disappointed
Deceived
everything fearers
Afraid
Hungry
Loving
Happy
Anxious
Satisfied
Energetic
Calm
food tech fearers
Pleasant/ Grateful
Suspicious
Neutral
Bored
food explorers
novel/disgust fearers
Uncertain
Adventurous
Amazed
Curious
Hopeful
2.5
0.0
-2.5
-5.0
-6
-3
0
3
6
Dim2 (18.5%)
Dim1 (59.3%)

540


C. Lab-grown Beef Burger
Unhappy/ Sad
Angry
Dissatisfied
Disgusted
Nostalgic
Disappointed
Deceived
Afraid
Hungry
Loving
Happy
Satisfied
Energetic
everything fearers
Anxious
Calm
Pleasant/ Grateful
Neutral
Bored
Suspicious
food tech fearers
Uncertain
novel/disgust fearers
Adventurous
Amazed
Curious
food explorers
Hopeful
Dim2 (18.5%)
Dim1 (59.3%)
2.5
0.0
-2.5
-5.0
-6
-3
0
3
6

541


D. Edible Insect Burger
everything fearers
Unhappy/ Sad
Angry
Dissatisfied
novel/disgust fearers
Disgusted
Nostalgic
Disappointed
Deceived
Afraid
Hungry
Loving
Happy
food tech fearers
Anxious
Satisfied
Energetic
Calm
Pleasant/ Grateful
Neutral
Bored
Suspicious
Uncertain
food explorers
Adventurous
Amazed
Curious
Hopeful
Dim2 (18.5%)
Dim1 (59.3%)
2.5
0.0
-2.5
-5.0
-6
-3
0
3
6

542

Figure 2-7 PCA biplot for four clusters of participants' emotional responses for the four protein sources. Notes: These four PCA graphs were original from one PCA biplot, where to help better understating separated by four products (A: Beef burger; B: Plant-based burger; C: Lab-grown beef burger; D: Edible insect burger). Emotions are classified into positive (n = 11, red), negative (n = 11, blue) and unclassified (n=2, green) groups based on Orr et al. (2023).

2.4 Discussion

This study provides key insights into consumer responses to protein alternatives, contributing to the growing field of sustainable food research. While traditional beef remains the most liked, alternative proteins, such as plant-based, insect-based, and lab-grown options, often evoked a wide range of emotions, ranging from positive to negative, including *adventurous, amazed* and *uncertain*. The results suggested that emotional responses play a central role in protein alternatives acceptance, highlighting the importance of addressing psychological and emotion barriers in future studies.

The effect of environmental information on expected liking was significant but small; however, its potential influence on consumer acceptance should not be overlooked. The psychological mechanisms through which such messages affect perception remain unclear, and this study only assessed expected, not actual liking. Therefore, future research is needed to further investigate how environmental messaging might shape real consumer preferences, particularly in contexts involving direct tasting or repeated exposure.

The research also identifies four consumer segments, with varying levels of openness or resistance to novel proteins. These differences are partly explained by personal traits such as food neophobia or attitudes toward technology and levels of disgust toward the harmful food. Since such traits can shift over time through

exposure and improve familiarity or knowledge related to new technology, tailored strategies may help engage different consumer profiles more effectively.

Overall, this study highlights the value of combining sensory science, psychology, and communication to support sustainable eating. Understanding how consumer expectation, can guide more targeted and impactful interventions before the launched marking.

2.4.1 Overall expected liking and emotional responses for the four different protein sources

This research agrees with previous studies that meat eaters most liked the conventional beef burger patty, with 53% of meat-eaters indicating extreme liking, showing a strong attachment to conventional beef protein (Grasso *et al.*, 2022). High meat attachment refers to a positive bond towards meat consumption. Circus and Robison (2019) reported that UK consumers have a high meat attachment, which could be the underlying reason behind this finding. Ford *et al.* (2024b) suggested consumers considered conventional meat as a necessary for health reasons and it is not considered as environmentally damaging. Conventional meat is often viewed as a standard and preferable option compared to protein alternatives (Ford *et al.*, 2024b). While the urgency of promoting a protein transition is widely recognised as a critical step toward achieving the Sustainable Development Goals, the findings presented here highlight a significant challenge: the strong hedonic appeal of beef with high levels of meat attachment among consumers may hinder efforts to shift dietary preferences toward more sustainable protein sources. These psychological and cultural barriers underline the complexity of driving behavioural change in food consumption despite growing awareness of environmental imperatives. This study is

593 also in general agreement with previous studies, where plant-based and lab-grown
594 meat are generally liked, whereas low acceptability was often found for edible
595 insects (Circus and Robison, 2019; Onwezen *et al.*, 2021; Pakseresht, Ahmadi Kaliji
596 and Canavari, 2022; Ford *et al.*, 2023b; Heijnk, Espey and Schuenemann, 2023).

597 This study used the recently published category-specific meat and plant-based
598 burger patty emotional lexicon by Orr *et al.* (2023) developed. Good discrimination of
599 emotional response associated with the four different protein sources was observed,
600 indicating that the category-specific burger patty emotional lexicon can effectively
601 measure emotional response associated with different protein alternatives.

602 The plant-based burger patty evoked *bored*, *calm* and *neutral* emotions associated
603 with plant-based. Plant-based burger patty is widely available on the market; it is
604 very likely that participants have indicated their emotional response based on their
605 previous experience. The data here suggests that plant-based burger patty evoked
606 *dissatisfied* and *disappointed* emotions compared to beef burgers patty. This could
607 be linked to the sensory experience associated with plant-based food. A recent
608 study by Gonzalez-Estanol *et al.* (2023) suggests that plant-based protein was
609 associated with dry sensation and lack of juiciness and tenderness. The negative
610 sensory experience could evoke emotions such as *dissatisfied* and *disappointed*,
611 suggesting consumers may be *dissatisfied* with the current marketed plant-based
612 products and find them *boring*. Ford *et al.* (2024b) highlighted that taste is one of the
613 most important motivating factors for consumers to adopt plant-based products,
614 therefore, optimising the taste and flavour of plant-based products is crucial to
615 promoting more positive emotional responses associated with plant-based products.
616 The data here suggests that to ensure the success of plant-based products, food

developers could focus on reformulating plant-based products to improve their sensory properties by using natural ingredients and focus on developing a product that would evoke more positive emotions.

Interestingly, lab-grown beef burgers patty evokes bipolar emotional responses among consumers. Positive emotions, such as *hopeful, amazed, adventurous*, along with *curious*, indicate that consumers are interested in this product category. However, negative emotions, including feelings of *deceived* and *uncertain*, suggest that some consumers feel misled and untrusted by this novel technology. These positive emotional responses may stem from consumers' fascination with the innovative technology and its potential benefits, such as producing meat without animal slaughter while maintaining the sensory qualities of conventional beef. Cultured meat is positioned as a sustainable alternative to traditional livestock farming, offering the promise of significantly lower greenhouse gas emissions, as well as is an innovative method to produce meat by collecting animal cells, proliferating them, differentiating them into mature muscle cells, fat cells and other cell types, and finally harvesting and processing (moulding, colouring and seasoning) in vitro culture environment (Bryant and Barnett, 2020). Despite its potential, some consumers are doubtful about its sustainability and raise concerns about its unnaturalness. Ford *et al.* (2024b) highlighted that UK consumers perceive lab-grown meat as unnatural, unnecessary, and unsustainable, along with findings by Bryant and Barnett (2020), who reported concerns about safety and beliefs that cultured meat is unhealthy or nutritionally inferior. Similarly, Weinrich, Strack and Neugebauer (2020) noted that emotional rejection of cultured meat is often driven by its perceived unnaturalness, consistent with the current study, where consumers

641 expressed *deceived* and *uncertain*. Although cultured meat is not yet available in the
642 UK, lab-grown meat products have entered the markets in the US and Singapore
643 (Jegede, 2023). The positive emotional responses observed in this study suggest
644 market potential for lab-grown meat in the UK. However, addressing consumers'
645 negative emotional reactions and perceptions of unnaturalness will be critical to
646 achieving widespread adoption.

647 As expected, imagining eating an edible insect burger patty mainly evoked negative
648 emotions and made consumers feel *suspicious*, *anxious*, *afraid*, and *angry* which
649 could contribute to the strong dislike (Mean = 2.6) and only 3% of consumers were
650 willing to choose edible insects as their final product, indicating a low adoption
651 (Jensen and Lieberoth, 2019; Onwezen *et al.*, 2019; Boehm *et al.*, 2021; Serpico *et*
652 *al.*, 2021). The key barrier to the acceptance of edible insect burger patty is
653 associated with aversive emotions (*disgust*, *anxious*, and *fear etc,).* Ford *et al*.
654 (2024b) has found that extremely unwilling consumers indicated that edible insects
655 are unappealing, disgusting, gross and scary, and normally have an unpleasant
656 appearances and consumers believe that it's necessary as there are plenty of other
657 alternatives available. In addition, western cultures do not have a history of eating
658 edible insects, therefore unfamiliarity could also contribute to the negative emotions
659 associated with edible insects (Lensvelt and Steenbekkers, 2014; Boehm *et al.*,
660 2021).

661 Current findings indicated that emotional responses offer insights beyond liking. In
662 this study, a significant difference in liking was found between plant-based burgers
663 and lab-grown beef burgers, while their emotional responses revealed more nuanced
664 differences between the two products. This finding further confirmed that emotional

responses can provide additional data beyond hedonic liking information (Ng, Chaya and Hort, 2013; Low *et al.*, 2022), and a category-specific emotion questionnaire can further enhance discrimination. This study offers preliminary insights into consumer attitudes towards meat alternatives, but its key limitation is that it measures expected responses rather than actual sensory experience. For launched foods already in the market, consumer expectations are significantly influenced by pre-existing consumption (sensory) experiences and the food packaging. The current study's design, by not fully accounting for the influence of these past experiences on expectations, may limit the generalisability of its findings to products already familiar to consumers. Therefore, future research should further examine consumers' actual liking and emotional responses following sensory engagement with meat alternatives and integrate sensory evaluation methodologies to provide a more comprehensive understanding of novel food acceptance. Furthermore, future studies could incorporate measures of past consumption experiences to analyse the complex interplay between expectations and consumer behaviour.

Measuring the expected liking rather than actual liking has important methodological and strategic implications, as expected liking captures pre-consumption evaluations shaped by beliefs, emotions, and prior knowledge, whereas actual liking reflects post-consumption sensory experience. Measuring consumer expected liking and emotional because some alternatives proteins products are not yet commercially available. Understanding consumers’ expected liking prior to product launch enables researchers and developers to identify potential barriers to acceptance and adjust product formulations accordingly, thereby reducing the risk of unfavourable market responses. Marketing and communication strategies differ across products, as they

need to be tailored to their respective expected liking and emotional responses findings.

For plant-based burgers, neutral expected liking combined with neutral emotions (e.g., *bored*, *disappointed*) suggests that consumers expected neutral sensory performance. From a product development perspective, these findings highlight the need to improve expected texture, juicy, and flavour. However, from a marketing perspective, suggesting that communication strategies should actively shape expectations by emphasising sensory improvements and similarity to conventional meat.

For lab-grown beef, neutral expected liking and bipolar emotional responses indicate hesitancy driven by conceptual concerns rather than purely sensory expectations. For lab-grown meat, consumer acceptance is not only determined by sensory quality but also by perceptions of '*unnaturalness*' and '*uncertainty*'. Even if the product tastes similar to conventional beef, these concerns may limit willingness to try. Therefore, marketing and communication strategies play a crucial role in addressing these psychological barriers through transparent messaging, such as introducing the lab-grown product, its processing, and its ingredients. In this context, expected liking is particularly valuable because it captures ethical concerns that can be addressed in advance, helping to improve consumer acceptance before market launch.

For edible insect burgers, strongly negative emotions and low expected liking reflect disgust and food neophobia. These responses suggest that barriers are primarily psychological rather than sensory. Product development alone is unlikely to overcome these barriers without changes in product format (e.g., making insects less visible). Marketing efforts should prioritise education and gradual exposure to reduce

consumer disgust towards insect-based products. Importantly, the low expected liking suggests that mitigating disgust and psychological barriers is a prerequisite for acceptance, indicating that sensory improvements alone may be insufficient to drive consumer acceptance at this stage.

2.4.2 Impact of information on expected liking

The video provided to participants in this study includes life cycle assessment, GHG emission data across different product categories, as well as introducing production method for lab-grown beef. Previous studies have shown that sharing information about environmental and health benefits significantly increases their acceptance of plant-based protein (Schouteten *et al.*, 2016; Lemken *et al.*, 2017; Segovia, Yu and Van Loo, 2023). However, no such difference was found in the current study for plant-based, edible insect and beef burger. Only a significant but small effect was found for lab-grown beef, which could be due to the video's particular emphasis on the production method of lab-grown meat. This significant information × product interaction suggests that the impact of information sharing is dependent on the type of protein sources.

2.4.3 Impact of personal trait cluster on overall liking

While previous research has explored these traits individually, their combined impact on consumer behaviour toward protein alternatives has not been systematically studied. This is the first study to use AHC to group FNS, FTNS and FDS, and has identified four clusters (*food explorers*, *everything fearers*, *novel/disgust fearers* and *food tech fearers*).

21% of consumers are identified as *food explorers* showing a low fear of novel, potentially harmful food, or high-tech-produced foods. This group demonstrates a significantly higher liking and more positive emotional responses towards all protein alternatives. Positive emotions such as *curious*, *satisfied*, or *adventurous* may enhance the perceived value of novel foods and encourage adoption. By focusing on the emotional dimension of consumer experience, future research and product development efforts may gain deeper insights into the drivers of acceptance, particularly for novel or unfamiliar food products. *Food explorers* can be considered as early adopters for novel protein sources, their unique personal traits make them more inclined to embrace novel food products. Therefore, highlighting the novelty, sustainability, and technological advancements of protein alternatives might resonate particularly well with this group. Identifying such receptive groups emphasises the value of consumer segmentation in both academic research and commercial practice. Moreover, their openness to innovation provides opportunities for early adoption, potentially driving the success of emerging food products. By understanding and engaging with these early adopters, food companies can develop more targeted communication and marketing strategies, potentially supporting the broader acceptance and adoption of alternative protein products.

25% of consumers are categorised as *food tech fearers*, exhibiting low levels of FNS (fear of new/ novel food), FDS (disgust of harmful food), and very high FTN (food made by novel technology) scores. *Food tech fearers* show the lowest overall liking for lab-grown meat, primarily due to their highest FTN scores, which are a significant barrier to accepting cultured meat (Wilks *et al.*, 2019; Krings, Dhont and Hodson, 2022). FTN is a psychological barrier in consumers' fear and scepticism towards

novel food technologies, especially when they differ from traditional meat production methods. A high FTN score reflects a strong aversion to lab-produced foods and technological advancements, driven by concerns about health risks, ethical issues, and a perceived disconnect from natural foods (Wendin and Nyberg, 2021). To effectively engage *food tech fearers*, strategies should prioritise reducing FNS, FDS, and FTNS levels through positive exposure, and familiarising consumers with these products to decrease their food neophobia levels. Additionally, emphasising the safety and benefits of lab-grown meat and educating consumers about its production process, which lets consumers feel that it is not as novel as they may perceive, can help reduce their food technology neophobia levels. Future research should explore effective methods to lower FTN scores, particularly among *food tech fearers*. While the *food tech fearers* represent 25% of the total participants, targeted interventions could significantly increase their acceptance of protein alternatives, thereby promoting these alternatives to a larger group of consumers. The limitation of this current study is that the robustness of these clusters requires further investigation. The stability of these four clusters over time and in larger populations has not been fully explored. Future studies should test the consistency of these clusters by applying the same methodology to new or larger populations to assess their reliability.

32% consumers identified as n*ovel/disgust fearers*, they have high scores on both the Food Neophobia Scale (FNS) and the Food Disgust Scale (FDS), indicating a strong aversion to unfamiliar foods, as well as the harmful food may more easier trigger disgust emotions. However, *novel/disgust fearers* register relatively low scores on the Food Technology Neophobia Scale (FTNS), suggesting that their fear

784 is more related to the novelty of the food itself than to the use of new technologies in
785 food production. As a result, *novel/disgust fearers* are likely to be unwilling to accept
786 plant-based or edible insect burgers, primarily due to the challenge of introducing
787 unfamiliar food sources/edible insects that may evoke negative emotional responses
788 (*afraid* and *disappointed*). It was expected that this cluster would demonstrate a
789 lower liking for edible insects, as disgust has been reported to be the biggest barrier
790 to edible insect acceptability. The findings from this study did support this hypothesis
791 as liking for edible insects is particularly low for this cluster (M = 2.30). This study
792 indicates that consumers who have higher food disgust sensitivity, are more likely to
793 feel disgusted by edible insects and, therefore reject the edible insect as a food
794 source, which agrees with Hartmann and Siegrist (2018)'s research. The FDS scale
795 aims to capture consumer reactions to both visceral repulsion and perceived moral
796 violations, as confirmed by Thibodeau *et al.* (2021). Jensen and Lieberoth (2019)
797 noted that particularly in Western contexts, there is a deep-seated aversion to
798 insects in food, especially when insect parts are visible in the food, which is primarily
799 a form of visceral disgust linked to contamination fear. Considering potential
800 strategies for *novel/disgust fearers*, introducing novel protein alternatives in familiar
801 or culturally normalised product formats and contexts might help mitigate fear and
802 unfamiliarity.

803 The final cluster, accounting for 22% of consumers, was identified as *Everything*
804 *Fearers*. This consumer segment has the highest level of Food Neophobia Scale
805 (FN), Food Technology Scale (FTN), and Food Disgust Scale (FD), indicating a
806 strong aversion towards novel food, food made by new technology, and food eliciting
807 disgust-related responses. Compared with *food explorers*, *everything fearers* show

808 significantly lower liking scores for plant-based, hybrid, and edible insect burger
809 patties. The emotional response results further supported this pattern, as e*verything*
810 *fearers* reported stronger negative emotions (e.g. *dissatisfied* and *disgust*) affect
811 when evaluating the lab-grown and edible insect burger patty. This emotional
812 aversion may play a crucial role in shaping their low hedonic levels towards lab-
813 grown and edible insect burger patties. Therefore, the hedonic and emotional
814 findings suggest that *everything fearers* are the least promising target consumers for
815 lab-grown and edible insect products at the current stage of market development.

816 The attitudinal profile of *everything fearers* reveal significant psychological barriers to
817 adopting protein alternatives. Their high levels of food neophobia, technology-related
818 fear, and disgust sensitivity appear to be deeply rooted personal traits for this
819 segment of consumers. These traits collectively limit their openness to unfamiliar
820 food concepts and innovative production methods, which are central characteristics
821 of current protein alternatives (Kirsch, Morales-Dalmau and Lavrentieva, 2023).
822 Importantly, this consumer group represents a considerable proportion of the
823 population for this study, accounting for nearly one quarter of consumers (22% of
824 total consumers). Therefore, completely disregarding *everything fearers* may not be
825 desirable from a long-term market perspective. Future research and industry efforts
826 should explore strategies aimed at reducing fear-related responses for this segment
827 of consumers.

828 Overall, the findings highlight meaningful differences in consumer responses across
829 the four identified clusters. *Food explorers* appear to be the most promising target
830 group for promoting alternative proteins in general, as they reported the highest
831 liking scores and the most positive emotional responses across all three types of

protein alternatives. When focusing on lab-grown beef burger patty, *novel/disgust fearers* show moderate levels of expected liking and are associated with positive emotional responses, suggesting that these segments may also be considered in targeted segment consumers. The edible insect burger patty appears to be best suited for promotion among f*ood explorers*, as participants from other clusters tended to report lower liking scores and were more frequently associated with negative emotional responses. *Everything fearers* may not be an appropriate target segment for promoting protein alternatives at this moment, as their stable personal traits act as significant barriers to the adoption of protein alternatives products, particularly for lab-grown beef and edible insect burger patties.

Impact on

2.5 Conclusion

As global concerns over sustainable food systems rise, this study highlights that UK consumers have a high liking associated with conventional beef burger patty over alternative meat (plant-based, lab-grown beef, and edible insect burger patties) suggests consumer acceptance of alternative proteins remains constrained and multiple approaches and interventions are needed to promote protein alternative adoption. This study revealed that beef highly elicited positive emotions, edible insect evoked negative emotions, lab-grown beef burger patty evoked bipolar emotions, and plant-based burger patty evoked neutral emotions. The information video showed a small but significant effect for lab-grown beef only, suggesting the information can be used to increase acceptance; however, it is dependent on product categories. The four consumer clusters have provided a more in-depth explanation of consumer responses. *Food Explorers*, who showed openness and high liking

across all protein sources, could be considered as early adopters, and should be the target consumers for novel foods. The *novel/disgust fearers* and *food tech fearers* showed lower acceptance towards protein alternatives, especially for insect and lab-grown burger patties. The *everything fearers* showed the lowest acceptance towards protein alternatives, particularly for lab-grown beef and edible insect burger patties.

These findings highlight the importance of tailored marketing strategies to address diverse consumer perceptions of protein alternatives. Further strategies could focus on increasing consumer familiarity via positive exposure to the protein alternatives to decrease the consumer's level of food neophobia. Additionally, to apply new informative approaches, such as introducing lab-grown meat production processing, which tries to reduce consumer food technology neophobia. These findings suggest that tailored communication and marketing strategies to address different segments of consumer acceptance and emotional responses to protein alternatives. Current research suggests that tailored marketing strategies can be more effectively developed by following individual personal traits to segment consumers prior to product launch.

Chapter 3.

Understanding the impact of information on consumer responses to protein alternatives: Evidence from a rating-based conjoint study

Yuchen Zhang[a], Margaret Thibodeau[a], Qian Yang[a] and Rebecca Ford[a]

[a] Sensory Science Centre, Division of Food, Nutrition, and Dietetics, University of Nottingham, Sutton Bonington Campus, LE12 5RD, UK

Highlights:

- Hybrid burgers attracted the highest ordering intention among protein alternatives.
- Sensory information had a stronger influence than nutritional or environmental cues.
- Multi-claim menus maximised ordering intention and positive emotional responses.
- No information led lowest ordering intention and negative emotions.
- Sharing information offers a low-cost tool to promote protein alternatives.

Abstract

Protein alternatives offer environmental benefits over traditional meat, making them a promising strategy for reducing food-related greenhouse gas emissions. However, limited research has examined how sensory, nutritional, and environmental information influences consumer choice and their associated emotional responses. This study investigated the impact of such information and its trade-offs on consumers' interest in ordering three protein alternatives (plant-based, hybrid and edible insect) burger products. A total of 119 UK consumers evaluated eight menu concepts for each protein alternative product in an online survey that stimulated a restaurant scenario. For each product, each participant evaluated eight concepts (sensory, nutritional, and environmental information, 2^3) and recorded their ordering intention for the product and their emotional responses towards it. Results show that consumers were most willing to order the hybrid burger, followed by the plant-based burger, with significantly lower interest in the edible insect burger. Sensory information had the strongest positive effect on ordering intention, while environmental and nutritional information showed smaller but significant effects. Combining sensory, environmental, and nutritional information produced the highest ordering intention score and elicited more positive emotions, whereas providing no information resulted in negative emotions and the lowest interest across all products. Their findings highlight the critical role of sensory expectation and suggest that multi-claim strategies represent an effective, low-cost intervention to support sustainable dietary transitions.

3.1 Introduction

The global food system is a major driver of environmental challenges, including greenhouse gas (GHG) emissions, land use, and biodiversity loss (Crippa *et al.*, 2021). In particular, meat production is resource-intensive, requiring significantly higher GHG emissions, higher land and water use, compared with plant-based protein alternatives (Gibbs and Cappuccio, 2022; Dominguez-Lacueva, Beriain and Aldaya, 2025). This presents a sustainability issue, as meat consumption is projected to rise globally (Gil *et al.*, 2024). In response, rapid innovation in alternative protein sources has emerged as a strategy to meet global protein needs whilst reducing environmental impact.

There are several categories of protein alternatives, including plant-based protein, insect proteins, cultured meat, algae, and hybrid products (Onwezen *et al.*, 2021; Siddiqui *et al.*, 2022), which are generally associated with lower GHG emissions and lower land and water requirements than conventional animal proteins (Lumanlan, Williams and Jayasena, 2022; Dominguez-Lacueva, Beriain and Aldaya, 2025). However, the development stage and market availability of these products vary considerably, and consumer acceptance is inconsistent across regions and product types. Among these protein alternatives, plant-based proteins are currently the most widely adopted. Traditional plant-based meat alternatives such as tofu, tempeh, and seitan have historically been staples in Asian diets. However, recent innovations aim to produce products that closely replicate the sensory qualities of conventional meat (e.g. burger patty or sausage). The traditional plant-based meat alternatives are mainly made from soy, pea, wheat, and other plant proteins (Zahari *et al.*, 2022). Advances in processing, particularly through combining various ingredients and

optimisation of extrusion have enabled the development of plant-based meats with improved texture and taste (Singh *et al.*, 2021). Current commercial examples include products from Beyond Meat™, light life™ and Impossible Foods™ (He *et al.*, 2020). From an environmental perspective, life cycle assessment (LCA) studies consistently show that plant-based meat alternatives generally produce lower GHG emissions and require less land and water than conventional meat (Bryant, 2022). Plant-based alternatives are generally well accepted by consumers due to their familiarity and ability to mimic meat-like sensory attributes.

Edible insects, by contrast, are naturally rich in protein and other essential nutrients. They can be produced sustainably by rearing them on waste streams or composted food by-products, converting low-value waste into high-quality protein (Ribeiro, Pintado and Cunha, 2024). LCA data indicate that edible insects can reduce GHG emissions by 64% compared to traditional beef production (Smetana *et al.*, 2015). However, despite the environmental and nutritional benefits, consumer acceptance remains a major challenge, particularly in Western countries, where entomophagy is culturally unfamiliar and evokes feelings of disgust (Kornher, Schellhorn and Vetter, 2019; Russell and Knott, 2021; Florença *et al.*, 2022).

Given these sensory and cultural barriers, hybrid meat has emerged as a more familiar compromise. By blending conventional meat with plant-based components, hybrid products aim to retain desirable sensory qualities while reducing environmental impact. There is no universally agreed definition of hybrid meat, which typically combines conventional meat, such as beef, with different ratios of plant-based proteins (Grasso, Asioli and Smith, 2022; Grasso, 2024), thereby maintaining some of the desirable sensory attributes of meat while reducing the proportion of

967 animal-based ingredients (Grasso and Goksen, 2023). Dominguez-Lacueva, Beriain
968 and Aldaya (2025) indicated that depending on the ratio of beef/plant-based
969 ingredients (50-50 ratio), GHG emissions of hybrid meat can be reduced by
970 approximately 50% compared to traditional beef. Due to consumers' strong
971 attachment to conventional meat, a complete transition to a fully plant-based diet
972 remains challenging for many individuals. Consequently, hybrid meat may facilitate
973 gradual dietary change. Due to evolving consumer preferences, a diverse range of
974 protein sources is increasingly recognised as essential to accommodate varying
975 consumer preferences and ensure the sustainability of future food systems.

976 3.1.1 Acceptance and information impact

977 A range of studies have investigated consumer acceptance and motivations to
978 protein alternatives, both Grasso *et al.* (2022) and Caputo, Sogari and Van Loo
979 (2023) found that consumers preferred beef burgers most, followed by hybrid
980 burgers, with plant-based burgers least preferred. In contrast, edible insects are
981 generally associated with low acceptance, with aversion and food neophobia
982 indicated as major barriers (Kröger *et al.*, 2022; Ribeiro, Pintado and Cunha, 2024).
983 Consumer adoption of these protein alternatives is strongly influenced by
984 fundamental food motives, particularly sensory pleasure, nutritional benefits, and
985 environmental consideration.

986 Sensory quality is a fundamental criterion in food choice, and protein alternatives
987 often underperform compared to conventional meat. Studies consistently report
988 consumers' dissatisfaction with the flavour, texture, and overall eating quality of
989 protein alternatives (Giacalone, Clausen and Jaeger, 2022). In the UK, sensory

appeal was rated as the most important factor influencing the adoption of protein alternatives (Ford *et al.*, 2024b).

Nutrition-related motives can also encourage consumers to try plant-based foods, as these protein alternatives are often perceived as being lower in fat and cholesterol and higher in protein or fibre (Asioli *et al.*, 2023; Choręziak *et al.*, 2025). Conversely, there are also concerns about the nutritional adequacy of the protein alternatives and the high level of processing in some protein alternatives, which can reduce their perceived healthfulness (Ford *et al.*, 2023a).

Environmental factors, such as the awareness of the environmental impact of meat consumption on sustainability and climate change, are essential drivers of consumer acceptance of protein alternatives. Protein alternatives are often perceived as more environmentally friendly than conventional meat, and this awareness appears to inform personal norms and behavioural intentions, meaning the consumers who are already orientated towards sustainability are willing to adopt protein alternatives (Ford *et al.*, 2023b).

When making purchasing decisions, consumers encounter a range of product-related cues either from on-pack messages in retail settings or from menus in a restaurant setting. Previous research indicates that information on food packaging significantly shapes consumers' acceptance and willingness to pay towards protein alternatives (Apostolidis and McLeay, 2016; Van Loo, Caputo and Lusk, 2020; Florença *et al.*, 2022; Asioli *et al.*, 2023). In the UK market, brands employ diverse strategies to communicate product benefits. For example, Quorn™ highlights mycoprotein with front-of-pack claims such as 'high in protein', 'low in saturated fat', and 'gluten free', while back-of-pack information emphasises nutrition and

sustainability certification (Quorn, 2025). Similarly, La Vie Plant-Based Bacon™ combines both nutritional and environmental claims, including ‘high in protein’ and ‘better for the planet’ (LAVIE, 2025). Juicy Marbles™ emphasize sensory aspects (‘juicy’ and ‘tender’) (Juicy Marbles, 2025). Although previous studies have examined the influence of nutritional, sensory, and environmental information on consumer purchase intention or overall liking, most have focused on these information types or attributes in isolation. It remains unclear how consumers respond when multiple types of information are presented simultaneously and if some information types are more important than others in consumers' decision-making. Therefore, this study employed a rating-based conjoint task to understand consumer decision-making when multiple product attributes interact. Specifically, it assessed the relative importance of sensory, nutritional, and environmental information on consumer purchase intent. This research is particularly novel and timely as real-world decision-making involves making trade-offs, and very few studies explore emotional responses alongside purchase intent. The objective of the study was: 1) Investigate consumer purchase intention and emotional responses to three types of protein alternatives, including plant-based, hybrid, and edible insect-based burgers. 2) Explore the effect of sensory, nutritional, and environmental information and their interactions on consumer purchase intent and expected emotional responses.

3.2 Materials and Methods

3.2.1 Overview of the experimental approach

The study was divided into three online surveys, each of them administered on the Prolific platform one week apart. Each survey focused on a different type of burger (plant-based, hybrid, insect), participants evaluated eight concepts (2^3) for the same

burger type by indicating their ordering intention for the burger, followed by their expected emotional responses for each concept. All concepts (n = 8) for each burger type were randomised within participants. The study was given a favourable opinion by the University of Nottingham, School of Biosciences Ethics team (REF: SBREC202324029FEO). All participants provided consent to the study and received a small cash reward for completing the survey.

3.2.2 Participants

A total of 180 participants consented to take part in the study. 46 participants (25%) were excluded for not completing all questions in all three surveys, and a further 15 participants were excluded for completing the questionnaire too quickly (exclusion criteria set at less than 60% of the median response time (11 minutes)) to remove potential 'fake participants' (Jaeger and Cardello, 2022). Thus, a total of 119 participants (59 female and 60 male, 38±12 years) were included in the data analysis. These participants identified as meat eaters and all lived in the UK for at least 3 months. The key demographic characteristics (living in the UK, length of time living in the UK, gender, ethnicity/race, education level, meat and protein alternatives consumption frequency) were collected in the first part of the survey (Appendix C).

3.2.3 Written Scenario & Products Description

A written scenario was used to simulate the context as follows: '*Imagine that you are in a restaurant and that you want to order a burger as your main course. Today, the restaurant has eight burgers on the menu. Please read the special menu listing for each burger (one per page) and answer the following questions*'. Participants were able to see an image of the burger names, ingredients, and different levels of information presented for each concept. The menu was designed to simulate a

restaurant environment and to make participants imagine that they are in a restaurant scene, and evaluate the product based on information shown on the restaurant's special menu. A background image of the front view of the restaurant table with a fork and knife, with the centre of the menu, was created on the Midjourney platform. Figure 3-1a shows an example of all factor information for the hybrid menu, and Figure 3-1b shows the same menu but with no factor information. The menu format and design were kept consistent across all three products and different information levels.

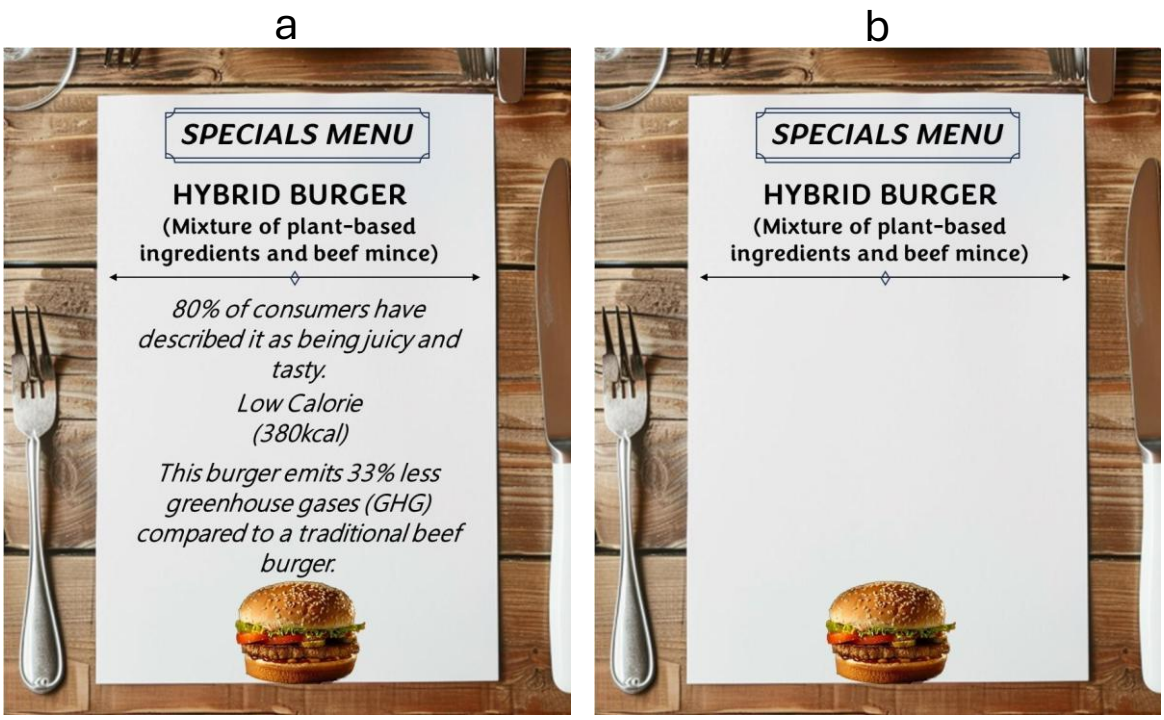


Figure 3-1 a)an example of the hybrid burger menu with all three types of information presented, and b)an example of the hybrid burger menu without any information presented.

Although the conventional beef burger could serve as a useful reference for comparison, this has already been established in Chapter 2, where consumers' positive emotional responses and liking towards beef were confirmed. The primary objective of the current study is to examine how information influences ordering

intention towards alternative proteins, rather than to re-establish baseline preferences against conventional meat. Furthermore, as the study focuses on the communication of environmental benefits, conventional beef does not represent an appropriate comparator in this context.

In this study, the term ‘insect burger’ consistently refers to a hybrid product composed of edible insect ingredients mixed with beef, rather than a fully insect-based product. This approach is motivated by the findings presented in Chapter 2, which indicate that consumer liking for fully insect-based products is considerably low. As a result, the use of a hybrid formulation allows the investigation of whether combining edible insects with a familiar and widely accepted product, such as beef burgers, may improve consumer acceptance.

Information (environmental, nutritional, and sensory) was presented at two levels each, based on a full 2^3 factorial design (8 concepts, C1–C8) per product. For each factor, the positive level presents a specific statement (information present), and the negative level presents the absence of the statement. For example, in the Figure 3-1a, the example menu shows the hybrid burger with all information present (positive level), whilst in Figure 3-1b, the example menu shows the hybrid burger with no information (negative levels) for all three factors.

For the sustainable information, comparative statements were used to communicate how much lower (GHG emissions) the protein alternatives were compared with a typical beef burger, which was calculated to emit 33.3 kg of CO_2 equivalents/ kg (Poore and Nemecek, 2018).

Table 3-1 The three protein alternative burger factors used in the research were defined based on a full 2^3 factorial design.

Product Name	Ingredients	Attribute	Attribute Name	Level Description
Plant-based Burger	100% plant-based ingredients	Factor 1 (+)	Sustainable claims	This burger emits 90% less greenhouse gases (GHG) compared to a traditional beef burger.
		Factor 1(-)		None
		Factor 2(+)	Nutrition Claims	Low Calorie (230kcal)
		Factor 2(-)		None
		Factor 3(+)	Sensory Claims	80% of consumers have described it as being juicy and tasty
		Factor 3(-)		None
Hybrid Burger	Mixture of plant-based ingredients and beef mince	Factor 1 (+)	Sustainable claims	This burger emits 33% less greenhouse gases (GHG) compared to a traditional beef burger.
		Factor 1(-)		None
		Factor 2(+)	Nutrition Claims	Low Calorie (380kcal)
		Factor 2(-)		None
		Factor 3(+)	Sensory Claims	80% of consumers have described it as being juicy and tasty
		Factor 3(-)		None
Edible Insect Burger	Mixture of edible insects and beef mince	Factor 1 (+)	Sustainable claims	This burger emits 64% less greenhouse gases (GHG) compared to a traditional beef burger.
		Factor 1(-)		None
		Factor 2(+)	Nutrition Claims	Low Calorie (280kcal)
		Factor 2(-)		None
		Factor 3(+)	Sensory Claims	80% of consumers have described it as being juicy and tasty
		Factor 3(-)		None

Notes: The 8 combination (Concept 1 to Concept 8) defined by the factorial design were: Concept 1 = F1-, F2-, F3-; Concept 2 = F1+, F2+, F3-; Concept 3 = F1+, F2-, F3+; Concept 4 = F1-, F2+, F3+; Concept 5 = F1+, F2-, F3-; Concept 6 = F1-, F2+, F3-; Concept 7 = F1-, F2-, F3+; Concept 8 = F1+, F2+, F3 +. All the claims included the product name and ingredient information presented by the special menu, refer Figure 3-1.

The plant-based burger was calculated to emit 3.2 kg of CO_2 equivalents per kilogram (Klimato, 2023a) which was 90% lower than the beef burger, the hybrid burger was calculated to emit approximately 9.9 kg of CO_2 equivalents per kilogram (Baune *et al.*, 2021) which was 33% lower and the edible insect burger was calculated to emit approximately 11.8 kg of CO_2 equivalents per kilogram (Smetana *et al.*, 2015) which was 64% lower. For the nutritional information, a low-calorie claim was used as it is one of the most commonly used and widely understood nutritional

cues. While high-protein claims are increasingly popular, their health value is debatable, and protein claims alone fail to specify the type of protein used, which ignores critical differences between plant and animal proteins in quality, digestibility and amino acid balance (Wood and Tavan, 2022). In everyday food choices, consumers often use calorie content as a simple indicator of healthfulness. As a result, products labelled as 'low calorie' tend to be perceived as healthier than their higher-calorie counterparts. For the sensory claims, the statement '80% of consumers described it as juicy and tasty' was used. This statement was chosen because an 80% endorsement reflects that a large proportion of consumers and previous studies show that the ideal burger is typically expected to be tasty and juicy (Greene, Yuheng Zhu and Dolnicar, 2024).

3.2.4 Rating-based conjoint task

This study used Rating-Based Conjoint Analysis as the primary method. It is a long-established methodology for quantifying the impact of systematically varied product factors at different levels on choice decisions. Previous studies have used this rating-based conjoint analysis to explore how different factors influence consumer willingness to buy various types of food (Asioli *et al.*, 2016; Saurabh and Dey, 2021; Jaeger, Chheang and Ares, 2023). The task requires participants to provide independent ratings for each product concept. In this study, participants were first shown a product concept and then asked, '*How interested are you in ordering this burger?*' using a 9-point Likert scale to assess their expected ordering intention for each type of product (1-Not at all interested in ordering to 9-Extremely interested in ordering). After participants completed the ordering intention question, they were asked to complete the emotional responses task.

3.2.5 Emotional responses task

Orr *et al.* (2023) developed product-specific emotion lexicons to capture emotional responses relevant to the broader meat and plant-based protein category. The emotion lexicons were 24 emotion attributes, 11 positive emotion terms, 11 negative emotion terms and 2 unclassified emotion terms (Orr *et al.*, 2023). Participants were asked to check all that applied to the emotion lexicons for each product concept.

3.2.6 Data analysis

A four-way Mixed Model ANOVA (burgers, sensory claims (present/absent), nutrition claims (present/absent), environmental claims (present/absent) with two-way interactions, and participants as a random factor with Tukey's HSD and partial eta^2 (η_p^2) as a post-hoc test was conducted to examine the impact of the burger type, information type, and interactions on ordering intention. The partial eta^2 (ηp^2) guideline is $\eta^2 < 0.01$ is 'negligible', $0.01 \leq \eta^2 < 0.06$ is 'small', $0.06 \leq \eta^2 < 0.14$ is 'medium' and $\eta^2 \geq 0.14$ is 'large' (Cohen, 2013; Jaeger, Chheang and Ares, 2025).

CHAID regression trees were performed on ordering intention for three protein alternatives (hybrid, plant, and edible) and on the presence or absence of three types of information (sensory, nutritional, and environmental), following the Ford *et al.* (2023b) method.

Three additional One-way Mixed model ANOVAs were performed for three burger types (plant, hybrid, insect), and the eight concepts (sensory, sensory × nutrition, sensory × environment, sensory × nutrition × environment, nutrition, environment, nutrition × environment, and no information) as fixed factors, with participants as a random factor.

For emotional responses, Cochran's Q with Sheskin's procedure as a post hoc test was conducted for pooled data across the three types of burgers (plant-based, hybrid, and insect) to understand overall emotional responses among the three products. To explore the impact of information, Cochran's Q with Sheskin's as post-hoc was conducted among the eight concepts (Sensory, Sensory × Nutrition, Sensory × Environment, Sensory × Nutrition × Environment, Nutrition, Environment, Nutrition × Environment, and No Information) for each product type, followed by a Correspondence Analysis to help visualise the results.

All statistical analyses were conducted in XLSTAT statistical and data analysis solution (version, 20231.1 Lumivero, USA). A significance value of $p<0.05$ was adopted.

3.3 Results

3.3.1 Ordering intention and emotional response for each product

Four-way ANOVA indicated a significant product effect, where participants expressed the highest ordering intention for the hybrid burger (M = 5.6), followed by the plant-based burger (M = 4.9). The edible insect burger (M = 2.9) received the lowest ordering intention ratings among the three protein alternatives ($F(2, 2723) = 700$, $p<0.0001$, effect size (η^2) = 0.34) (Figure 3-2).

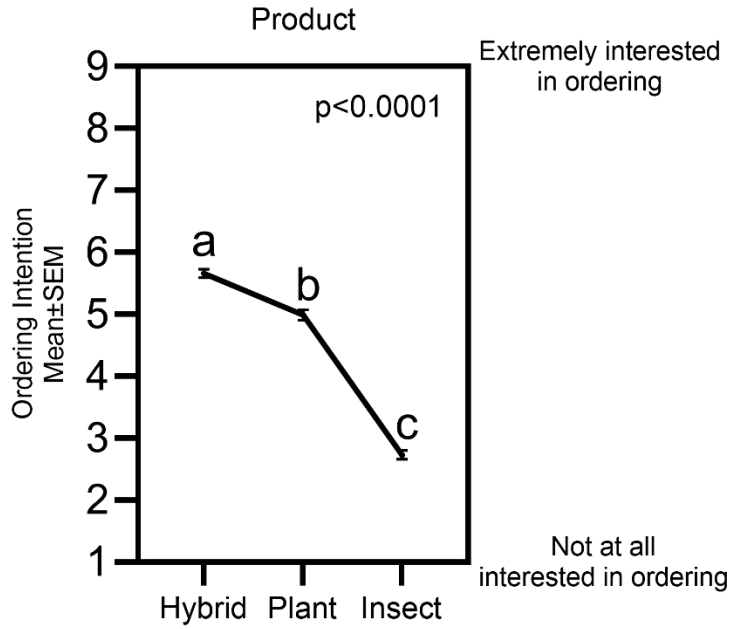


Figure 3-2 The average ordering intention of the three products (Plant-based, Hybrid and Edible insect burgers). Different letters indicate a significant difference across the product type at p<0.05 (n = 119, four-way ANOVA)

For emotional responses, Cochran's Q test revealed significant differences for 22 of the 24 emotions (p<0.05, Table 3-2). No significant differences were observed for *adventurous* and *nostalgic* emotions (p>0.05). The plant-based burger evoked significantly more positive emotions (*pleasant/ grateful*, *amazed*, *hopeful*, *hungry*, *curious*, *neutral*, and *bored)* than the edible insect burger. The hybrid burger evoked more *energetic*, *happy*, and *satisfied* emotions than the plant-based and edible insect burgers. In contrast, the edible insect burger evoked more negative emotions, including *unhappy*, *dissatisfied*, *angry*, *afraid,* and *anxious*.

Table 3-2 Proportion of emotional terms across products

Emotion	Plant	Hybrid	Insect	p value
Calm+	23% (a)	19.96% (a)	3.99% (b)	<0.0001
Adventurous+	19.75% (a)	23.84% (a)	19.85% (a)	0.044
Energetic+	4.94% (b)	7.67% (a)	2.73% (b)	<0.0001
Pleasant/ Grateful+	23.63% (a)	23.21% (a)	5.57% (b)	<0.0001
Loving+	5.36% (a)	7.25% (a)	2.63% (b)	<0.0001
Amazed+	10.4% (a)	10.19% (a)	4.52% (b)	<0.0001
Hopeful+	32.46% (a)	36.34% (a)	12.08% (b)	<0.0001
Happy+	20.59% (b)	27.21% (a)	5.04% (c)	<0.0001
Hungry+	24.47% (a)	26.68% (a)	7.25% (b)	<0.0001
Nostalgic+	1.79% (a)	1.16% (a)	1.79% (a)	0.444
Satisfied+	18.91% (b)	26.16% (a)	5.67% (c)	<0.0001
Unhappy/ Sad-	4.52% (b)	2.84% (b)	18.49% (a)	<0.0001
Dissatisfied-	12.5% (b)	4.83% (c)	22.58% (a)	<0.0001
Angry-	1.58% (b)	0.84% (b)	8.72% (a)	<0.0001
Anxious-	8.4% (b)	7.04% (b)	33.61% (a)	<0.0001
Afraid-	1.58% (b)	3.05% (b)	21.95% (a)	<0.0001
Suspicious-	16.07% (b)	18.17% (b)	36.03% (a)	<0.0001
Bored-	5.57% (a)	4.73% (a)	1.37% (b)	<0.0001
Disappointed-	11.87% (b)	4.31% (c)	17.86% (a)	<0.0001
Deceived-	5.15% (b)	3.05% (b)	9.87% (a)	<0.0001
Disgusted-	5.04% (b)	2.84% (b)	53.05% (a)	<0.0001
Uncertain-	32.88% (b)	27% (c)	51.47% (a)	<0.0001
Curious*	47.48% (a)	50.84% (a)	34.77% (b)	<0.0001
Neutral*	26.47% (a)	23.63% (a)	6.83% (b)	<0.0001

Note: +Positive emotion, -Negative emotion, and *Unclassified emotion. a, b, c proportions of emotional terms with different letter codes are significantly different across the products.

3.3.2 Impact of information on ordering intention

Four-way ANOVA showed that a significant overall sensory, environmental, and nutritional information effect on consumers' ordering intention (Figure 3-3). Sensory information had the strongest overall effect with medium effect size ($\eta^2 = 0.058$, $p<0.0001$), where the pooled ordering intention score increased from M = 4.0 (no claims presented) to M = 4.8 (sensory information presented). Environmental information had a small effect ($\eta^2 = 0.013$, $p<0.0001$), with the pooled ordering

intention score significantly increased from M = 4.2 (no information presented) to M = 4.6 (environmental information presented). Nutritional information had the smallest effect ($\eta^2 = 0.003$, $P<0.01$), with the pooled ordering intention scores increasing significantly, from M = 4.3 (no nutritional information) to M = 4.5 (nutritional information presented). Taken together, the sensory information had a significant moderate impact on consumers' ordering intention for protein alternatives, followed by environmental information, while nutritional information showed the smallest effect.

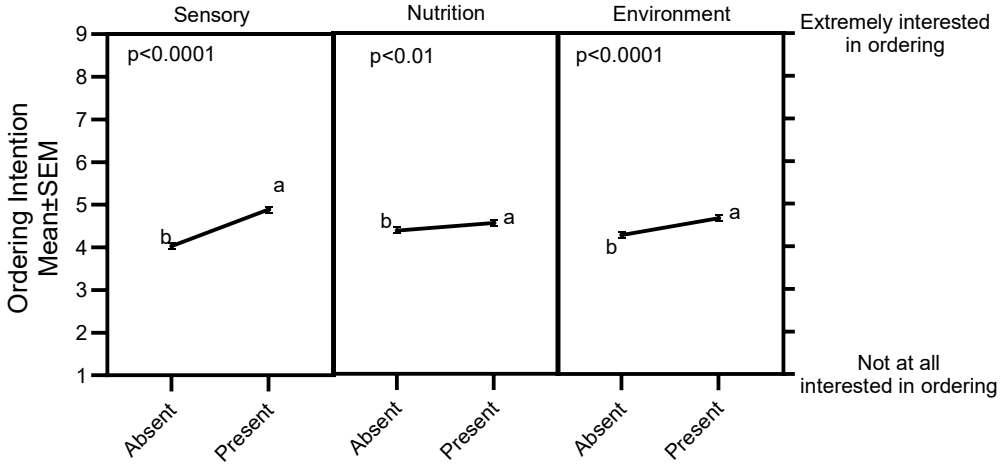


Figure 3-3 Impact of sensory, nutritional, and environmental information on consumer ordering intention. Different letters indicate significant differences between means across three types of information obtained from Tukey's HSD (n = 119, Four-way ANOVA.

The only significant interaction observed was a significant environment × sensory interaction ($p = 0.022$, $\eta^2 = 0.006$). However, when reviewing the interaction plot (Figure 3-4), the interaction is a magnitude interaction, which means that when sensory information is absent, environmental information increases ordering intention more than when sensory information is present. This indicates that sensory

information is the main driver of ordering intention, followed by environmental information.

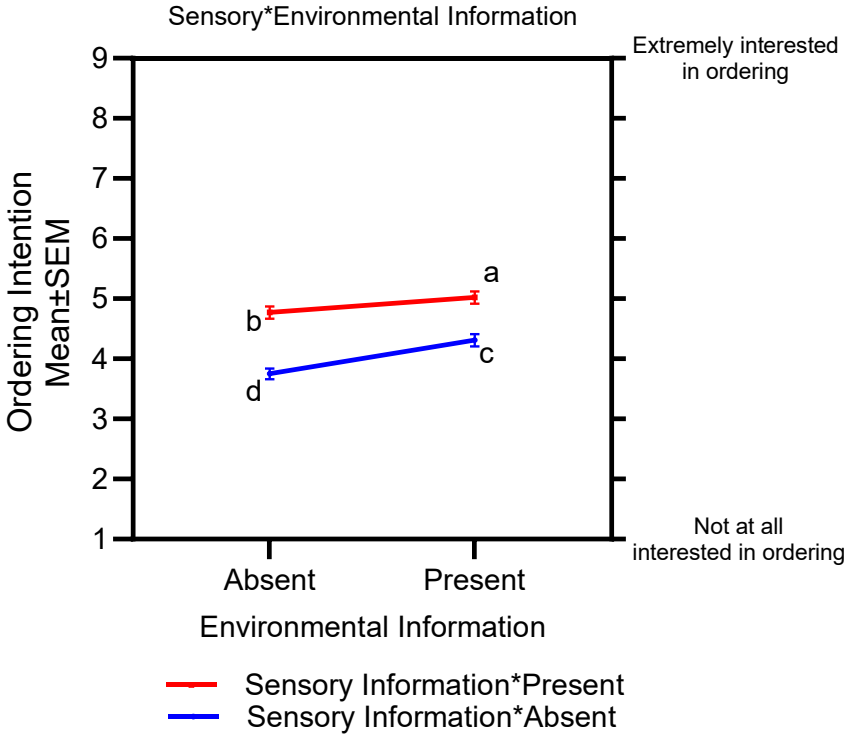


Figure 3-4 The impact of sensory × environmental information interaction on ordering intention. Different letters indicate significant differences between means of sensory information and environment information obtained from Tukey's HSD (n = 119, Four-way ANOVA).

From the Figure 3-2, Figure 3-3, and Figure 3-4, the ANOVA found that information significant impact consumer ordering intention for protein alternatives. However, the ANOVA cannot indicate the magnitude of difference nor the sequential influence of different information types. To address this gap, a regression tree analysis was conducted. The regression tree revealed the hierarchical importance of information types in driving ordering intention across three types of protein alternatives (Figure 3-5). The regression tree analysis revealed a clear hierarchy of factors influencing

ordering intention. The first and most important split was based on product type, with the hybrid burger having the highest ordering intention (M = 5.6), followed by the plant-based burger (M = 4.9) and the edible insect burger (M = 2.9). This indicates that differences between product categories are the primary driver of consumer responses. Within each product category, the next key split was based on information type, with sensory information proving the most influential factor.

Among the three protein alternatives, including sensory information consistently resulted in higher ordering intention compared to those without it. Presenting sensory information significantly increased ordering intention for all three protein alternatives. For the hybrid burger, the presence of sensory information increased ordering intention from M = 5.1 to M = 6.1. A similar pattern was observed for the plant-based burger, where ordering intention increased from M = 4.4 (absence of sensory information) to M = 5.1 (presence of sensory information). In contrast, for the edible insect product, sensory information had no effect, with mean ordering intention remaining constant at M = 2.5 regardless of its presence. In the absence of sensory information, environmental information became the next most important factor influencing ordering intention, indicating a secondary effect. In the absence of sensory information, environmental information significantly increased ordering intention across all product types, including hybrid burgers (M = 4.8 to M = 5.4), plant-based burgers (M = 4.1 to M = 4.7), and edible insect burgers (M = 2.2 to M = 2.7). This pattern was consistent across all three protein alternatives, suggesting that environmental information plays a meaningful role only when sensory cues are not provided. In contrast, nutritional information was not identified as a significant predictor in the regression tree analysis.

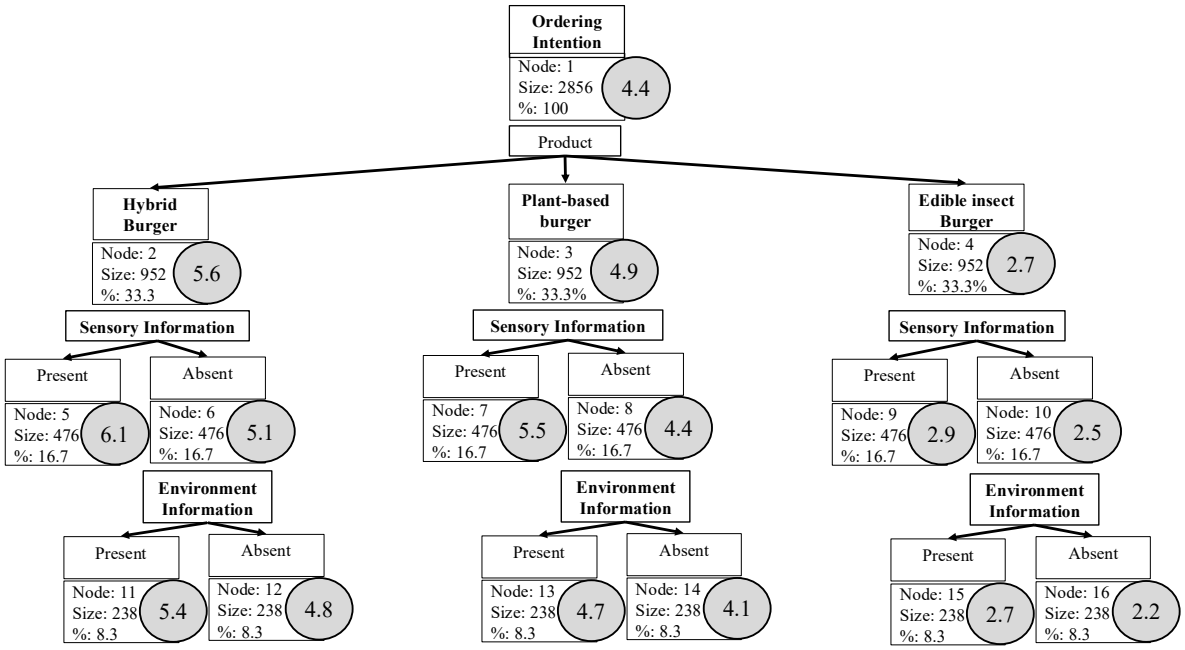


Figure 3-5 A regression tree was generated from ordering intention with product type and three information types as independent variables. Please Note: Size=number of responses, and%=responses proportion. The mean value was shown in the grey circle based on the actual purchase intention scale, 1 = 'Not at all interested in ordering' and 9 = 'Extremely interested in ordering'.

To further understand the data, three separate one-way ANOVAs were conducted for each concept within each product type (Figure 3-6). Across all three products, the presence of all three information types together resulted in the highest ordering intention; however, this was not significantly different from any of the concepts that present sensory information. No information is also consistently presented as the lowest in ordering intention. The difference between presenting all three information and no information is fairly large, with hybrid (absent M = 4.62, SE = 0.11 to present M = 6.47), plant-based burger (absent M = 3.7 to present M = 5.7), and edible insect

(absent M = 2.7 to present M = 3.1).

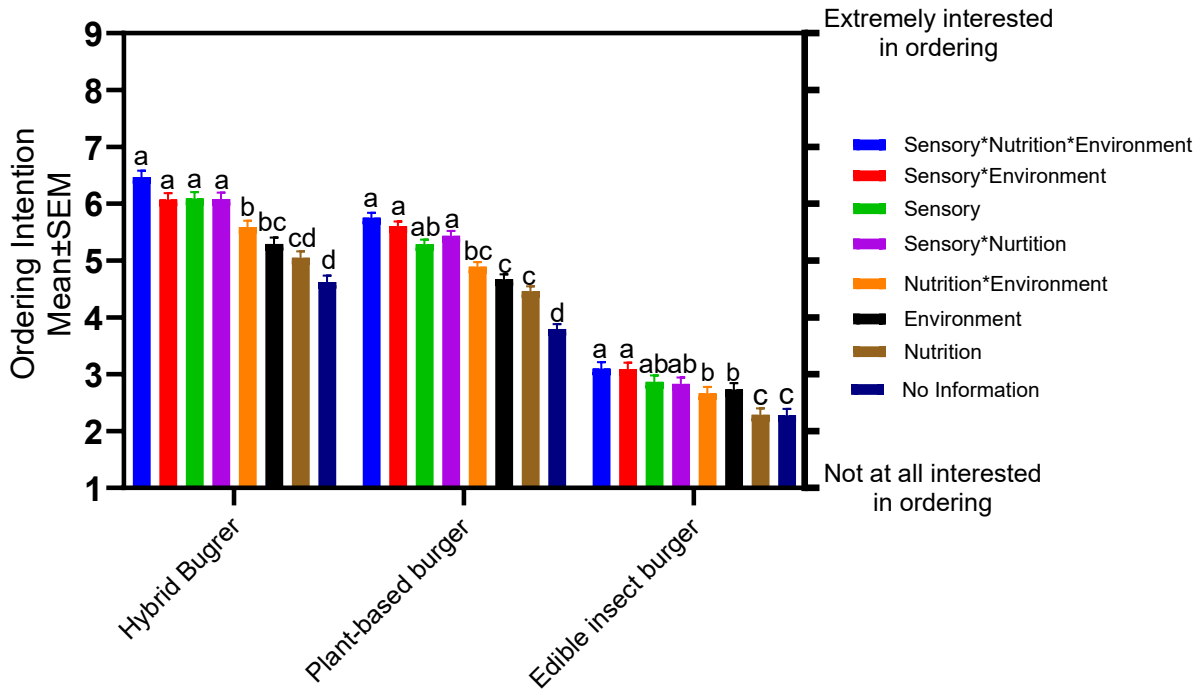


Figure 3-6 Mean ordering intention ratings (±SE) by product for eight claims, Sensory × nutrition × environment, sensory × environment, sensory, sensory × nutrition, nutrition, nutrition × environment, environment, nutrition and no information. Different letters indicate significance differences in ordering intention between the burgers and information at p≤0.05 (n = 119, 2-way ANOVA, Tukey's HSD). The hybrid burger F (7, 699) = 31.7, η^2 =0.036, p<0.0001; the plant-based burger F (7, 699) = 52.0, η^2 = 0.024, p<0.0001, the edible insect, F (7, 699) = 14.6, η^2 = 0.11, p<0.000.

Cochran's Q test showed a significant difference in citation proportion for 16 out of 24 emotional terms across eight concepts (p<0.05, Appendix C) for the plant-based product. A correspondence analysis was performed to visualise the results. Dimension 1 explained 81.44% of the variance and separated the emotions from negative emotions (*uncertain*, *disappointed*, *bored*, *suspicious*, *deceived*) to positive (*satisfied*, *happy*, *amazed*, *loving*, *energetic*). Dimension 2 explained 7.74%, which separated from *angry* to *hungry* emotions. As shown in Figure 3-7, when sensory information was presented either alone or combined with environmental or nutritional information, participants felt more *amazed*, *hopeful*, *satisfied*, *adventurous*, *happy*

and *curious* ($p<0.05$). When no information was presented, more negative emotions were generally evoked, such as *unhappy*, *dissatisfied*, *bored*, *disappointed*, and *uncertain*. When only nutrition or environmental information was presented, the plant-based burger evoked generally fewer emotions, regardless of positive or negative. However, the nutrition information evoked significantly more *hungry* than the environmental information presented alone.

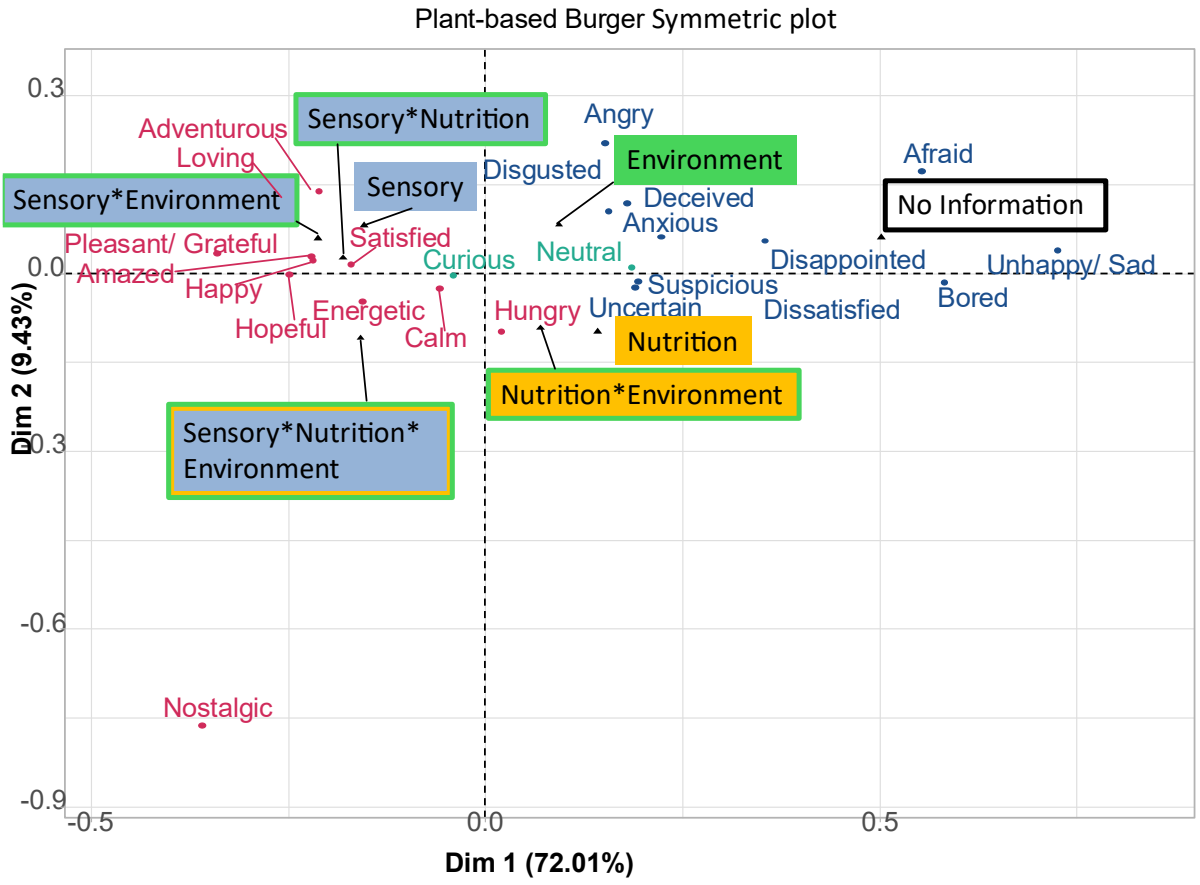


Figure 3-7 Correspondence Analysis plot for differences in emotional responses to plant-based burgers across eight product concepts (n = 119). Emotions are classified into positive (n = 11, red), negative (n = 11, blue) and unclassified (n = 2, green) groups based on Orr et al. (2023). The three information types are colour-coded: sensory (blue), nutrition (yellow), and environment (green) and combinations are represented using corresponding outline/broader colour, where the background reflects one information type colour and the outline colour indicates the additional

information types. The no-information condition is displayed with a white fill and a black outline.

For the hybrid burger, Cochran's Q test showed a significant difference in citation proportions for 13 of 24 emotional terms across eight concepts ($p<0.05$; Appendix E). Dimension 1 from Correspondence Analysis explained 79.64% of variance, and separated from negative emotions (*afraid*, *neutral*, *suspicious*, *anxious*, and *disappointed) to positive emotions* (*hopeful*, *happy*, *satisfied*, *adventurous*, *pleasant/ grateful*), which primarily differentiated the eight concepts. Dimension 2 contributed 8.19% of the variance, separated from *nostalgic/angry* to *dissatisfied*, as shown in Figure 3-8. When sensory information was present, either alone or in combination with environmental or nutritional information, more positive emotions such as *hopeful*, *happy*, satisfied, and *amazed* were evoked ($p<0.05$). In contrast, when no information was presented, more negative and neutral emotions were mostly selected, such as *suspicious*, *bored*, *uncertain,* and *neutral*.

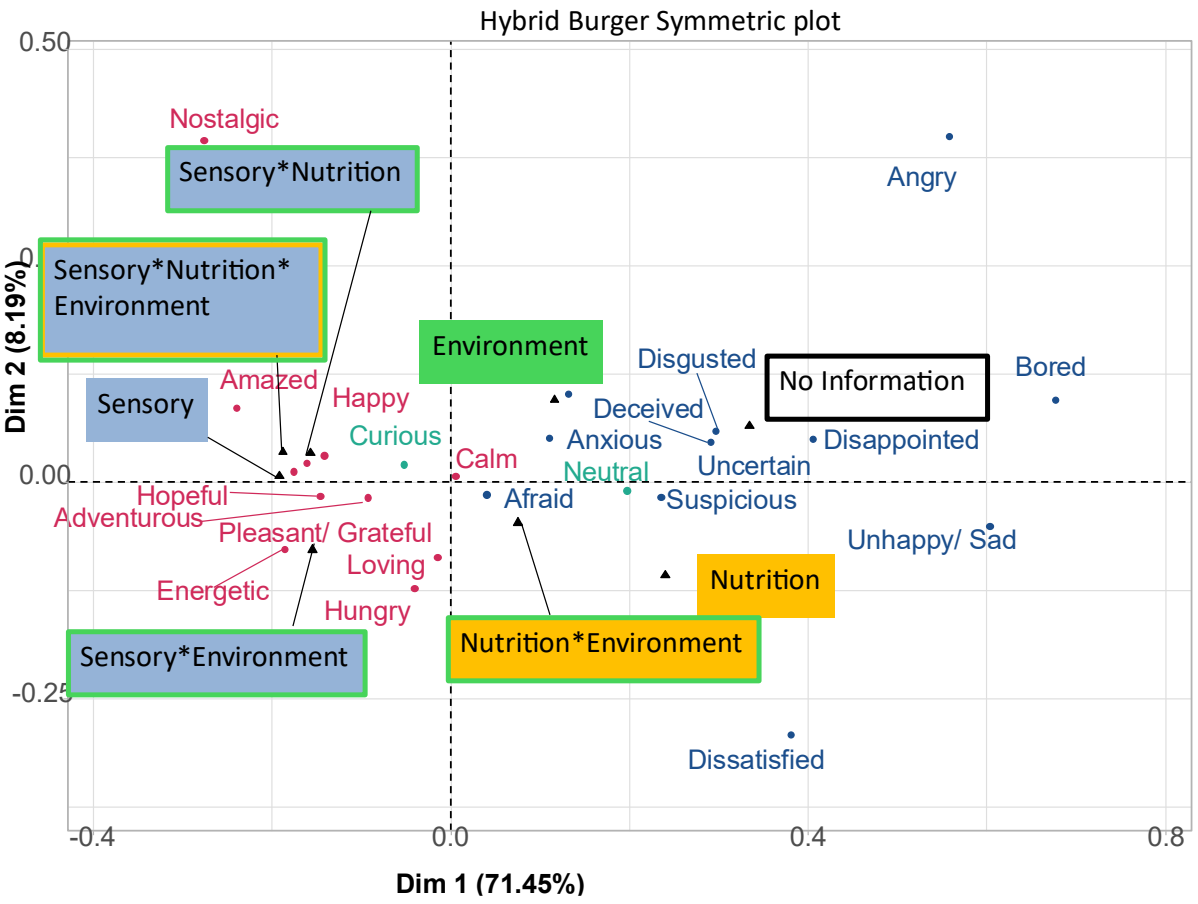


Figure 3-8 Correspondence Analysis plot for differences in emotional responses to hybrid burgers across eight product concepts (n = 119). Emotions are classified into positive (n = 11, red), negative (n = 11, blue) and unclassified (n = 2, green) groups based on Orr et al. (2023). The three information types are colour-coded: sensory (blue), nutrition (yellow), and environment (green), and combinations are represented using corresponding outline/broader colour, where the background reflects one information type colour and the outline colour indicates the additional information types. The no-information condition is displayed with a white fill and a black outline.

Cochran Q test showed a significant difference in citation proportion across 6 of 24 emotions across eight concepts for the edible insect burger ($p<0.05$, Appendix F). The correspondence analysis was performed to visualise the results. Dimension 1 from Correspondence Analysis explained 67.73% of variance, and separated the from negative emotions (*disgusted*, *dissatisfied*, *uncertain*, and anxious) to positive (*adventurous*, *hungry*, and *energetic*). Dimension 2 contributed 16.18% of variance (Figure 3-9), explained positive emotions (*pleasant*, *satisfied*, and *happy*) and

negative emotions (*deceived*, *neutral* and *calm*). When sensory information was presented, either alone or in combination with the other two information types it evoked more positive emotions, compared to no information, which evoked angry emotion. Interestingly, nutrition information on its own evoked more negative emotions, such as *angry* and *sad*, which were similar to when no information was presented.

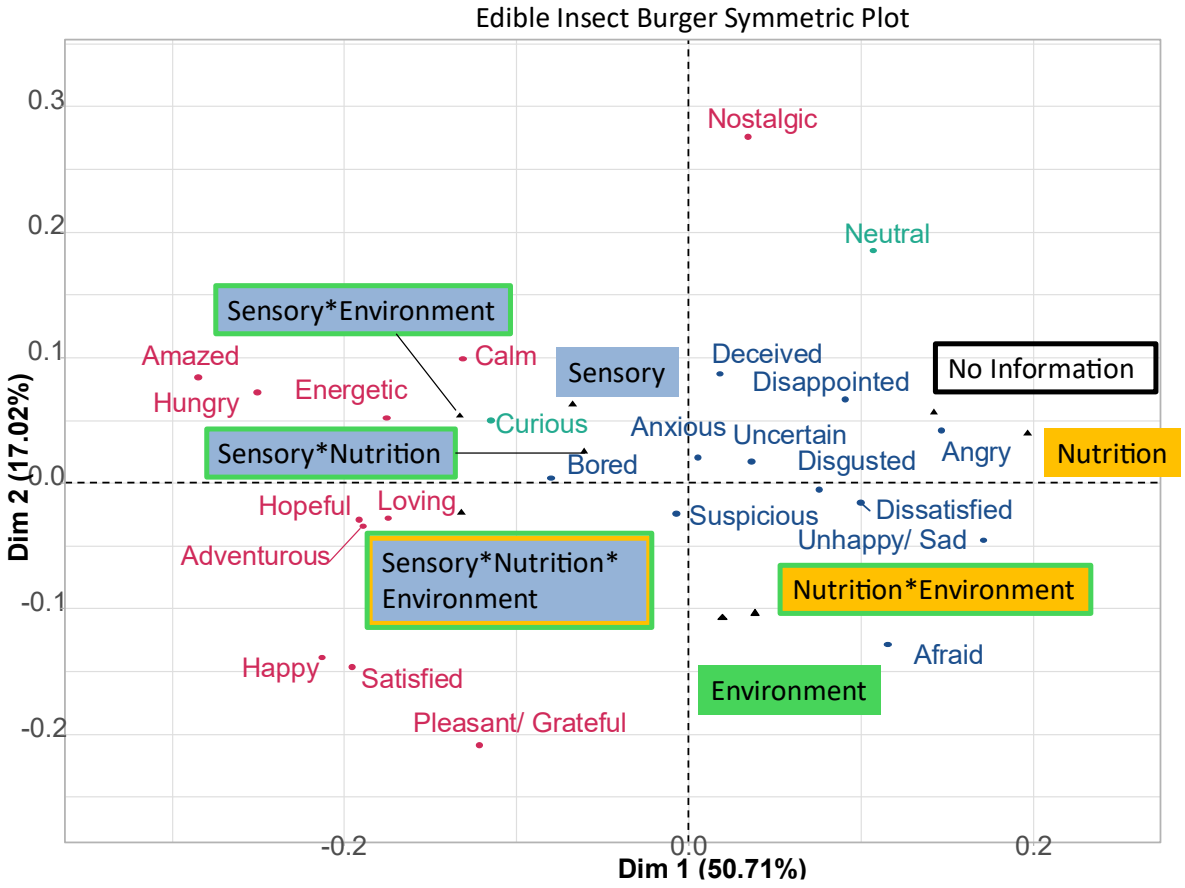


Figure 3-9 Correspondence Analysis plot for differences in emotional responses to edible insect burgers across eight product concepts (n = 119). Emotions are classified into positive (n = 11, red), negative (n = 11, blue) and unclassified (n = 2, green) groups based on Orr et al. (2023). The three information types are colour-coded: sensory (blue), nutrition (yellow), and environment (green) and combinations are represented using corresponding outline/broader colour, where the background reflects one information type colour and the outline colour indicates the additional

information types. The no-information condition is displayed with a white fill and a black outline.

3.4 Discussion

This study used a rating-based conjoint analysis to investigate UK consumers' ordering intention of a burger with different alternative protein ingredients and to examine the influence of different types of information (sensory, environmental, and nutritional). Beyond traditional rating conjoint measurement, this study expanded to capture emotional responses to provide insights into the ordering intention data.

3.4.1 Overall ordering intention and emotional responses towards three protein alternatives

This study found clear differences in ordering intention and emotional responses across the three protein alternatives, providing important insights for strategies to promote sustainable food choices. Among the protein alternatives tested, the hybrid burger received the highest ordering intention score (M = 5.6) and was strongly associated with positive emotions such as *pleasant*, *curious*, and *hopeful*. Although this score was the highest, it's just above the middle point on the 9-point Likert scale, suggesting that while the hybrid burger may be more appealing than plant-based or insect-based alternatives, overall consumer enthusiasm remains modest. This indicates that hybrid products could serve as a transitional solution for consumers hesitant to adopt fully plant-based diets, offering familiarity while introducing sustainable benefits. The emotional profile of the hybrid burger reinforces this interpretation as positive emotions such as *energetic*, *happy* and *satisfied* were more frequently cited than for the plant-based and edible insect burgers. Interestingly, the hybrid burger's mean ordering intention score (5.6) is comparable to findings by Sogari *et al.* (2024), who reported an overall liking mean score of 6.3 on a 9-point

hedonic scale for hybrid products among US consumers. Despite cultural and methodological differences, both studies suggest that hybrid products occupy a middle ground where they are considered more acceptable than insect-based options but not as strongly preferred as traditional meat. This reinforces the notion that hybrid products may act as a bridge toward sustainable eating, appealing to consumers who are curious but not ready for radical change.

For the plant-based burger ordering intention was close to the middle point, yet it evoked more positive emotions than the edible insect burger. This contrasts with previous studies where plant-based products often elicited neutral or even negative emotions, such as *bored* (Chapter 2). The difference could be explained by the fact that the current study did not include the beef burger. In Chapter 2, plant-based products were compared against beef burgers, which typically evoke highly positive emotions. In the current study, plant-based burgers were compared to insect-based burgers, which were strongly associated with negative emotions, indicating that the plant-based options appear relatively more appealing. Additionally, the data were pooled across eight concepts, reflecting the influence of sensory, nutritional, and environmental information, which contribute to the strengths of plant-based products. Prior research suggests that health, ethical, and environmental benefits evoke *pride* and *hope* emotions (Tarrega *et al.*, 2020; Zandstra, Ossel and Neufingerl, 2024), supporting some of the positive emotions observed here. However, the ordering intention score indicates that consumers' willingness to choose plant-based burgers remains low. This could be partly explained by low sensory expectations of plant-based products (Apostolidis and McLeay, 2016; Sogari *et al.*, 2024).

As expected, the edible insect burger received the lowest ordering intention score (M = 2.9) and was primarily associated with negative emotions, consistent with previous studies (Sogari, Menozzi and Mora, 2017; Russell and Knott, 2021) and Chapter 2. Emotions such as *disgust*, *worry*, *fear*, *uncertainty*, *disappointment*, and *dissatisfaction* have been widely documented as barriers to insect consumption (Gurdian *et al.*, 2021; Florença *et al.*, 2022; Ribeiro, Pintado and Cunha, 2024). Although the edible insect ingredients in this study were mixed with beef and the specific mixing ratio was not disclosed, no significant improvement in consumer expected liking was observed compared with Chapter 2, where a fully edible insect powder was used. This finding may be explained by two possible reasons. First, consumers may have overlooked the ingredient information provided in the menu and instead focused primarily on the product name, ‘edible insect burger’. As a result, they may have implicitly perceived the product as a fully insect-based burger. Another possible explanation is the psychological disgust associated with edible insects, which may continue to negatively influence consumer acceptance regardless of product formulation. This negative response is often driven by food neophobia, unfavourable sensory expectations, and cultural perceptions of insects as contaminants rather than food. While some studies have reported positive emotions such as curiosity and interest towards insect-based products, these emotions and sensory-related appeal (Gurdian *et al.*, 2021; Florença *et al.*, 2022). Presentation format also plays a critical role in influencing consumer acceptance of insect-based foods. Previous research suggests that edible insect-based products are more acceptable when insects are incorporated in a non-visible form (e.g., protein bars) compared with whole or visibly identifiable insects (Gmuer *et al.*, 2016; Lucchese-Cheung *et al.*, 2020; Herbert and Beacom, 2021). In the current study,

although whole insects were not shown on the menu, it clearly stated that edible insects were the main ingredients, which may have contributed to negative perceptions. These findings suggest that adoption of insect-based foods remains a significant challenge and will require strategies that minimise visibility and emphasise benefits such as sustainability and nutrition.

3.4.2 The impact of sensory, nutritional, and environmental information on consumers' ordering intention for protein alternatives

This study found that information provision can be an effective intervention for increasing consumers' ordering intention novel protein-alternative products, including hybrid, plant-based, and edible insect burgers. When sensory, environmental, and nutritional information together led to much higher ordering intention than the no-information conditions. The results support that consumers were influenced by external information. These findings align with earlier work showing that targeted information can shift consumer valuation of meat alternatives (Lang, 2020; Asioli *et al.*, 2023).

Among the three claim types, sensory information had the greatest effect size, followed by environmental and nutritional information. The statement '80% of consumers have described it as being juicy and tasty' appeared to be particularly effective, likely because it addressed consumers' main concerns regarding sensory expectations of taste and texture. By referencing the results of a hypothetical sensory experiment with high consumer agreement (80%), the claim conveys credibility and scientific backing, thereby enhancing consumer trust. Furthermore, the use of descriptors such as 'juicy' and 'tasty' are attributes strongly associated with a conventional beef burger (Grasso, Asioli and Smith, 2022; Greene, Yuheng

Zhu and Dolnicar, 2024), which implies a familiar and positive sensory experience. This is consistent with prior findings that consumers are more willing to adopt hybrid and plant-based products when they successfully mimic the sensory qualities (taste, texture, and flavour) of conventional meat (Sogari *et al.*, 2024). In the current study, sensory information not only increased ordering intention but also elicited positive emotions across all three protein alternatives, reinforcing the critical role of sensory expectations for consumer acceptance.

Environmental claims also showed a significant, though smaller effect size. The current study used a clear comparative statement that directly compared GHG emissions with those of a conventional burger, allowing consumers to make a quick, intuitive judgment without requiring complex calculations or prior knowledge of GHG emissions. This approach agrees with previous research showing that 'Carbon Trust Label' significantly increases consumers' ordering intention for a hybrid burger (Asioli *et al.*, 2023) and environmental claims (e.g., reducing the environmental impact of meat consumption) can significantly increase their willingness to purchase protein alternatives (Lang, 2020). When consumers become aware of environmental issues, they often develop a sense of responsibility, feeling that they should choose more sustainable protein alternatives. Environmental information may activate a sense of responsibility, encouraging consumers to choose more sustainable options. Importantly, when environmental claims are presented alongside sensory claims, the effect was amplified. It appeared that consumers could satisfy their taste expectations while feeling environmentally responsible. This sensory and environmental combination not only significantly increased ordering intention but also evoked positive emotions such as *satisfied*, *happy*, and *hope*. Suggesting that multi-

claim strategies could help consumers feel good about their choices, enhancing both cognitive and emotional drivers of choice. Combining sensory and environmental information may represent the most effective strategy for encouraging wider acceptance of protein alternatives.

From an environmental perspective, protein alternatives are widely regarded as more sustainable than red meat, particularly beef. This assessment is typically supported by different environmental indicators such as greenhouse gas emissions (GHG), land use, energy consumption, and food miles. However, the effectiveness of these environmental indicators in influencing consumer behaviour depends not only on the content of the information but also on how it is communicated.

In the current study, rather than presenting precise numerical values for environmental impacts, simplified and comparative statements were used. This decision was based on the assumption that quantitative environmental data can be too abstract for the consumer, who may lack the contextual knowledge needed to interpret figures such as kilograms of CO_2 emissions. As a result, relative comparisons (e.g., *This burger emits 90% less greenhouse gases compared to traditional beef*) may enhance comprehension and be easier to understand. Different types of environmental informational cues may trigger different consumer responses. For example, land use provides another angle of environmental benefits for protein alternatives. Beef production requires substantially more land due to grazing and feed cultivation. Prior research indicates that a single serving of beef may require approximately 12.4 m² of land, compared to only 1.44 m² for plant-based alternatives (Boronowsky *et al.*, 2022). These significant differences in land use between beef

and plant-based alternatives highlight the potential of land use as a salient environmental indicator.

The food miles represent another type of informational cue that may influence consumer responses. Food miles focus specifically on transportation distance, which is often easier for consumers to visualise. For example, beef imported by air from Washington, D.C. to London (approximately 5,899 miles) generates significantly higher transport-related emissions (e.g., 1,320 kg CO_2) compared to locally produced beef. While life cycle assessment (LCA) metrics provide a more comprehensive evaluation of environmental impact, food miles isolate the transportation component. The food miles may shape consumer responses in a simpler way, such as the idea that ‘local food is better’. This can further support consumers' association of shorter transport distances with freshness, higher quality, and lower environmental impact. However, because food miles account only for the transportation stage, they may mislead consumers by conflating transport-related emissions with total lifecycle greenhouse gas (GHG) emissions. This represents a limitation of using food miles as an informational cue. Future applications should therefore clearly communicate that food miles capture only transportation impacts, rather than the full environmental footprint.

The nutritional information, while significant, showed the smallest effect size, which is likely due to the type of nutritional information that was chosen. ‘Low in calories’ was less impactful because calorie-related information is familiar and widely understood, reducing its novelty and perceived relevance. In contrast, sensory and environmental information likely benefited from a novelty effect and a stronger emotional appeal. Previous studies indicate that related health claims such as ‘high

in protein' and 'low in fat' increase willingness to adopt hybrid products (Grasso, Asioli and Smith, 2022; Asioli *et al.*, 2023), suggesting that future research should explore alternative nutritional messages that resonate more strongly with consumer priorities.

Within nutritional information, protein content can be considered one of the indicators influencing consumer responses. In general, products labelled as 'high in protein' are perceived as more nutritious and healthier, which can increase their attractiveness. However, a previous study found that the effect of 'high in protein' claims may be more limited than expected. Ketelings *et al.* (2023) found that Dutch consumers perceived plant-based meat alternatives labelled as 'high in protein' to contain significantly more protein than they actually did. But no significant effect on perceived healthiness or willingness to buy the plant-based meat alternatives. This indicates that protein claims mainly influence a perception of protein content rather than overall product preferences.

Fat content may influence consumer responses in a different way, as it is more closely associated with health concerns. Consumers associate high fat content, particularly saturated fat, with negative health outcomes such as weight gain or cardiovascular disease. As a result, products labelled as 'reduced fat' are often perceived as healthier (Godfray *et al.*, 2018). Asioli *et al.* (2023) suggests that fat content is one of the most important nutritional attributes when consumers evaluate meat products, and reduced-fat claims can increase both preference and willingness to pay. Consumers in the UK and Spain demonstrate a clear preference for reduced-fat hybrid burgers. However, reduced-fat information does not significantly influence Danish consumers, who tend to prefer hybrid burgers with regular fat content.

3.4.3 Methodology considerations

This study used a Rating-Based Conjoint Analysis to assess the impact of sensory, nutritional and environmental information on consumers' ordering intention of protein alternatives. The results confirm that this method effectively captures the influence of information on consumer decision-making, with sensory information having the strongest positive effect and multi-information claims producing overall interest compared to the no-information condition. These results reinforce the effectiveness of rating-based conjoint analysis in understanding how information shapes consumer decision-making. While conjoint analysis identified main effects, emotional responses differentiated between combinations more clearly. For example, when sensory information was combined with nutritional and environmental information, emotional responses showed significantly bigger differences than those identified by conjoint analysis. This pattern was consistent across all three product types, suggesting that emotional response data is needed to understand motivational drivers behind consumer perceptions that simple rating scales cannot provide. These findings align with previous research, emphasising the value of emotional measures in food choice studies (Low *et al.*, 2022; Onwezen, Verain and Dagevos, 2022). Overall, combining the rating-based conjoint analysis with emotion measurement methods provides a more comprehensive analytical framework for examining how information influences consumer behaviour. This dual approach enables researchers to capture both cognitive evaluations (e.g., expected purchase intent) and affective responses (e.g. emotional response), which together provide the motivational drivers behind consumer decision-making.

3.5 Future research and practical implications

The findings of this study highlight several areas for future investigation. This research has examined the impact of sharing sensory, nutritional, and environmental information on consumers' ordering intention of protein alternatives. While rating-based conjoint analysis is a robust method for estimating expected ordering intention, it does not fully capture actual food choice behaviour, which is influenced by situational factors, prior experiences and competing options (trade-offs). In real-life settings, protein alternatives compete directly with conventional meat products such as beef, chicken, or pork in consumers’ choice contexts. Understanding how information-based interventions perform in these competitive environments is critical for translating experimental insights into practical strategies.

Longitudinal studies could also examine whether emotional responses predict long-term adoption of sustainable protein alternatives, offering valuable guidance for product development and marketing. Additionally, future research should investigate the relative effectiveness of different nutritional claims (e.g., high in protein, low in fat) and explore how this influences trust and emotional engagement. Expanding the emotional lexicon to include terms such as worried may provide a more complete picture of consumer reactions. Finally, demographic and cultural differences, as well as real-world purchase scenarios, should be examined to identify differences in consumer segments.

The results of this study are valuable for food manufacturers and marketers seeking to promote sustainable protein alternatives. For hybrid products, leveraging positive emotions such as curiosity and hope by framing them as innovative yet familiar could reduce perceived risk. For plant-based products, emphasising sensory quality

alongside health and environmental benefits may help overcome neutral interest levels and address concerns about taste and texture. For insect-based products, where neophobia and sensory expectations pose significant barriers, strategies should focus on minimising the visibility of insect components and highlighting functional and environmental benefits may help to alleviate negative perceptions.

Overall, multi-claim approaches that integrate sensory reassurance with environmental and nutritional messages appear to be the most effective strategy for increasing consumer acceptance. Combining sensory and environmental claims not only increased willingness to order but also evoked positive emotions such as *satisfied* and *hopeful*, reinforcing both hedonic and ethical motivations. These insights can inform product positioning, packaging, and communication strategies aimed at accelerating the transition toward more sustainable diets.

3.6 Conclusions

This study demonstrates that presenting sensory, environmental, and nutritional information on food menus can significantly increase consumers' willingness to order protein alternatives. Among these, sensory information emerged as the most influential factor, highlighting the critical role of taste expectations in overcoming barriers towards alternative protein consumption. Importantly, combining sensory, environmental, and nutritional information proved more effective than presenting any single information source alone, suggesting that multi-claim strategies reduce uncertainty and create a balanced appeal by addressing taste, sustainability, and health concerns simultaneously. From a broader perspective, information-based interventions represent a practical, low-cost approach to supporting sustainable dietary transitions. By leveraging simple yet targeted information, food service

providers and manufacturers can influence consumer perceptions and encourage adoption of alternative proteins without requiring major changes to product formulation or pricing.

Future research should examine whether these increases in stated willingness to order translate into actual food choices in real-world settings, where consumers face competing options such as conventional meat. Investigating the long-term impact of emotional responses, optimising how and what information is shared, and testing interventions in diverse cultural and demographic contexts will be essential for developing effective strategies that accelerate the shift toward more sustainable diets.

Chapter 4.

Sensory experience and environmental information impact real-world selection of beef, hybrid and plant-based burgers over three weeks: A pilot study

Yuchen Zhang[a], Margaret Thibodeau[a], Rebecca Ford[a], Julia Low[b] and Qian Yang[a]

[a] Sensory Science Centre, Division of Food, Nutrition, and Dietetics, University of Nottingham, Sutton Bonington Campus, LE12 5RD, UK

[a] Sensory and Consumer Science Research Group, School of Science, STEM College, RMIT University, Victoria, Australia

*Corresponding Author: Qian Yang, email: qian.yang@nottingham.ac.uk

Highlights:

- A three-visit cafeteria study examined real-world burger selection.
- Hybrid burger selection dropped from 53% to 17% after repeated sensory exposure.
- Plant-based selection increased to 28% following repeated sensory exposure.
- Repeated positive sensory experience shifted choice toward protein alternatives.

Abstract

Plant-based and hybrid meat products generally have a lower carbon footprint than conventional meat, offering a potential pathway for reducing food-related greenhouse gas emissions. However, little is known about how consumers integrate sensory experiences and environmental information when making food choices in real-world settings. This pilot study employed a three-visit ecologically valid design to examine the selection of a plant-based, hybrid (40%plant/60%beef) and beef burger in a university cafeteria.

In Week 1, participants (n = 58) selected a burger during routine cafeteria service without environmental information. In Week 2, they tasted all three burgers in the central location test where environmental information was provided. In Week 3, participants again selected a burger in the cafeteria with environmental information presented. During Week 1, 53% of participants selected the hybrid burger, while no participants selected the plant-based option. Following taste and information exposure in Weeks 1 and 2, hybrid burger selection declined by Week 3 (17%), whereas plant-based selection increased (28%).

Overall, these findings highlight that sensory experience plays a central role in repeated food choice. When positive tasting experiences are paired with environmental information repeatedly across several exposures, consumers may be more willing to select plant-based options in real-world contexts.

4.1 Introduction

Food production, processing, distribution, and consumption together account for approximately one-quarter of global greenhouse gas (GHG) emissions, representing a major contribution to climate change (Poore and Nemecek, 2018). Animal-based food production accounts for 57% of all food-related GHG emissions, making it one of the most significant sources of environmental impact within the food system (Xu *et al.*, 2021). Research shows that dietary changes towards more plant-based eating could reduce GHG emissions and land use by up to 50% compared to the current diet (Hallström, Carlsson-Kanyama and Börjesson, 2015). To meet the goals of the 2015 Paris Agreement, which seeks to limit global warming to below 2°C, systemic changes in the food system are required. Promoting a shift towards healthier, more sustainable diets is a critical component of this transition (Crippa *et al.*, 2021).

Within animal-based food products, beef production has the highest carbon footprint due to its significant land use requirements, low feed conversion efficiency, and high methane emissions (Kovacs *et al.*, 2021). Consequently, reduced meat consumption is often highlighted as an important strategy to mitigate climate change. However, promoting a reduced meat consumption among consumers is challenging because meat consumption is a core part of the established food culture and a daily habit for many people (Stoll-Kleemann and Schmidt, 2017; Kwasny, Dobernig and Riefler, 2022). Thus, encouraging consumers to shift toward more sustainable protein sources has received increasing attention. The protein alternatives were broadly defined as ‘food products that can replace animal proteins’, which could include meat substitutes, plant-based proteins, cultivated meats, mycoproteins, algae, insects, and hybrid meats that substitute or extend traditional ‘meat’ products (Nguyen *et al.*,

2022). Hybrid meat is also evolving; while it does not have a detailed definition, hybrids are commonly described as meat products incorporating varying amounts of plant-based ingredients (Grasso and Goksen, 2023; Grasso, 2024). This category has grown in popularity in recent years, as it is considered more environmentally friendly than conventional meat products and offers an enhanced sensory and nutritional profile compared to entirely plant-based products. While a wide range of alternative protein sources exists, this study focuses specifically on plant-based and hybrid meat burgers due to market availability and the increasing interest in the hybrid meat category.

Plant-based and hybrid meat are generally considered to be more sustainable sources than beef, as they require significantly less land, water, and energy to produce and generate significantly less greenhouse gas emissions compared with conventional beef. According to Life Cycle Assessment (LCA), the carbon footprint of a beef burger is 13 times higher than a plant-based burger, and 2 times higher than a hybrid burger produced in Spain (Dominguez-Lacueva, Beriain and Aldaya, 2025). In another study, the beef burger is 6.47 times higher than a plant-based burger, which is produced in the UK (Tang *et al.*, 2024). The larger GHG emission difference is due to differences in production systems, locations, and supply chains. For example, the farming systems in animal production, the type of feed, and the processing complexity for plant-based protein (Hallström, Carlsson-Kanyama and Börjesson, 2015; Poore and Nemecek, 2018). Although the calculations and methodologies vary, the main conclusion is that the overall environmental impact of plant-based alternatives is still considered to be much lower than that of a beef burger.

Since 2010, the market for plant-based protein has expanded rapidly, with significant growth from the mid-2010s to 2022 (Aschemann-Witzel *et al.*, 2021; Appiani, Cattaneo and Laureati, 2023). In the United States, the plant-based food retail market totalled $8.1 billion in 2024. However, recent reports suggest that market growth has slowed since 2022 (GFI, 2024b), potentially reflecting a combination of product-related challenges such as sensory expectations and price (Guadarrama, 2020; Szenderák, Fróna and Rákos, 2022), alongside broader socio-economic factors including the cost of living crisis and debates around ultra processed foods (Emma, 2022; Lee, Lee and Hur, 2024). The global market for hybrid meat products remains relatively small, with estimates placing its value at approximately $41 million in 2023 (GFI, 2024a). Although several hybrid meat products have been launched in countries such as the UK, Spain, and the US, few have achieved sustained market presence, suggesting that the category remains emerging and faces challenges in consumer adoption (Grasso, 2024).

In terms of consumer acceptance of beef, plant-based and hybrid burgers. Caputo, Sogari and Van Loo (2023) showed that in blind tasting conditions, hybrid burgers received liking scores comparable to beef and higher than plant-based burgers. However, when product information was disclosed, liking for hybrid burgers decreased while liking for plant-based burgers increased. Similarly, an online survey repeated a greater stated willingness to buy hybrid meat compared with plant-based meat in both the Netherlands and Finland (Van Dijk *et al.*, 2023).

Together, these findings suggest that consumer evaluation of plant-based and hybrid burgers was highly sensitive to contextual cues such as product information,

expectations, and tasting environments. This highlights the need to examine how these products are chosen and experienced in real-world food contexts.

Consumer acceptance of protein alternatives is influenced by multiple factors, including psychological, economic, product-related, and personal considerations (Hoek *et al.*, 2011; Ran *et al.*, 2022). Among these, sensory experience consistently emerges as one of the most important determinants of food choice, often outweighing considerations such as health or environmental benefits (Schouteten *et al.*, 2016; Giacalone, Clausen and Jaeger, 2022; Sogari *et al.*, 2023). For example, consumers are typically exposed to various forms of information at the point of choice, such as menu descriptions or packaging cues, which can shape expectations prior to tasting (Antúnez *et al.*, 2015; Elzerman *et al.*, 2015). Environmental information, including carbon footprint labels, has therefore received increasing attention as a potential means of influencing consumer acceptance of alternative protein products (Holenweger, Stöckli and Brügger, 2023).

4.1.1 Measuring consumer responses and food choice

The majority of previous research has focused on measuring liking or purchase intention through surveys or controlled laboratory experiments (Grasso *et al.*, 2022; Asioli *et al.*, 2023; Katare *et al.*, 2023). While these controlled studies provide valuable insights into sensory preferences and can inform the development of protein alternatives with enhanced taste, texture, and overall appeal, they often fail to capture the full complexity of real-world food choices (King *et al.*, 2004; Caputo, Sogari and Van Loo, 2023). As a result, the relationship between sensory responses and observed food choice remains insufficiently understood.

Although a range of methods has been used to study food choice, most studies rely on single-session evaluations or stated intentions (e.g., acceptability testing, purchase intention, simulated choice tasks), which may not reflect how consumers make decisions in everyday eating contexts (Asioli *et al.*, 2016; Puurtinen *et al.*, 2021; Wang and Scrimgeour, 2021). Particularly, food choice is influenced not only by liking, but also by expectations, prior experience, and contextual factors, which can evolve following tasting or information exposure (Fernqvist, Spendrup and Tellström, 2024). Importantly, eating is dynamic, with expectations before consumption potentially changing after tasting and shaping subsequent choices over time (Dijksterhuis and Piggott, 2000; Alcaire *et al.*, 2017). However, few studies have examined repeated food choices of protein alternatives in real-world settings while capturing these changes.

Accordingly, this exploratory three-visit study combined real-world cafeteria choice with a central location tasting task to examine repeated selection of beef, hybrid, and plant-based burgers. The study aimed to:

1) Examine consumer choices among beef, hybrid, and plant-based burgers in a real food service context.
2) Access how tasting experience and environmental information are associated with changes in burger selection across repeated visits; and
3) Explore how expectations, sensory perceptions, and emotional responses relate to food choice before, during, and after consumption.

4.2 Materials & Methods

4.2.1 Experimental design

This study collaborated with the catering team at the University of Nottingham's Sutton Bonington Campus (United Kingdom) to provide a real-world food choice environment in a cafeteria setting. The study followed a three-work repeated-measures design conducted over three consecutive Mondays during lunch service. Participants were obliged to avoid eating for at least one hour before the test began.

In Week 1, participants conducted the testing in the University Cafeteria setting, with ingredients-only information presented in a menu format. Participants then made an actual choice among three burger options (beef, plant-based, and hybrid). Before consumption, participants completed measures of expected liking, emotional responses, and sensory properties for all three burger options. Participants then consumed their chosen burger as part of their lunch and rated liking, emotional responses and sensory properties after two bites (early consumption), and again after finishing the meal (post consumption) (Figure 4-1).

In week 2, participants returned for a central location test (CLT), where they evaluated all three burger samples. Each sample was presented as a quarter-sized burger in a randomised order, with both ingredients and environmental information provided. Participants rated liking, emotional responses, and sensory properties after two bites (early consumption) and after finishing each sample (post-consumption) (Figure 4-1). In Week 3, participants again completed the study in the cafeteria setting following the same procedure as in Week 1. However, in this week, both ingredients and environmental menu were provided.

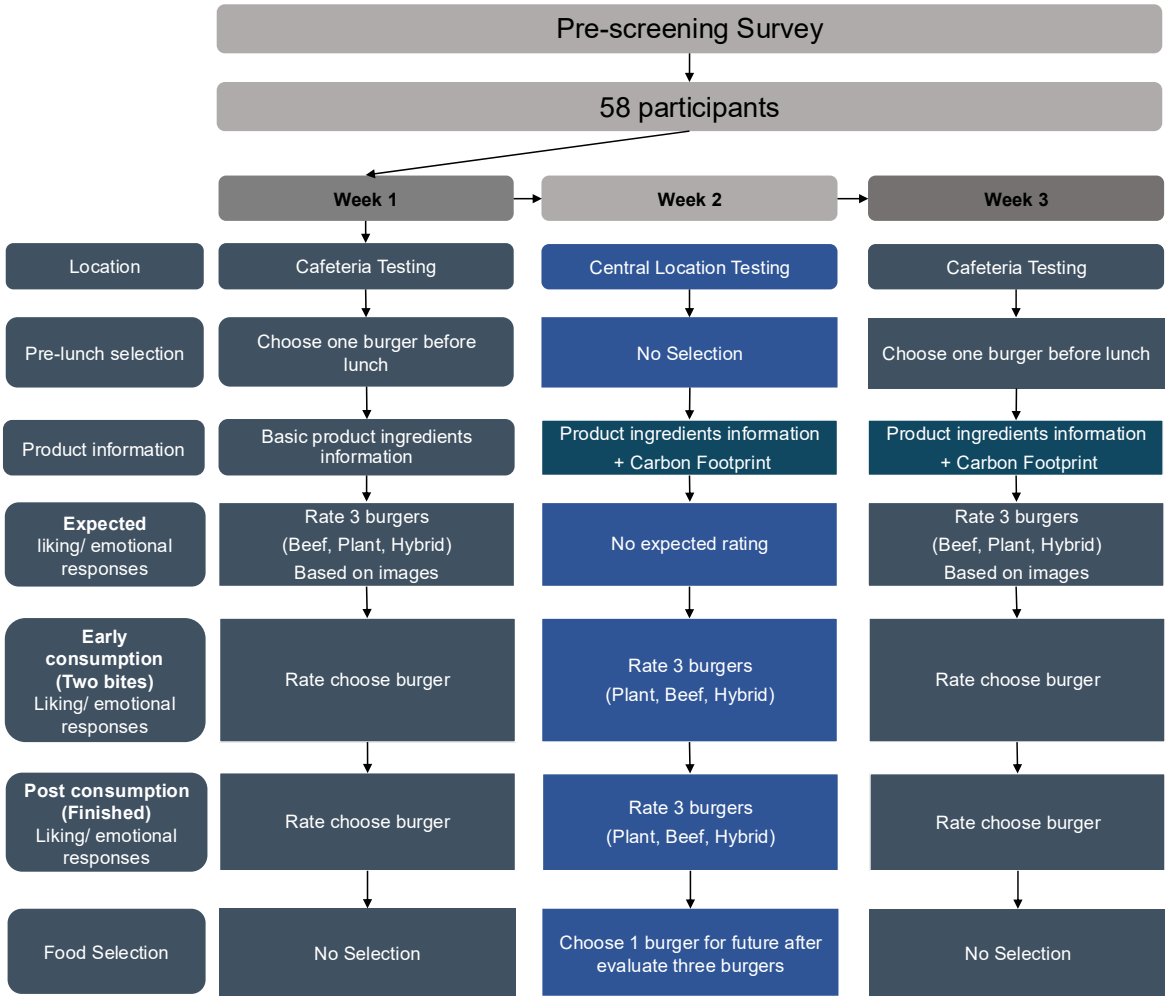


Figure 4-1 The research design framework

4.2.2 Participants

Due to this being a cross-over study design, 96 participants completed testing in Week 1, 74 returned for Week 2, and 58 completed testing in Week 3. Therefore, a total of 58 participants (21 males and 35 females, aged 18-59 years) completed all three sessions and were included in the final dataset. All participants were regular beef consumers, defined as consuming beef at least once per week, and reported no food allergies or intolerances. This research was approved by the School of Bioscience Research Ethics Committee of the University of Nottingham (Ethics

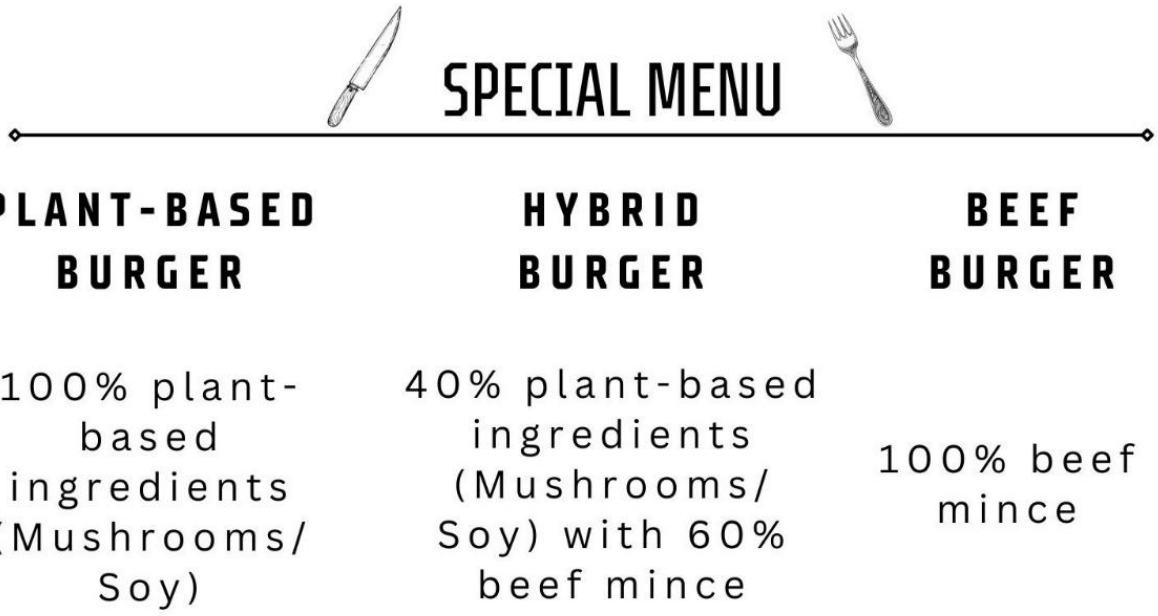
reference Number: SBREC202425012FEO). All participants provided informed consent prior to taking part in the study.

4.2.3 Sample preparation and information presented

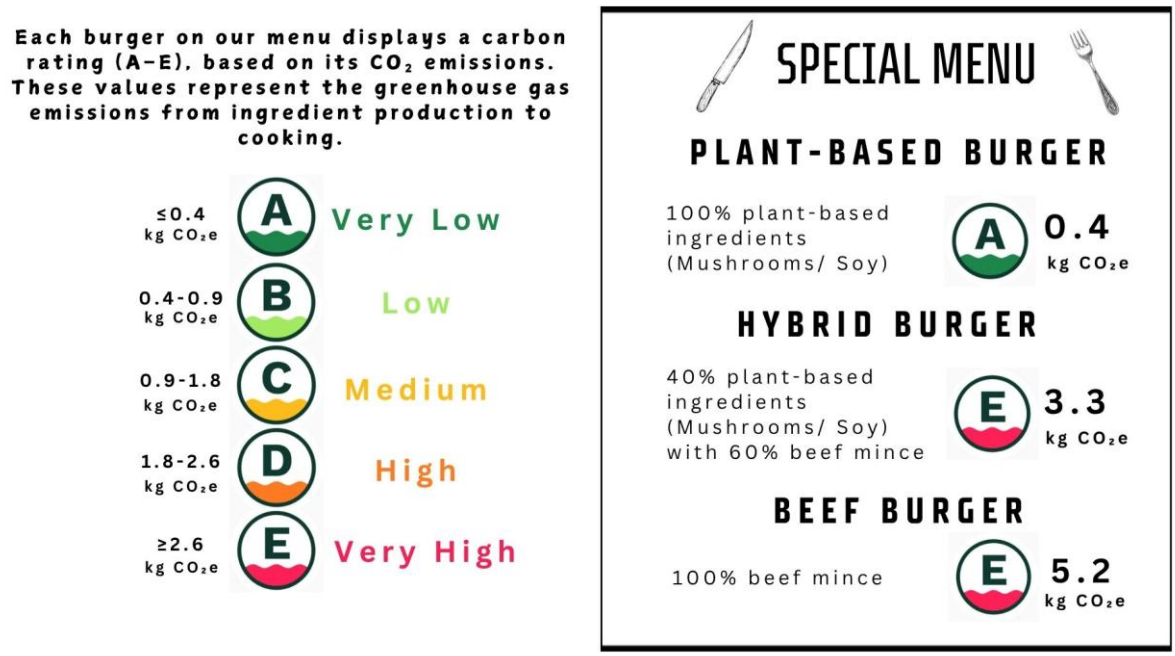
Samples were selected based on availability in the food service setting and included a commercial: beef patty (Brakes™, UK) and a plant-based patty primarily composed of mushroom- and soy-based ingredients (Moving Mountains™, United Kingdom). As a commercial hybrid burger patty was not available, the hybrid sample was prepared by the catering team by simply blending beef and a plant-based patty. The decision not to optimise the hybrid burger for flavour and texture was primarily driven by practical resource constraints, due to the kitchen without capacity for product development. However, a pilot study (n = 9) was conducted to determine the acceptable ratio of beef patty to plant-based patty and to achieve the maximum potential environmental benefits while maintaining anticipated sensory acceptability. Three plant-based proportions (20%, 30%, and 40%) were evaluated. Based on sensory evaluation, the formulation containing 40% plant-based patty was perceived as acceptable. Therefore, the hybrid burger patty was made with a 60% beef, 40% plant-based ratio. All patties were cooked by the catering team using a standardised cooking procedure to ensure consistency across sessions.

In Week 1 and Week 3, cooked patties were displayed at the cafeteria counter for participant selection and assembled with a bun, lettuce, and tomato. Participants were free to add sauces and select up to two side dishes (baked beans, green peas, broccoli, sweet corn, and chips) based on their usual eating habits. In Week 1, participants with an ‘ingredient-only menu’ were given a listing of the composition of each burger option (Figure 4-2).

In Week 2, burgers were assembled with a bun, lettuce, and tomato, cut into quarter portions, and presented in a randomised order during the central location test. Each portion was labelled and packaged in foil wrap; participants were presented with both ingredient and environmental information, including a definition of the carbon foodprint and the labels. Carbon emission values were 5.2 kg of CO_2 equivalents for one portion of the beef burger patty (roughly 120 g), and 0.4 kg of CO_2 equivalents for one portion of the plant-based burger patty (roughly 120 g, carbon emission values cited from (Klimato, 2023a; Klimato, 2023b). The carbon emissions of the hybrid burger patty were calculated proportionally (60% beef and 40% plant-based, roughly 120 g). Emissions were presented using Klimato's colour-coded carbon labelling system (A-E) alongside ingredient information (where UK consumers were familiar with the nutrition labelling, which was mandatory on prepacked food, shown in Figure 4-3).



1862 *Figure 4-2 Week 1 menu: product ingredients*



1863

1864 *Figure 4-3 Week 2 and Week 3 menu: product ingredients and environmental*
1865 *information*

1866 4.2.4 Sensory attributes and emotion responses across the eating episode

1867 Overall liking was captured using a nine-point hedonic scale (1 = extremely dislike, 9
1868 = extremely like). Emotional responses were measured using the meat and plant-
1869 based protein lexicons developed by Orr *et al.* (2023), which included 24 items (11
1870 positive emotion terms, 11 negative terms, and 2 unclassified terms). Participants
1871 evaluated their liking, emotional, and sensory responses at three time points: before
1872 consumption, early consumption after two bites, and post consumption after finishing
1873 the entire sample. For both emotional responses and sensory properties, participants
1874 were instructed to complete a check-all-that-apply (CATA) task (Jaeger and Ares,
1875 2023).

1876 To capture the sensory properties of samples, an initial list of sensory attributes was
1877 compiled based on Giezenaar *et al.* (2024). A pilot test (n = 9) was conducted to

refine this list. During the pilot, participants tasted the plant-based, beef, and hybrid burger (40% plant-based and 60% beef) samples and selected all applicable attributes from a preliminary list, with the option to report additional attributes they perceived. Following review and discussion, a final list of 15 attributes covering taste, flavour, and texture was established (Appendix G). All participants were provided with a printed list and definitions of the sensory attributes for familiarisation prior to evaluation in all sessions using CATA. The order of the emotion and sensory attributes was randomised between participants.

4.2.5 Data analysis

All statistical analyses were completed in XLSTAT statistical and data analysis solution (version 2023.1.1 Lumivero, New York). A significance level of $p < 0.05$ was used. Tukey's HSD was used as the post-hoc test.

To explore food choice across the three weeks, a Sankey diagram was used to descriptively visualisations of shifts in product choice across the study weeks. To explore how repeated visits (week) impact liking for all three products, a mixed ANOVA was used to examine differences in overall liking (expected liking from Week 1 and Week 3, actual liking from Week 2), 'Product' (3 levels) and 'Week' (3 levels) specified as fixed effects and 'Participants' as a random effect. To explore how repeated visits and product impact on emotional and sensory responses, Correspondence Analysis (CA) was conducted. Cochran's Q tests were applied to assess whether each individual emotional and sensory attribute differed significantly across 'Products' and 'Weeks'. For attributes showing a significant effect, Sheskin's Critical Difference (CD) procedure was used for post-hoc pairwise.

To explore how liking, emotional, and sensory responses change during the consumption journey. The chosen burger data in Weeks 1 and 3 were used, as the data is only available for the chosen product, resulting in an unbalanced dataset. Separate mixed-effect ANOVAs were conducted for Weeks 1 and 3, with 'Product' and 'Consumption stages (3 levels, before consumption, early consumption, and post-consumption) specified as fixed effects and 'Participant' as a random effect. For emotional and sensory attributes, citation proportions were calculated by dividing the number of citations by the number of participants for each product and consumption stage. Principal Component Analysis (PCA) was used to illustrate relationships between sensory attributes and emotional responses across consumption stages. Sensory attributes were included as supplementary variables in the PCA.

4.3 Results

4.3.1 Consumer food choice across three weeks

During Week 1, of the 58 participants, 31 (53%) participants selected the hybrid burger, and 27 (47%) participants selected the beef burger, while no participants selected the plant-based burger (Figure 4-4).

During Week 2 (CLT), participants tasted all three burgers with environmental information provided and indicated which option they would choose for a future meal. Interestingly, 19 (33%) participants chosen plant-based option, and 15 participants (26%) chosen hybrid option, with the beef choice remaining relatively stable at 41% (n = 24) (Figure 4-4). During Week 3, when participants selected a burger in the cafeteria with environmental information provided, plant-based choice remained elevated (28%, n = 16), hybrid choice declined further (17%, n = 10), and beef

choice increased to 55% (n = 32) (Figure 4-4). The choice results will be combined with liking, emotional responses, and sensory perception to be discussed together.

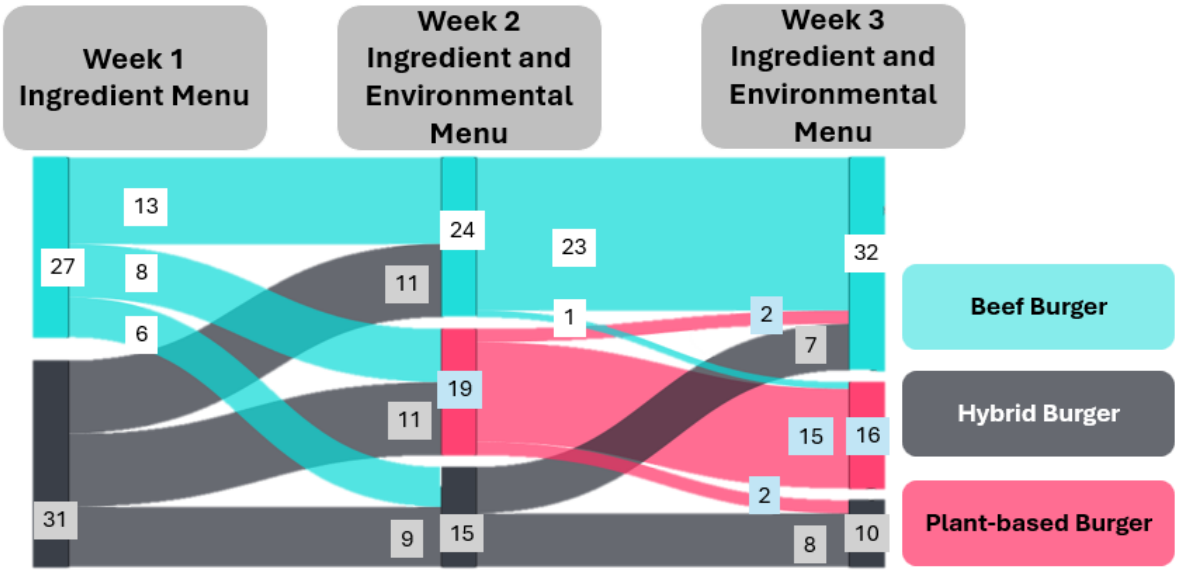


Figure 4-4 The Sankey plot of participants' Food Choices changed across the three weeks. The beef used the blue colour, the hybrid burger used the grey, and the plant-based burger used the pink colour. In the Sankey plot, the number of participants (n = 58) associated with each burger choice and shift is denoted.

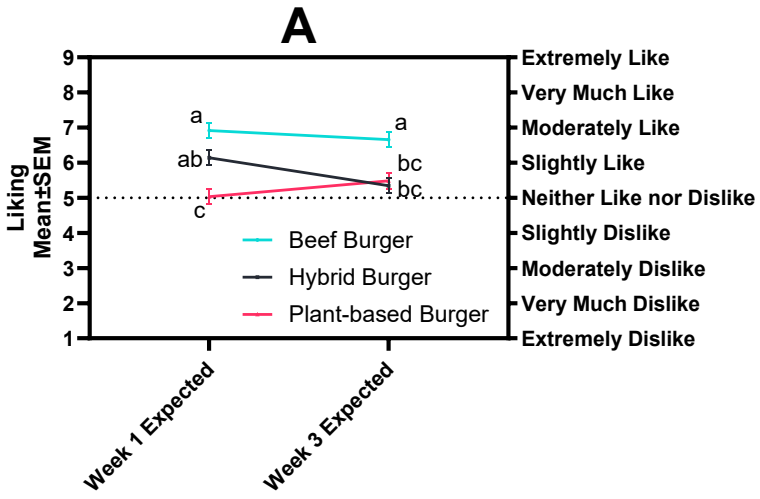
4.3.2 Liking across three weeks

Participants' liking of the three burger types was examined by distinguishing between expected liking (Week 1 and Week 3) and experienced liking (Week 2).

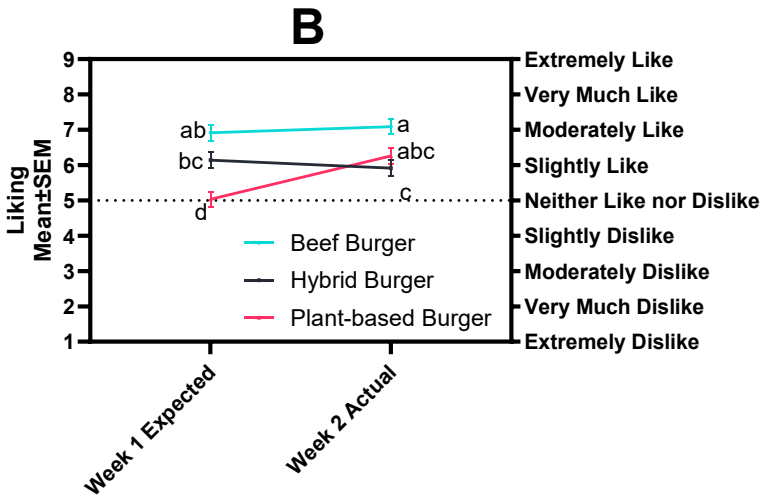
For the hybrid burger, expected liking was initially rated between slightly and moderately liked in Week 1 (M = 6.13). Following the tasting experience and environmental information, expected liking in Week 3 decreased slightly (M = 5.34); however, this difference was not statistically significant (Figure 4-5A). Actual liking during Week 2 (M = 5.91) was not significantly different from both expectations in Week 1 (Figure 4-5B) and Week 3 (Figure 4-5C), indicating that the tasting experience and environmental information did not substantially alter participants' expectations of the hybrid burger.

For the plant-based burger, participants reported relatively low expected liking in Week 1 (M = 5.00), approximately at the neutral level on the scale. However, after tasting the product in Week 2, experienced actual liking increased significantly to a level above the slightly like (M = 6.25, Figure 4-5B). But the increase in liking was not fully sustained; in Week 3, the expected liking declined to M = 5.48 (Figure 4-5C). This result suggests that although actual liking in Week 2 was higher than both in Week 1 and Week 3, the effect of positive sensory experiences was only partially retained over time.

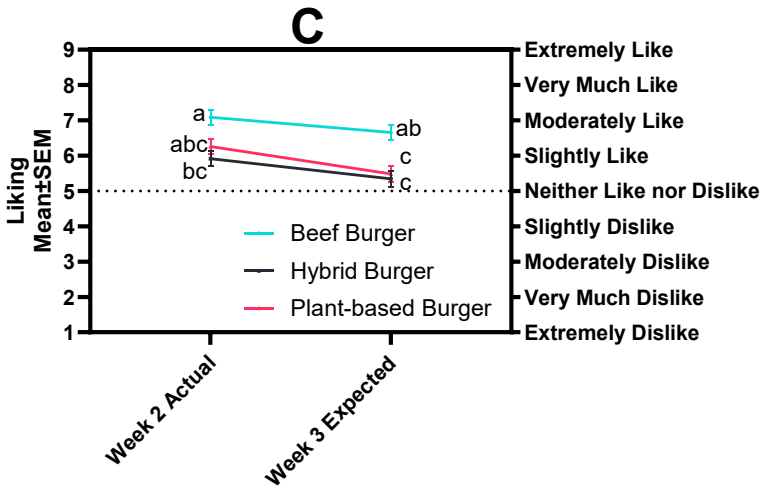
The beef burger consistently received the highest liking ratings across all three weeks. Expected liking remained stable between Week 1 and Week 3, and the tasting experience in Week 2 did not significantly alter this pattern. This suggests that participants' preferences for the beef burger were well established and were not influenced by additional environmental information or tasting experience.



Week main impact: F(1,342)=1.2, p<0.270, η²=0.004
Product main impact: F(2,342)=24.4, p<0.0001, η²=0.12
Week*Product: F=(2,342)=3.9, p<0.02, η²=0.022



Week main impact: F(1,342)=5.1, p<0.024, η²=0.015
Product main impact: F(2,342)=21.9, p<0.0001, η²=0.11
Week*Product: F=(2,342)=6.3, p<0.002, η²=0.036



Week main impact: F(1,342)=10.3, p<0.001, η²=0.002
Product main impact: F(2,342)=17.0, p<0.0001, η²=0.09
Week*Product: F=(2,342)=0.2, p<0.74, η²=0.002

Figure 4-5 Three ANOVA results summary of liking scores (Mean ± standard error) of each sample compared week 1 and week 3 (A), compared week 1 and week 2(B), compared week 2 and week 3 (C) (n = 58). F and p values derived from mixed-model ANOVA, which are at the bottom of the Figure. Different letters indicate significant differences between means across samples and weeks obtained from Tukey's HSD.

4.3.3 Emotional responses across three weeks

Emotional responses were significantly difference across products, with 15 of the 23 emotion terms showing significant differences in citation proportion when data from all three weeks were combined ($p<0.05$; Appendix H). The hybrid burger elicited higher citations of *adventurous* and *suspicious* compared with beef burger ($p<0.05$). Plant-based burgers were associated with higher citation proportions of negatively valence emotion terms, including *dissatisfied*, *anxious*, *suspicious*, *disappointed*, *uncertain*, and *curious,* whereas the beef burger evoked higher citations of positive emotions such as *energetic*, *pleasant/ grateful*, *happy*, *hungry*, *nostalgic*, and *satisfied ($p<0.05$),* and fewer negative emotions.

When the sample and week were compared, this yielded 6 combinations (Product (n = 3) × Week (n = 2, Week1 and Week 3)), the Week 2 three products' emotional responses as the supplementary for the correspondence analysis. Figure 4-6, Correspondence Analysis indicated that Dimension 1 explained 65.85% of the variance and separated positive from negative emotion terms and largely discriminated samples by product type, while Dimension 2 explained 20.01% of the variance and was more weakly associated with week. As observed in Figure 4-6, the results suggest that the differences in emotional responses were more attributed to product types. Different weeks showed that the tasting experience and environmental information were mainly product dependent, with only subtle modulation across weeks. Although hybrid burgers in Week 1 were associated with

adventurous, *curious*, and *neutral*, and those in Weeks 2 and 3 were closer to the centre and linked to *amazed* and negative emotions, these differences were relatively minor. This is because the observed separation occurred primarily along the Dimension 2, which explained only approximately 20.01% of the total variance.

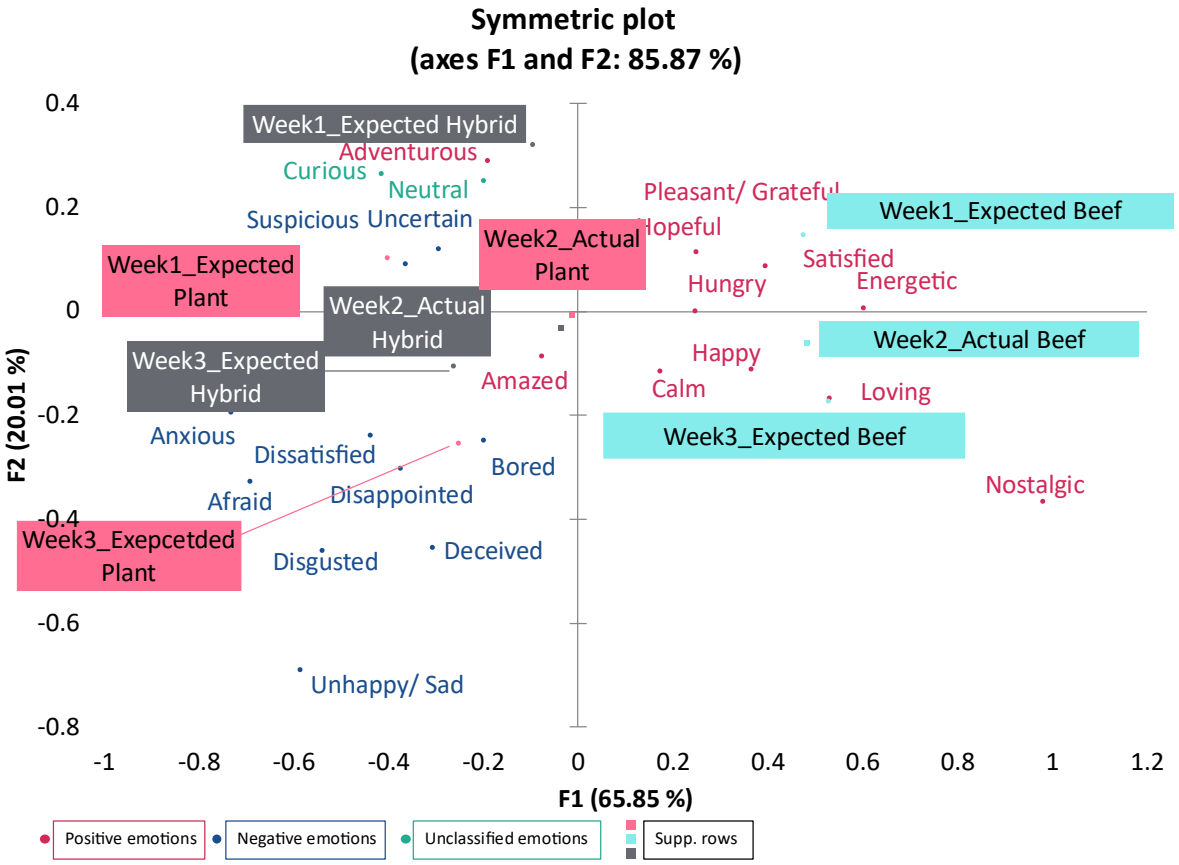


Figure 4-6 Correspondence Analysis symmetric plot for emotional responses differences between three products across three weeks. The emotions are classified into positive (n = 11, red), and negative (n = 11, blue), and unclassified (n = 2, green) groups based on Orr et al. (2023). The beef burger had a blue background colour, the plant-based burger had a pink background colour, and the hybrid burger had a grey background colour. The Week 2 data are used as supplementary data for correspondence analysis (square shape in the symmetric plot).

4.3.4 Sensory responses across three weeks

A significant difference in citation proportion for 10 out of 15 sensory attributes for the three samples by combining data for two weeks was observed ($p<0.05$, Appendix I).

Participants perceived the plant-based burger significantly more *beany*, *mushroom/ earthy*, *soft*, *dry*, and *flavourless* compared with hybrid and beef burgers ($p<0.05$). The hybrid burger was perceived as more *meaty*, *cohesive*, *dense*, and *fatty,* and less *soft* and *beany* than the plant-based burger.

Examining product × week combination (n = 9), significant differences in the citation proportion were found for 14 out of the 15 sensory attributes ($p<0.05$). As shown in the Appendix I, significant differences were mainly driven by product. When examining the significant differences between weeks for each product. The hybrid burger was expected to have more *beany* and *red pepper* flavours and less *flavourless* during week 1. However, when participants tasted the sample in Week 2, the hybrid burger was rated significantly more *flavourless* and with less *red pepper*. The results between Week 3 and Week 1 were similar, with no significant difference observed ($p>0.05$). For the plant-based burger, tasting in Week 2 elicited significantly more *soft*, less *dry*, and *red pepper* attributes than in Week 1 and Week 3. No significant differences were found among the three weeks for the beef burger.

Finally, as shown in Figure 4-7, Correspondence Analysis showed Dimension 1 explained 90.05% of the variance, and separated meat flavour and taste (*meat flavour*, *fat flavour*, *savoury*, *greasy/oily*) to plant-based flavour (*mushroom/ earthy* and *beany/ legume*), and was primarily separated by different types of samples. Dimension 2 explained 4.26% of the variance, and separated sensory attributes primarily for texture terms, *dry*, *flavourless*, *dense/ compact*, and *soft*. Taken together, the results suggest that the differences in sensory attributes were more different across product types than between weeks. However, the Week 2 actual tasting experience produced sensory attributes that differed from those in Weeks 1

and 3 for both the plant-based and hybrid burgers, suggesting that consumers' expectations did not fully align with their sensory experiences. Given that Dimension 2 explained only 4.26% of the total variance, the observed differences should be considered minor. Within this limited variation, the plant-based burger in Week 1 and Week 3 was more closely associated with beany/legume and dry sensory attributes, whereas in Week 2, it was more strongly associated with a soft texture. In contrast, the hybrid burger in Week 1 and Week 3 shows sensory characteristics similar to the Week 2 plant-based burger, for example, softness. However, in Week 2, hybrid burgers were more closely aligned with dry attributes and similar to the sensory profile of plant-based samples from Week 1 and Week 3. Across all weeks, the plant-based and hybrid burgers did not show sensory similarity to beef. In contrast, for the beef burger, consumers' expectations were consistent with the tasting experience.

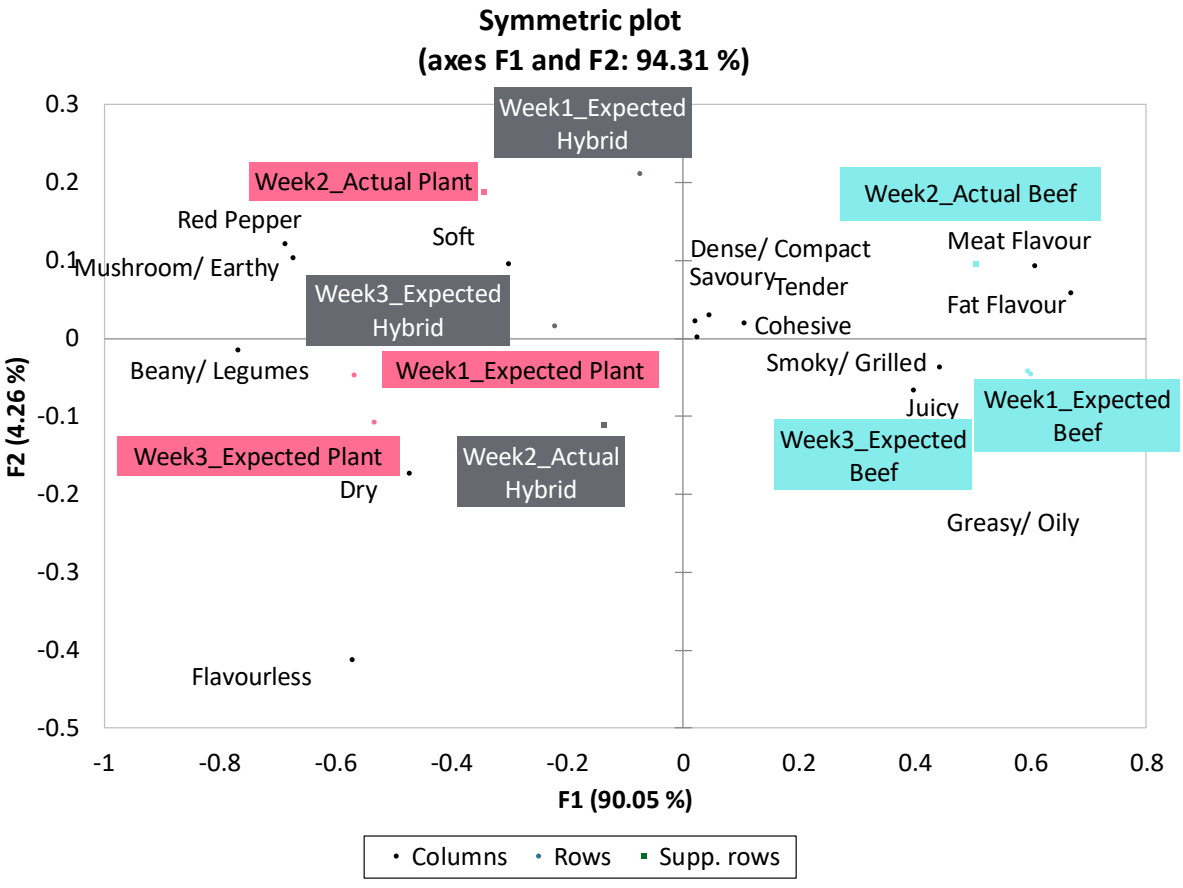


Figure 4-7 Correspondence Analysis symmetric plot for sensory responses differences between three products across three weeks. The Week 2 data were used as supplementary data for correspondence analysis and presented in a square shape. The beef burger had a blue background colour, the plant-based burger had a pink background colour, and the hybrid burger had a grey background colour.

4.3.5 Understanding consumer responses across the full eating journey: Before, Early and Post-Consumption

Only the actual chosen product data in Cafeteria (Week 1 and Week 3) generated data cross the full eating journey from before eating to early and post-consumption, therefore the dataset is unbalanced, and separate ANOVAs were performed for liking in Week 1 (Appendix J) and Week 3 (Appendix K). In both Week 1 and Week 3, no significant difference was observed in liking scores across three stages of eating for all three burgers, respectively. These findings suggest that participants' expected liking matches the liking during and after eating. Dimension 1 accounted for 30.11% of the variance, separating emotions into positive (*happy*, *satisfied*, *pleasant/ grateful*) and meat-like attributes (*juicy*, *smoky/ grilled* and *greasy/ oily*) to negative (*disappointed*, *dissatisfied*, *uncertain*, *disgusted*, *anxious*) emotions. The supplementary sensory data separated on Dimension 1 from meat-like attributes (*juicy*, *smoky/ grilled* and *greasy/ oily*) to plant-based attributes (*dense*, *compact*, *dry* and *flavourless*). Dimension 2 explained 16.05% of the variance and separated emotions from *adventurous*, and supplementary sensory data separated from *fat* to *red pepper*.

Figure 4-8A showed the hybrid burger results, for those selected hybrid burger options in Week 1(58% participants) and Week 3 (17% participants). During initial selection (Week 1), they expected the hybrid burger to evoke *curious* and *suspicious* emotions, but they also expected the hybrid burger to have *mushroom/ earthy*

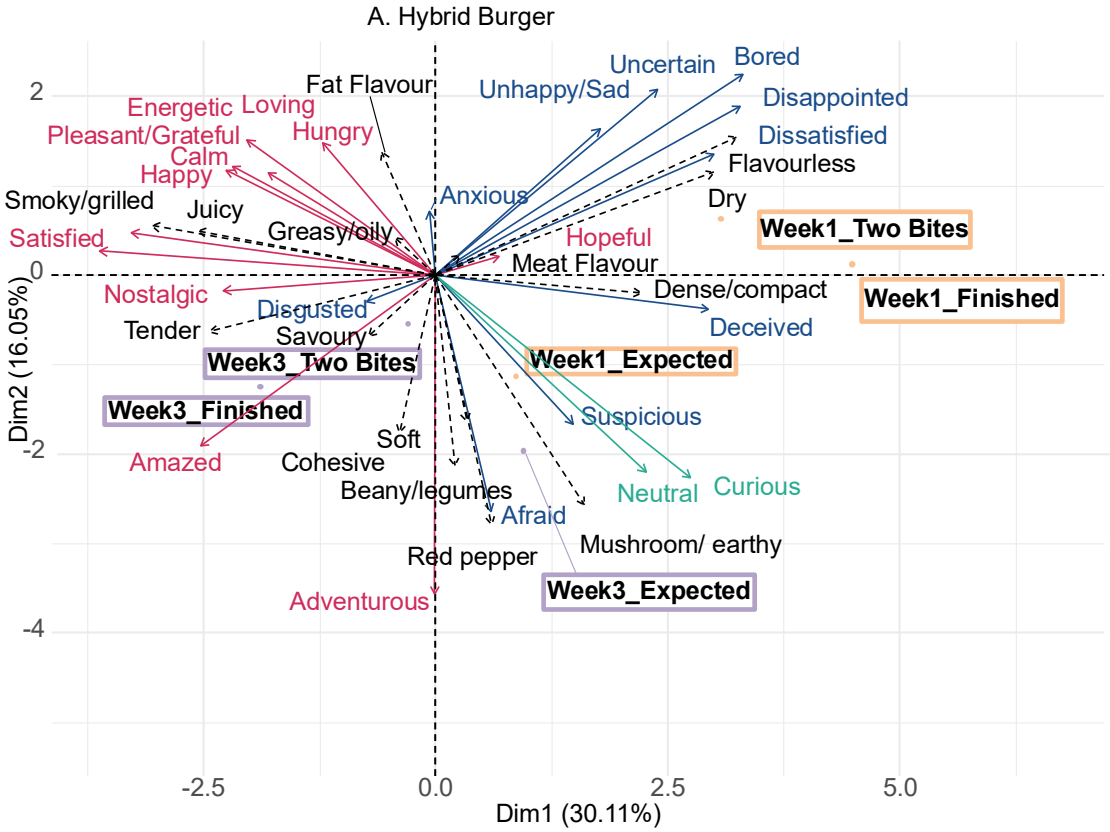
sensory attributes. However, during actual consumption, hybrid burger stated to evoke more negative emotions (*dissatisfied*, *disappointed* and *deceived*) and was also associated with negative sensory attributes such as *dry*, *flavourless* and *dense/ compact*. After the Week 1 and Week 2 tasting experience, there are significantly fewer participants who select the hybrid burger in Week 3. For those who chose the hybrid burger in Week 3 (17%), they could be considered as truly liking hybrid burgers, representing hybrid burger consumers. Therefore, when these consumers consumed the hybrid burgers, it evoked more *amazed*, *nostalgic* emotions, as well as more positive sensory attributes such as *savoury* and *tender*.

For the plant-based burger, as no participants chose plant-based in Week 1, only data from Week 3 were shown in the Figure 4-8B. Participants who chose to eat plant-based food did not have many expected emotions before eating; however, eating the plant-based burger evoked significantly more positive emotions, such as *satisfied, happy,* and *nostalgic*. Meanwhile, more positive sensory attributes were perceived, including tender, smoky, and juicy.

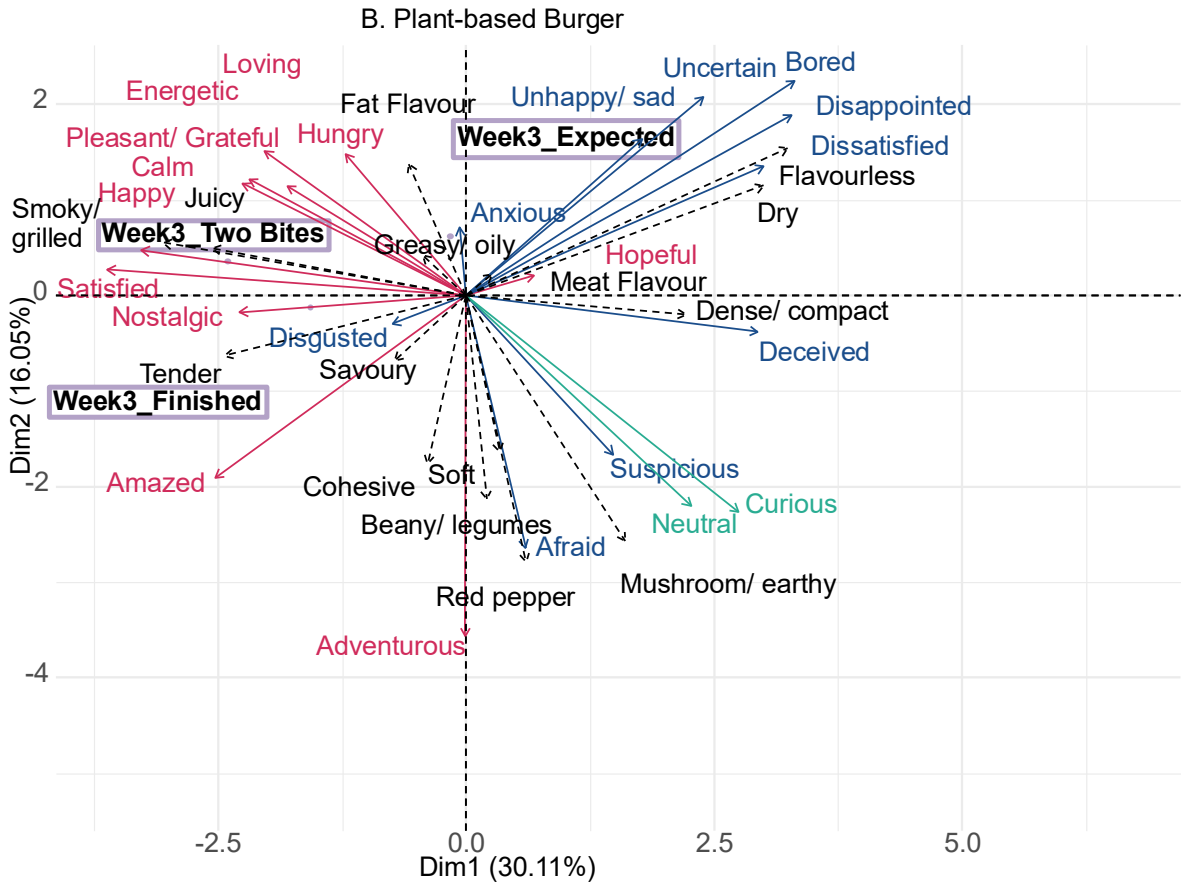
For the beef burger, emotional and sensory responses remained consistent among expectations, two bites, and finished for both Week 1 and Week 3, as shown in Figure 4-8C. The data suggest that consumer expectations for a beef burger are met by the sensory and emotional profile of the beef burger. Across three product categories, no clear difference was found between two bites and finished results,

2082 suggesting early sensory input establishes most of the sensory impression and

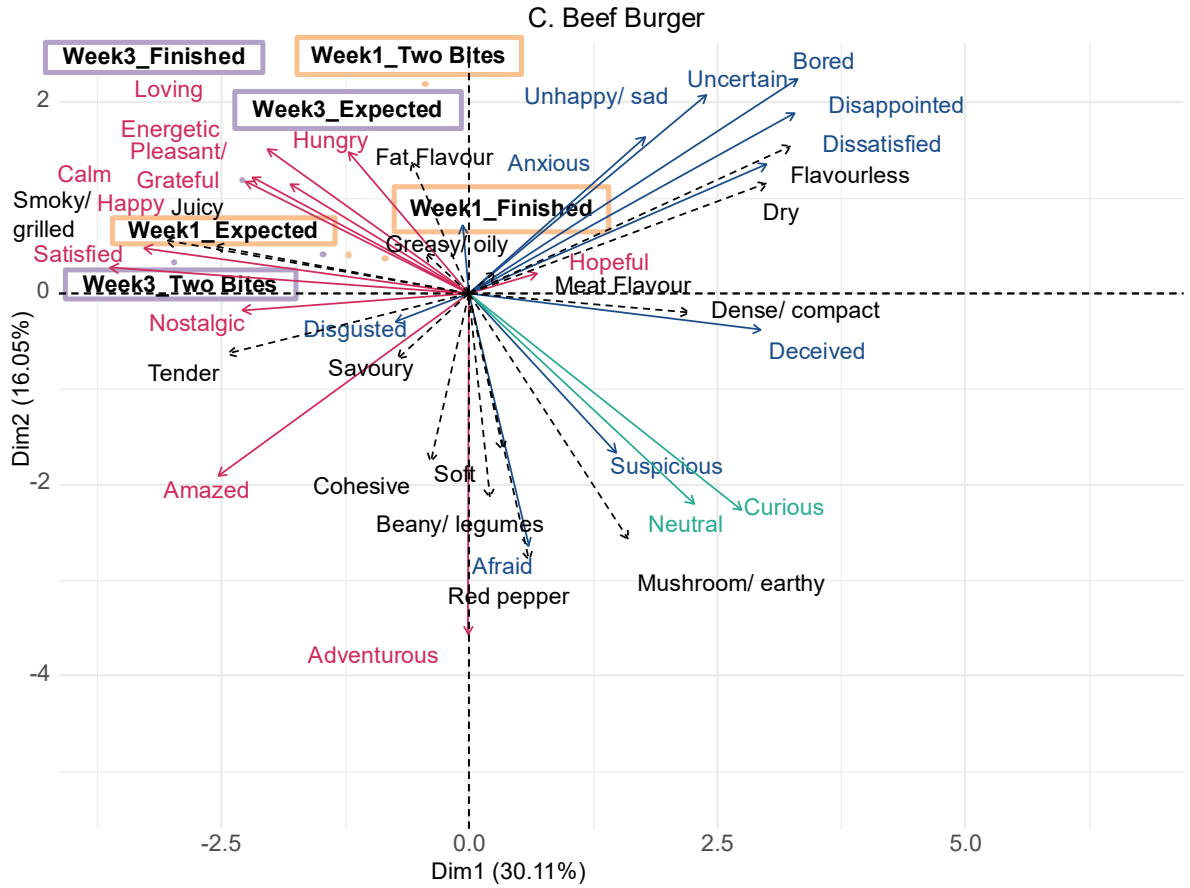
2083 overall liking can be formed at an early stage of eating and remains stable.



2084


B. Plant-based Burger
Loving
Energetic
Fat Flavour
Unhappy/ sad
Uncertain
Bored
Disappointed
Dissatisfied
Flavourless
Dry
Pleasant/ Grateful
Hungry
Week3_Expected
Calm
Happy
Juicy
Smoky/
grilled
Week3_Two Bites
Anxious
Greasy/ oily
Hopeful
Meat Flavour
Satisfied
Nostalgic
Dense/ compact
Deceived
Disgusted
Savoury
Tender
Week3_Finished
Amazed
Cohesive
Soft
Suspicious
Curious
Neutral
Beany/ legumes
Afraid
Mushroom/ earthy
Red pepper
Adventurous
2
0
-2
-4
-2.5
0.0
2.5
5.0
Dim2 (16.05%)
Dim1 (30.11%)

2085



2086

2087 *Figure 4-8 Comparison of emotional responses and sensory responses of selected*
2088 *hybrid burger (A), plant-based burger (B), and beef burger (C) choices between*
2089 *Week 1 (n = 31, 53% selected) and Week 3 (n = 10, 17% selected) at the expected,*
2090 *two-bite, and finished stages. The emotion are classified into positive (n = 11, red)*
2091 *and negative (n = 11, blue) and unclassified (n = 2, green) group based on Orr et al.*
2092 *(2023). The Sensory attributes were treated as supplementary variables and overlaid*
2093 *onto the emotional responses PCA, shown in black in this Figure. Week 1 expected*
2094 *two bites and finished were used orange colour as outline colour and week 3*
2095 *expected, two bites and finished were used purple colour as outline colour.*

2096

4.4 Discussion

This study provides novel insights into how consumer expectations evolve across repeated exposure to protein alternatives, and how these expectations interact with actual sensory experience over time. Unlike previous research that typically relies on a single sensory and consumer evaluation in a sensory lab, this exploratory study investigated multiple visits in a real-world consumption environment. The multiple-visits design provided a dynamic understanding of the alignment between expectations and experiences for hybrid and plant-based burgers.

4.4.1 Measuring consumer food choice in a real environment

This study explored consumers' food choices of protein alternatives in a real-world setting. Previous consumer studies on plant-based and hybrid meat products have been mainly conducted in either an online survey (Greene, Yuheng Zhu and Dolnicar, 2023; Ford *et al.*, 2024b; Zandstra, Ossel and Neufingerl, 2024) or in the controlled sensory environment (Appiani, Cattaneo and Laureati, 2023; Giezenaar *et al.*, 2024; Sogari *et al.*, 2024). Many studies have explored how presenting different levels of information impacts consumer responses (e.g., liking or willingness to buy) for protein alternatives (Asioli *et al.*, 2023; Coucke, Slabbinck and Vermeir, 2023). But limited research has examined this in a real-world consumption context and the repeated choice.

This study is the first to explore the research through a three-visit experiment in a University Cafeteria, examining real food choices and the effects of eating experience and environmental information on repeated decisions. This exploratory study investigated consumer responses from expectations before consumption

through the consumption period and into the post-consumption period, examining liking, emotional responses and perceived sensory attributes among actual consumers (those who selected the options).

4.4.2 Consumer food choice, liking, emotions, and sensory properties across three weeks

During Week 1, when participants made their initial burger selection was made without providing environmental information, 53% of participants selected the hybrid burger, 47% selected the beef burger, and none selected the plant-based burger. The novelty effect could explain the high choice for the hybrid. Since participants do not usually have a hybrid burger option as part of the cafeteria offering. Participants were encountering this product for the first time, which may have encouraged them to choose it out of curiosity or because they held particularly high expectations for a newly introduced item.

Previous studies also suggest that consumers tend to hold high expectations and a high liking for hybrid products. Although no research has examined real-world food choices, the current study's hybrid burger liking is M = 6.13 on a 9-point hedonic scale, and previous studies indicated that liking scores for hybrid products were approximately 6.31 (Sogari *et al.*, 2024) and 6.68 (Caputo, Sogari and Van Loo, 2023) on a 9-point hedonic scale. Current results indicate that consumers slightly like the hybrid burger, which aligns with previous studies showing initial positive reactions to hybrid burgers. However, liking was decreased in Week 2 (M = 5.91 in Week 2), and choice was significantly reduced from 53% to 26% in Week 2. This could be due to unexpected sensory experiences, which were perceived as dry and flavourless in Week 2. As a result of this tasting experience, liking and choice for the hybrid burger

has further declined in Week 3 (17% selected and expected liking M = 5.34). The decline in choice and liking over three weeks also suggests that the additional environmental information for the hybrid burger had minimal impact on consumer liking and choice when sensory expectations were not met. In addition, the hybrid burger's GHG emissions were reduced by only 36.5% compared to beef, and both beef and the hybrid burger fall under the same category on Klimato's carbon label, which is classified as high GHG emissions. Therefore, this may make participants felt it may not be worth to sacrifice the sensory experiences, therefore has reverted back to their usual beef choice (n = 11 (19%) converted their choice from hybrid in Week 1 to beef in Week 2) or they decided to choose a more pronounced environmental friendly option - plant-based option (n = 11 (19%) converted their choice from hybrid in Week 1 to plant-based in Week 2). Although consumers reported high expectations for hybrid meat, this study highlights that incorporating plant-based ingredients into animal-based ingredients is not an easy task and would require significant support from food scientists or product development teams to optimise the sensory properties of the products. This aligns with the previous study, which reported a limitation associated with incorporating higher plant proportions often leads to changes in texture and flavour, thereby reducing perceived meatiness (Grasso, 2024).

Hybrid products remain a highly promising concept, supported by the high choice in Week 1. Hybrid products can be positioned as an environmentally friendlier alternative that can appeal to both meat-eaters and flexitarians by offering a bridge between taste and sustainability (Grasso and Goksen, 2023). However, this study indicates that when sensory qualities are unsatisfactory, the environmental

advantages have little impact, as consumers either revert to their usual beef choice or opt for the plant-based alternative, which offers a significantly higher environmental benefit.

This outcome may, in part, be explained by the limited optimisation of the hybrid burger used in this study. Due to practical constraints, the product was not extensively refined for flavour and texture, unlike the commercial products, which are typically developed through iterative sensory optimisation. As a result, the hybrid burger may have been at a disadvantage in terms of sensory appeal, potentially influencing consumer responses and reducing its competitiveness compared with the beef burger. Therefore, the lower acceptance observed may not fully reflect the true potential of hybrid products, but rather highlight the importance of achieving acceptable sensory quality in order for environmental messaging to be effective. This is particularly evident when considering commercially available hybrid products, which are likely to undergo extensive sensory optimisation and may therefore achieve higher levels of consumer acceptance than the prototype tested in this study.

For the plant-based burger, surprisingly, no one selected the plant-based burger during Week 1. The reasons for this are unknown, but it could be due to the fact that this study recruited beef eaters, as we require all participants to be able to try all three burgers. This could lead to beef eaters might have a strong preference and attachment to beef. In addition, expected liking for plant-based products was ‘neither like nor dislike’ during Week 1, suggesting that consumers’ expectations of plant-based burgers are generally low, which may be influenced by prior negative sensory experiences. This was supported by the sensory results, where dry and flavourless

were the dominant attributes for expected sensory properties for plant-based in Week 1. Previous studies indicated that plant-based meat often has an undesirable taste and unappealing appearance, which significantly reduces consumer acceptance (Sogari et al., 2021; Grasso, Asioli and Smith, 2022). The liking data is consistent with the choice data, which suggests that when consumers feel neutral toward a product (neither like nor dislike), they are unlikely to choose it. In other words, participants need to express some level of liking before deciding to choose and consume a product. However, a promising trend was found that plant-based burger choice increased significantly in Week 2 (33%) and Week 3 (28%). Tasting experience in Week 2 has shifted plant-based sensory experience towards softer attributes and less *dry* and *flavourless* sensory attributes. The positive sensory experience and additional environmental information have successfully shifted consumer choice from 0% to 33% towards a plant-based option in Week 2, with the majority of participants sustained during the repeat choice in Week 3 (28%), suggesting that tasting experience and additional environmental information can be used to promote plant-based choice. However, the liking data and emotional responses data did not fully support the increased plant-based choice in Week 3. Since the liking and emotional responses in Week 3 are more similar to those in Week 1. This suggests the complex relationship between food choice, liking, and emotional responses, and how expectations can be difficult to shape. Future studies should explore how multiple tasting experiences can shape expectations and more effectively promote plant-based options.

Overall, the findings suggest that consumer choice is driven by a dynamic interaction between sensory evaluation, environmental information, and habitual behaviour.

Across all three burger types, sensory perception emerged as the dominant driver of sustained choice, more important than environmental information and initial expectations. While environmental informational cues were effective in prompting short-term behavioural shifts, particularly towards plant-based options in Week 2, these changes were not consistently maintained, indicating the presence of an intention–behaviour gap.

Furthermore, the results highlight the role of habitual consumption, as participants often returned to familiar beef options after trying alternatives. This suggests that changing food habits requires more than just information and may depend on repeated positive sensory experiences. The hybrid burger choice results show that there are challenges in positioning intermediate products. Despite initial interest driven by novelty and curiosity, its declining selection over time indicates that it failed to deliver sufficient sensory satisfaction while also lacking a strong environmental advantage. Taken together, these findings suggest that encouraging alternative protein choices requires not only providing environmental information but also improving sensory quality and creating positive consumption experiences, as these are key to long-term behavioural change.

4.4.3 Impact of environmental information on the choice of hybrid burger

In the current study, the environmental benefits of the hybrid burger may not have been clearly communicated, as it was assigned to the same greenhouse gas (GHG) emissions category (level E) as the beef burger, which represents the highest level of emissions in Klimato's system. Specifically, the hybrid burger's GHG emissions were calculated using a weighted combination of its components, consisting of 40% plant-

based ingredients and 60% beef, and the resulting value was then classified using Klimato's colour-coded carbon labelling system.

The design of this system may have further contributed to this outcome, as it is a commercial labelling system with relatively broad categories. For example, all products with emissions above 2.6 kg CO_2e are classified as level E, while those below 0.4 kg CO_2e are considered very low. In this study, the beef burger had emissions of around 5.2 kg CO_2e, and although the hybrid burger had lower emissions (3.3 kg CO_2e), it still exceeded the 2.6 threshold. Consequently, both products were placed in the same category, which may have reduced the visibility of their environmental differences.

As a result, participants may have perceived the two options as environmentally similar. This perception may have persisted even though numerical GHG values were presented alongside the label, as the shared category likely reinforced a sense of equivalence between the products. This may have reduced consumers' awareness of the hybrid burger's environmental benefits and limited their ability to differentiate between the options.

The observed changes in choice behaviour further support this interpretation. While 53% of participants initially selected the hybrid burger, this proportion decreased to 26% after exposure to environmental information and sensory experience. This shift may be explained by the limited differentiation communicated by the label, combined with sensory evaluations that did not meet participants' expectations, ultimately influencing consumer choice behaviour.

4.4.4 Consumer responses across the full eating journey: Before, Early Consumption, and Post-Consumption

Capturing consumer responses before, during, and after consumption is important to uncover the relationship between expectation, initial tasting experience, and post-consumption experiences. Post-consumption experiences incorporate overall satisfaction and satiation effects. This approach captures different phases: from expectations and first impressions based on sensory experiences to post-consumption, which reflects overall satisfaction with the meal and is influenced by satiety. Looking at the results, no clear difference for liking and emotional responses was observed between early consumption and post consumption results. However, results from expectation did show some differences from actual eating data, especially for the hybrid burger.

At initial tasting (Week 1), a significantly higher proportion of participants (n = 31, 53%) selected the hybrid burger, and evoked more curious emotion. This suggests that curiosity may be an important emotional driver of initial food choice, thereby motivating consumers to select a novel product despite the underlying uncertainty participants also feel. Previous studies indicated that consumer curiosity about protein alternatives can also increase their acceptance (Northstone and Emmett, 2008; Laureati *et al.*, 2024). However, when these participants started to eat their chosen hybrid burger, they started to perceive some undesirable sensory properties and evoked much more negative emotions. This has led to a significantly lower proportion of hybrid burger choice in Week 3 (n = 10, 17%). Although the number is low, this could represent the loyal consumers for the hybrid burger, who showed

more *adventurous* emotions and associated with more positive sensory attributes during and after eating the hybrid burger.

For plant-based, as no one selected it during Week 1, only Week 3 data are available, representing consumers who converted from their initial beef or hybrid options to a plant-based option in Week 3. Even though not many emotions were evoked for expected emotional responses for plant-based, this still led to 16 participants (27%) choose a plant-based burger. When participants started eating the plant-based burger, positive emotions and positive sensory attributes were evoked and perceived. This indicates that although the earlier tasting experiences effectively influenced consumer choice, participants might still have low expectations. Therefore, future research should explore how repeated positive tasting experiences appear to be necessary to enhance positive associations for plant-based burgers or other novel foods.

Interestingly, the beef burger results were consistent among the before, early, and post consumption stages for liking, emotional responses, and sensory attributes, suggesting beef burgers have stable, well-established expectations in consumers' minds. In contrast, novel products such as plant-based and hybrid burgers do not have these stable, positive expectations; therefore, shaping and reinforcing expectations for novel foods through repeated positive sensory experiences are critical for novel food success. This exploratory study has provided additional insights into consumer expectations, how participants align with eating experiences, and how prior eating experiences and additional environmental information shape repeated choices and expectations.

4.4.5 Limitations and Future Directions

One limitation of this study is that it is difficult to isolate the independent effects of sensory experience and environmental information on consumer choices. In Week 2, participants tasted three burgers and received environmental information, then made hypothetical choices. Because both sensory experience and information were presented together, the resulting preferences likely reflect a combination of the two factors rather than their separate effects. In Week 3, participants made real choices based on their past tasting sensory experiences and environmental information, showing how actual behaviour is shaped by the interaction of sensory experience and environmental cues. This confounding effect in Week 2 limits the ability to draw clear conclusions about the independent contribution of each factor. Future research could use a factorial design, giving participants only environmental information or only sensory experience, to better estimate both the independent and combined effects of their choice and responses.

One of the limitations of this exploratory study is the sample size. First, unlike previous studies, which captured participants' responses in a single experiment, the current study collected repeated responses across three weeks exposed in different conditions. Although this design enabled tracking of participants' responses, the sample size was relatively small (n = 58). Secondly, the hybrid burger was not optimised for product formulation. As the hybrid patties are not currently available in the UK, the hybrid burger was created by blending a commercial plant-based patty and beef patty. This study demonstrates the role of sensory experience in food choice and highlights the need to optimise the taste, flavour, and texture of novel foods by engaging expert food developers.

Future studies should recruit larger sample sizes to validate the robustness of the current results, particularly the environmental information and sensory experience in food choice. In addition, future studies should optimise the hybrid product's taste, flavour, and texture, and then test whether consumers will have positive responses towards the hybrid burger if it meets their sensory expectations. Finally, future studies could examine how individual differences (food neophobia status, food disgust sensitivity, and sustainability awareness) influence actual food choice.

4.5 Conclusion

This exploratory study has offered insight into consumer responses to hybrid and plant-based foods and their food choices in real-world settings. The choice of the hybrid burger was significantly influenced by tasting experience and environmental information. Participants initially held high expectations for the hybrid burger: 53% selected and reported high expected liking in week 1. However, after tasting and receiving the environmental information, the sensory experience did not meet their expectations. As a result, some participants reverted their choice back to either beef burger or plant-based options, resulting in 17% participants selected hybrid in Week 3. For a plant-based burger, none selected plant-based in Week 1. Interestingly, after tasting and receiving environmental information, liking and selection increased significantly in Week 2 (33%) and Week 3 (28%). Examining the consumer responses across the whole eating journey provided in-depth insights into actual consumers' emotions and sensory experiences of the chosen products. The current study highlights that if sensory quality does not meet consumer expectations, environmental information alone is insufficient to influence their food choices.

Furthermore, this study suggests a possible approach to promoting protein alternatives by repeated exposure to enjoyable sensory experiences.

Chapter 5.
Discussion and Conclusion

5.1 Summary of Key findings and contributions

Global challenges such as population growth, water scarcity, and climate change pose significant pressures on current food systems (United Nations, 2025). The global population is projected to reach 9.1 billion by 2050 and to increase further to 11.2 billion by 2100 (United Nations, 2017). However, the current global food system is already environmentally unsustainable, with agricultural and food systems contributing more than 25% of total greenhouse gas (GHG) emissions (Poore and Nemecek, 2018). To meet future demand, global food production is estimated to increase by approximately 70% by 2050. Together, these challenges highlight the urgent need to transition towards more sustainable food systems. Research councils and funding organisations (e.g., Good Food Institute) have launched targeted funding opportunities on protein alternatives, a growing body of scientific publications, expanding market availability, and rising consumer interest, a growing body of scientific literature, expanding market availability, and increasing consumer interest.

In the UK, beef is one of the most important components of meat consumption. According to recent market data, beef consumption in the UK reached approximately 4.11 million tonnes in 2023 (Ritchie, Rosado and Roser, 2023). However, average daily meat intake per capita has declined over the past decade. In the UK, the daily

total meat consumption has decreased by 17.4 g over 10 years (2008/09–2018/19) (Gouela, Stergiadis and Clegg, 2025). To further achieve a reduction in meat consumption, particularly beef, a diverse source of protein alternatives is needed to meet different consumers' needs and the increasing demand.

This thesis meets its objectives and contributes to existing literature by systematically examining UK consumers' responses to a range of sustainable protein options across both simulated and real-world contexts. Specifically, it first explored consumers' expected liking and emotional responses to plant-based, edible insect, lab-grown beef, and conventional beef burgers, while also assessing how environmental information and individual personal traits shape these responses (Chapter 2). Building on this, Chapter 3 investigated the influence of sensory, nutritional, and environmental information on interest of order and emotional responses towards plant-based, hybrid, and edible insect burgers using rating-based conjoint analysis (Chapter 3). Extending these insights into a real-world environment to study real-world food choice, Chapter 4 examined how sensory experience and environmental information affect consumers' actual selection of plant-based, hybrid, and beef burgers in the University cafeteria over a three-visit period. Taken together, these findings provide a more in-depth understanding of UK consumers' responses to protein alternatives, offering advanced insights to support the development of targeted strategies to increase the adoption of sustainable protein products in the UK.

Chapter 2 highlighted that expected liking and emotional responses differed significantly across plant-based, lab-grown beef, edible insect, and conventional beef burger patties. As expected, conventional beef patties received the highest expected

liking and were associated with positive emotions, indicating that UK consumers have a strong attachment to meat. Plant-based burgers were moderately liked and evoked neutral emotions (*bored* and *neutral*), suggesting plant-based burgers were accepted but did not generate strong emotional engagement. In contrast, edible insect burger patties were least liked and elicited negative emotion (*disgust*), suggesting that consumers are strongly unwilling to accept them. Lab-grown beef burger evoked moderate overall liking and elicited bipolar emotions, with both positive emotions (*amazed* and *hopeful*) and negative emotions (*deceived* and *uncertain*), indicating its potential but also highlighting the potential risk that consumers might feel deceived or uncertain.

The video information includes GHG emissions for a range of protein sources, as well as the production method for lab-grown beef. The video information only significantly increases liking for lab-grown beef, but not plant-based, edible insect, or conventional beef burger. This suggests that information can be used to increase consumer liking, the effect is dependent on different product categories. According to Ford *et al.* (2024), food safety, environmental benefits, sensory appeal, and health benefits are among the top four drivers for adopting protein alternatives.

Taken together, the findings from Chapter 2 begin to establish an underlying hierarchy of consumer acceptance across protein sources, which is consistently reflected in subsequent chapters. Rather than isolated product-specific reactions, these responses indicate a broader, relatively stable preference structure characterised by strong attachment to conventional meat, cautious openness to plant-based and lab-grown meat alternatives, and persistent resistance to edible insects. This hierarchy suggests that familiarity and prior food experience play a

central role in shaping expected liking and emotional responses, with conventional beef benefiting from consumption habits and positive emotion associations. In contrast, plant-based and lab-grown products show a neutral level of expected liking, reflecting a balance between perceived health/ environmental benefits and expected sensory uncertainty. The particularly strong negative response toward edible insect products further indicates that certain food categories may face not only sensory barriers but also culturally embedded disgust responses, which are more resistant to change through information alone. These findings from Chapter 2 suggest that early-stage consumer evaluations of protein alternatives primarily reflect an expectation-based baseline, as responses are formed without direct sensory experience of the products. This baseline is likely shaped by familiarity, experiment-designed food packaging/ environmental information, and expected sensory properties, and therefore represents an important reference point for understanding how consumers initially position protein alternative products before consumption. This reference point provides a foundation against which the effects of informational framing and sensory experiences can be meaningfully assessed in subsequent studies.

Therefore, Chapter 3 focuses on the relative importance of environmental, sensory, and nutritional claims for consumer acceptance of protein alternatives, using rating-based conjoint analysis to examine ordering intention in a written simulated restaurant scenario. Three types of protein alternatives (plant-based, hybrid, and edible insect burgers) were included to examine how sensory, nutritional, and environmental information, as well as their combinations, influence consumers' interest in ordering and emotional responses. Chapter 3 showed that participants were most willing to order the hybrid burger, followed by the plant-based burger, and

were less willing to order the edible insect burger. Regarding the influence of different types of information, sensory information had the strongest positive impact on order of interest, followed by environmental information, then nutritional information. The data suggest that sensory information is the most effective information in increasing the likelihood of ordering, followed by environmental and nutritional information. Examining all combinations showed that combining all three types of information resulted in the highest scores for ordering intention and evoked more positive emotional responses across all three burger types, particularly for hybrid and plant-based burgers. This suggests that the combined information served as the strongest message frames; however, caution is needed when implementing these in real-life scenarios to avoid overloading consumers, which can cause confusion. However, the lack of information led to the lowest level of interest, suggesting that providing information could help consumers make food choices toward protein alternatives.

Building on the expectation baseline identified in Chapter 2, the findings from Chapter 3 show that consumer responses to protein alternatives can be shaped before actual consumption through information framing. The conjoint analysis shows a clear trend in the impact of different types of information. Sensory information has the strongest effect on ordering intention, followed by environmental claims and then nutritional information. These results suggest that, even without direct product experience, expected sensory attributes play a more important role in shaping consumer preferences, whereas other information serves a supporting role.

Chapter 3 represents an intermediate stage between expectations and actual behaviour. While information can influence stated ordering intentions, these

responses were still based on expectations rather than direct product experience. The shifts in ordering intention observed in Chapter 3 may reflect changes in how consumers anticipate products, rather than how they respond after tasting them. As a result, the effects of sensory, environmental, and nutritional information identified in Chapter 3 do not necessarily translate directly into real-world choices.

The results in Chapters 2 and 3 have provided valuable insights into UK consumer responses to a range of protein alternatives and how presenting information, particularly sensory, environmental, and nutritional information, influences consumer responses. However, the data were collected via an online survey, so the responses primarily focused on consumers' expectations. To further investigate consumer responses and inform the development of effective strategies to promote protein alternatives, it is necessary to understand how consumers choose them in real-world settings. Therefore, Chapter 4 builds on the findings from Chapters 2 and 3 and further explores consumer choice among plant-based, hybrid, and beef burgers, and how sensory experience and environmental information shape consumer choice in a repeated experiment conducted in a university cafeteria setting. Chapter 4 could not include novel protein sources such as lab-grown beef or edible insects, as these products are not yet available on the market, which poses significant challenges for running a tasting experiment. Chapter 4’s study incorporates a three-visit experiment that examines consumer initial choice (Week 1), food-tasting experiences with environmental information (Week 2), and consumer final choice (Week 3). The results showed that the hybrid burger had the highest initial selection (53% in Week 1), indicating strong initial interest. The hybrid burger in Week 1 evoked a curious emotion, suggesting that *curious* emotion could be a key emotion driver of initial

selection. However, the selection has dropped to 17% in Week 3, which may be due to the hybrid burger not being optimised for its sensory properties. In contrast, no one selected the plant-based burger in week 1. This was due to plant-based burgers being associated with more negative sensory expectations (e.g., *dry* and *flavourless*). However, the selection has increased significantly to 28% in Week 3. This was driven by a positive sensory experience during the Week 2 tasting session and by the environmental information provided. These results suggest that tasting experiences and environmental information can increase consumer choice for plant-based options when sensory properties are optimised.

Beef burgers remained relatively stable across the three weeks, suggesting that they have well-established expectations in consumers' minds. The additional environmental information about beef did not change this group's choice, indicating a strong attachment to meat.

Chapters 2 and 3 focused on consumers' expected responses in written simulated scenarios, yet it is important to validate these findings in real-world contexts. Chapter 4's findings help address this gap by examining consumer decision-making in an actual consumption setting. The findings suggest that sensory experiences and information sharing are both important in promoting consumer choice towards protein alternatives. While information can shape expectations and increase initial interest, as shown in Chapters 2 and 3, sensory experience appears to play a more critical role in determining whether these initial responses are sustained in real-world settings.

A clear example of the expectation–experience gap emerges when linking the findings from Chapters 3 and 4. In Chapter 3, the hybrid burger consistently had the

highest ordering intention in the expectation stages, suggesting that expectations were strongly accepted before consumption, with information and expected product attributes playing a primary role. However, this pattern was not sustained in the real-world setting examined in Chapter 4, where selection of the hybrid burger and liking (actual liking in Week 2 of Chapter 4) declined over time. This contrast suggests that the high level of interest observed under hypothetical conditions may reflect favourable expectations rather than stable consumer preferences. Once participants had experienced the product, these expectations may not have been fully met, leading to reduced selection.

In contrast, the plant-based burger showed the opposite pattern. The plant-based burger received lower expected liking than the hybrid burger in both Chapter 3 and the first week of Chapter 4. However, plant-based burger selection increased after tasting, indicating that a positive sensory experience can initially improve expectations. These results highlight a gap between expectation responses and actual behaviour. Consumers may express willingness under hypothetical conditions, but their final choices are more strongly influenced by direct sensory experience with the product. These findings indicate that although information is effective in shaping expectations, sustained consumer acceptance depends on how far sensory experiences confirm or exceed those expectations. Positive tasting experiences can reinforce or improve prior expectations, while negative experiences may lead to disappointment and reduced acceptance, even when initial expectations are favourable.

5.1.1 Comparing products across chapters

Plant-based products are widely available on the market. Across the three chapters, consumer liking for plant-based burgers remained relatively stable, with mean scores around neutral levels (Chapter 2: M = 4.83, which is higher than neutral but lower then slightly like on a 7-point scale (converted to 9-point scale M = 6.11); Chapter 3: M = 4.9 (neutral); Chapter 4: M = 5.0 (neutral) on a 9-point scale). This consistency indicates that consumers' expected liking of plant-based burgers did not significantly change across the studies. However, when examining emotional responses, significant differences were found in Chapters 2 and 3, which relied on online surveys using product images, plant-based burgers elicited *neutral* or *bored* emotions. In contrast, Chapter 4 involved participants assessing their expected liking based on the actual sample after seeing the product in person. In Chapter 4, plant-based burgers evoked more negative emotions, such as *dissatisfied, anxious, suspicious, and disappointed*.

Liking scores remained relatively stable across chapters, whereas emotional responses varied, likely due to methodological and sample differences. In Chapters 2 and 3, online image-based evaluations limited sensory engagement, leading participants to rely on imagined perceptions or prior knowledge, which may have resulted in neutral or bored emotions. In contrast, in-person evaluation in Chapter 4 provided a more complete sensory experience, allowing participants to notice differences between expectations and the actual experiences, particularly in appearance, which elicited stronger negative emotional responses despite similar liking scores. Demographic differences may have further contributed to these results. Participants in Chapter 4 were university students who may have been familiar with

the plant-based burger from the campus cafeteria. This prior exposure could have shaped their expectations and contributed to the more negative emotional responses observed.

Hybrid burgers generated positive consumer expectations in both Chapters 3 and 4. In Chapter 3, expected ordering intention for hybrid burgers was M = 5.60, and in Chapter 4, the expected liking increased to M = 6.13. In Chapter 2, hybrid burgers elicited more energetic, happy, and satisfied emotions than both plant-based and edible insect burgers, suggesting greater emotional engagement. In Chapter 3, hybrid burgers elicited significantly more citations of *adventurous* and *suspicious* emotions compared with beef burgers ($p < 0.05$), reflecting a mix of *curiosity* and mild *uncertainty*.

This pattern suggests that consumers have high expectations of hybrid burgers, as reflected in Chapter 4, where over 50% of participants selected the hybrid option. Hybrid burgers are positioned as a middle ground between conventional meat and plant-based products, combining familiar sensory qualities with perceived nutritional and environmental benefits. Previous studies show that consumers prefer alternative protein products that closely resemble meat in sensory attributes, particularly flavour, juiciness, and texture (Grasso and Goksen, 2023). Hybrid burgers have been proposed as ‘transition products’ that can achieve acceptability comparable to meat when their sensory attributes are well balanced (Caputo, Sogari and Van Loo, 2023; Grasso, 2024). However, when sensory expectations are not met, the mismatch between expectation and actual experience leads to *disappointed* and stronger negative emotional responses, even when overall liking remains relatively high.

Across Chapters 2 and 3, expectations toward edible insect-based burgers were consistently low and stable. Expected liking (M = 2.65 on a 7-point scale, close to 'dislike moderately') and ordering intention (M = 2.9 on a 9-point scale) remained low across contexts. Emotional responses were also consistent, with strong negative emotions, particularly *disgust*. This stability suggests that disgust is a primary emotional barrier to consumer acceptance of insect-based burgers. These findings are consistent with previous studies identifying disgust as a primary barrier to consumer acceptance of insect-based foods (Castro and Chambers, 2019; Florença *et al.*, 2022).

5.2 Implication

Three key implications for stakeholders, including alternative protein industries, marketers, policymakers, fellow researchers, and consumers, are derived from this thesis. Firstly, information interventions can be a useful tool for influencing consumer responses. Secondly, personal traits can be used to segment consumers and identify early adopters of novel protein alternatives. Thirdly, these findings highlight the importance of sensory optimisation to enhance consumer acceptance of alternative protein products. Finally, the findings on emotional responses can support further product development to help promote protein alternatives.

5.2.1 Implications for information as intervention tools

Taken together, the findings across Chapters 2–4 demonstrate that information interventions can be an effective means of promoting consumer acceptance of sustainable protein products. However, the success of these interventions depends on the type of information provided and how it is integrated with other information.

Sensory information presented to consumers, or positive sensory experiences, consistently emerge as primary drivers of consumer acceptance of protein alternatives. Environmental information also has a significant effect, although its impact is weaker than that of sensory information. Nutritional information has been shown to be the least effective, which may be explained by consumers' familiarity with calorie information on menus and packaging, leading to reduced sensitivity to such nutritional cues. Notably, combined information has been shown to have a stronger impact than single information alone.

The findings suggest that communication strategies for alternative protein products should be restructured to prioritise sensory appeal as the primary message in marketing and product communication. Environmental and nutritional claims, while still relevant, appear to function more effectively as secondary or supportive messages rather than primary selling points. In marketing practice, this could involve placing environmental claims in secondary layers of communication (e.g. on packaging backs, in QR-code content, or at the bottom of menus), while nutritional claims can be reframed to emphasise health benefits (e.g. 'supports a balanced diet' rather than calorie or fat content). Overall, sensory appeal serves as the initial trigger by lowering perceived uncertainty in sensory attributes and encouraging trial. Following this, environmental and nutritional information support the decision to proceed once initial acceptance has been established. This sequential role indicates that the main benefit of environmental and nutritional information is to support long-term attitude development and encourage repeat purchases, rather than to promote initial adoption.

5.2.2 Implications for personal traits

The study underscores the importance of tailoring strategies to consumers' personal traits when promoting alternative protein products. Different consumer segments, such as *food explorers*, *neutral eaters*, *novelty/disgust fearers*, and *everything fearers*, showed different patterns of overall liking and emotional responses toward plant-based, insect-based, and lab-grown meat products. *Food explorers*, with their high openness and positive emotional reactions, represent the most promising target for broad adoption, while *neutral eaters* and *novelty/disgust fearers* may respond more carefully to accepted plant-based options. Lab-grown meat, which evokes mixed emotions, may require targeted messaging and experiential strategies to address specific concerns.

A one-size-fits-all approach is unlikely to be effective when promoting alternative protein products. The findings suggest that strategies should be adapted to different consumer segments, as these groups differ in their levels of food-related fear, uncertainty, and emotional responses. From an implications aspect, this means that increasing acceptance is not only about improving product sensory properties, but also about addressing these psychological barriers. In particular, *novel/disgust fearers* and *everything fearers* may need support in reducing feelings of risk, uncertainty, and negative emotion, rather than simply being provided more information and sensory exposure. For *food explorers*, strategies may focus more on maintaining their positive attitudes and interest. In contrast, for *neutral eaters*, strategies may need to reduce uncertainty, helping them feel more comfortable with alternative protein products.

5.2.3 Implications for sensory optimisation

The findings imply that sensory optimisation is important in shaping consumer acceptance of protein alternatives. Consumers may hold negative expectations based on the prior experience with commercially available plant-based products, which causes no participant to select it. A positive tasting experience can effectively modify these expectations and influence product choice, showing that direct sensory engagement is a powerful tool for promoting protein alternatives.

However, the effectiveness of this approach depends on the quality of sensory properties at the initial stage. If initial experience fails to meet expectations in terms of flavour, texture, and appearance, negative emotional responses may occur and reduce product selection, as observed with hybrid burgers in Chapter 4.

A key implication of these findings is that sensory optimisation should not only focus on improving product quality, but also on managing consumer expectations prior to consumption. In practice, this may involve avoiding overly positive sensory claims in communication, as unrealistic expectations may increase the risk of disappointment if the actual product experience does not fully match them. Instead, providing realistic and balanced descriptions of sensory attributes may help align expectations with actual product performance. In addition, the findings highlight the importance of the first consumption experience. This suggests that early product exposure should be carefully designed to maximise the likelihood of a positive experience. For example, this may include providing sampling opportunities in controlled environments such as supermarkets, food fairs, or in-store tastings, where product preparation and context can be managed to ensure consistency and quality. Overall, the implication is that acceptance of alternative protein products is shaped not only

by sensory quality but also by the alignment between expected and actual sensory experience. Therefore, sensory optimisation should be understood as a combination of product development and expectation management, rather than product improvement alone.

5.2.4 Implications for emotional responses

The emotional profiles identified in this study provide more detailed insight than hedonic evaluations alone, helping to explain consumer acceptance and rejection of alternative protein products.

For plant-based burgers, emotional responses were generally neutral or mildly negative, including *bored*, *dissatisfied*, and *disappointed*. This suggests that the main challenge is not strong rejection but rather low emotional engagement and unmet expectations. From a product development perspective, this indicated a need to increase positive emotional engagement, rather than merely improving overall acceptability. The neutral and bored emotional responses indicate that the product might not be engaging enough to trigger positive feelings like interest or satisfaction. Therefore, product development may need to focus on enhancing aspects of the product that elicit stronger positive emotional responses during consumption. In addition, the *disappointed* emotional responses indicate that product experiences may not fully meet consumer expectations, suggesting that improving the consistency and reliability of the sensory experience may also be important.

For edible insect burgers, the dominant emotional response was *disgust*, indicating a strong psychological barrier to acceptance. This suggests that consumer rejection may occur at an early stage, before sensory evaluation. From a product development perspective, this indicated that increasing acceptance may require

reducing disgust-related responses, rather than focusing solely on improving overall liking. In particular, strategies that make the insect origin less visible may be useful, as this may help reduce immediate negative emotional responses and enable consumers to engage with insect ingredients. For example, integrating the edible insect product into commonly recognised formats or dishes may help reduce initial rejection. In addition, careful consideration of product naming and appearance may help reduce negative emotional responses, as these elements shape consumers' perceptions of the product before tasting. For example, using more neutral or familiar naming may therefore help reduce immediate negative responses and support willingness to engage with the product.

For lab-grown beef burgers, the presence of both positive emotions (e.g. *amazed* and *hopeful*) and negative emotions (e.g. *uncertain* and *deceived*) suggests an ambivalent emotional response toward the product. This suggests that, although the product may generate interest and positive expectations, these are accompanied by uncertainty and potential distrust. From a product development perspective, this suggests that increasing acceptance of lab-grown meat may depend on reducing uncertainty rather than on first enhancing its positive sensory appeal. For example, product naming can influence how consumers perceive the product. The term ‘lab-grown’ might highlight the product's technological and laboratory origins, potentially leading to feelings of uncertainty or perceptions of it as unnatural. In contrast, alternative terms such as ‘cultured meat’ or ‘cultivated meat’ may be perceived as more neutral or more consistent with familiar food-related language (Food Standards Agency, 2025).

For hybrid burgers, the results showed generally positive emotional responses, such as feeling *happy* and *satisfied*, alongside some degree of *suspicious*. This suggests that, unlike plant-based products, which were often associated with neutral or low-engagement emotions, hybrid products can already evoke positive emotions but may still face uncertainty about how they are perceived. From an implication's perspective, this indicates that product development for hybrid products should not only maintain positive sensory qualities but also address concerns and strengthen consumer confidence. For example, in contrast to plant-based products, where consumers may already have some reference points for expected taste based on prior experience with plant-based or conventional meat products, hybrid products may lack a clear sensory reference. This may make it more difficult for consumers to form expectations about the product's taste, leading to *uncertain* or *suspicious* emotional responses. In practice, this suggests that product development and communication should aim to provide clearer sensory cues so that consumers can form more concrete expectations prior to consumption. Providing simple and reliable descriptions of flavour or eating experience for a hybrid meat product may also support expectation formation and reduce hesitation.

5.3 Limitations and future research opportunities

Although this research contributes to a deeper understanding of acceptance of protein alternatives, several limitations should be acknowledged and serve as directions for future research.

One limitation in Chapters 2 and 3 concerns the use of a hypothesis-driven design in an online research environment. While plant-based products have become increasingly available in the UK market over the past five years, suggesting that

some participants may have prior exposure and pre-formed expectations, the present studies did not assess participants' prior experience with such products. In addition, Chapters 2 and 3 included novel and not-yet-commercialised protein alternatives, such as lab-grown meat (Chapter 2) and edible insect-based products (Chapter 3). Consequently, participants' evaluations of these unfamiliar products were likely based on inferred expectations rather than direct sensory experience. This reliance on expectation-based judgments might have widened the gap between expected and actual product quality, especially in taste, texture, and overall acceptability.

Furthermore, the use of hypothetical shopping scenarios in Chapters 2 and 3 does not fully reflect real-world decision-making. Although text-based scenarios were provided to help participants understand the context and engage with the task, they cannot capture the complexity of real-life situations. In everyday settings, food choices are shaped by a range of situational and structural factors, including price sensitivity, cultural norms, individual knowledge and cooking skills, product availability, and habitual behaviours (Chen and Antonelli, 2020). Thus, the findings of Chapters 2 and 3 may be subject to hypothetical bias, defined as the discrepancy between stated responses in simulated environments and actual behaviour in real-life situations (Haghani *et al.*, 2021). Therefore, the reported preferences and emotional responses should be interpreted with caution, as they reflect anticipated judgments rather than verified post-consumption evaluations.

A primary limitation across all three empirical chapters is the use of convenience sampling. Participants were recruited through online surveys, including university-based recruitment and online survey platforms (Prolific). While this approach

enabled efficient data collection and ensured that participants met the study criteria, convenience sampling limits the generalisability of the findings. In particular, it restricts the ability to control for key demographic characteristics such as gender, education level, income, and age. Although the main objectives of this thesis were not to examine the effects of individual demographic variables on acceptance and ordering intention of protein alternatives, previous studies have demonstrated that demographic factors play a significant role in consumer acceptance, with younger and more highly educated consumers being more willing to adopt protein alternatives (de Boer, Schösler and Boersema, 2013; Wilks *et al.*, 2019; Onwezen *et al.*, 2021). To address this limitation, future research should consider employing representative sampling designs, which would allow the target population to be divided into subgroups based on key demographic variables. This approach would improve the external validity of the findings and enable a more robust examination of demographic influences. Chapters 2, 3, and 4 used convenience sampling and did not control for important demographic variables like age and gender. In Chapter 2, the sample consisted predominantly of young female participants, while Chapter 3 included a more balanced gender distribution but was still largely composed of younger individuals. Similarly, the sample in Chapter 4 mainly comprised university students and female participants. As a result, the findings may not fully represent the broader UK population. Instead, the results should be interpreted as exploratory insights into patterns of consumer responses within the sampled group, rather than as generalisable conclusions.

The limitation of Chapter 3 is the restricted choice set, as the study focused exclusively on protein alternatives. In real-world consumption contexts, consumers

typically choose between protein alternatives and conventional meat products (e.g., beef, chicken, or pork). The absence of traditional meat options limits the applicability of the findings to real-world food choice scenarios. An additional limitation in Chapter 3 concerns product naming. The edible insect burger examined in the study was, in fact, a mixture of insect and beef; however, the product was simply labelled as ‘edible insect’. A more precise description would be ‘hybrid insect–beef burger’, particularly given that another product in the study was positioned as a hybrid (plant-based and beef). This inconsistency in naming may have influenced participants’ perceptions and evaluations, as product labels can shape expectations and acceptance. Furthermore, the use of conjoint analysis may have introduced participant fatigue. Although the study design attempted to mitigate this by separating the tasks over three weeks, some degree of cognitive burden and fatigue cannot be ruled out. This may have affected the consistency and reliability of participants’ responses.

Chapter 4 involves the collection of actual choices and sensory evaluations over a three-visit period, but the sample size was relatively small (n = 58). This small sample size may reduce the analysis's statistical power, making it more difficult to detect significant differences in liking, emotional responses, and sensory perceptions across products. It also limited the representativeness of the findings, as the sample may not adequately reflect the diversity of UK consumers with different dietary preferences and demographic backgrounds. Another limitation of Chapter 4 concerns the not optimized formulation of the hybrid burgers. As hybrid (plant and beef) patties are not yet commercially available in the UK, the products used in this study were prepared by directly mixing commercial plant-based patties with beef

patties. This formulation may not reflect the sensory quality of future commercially developed hybrid products and could have influenced participants' evaluations. Given the critical role of sensory experience in shaping consumer attitudes and acceptance of novel protein alternatives, the use of a non-optimised product may have led to an under- or overestimation of consumer acceptance.

To address these limitations, future research should pursue several directions. First, studies should recruit larger and more diverse samples using representative or stratified sampling methods to enhance both statistical power and generalisability. Second, future research should incorporate more realistic experimental settings, such as field studies conducted in actual restaurants or retail environments, and include both protein alternatives and conventional meat options within the choice set. Finally, close collaboration with food developers is needed to optimise the sensory characteristics of protein alternative products, particularly hybrid products. Improving product formulation to achieve sensory qualities closer to conventional meat would provide more accurate insights into consumers' true acceptance and purchase intentions.

Price is widely recognised as a key determinant of consumer adoption of alternative protein products. In the UK, cost is consistently ranked among the most important drivers of food choice, and is often identified as a major barrier to the uptake of meat alternatives (Ford *et al.*, 2023b). Market data further indicate that meat substitutes are not necessarily cheaper than conventional meat; for example, Quorn products in the UK can be priced at approximately £18.2/kg compared to £17.4/kg for beef steak (Ritchie, Rosado and Roser, 2023). Evidence from the US also suggests that

consumers exhibit strong price sensitivity towards plant-based products and are generally willing to pay less for them than for conventional meat (Katare *et al.*, 2023).

However, the importance of price is context dependent. In some markets, such as China and Australia, consumers may prioritise attributes such as health benefits and food safety over price when evaluating alternative proteins (Ford *et al.*, 2023b). This suggests that consumers may accept higher prices if products are perceived as healthier or safer (Estell, Hughes and Grafenauer, 2021).

Price factor was not included as a primary attribute in the experimental designs of Chapters 3 and 4. In Chapter 3, the main goal was to focus on information-based factors, such as product framing and sustainability messages. Including price would have increased the design's complexity and made it more difficult to clearly interpret the effects of the information. Similarly, in Chapter 4, price was excluded because the experimental setup was already complex, involving a three-week intervention that incorporated sensory experiences and environmental information. While including price in such a real-world context could have improved ecological validity and better reflected actual consumer decision-making, it would also have additional challenges. For example, it would require controlling for menu pricing, promotions, and perceived value. This would make it more difficult to isolate the effects of the sensory and informational interventions. Therefore, the absence of price as an attribute represents a limitation of this research. The findings should be interpreted with caution, as they may not fully capture real-world trade-offs where cost plays a central role. Future research should aim to incorporate price alongside informational and sensory experiences to provide a more detailed understanding of consumer decision-making when adopting alternative proteins.

5.4 Beyond this thesis: Consumer behaviour towards future protein alternatives

To further explore the current thesis on consumer behaviour towards protein alternatives, the following suggestions can serve as potential cues for future studies.

Current studies agree that the sensory, nutritional, and environmental information can influence consumer purchase intention towards protein alternatives. Future research could further explore the impact of other motivational factors on consumers, such as price, convenience (e.g., ease of cooking), food safety, and product brand, using the existing rating-based model. This extension would enhance understanding of diverse information types, influence consumers' purchase intentions, and provide more targeted insights for designing information-based intervention strategies.

In the current thesis, participants were recruited from the UK. Future research could expand to a cross-cultural context by investigating attributes and behaviour toward protein alternatives among consumers from different countries. Ford *et al.* (2024b) have adopted the same survey across the UK, China, and Australia and have found that cultural differences lead to variations in consumers' attitudes toward protein alternatives and reduced meat consumption. Since Chapter 2 also used a questionnaire-based approach, future research can use the current design to explore cross-cultural differences.

Furthermore, future research should examine other real-world consumption environments to better understand consumer behaviour towards protein alternatives, such as supermarkets and restaurants. The current study examined consumer food choices in a university cafeteria that offers only three options, compared with a restaurant that offers several options. Supermarkets are typical places where

consumers frequently buy food. Here, consumers often have more choices and can think about other factors, like how easy it is to prepare meals at home. Studying how consumers make choices in supermarkets and restaurants offers more practical insights for product developers and researchers.

Another direction is to complement the current study's self-reported measures of food choice, liking, emotions, and sensory perception with an evaluation of implicit responses. Implicit emotional responses are thought to differ from explicit attitudes in decision-making and can be captured using various novel biometric technologies. The technology for analysis the implicit emotional responses includes facial expression analysis, eye-tracking, heart rate, skin conductance, body temperature, and brain activity (Danner *et al.*, 2014; Wakihira *et al.*, 2022). Given the widespread use of cameras in UK supermarkets, future studies could analyse in-store footage to investigate consumers' actual food choices. This non-intrusive approach would allow researchers to observe consumer decisions without interfering with their natural choice processes. Therefore, capturing more unbiased behavioural data regarding their selection of protein alternatives in real supermarket settings.

Chapter 6.
Appendix

6.1 Appendix A Chapter 2 Video Transcript

This video relates to the environmental impact of food. Of course, this is a complex topic as there are numerous factors to consider including but not limited to biodiversity loss, land and water use and pollution issues. But during this video we will just be focusing on foods Green House Gas Emissions and the effect on the climate. Eating is arguably one of the greatest pleasures and a necessity to human life. However, it has been reported that global food production is responsible for about 26% of all human greenhouse gas emissions, of which half comes from meat production. So, there is no doubt that the food we eat to some extent contributes to climate change.

Foods' climate impact is most often based on "life cycle assessments", which is a method used to assess the environmental impact associated with all stages of a foods life cycle. Assessments take into account the production method, transportation, packaging and finally use and waste management. So, based on this assessment, emissions for different food items can vary a lot. Reviewing the most current and comprehensive lifecycle assessments, we can compare different food products. For example, let's compare burgers made from different types of meat. A kilogram of beef burgers (that's approximately 8 regular burgers) emits an estimated 54 kg of CO_2 equivalents – on average that's the same as a flight from London to Paris! A lamb burger is also high at 27, whilst a chicken and meat-free burger are considerably lower.

In terms of dairy products, 1 kg cheddar cheese (approximate 12 servings) is higher than some meats at 21 kg of CO_2 equivalents, whilst milk, butter and yoghurt range from 4-3. However, the lowest carbon emissions relate to lots of plant-based foods, such as tomatoes, beans, apples and potatoes.

Although more organic and regenerative ways of farming can help further reduce the carbon footprint of foods, especially meat, new food technologies such as cellular agriculture also have the potential to be more sustainable.

Cellular agriculture produces animal derived products without the need to breed, rear or slaughter animals. The process for making lab grown meat and precision fermented dairy are similar.

In its simplest form the process for making lab grown meat is as follows;

A small amount of cells are taken from a cow non-invasively like a biopsy. The cells are fed animal-free nutrients, transferred to fermentation tanks until they multiply into muscle strands and resemble meat. The process is similar for making precision fermented dairy:

To start, a small amount of DNA is taken from a cow non-invasively and then introduced into a microorganism like a yeast cell.

The microorganisms are then transferred into fermentation tanks along with feedstock, such as nutrients and sugar.

Milk proteins which are identical to those found in conventional cow's milk are produced which can then be made into any dairy product including cheese and yoghurt.

As these technologies take away the need to rear animals, the carbon footprints are estimated to be substantially lower. This is more so the case for beef and dairy cattle compared to other meat such as chicken or pork.

A recent study using Lifecycle assessment comparing a lab grown beef burger to a conventional burger claimed it uses an estimated 87% less GHG emissions. Life cycle assessment analysis comparing conventional dairy production with large-scale precision fermented dairy, estimated a reduction in GHG emissions by 35-65%. Future foods could also include novel ingredients from more sustainable sources such as edible insects. Meal worms are already a popular source of protein, estimated to emit around 50 times less emissions than beef. In general, working out how to feed the world in a more sustainable way continues to be one of the biggest global challenges. Thank you for your attention.

6.2 Appendix B: Chapter 2 Supplementary materials

Table S 6-1Summary of the overall citation proportions for the emotion term and corresponding Cochran's Q test results. Products that differ significant in citation proportions are marked with different letters (Critical difference, Sheskin procedure). Emotions are classified into positive, negative and unclassified groups based on Orr et al. (2023).Citation proportion above 0.1 have coloured grey, where higher citation proportions are a darker shade.

	Citation proportion				
Emotion	Conventional beef burger patty	Plant-based burger patty	Lab grown beef burger patty	Edible insect burger patty	p-value
Positive emotions					
Calm	0.251 (b)	0.202 (b)	0.064 (a)	0.026 (a)	<0.0001
Adventurous	0.023 (a)	0.146 (b)	0.303 (c)	0.277 (c)	<0.0001
Energetic	0.101 (b)	0.037 (a)	0.031 (a)	0.026 (a)	<0.0001
Pleasant/ Grateful	0.451 (d)	0.220 (c)	0.108 (b)	0.042 (a)	<0.0001
Loving	0.120 (c)	0.044 (b)	0.017 (ab)	0.005 (a)	<0.0001
Amazed	0.068 (a)	0.066 (a)	0.172 (b)	0.078 (a)	<0.0001
Hopeful	0.085 (a)	0.260 (b)	0.268 (b)	0.131 (a)	<0.0001
Happy	0.549 (d)	0.211 (c)	0.108 (b)	0.023 (a)	<0.0001
Hungry	0.406 (d)	0.225 (c)	0.141 (b)	0.066 (a)	<0.0001
Nostalgic	0.150 (b)	0.010 (a)	0.014 (a)	0.010 (a)	<0.0001
Satisfied	0.692 (d)	0.282 (c)	0.159 (b)	0.033 (a)	<0.0001
Negative emotions					
Unhappy/ Sad	0.040 (a)	0.047 (a)	0.051 (a)	0.141 (b)	<0.0001
Dissatisfied	0.030 (a)	0.169 (c)	0.089 (b)	0.226 (d)	<0.0001
Angry	0.010 (a)	0.009 (a)	0.024 (a)	0.054 (b)	<0.0001
Anxious	0.024 (a)	0.047 (a)	0.228 (b)	0.319 (c)	<0.0001
Afraid	0.005 (a)	0.023 (a)	0.136 (b)	0.280 (c)	<0.0001
Suspicious	0.010 (a)	0.124 (b)	0.418 (c)	0.470 (c)	<0.0001
Bored	0.012 (a)	0.077 (b)	0.009 (a)	0.005 (a)	<0.0001
Disappointed	0.033 (a)	0.166 (c)	0.064 (a)	0.115 (b)	<0.0001
Deceived	0.007 (a)	0.047 (b)	0.061 (b)	0.066 (b)	<0.0001
Disgusted	0.026 (a)	0.042 (a)	0.136 (b)	0.530 (c)	<0.0001
Uncertain	0.024 (a)	0.263 (b)	0.477 (c)	0.488 (c)	<0.0001
Unclassified emotions					
Curious	0.028 (a)	0.383 (b)	0.544 (c)	0.392 (b)	<0.0001
Neutral	0.209 (c)	0.284 (d)	0.127 (b)	0.045 (a)	<0.0001

Table S 6-2 Personal trait and demographic differences between the clusters. Different letters indicate significant differences for the ANOVAs. For chi-square, post hoc-results are shown with "+" and "–", which indicate a higher or lower than chance percentage of participants for a given group.

Cluster	Mean (+/- SE)				
	Food Explorers	Food Tech Fearers	Novel/Disgust Fearers	Everything fearers	Statistics
Number of participants	122 (21%)	142 (25%)	182 (32%)	128 (22%)	N/A
FNS (Range 10-70)[1]	19.0±0.7 D	23.3±0.6 C	32.0 ±0.6 B	41.8±0.7 A	F = 219 p < 0.0001 η^2 = 0.54
FTNS (Range 23-91)[1]	41 ± 0.7 D	58 ±0.7 B	50.3 ±0.6 C	62.3 ±0.7 A	F = 158 p < 0.0001 η^2 = 0.45
FDS (Range 9-42)[1]	21± 0.4 C	17 ±0.4 D	28 ±0.3 B	29 ±0.4 D	F = 219 p < 0.0001 η^2 = 0.57
Age[1]	31.8 ±0.50	33.8±0.50	34.2 ±0.40	34 .1± 0.52	F = 1.2 p = 0.31 η^2 < 0.01
Gender[2]					
Female	63.11%	73.24%	75.82%	69.53%	
Male	36.07%	26.76%	23.63%	30.47%	χ^2= 11.9
Other	0.82%	0%	0%	0%	p = 0.21
Prefer not to say	0%	0%	0.55%	0%	
Education[2]					
Secondary school	9.0%	17.6%	12.1%	15.6%	
College diploma or certificate	16.4%	19.7%	22.5%	21.1%	
Undergraduate University degree (e.g. Bachelors degree)	38.5%	42.3%	39.0%	41.4 %	χ^2= 15.5 p = 0.2
Postgraduate University degree (e.g. Master's, Medical doctorate, PhD)	36.1%	20.4%	25.8%	21.8%	
Ethnicity[3]					
Arab	0%	0.7%	1.1%	3.13%	
Asian or Asian British	7.38%	4.93%	12.09%	11.72%	
Black or Black British	1.64%	3.52%	2.2%	7.81%	
Chinese	3.28%	3.52%	4.95%	3.91%	N/A
Mixed	2.46%	1.41%	1.1%	0.78%	
White	79.51%	84.5%	76.93%	70.32%	
Any other Ethnic Origin Group	5.73%	1.42%	0.53%	0.77%	
Prefer not to say	0%	0%	1.1%	1.56%	
Diet[2]					
Flexitarian	4.92%	4.93%	12.64% +	3.91%	χ^2= 12.2
Omnivore	95.08%	95.07%	87.36% –	96.09%	p = 0.007
Information sharing condition[2]					
Willing to watch the video	91.80%+	89.43%	81.31%	78.12%+	χ^2= 13.1
Unwilling to watch the video	8.20%-	10.57%	18.69%	21.88%-	p = 0.004

Statistics used: [1]One-way ANOVA, [2]Chi-square, [3]Not tested

6.3 Appendix C Chapter 3 Summary of the Conjoint Study Demographics

Living in the UK Length	Percentage of participants (%)
6 - 12 months	0.8
1 - 2 years	1.7
2 - 4 years	1.7
5 years or more	95.8
Meat Consumption Frequency	
Less than once a week	5
One or two days a week	20.2
Three or four days a week	20.2
Five or six days a week	31.1
Everyday	23.5
Protein Alternatives Consumption Frequency	
Never	45.4
Less than once a week	28.6
One or two days a week	16
Three or four days a week	7.5
Five or six days a week	1.7
Everyday	0.8
Gender	
Female	51.3
Male	48.7
Education	
Some secondary schools	11.7
Technical/ trade/ diploma/ vocational training	26.1
Completed University graduate (Bachelor’s degree)	41.2
Completed Postgraduate/ Doctorate degree	19.3
Prefer not to say	1.7

6.4 Appendix D: Chapter 3 Average citation proportions of emotional terms towards plant-based burgers across the eight concepts

Emotion	No Information	Present Environment	Present Nutrition & Environment	Present Nutrition	Present Sensory & Environment	Present Sensory & Nutrition	Sensory & Nutrition & Environment	Present Sensory	p-values
Calm+	16.81%(a)	19.33%(ab)	26.05%(ab)	21.85%(ab)	22.69%(ab)	22.69%(ab)	29.41%(b)	25.21%(ab)	0.026
Adventurous+	11.76%(a)	17.65%(abc)	13.45%(a)	14.29%(ab)	27.73%(c)	20.17%(abc)	26.05%(bc)	26.89%(c)	<0.0001
Energetic+	4.2%(a)	2.52%(a)	4.2%(a)	2.52%(a)	5.04%(a)	7.56%(a)	5.88%(a)	7.56%(a)	0.071
Pleasant/ Grateful+	10.92%(a)	22.69%(abc)	24.37%(bc)	14.29%(ab)	26.89%(bc)	27.73%(c)	35.29%(c)	26.89%(bc)	<0.0001
Loving+	2.52%(a)	5.04%(a)	4.2%(a)	3.36%(a)	8.4%(a)	5.88%(a)	6.72%(a)	6.72%(a)	0.088
Amazed+	1.68%(a)	7.56%(ab)	10.92%(ab)	8.4%(ab)	15.97%(b)	10.08%(ab)	14.29%(b)	14.29%(b)	0.000
Hopeful+	15.97%(a)	27.73%(ab)	35.29%(b)	31.09%(b)	40.34%(b)	36.97%(b)	36.13%(b)	36.13%(b)	<0.0001
Happy+	7.56%(a)	18.49%(abc)	18.49%(abc)	17.65%(ab)	29.41%(bc)	23.53%(bc)	30.25%(c)	19.33%(abc)	<0.0001
Hungry+	21.01%(ab)	16.81%(a)	24.37%(ab)	32.77%(b)	24.37%(ab)	26.05%(ab)	23.53%(ab)	26.89%(ab)	0.010
Nostalgic+	0%(a)	0%(a)	3.36%(ab)	1.68%(ab)	1.68%(ab)	5.04%(b)	2.52%(ab)	0%(a)	0.003
Satisfied+	9.24%(a)	15.13%(abc)	18.49%(abc)	14.29%(ab)	26.05%(c)	21.85%(bc)	22.69%(bc)	23.53%(bc)	<0.0001
Unhappy/ Sad-	10.92%(b)	5.88%(ab)	5.04%(ab)	5.88%(ab)	1.68%(a)	2.52%(a)	2.52%(a)	1.68%(a)	0.001
Dissatisfied-	16.81%(a)	10.92%(a)	16.81%(a)	15.13%(a)	9.24%(a)	10.92%(a)	10.08%(a)	10.08%(a)	0.017
Angry-	2.52%(a)	1.68%(a)	0.84%(a)	0.84%(a)	1.68%(a)	1.68%(a)	1.68%(a)	1.68%(a)	0.809
Anxious-	11.76%(a)	8.4%(a)	10.92%(a)	6.72%(a)	5.88%(a)	5.88%(a)	9.24%(a)	8.4%(a)	0.174
Afraid-	4.2%(a)	0.84%(a)	1.68%(a)	0.84%(a)	0.84%(a)	0.84%(a)	2.52%(a)	0.84%(a)	0.297
Suspicious-	21.01%(a)	15.13%(a)	18.49%(a)	15.97%(a)	11.76%(a)	15.13%(a)	15.97%(a)	15.13%(a)	0.345
Bored-	10.92%(b)	7.56%(ab)	5.88%(ab)	8.4%(ab)	3.36%(ab)	3.36%(ab)	3.36%(ab)	1.68%(a)	0.007

Appendix D (continued): Average citation proportions of emotional terms towards <u>plant-based burgers</u> across the eight concepts

Emotion	No Information	Present Environment	Present Nutrition & Environment	Present Nutrition	Present Sensory & Environment	Present Sensory & Nutrition	Sensory & Nutrition & Environment	Present Sensory	p-values
Disappointed-	19.33%(b)	11.76%(ab)	13.45%(ab)	14.29%(ab)	10.08%(ab)	6.72%(a)	8.4%(a)	10.92%(ab)	0.003
Deceived-	6.72%(a)	5.04%(a)	5.04%(a)	5.04%(a)	6.72%(a)	3.36%(a)	5.04%(a)	4.2%(a)	0.545
Disgusted-	6.72%(a)	5.88%(a)	5.04%(a)	4.2%(a)	5.88%(a)	4.2%(a)	3.36%(a)	5.04%(a)	0.264
Uncertain-	42.02%(a)	29.41%(a)	41.18%(a)	33.61%(a)	29.41%(a)	28.57%(a)	29.41%(a)	29.41%(a)	0.004
Curious*	36.13%(a)	47.9%(abc)	53.78%(bc)	40.34%(ab)	50.42%(abc)	48.74%(abc)	56.3%(c)	46.22%(abc)	0.001
Neutral*	30.25%(ab)	34.45%(b)	30.25%(ab)	26.89%(ab)	21.01%(a)	23.53%(ab)	23.53%(ab)	21.85%(ab)	0.009

Note: +Positive emotion, -Negative emotion and *Unclassified emotion. a, b, c Frequency of emotional terms with different letter codes is significantly different between the eight information combinations for the plant-based burger.

6.5 Appendix E: Chapter 3 Average citation proportions of emotional terms towards hybrid burgers across the eight concepts

Emotion	No Information	Present Environment	Present Nutrition & Environment	Present Nutrition	Present Sensory & Environment	Present Sensory & Nutrition	Sensory & Nutrition & Environment	Present Sensory	p-values
Calm+	17.65%(a)	18.49%(a)	21.01%(a)	20.17%(a)	22.69%(a)	17.65%(a)	21.01%(a)	21.01%(a)	0.751
Adventurous+	16.81%(a)	22.69%(a)	26.05%(a)	19.33%(a)	26.89%(a)	27.73%(a)	23.53%(a)	27.73%(a)	0.020
Energetic+	3.36%(a)	5.88%(ab)	9.24%(ab)	6.72%(ab)	7.56%(ab)	8.4%(ab)	10.92%(b)	9.24%(ab)	0.034
Pleasant/ Grateful+	14.29%(a)	21.01%(ab)	21.01%(ab)	20.17%(ab)	26.89%(b)	27.73%(b)	30.25%(b)	24.37%(ab)	0.001
Loving+	5.04%(a)	5.88%(a)	10.08%(a)	7.56%(a)	7.56%(a)	6.72%(a)	7.56%(a)	7.56%(a)	0.500
Amazed+	5.88%(a)	9.24%(ab)	9.24%(ab)	5.88%(a)	12.61%(ab)	10.92%(ab)	16.81%(b)	10.92%(ab)	0.012
Hopeful+	21.01%(a)	33.61%(ab)	32.77%(ab)	29.41%(ab)	42.02%(bc)	38.66%(bc)	43.7%(bc)	49.58%(c)	<0.0001
Happy+	18.49%(a)	25.21%(ab)	26.89%(ab)	20.17%(a)	33.61%(b)	30.25%(ab)	35.29%(b)	27.73%(ab)	0.000
Hungry+	21.01%(a)	19.33%(a)	26.05%(ab)	30.25%(ab)	26.05%(ab)	33.61%(b)	29.41%(ab)	27.73%(ab)	0.004
Nostalgic+	0.84%(a)	1.68%(a)	0.84%(a)	0%(a)	1.68%(a)	0.84%(a)	1.68%(a)	1.68%(a)	0.380
Satisfied+	19.33%(a)	23.53%(ab)	21.85%(ab)	18.49%(a)	29.41%(ab)	33.61%(b)	33.61%(b)	29.41%(ab)	<0.0001
Unhappy/ Sad-	4.2%(a)	4.2%(a)	3.36%(a)	5.88%(a)	0.84%(a)	0.84%(a)	1.68%(a)	1.68%(a)	0.054
Dissatisfied-	6.72%(a)	2.52%(a)	7.56%(a)	8.4%(a)	3.36%(a)	5.04%(a)	2.52%(a)	2.52%(a)	0.062
Angry-	1.68%(a)	1.68%(a)	0.84%(a)	0.84%(a)	0.84%(a)	0%(a)	0%(a)	0.84%(a)	0.723
Anxious-	9.24%(a)	7.56%(a)	6.72%(a)	5.88%(a)	4.2%(a)	8.4%(a)	7.56%(a)	6.72%(a)	0.620
Afraid-	2.52%(a)	2.52%(a)	4.2%(a)	3.36%(a)	3.36%(a)	1.68%(a)	3.36%(a)	3.36%(a)	0.888
Suspicious-	21.85%(ab)	21.85%(ab)	14.29%(ab)	26.05%(b)	15.97%(ab)	17.65%(ab)	14.29%(ab)	13.45%(a)	0.008
Bored-	10.08%(b)	5.88%(ab)	5.04%(ab)	8.4%(ab)	2.52%(ab)	0.84%(a)	3.36%(ab)	1.68%(a)	0.001
Disappointed-	5.88%(a)	5.88%(a)	5.04%(a)	6.72%(a)	2.52%(a)	1.68%(a)	4.2%(a)	2.52%(a)	0.324
Deceived-	5.04%(a)	2.52%(a)	2.52%(a)	4.2%(a)	2.52%(a)	1.68%(a)	3.36%(a)	2.52%(a)	0.752
Disgusted-	4.2%(a)	1.68%(a)	3.36%(a)	2.52%(a)	4.2%(a)	1.68%(a)	3.36%(a)	1.68%(a)	0.577
Uncertain-	37.82%(d)	32.77%(bcd)	33.61%(cd)	30.25%(abcd)	21.01%(abc)	21.85%(abc)	20.17%(ab)	18.49%(a)	<0.0001
Curious*	47.9%(abc)	41.18%(a)	48.74%(abc)	43.7%(ab)	57.98%(bc)	52.1%(abc)	59.66%(c)	55.46%(abc)	0.001
Neutral*	26.89%(a)	27.73%(a)	28.57%(a)	26.89%(a)	20.17%(a)	22.69%(a)	17.65%(a)	18.49%(a)	0.036

Note: +Positive emotion, -Negative emotion and *Unclassified emotion. a, b, c Frequency of emotional terms with different letter codes is significantly different between the eight-information combination for the hybrid burger

6.6 Appendix F: Chapter 3 Average citation proportions of emotional terms towards edible insect burgers across the eight concepts

Emotion	No Information	Present Environment	Present Nutrition & Environment	Present Nutrition	Present Sensory & Environment	Present Sensory & Nutrition	Sensory & Nutrition & Environment	Present Sensory	p-values
Calm+	3.36%(a)	3.36%(a)	3.36%(a)	3.36%(a)	5.04%(a)	4.2%(a)	4.2%(a)	5.04%(a)	0.898
Adventurous+	15.13%(a)	20.17%(ab)	20.17%(ab)	12.61%(a)	25.21%(b)	20.17%(ab)	25.21%(b)	20.17%(ab)	0.000
Energetic+	2.52%(a)	1.68%(a)	2.52%(a)	1.68%(a)	1.68%(a)	5.04%(a)	4.2%(a)	2.52%(a)	0.342
Pleasant/ Grateful+	3.36%(a)	5.88%(a)	8.4%(a)	4.2%(a)	5.88%(a)	5.04%(a)	7.56%(a)	4.2%(a)	0.032
Loving+	2.52%(a)	1.68%(a)	3.36%(a)	1.68%(a)	3.36%(a)	1.68%(a)	4.2%(a)	2.52%(a)	0.273
Amazed+	4.2%(a)	4.2%(a)	3.36%(a)	1.68%(a)	6.72%(a)	4.2%(a)	5.88%(a)	5.88%(a)	0.385
Hopeful+	10.08%(ab)	11.76%(ab)	13.45%(ab)	6.72%(a)	16.81%(b)	10.92%(ab)	14.29%(ab)	12.61%(ab)	0.036
Happy+	2.52%(a)	6.72%(a)	5.88%(a)	2.52%(a)	5.88%(a)	5.88%(a)	5.04%(a)	5.88%(a)	0.214
Hungry+	3.36%(a)	6.72%(a)	5.04%(a)	5.88%(a)	9.24%(a)	9.24%(a)	9.24%(a)	9.24%(a)	0.126
Nostalgic+	2.52%(a)	0.84%(a)	1.68%(a)	1.68%(a)	2.52%(a)	1.68%(a)	0.84%(a)	2.52%(a)	0.391
Satisfied+	3.36%(a)	7.56%(a)	5.88%(a)	3.36%(a)	5.88%(a)	5.88%(a)	7.56%(a)	5.88%(a)	0.242
Unhappy/ Sad-	21.85%(a)	20.17%(a)	21.85%(a)	22.69%(a)	14.29%(a)	15.13%(a)	15.13%(a)	16.81%(a)	0.109
Dissatisfied-	23.53%(a)	26.05%(a)	22.69%(a)	26.89%(a)	21.01%(a)	18.49%(a)	19.33%(a)	22.69%(a)	0.338
Angry-	10.92%(a)	6.72%(a)	9.24%(a)	11.76%(a)	7.56%(a)	5.88%(a)	10.08%(a)	7.56%(a)	0.066
Anxious-	36.97%(a)	30.25%(a)	34.45%(a)	31.93%(a)	33.61%(a)	35.29%(a)	35.29%(a)	31.09%(a)	0.534
Afraid-	22.69%(a)	27.73%(a)	26.89%(a)	24.37%(a)	17.65%(a)	19.33%(a)	20.17%(a)	16.81%(a)	0.016
Suspicious-	32.77%(a)	36.97%(a)	36.13%(a)	36.97%(a)	33.61%(a)	37.82%(a)	40.34%(a)	33.61%(a)	0.645
Bored-	2.52%(a)	0.84%(a)	1.68%(a)	0%(a)	0.84%(a)	2.52%(a)	1.68%(a)	0.84%(a)	0.589
Disappointed-	18.49%(a)	15.13%(a)	18.49%(a)	21.85%(a)	15.97%(a)	18.49%(a)	14.29%(a)	20.17%(a)	0.380
Deceived-	10.92%(a)	9.24%(a)	7.56%(a)	10.92%(a)	10.08%(a)	8.4%(a)	10.92%(a)	10.92%(a)	0.809
Disgusted-	63.03%(b)	53.78%(ab)	57.14%(ab)	54.62%(ab)	51.26%(a)	47.9%(a)	48.74%(a)	47.9%(a)	<0.0001
Uncertain-	56.3%(a)	47.06%(a)	53.78%(a)	52.94%(a)	49.58%(a)	52.94%(a)	51.26%(a)	47.9%(a)	0.465
Curious*	31.09%(ab)	31.09%(ab)	31.09%(ab)	29.41%(a)	42.86%(b)	33.61%(ab)	41.18%(ab)	37.82%(ab)	0.001
Neutral*	8.4%(a)	5.88%(a)	4.2%(a)	9.24%(a)	8.4%(a)	7.56%(a)	5.04%(a)	5.88%(a)	0.311

Note: +Positive emotion, -Negative emotion and *Unclassified emotion. a, b, c Frequency of emotional terms with different letter codes is significantly different between the eight information combinations for the edible insect burger.

6.7 Appendix G Chapter 4 The sensory attribute and definition

Sensory Attribute	Sensory definition
Beany/ legumes	Flavour of beans e.g., chickpeas or soybean
Meat flavour	Flavour of meat e.g. beef, chicken, pork
Mushroom/earthy	Flavour of mushroom or dirt, musty
Savoury	Flavour of soy sauce, miso, vegemite, broth-like and salty
Cohesive (holds together)	Sticks together and does not fall apart easily
Dense/compact	Is difficult to break/ takes effort to bite and chew
Greasy/ oily	Leaves an oily or greasy coating in the mouth
Juicy	Moisture/ juice is released from the sample during chewing
Soft	Easy to bite/break
Tender	The sample is easy to bite into
Fat flavour	Flavour of (animal) fat
Smoky/ grilled	Flavour of smoke e.g. ashy, woody, burnt
Dry	Is lacking moisture
Flavourless	Lacking flavour, bland, tasteless
Red pepper	Flavour of red pepper

6.8 Appendix H Chapter 4 Differences in the proportion of emotional responses towards the product

Emotion	Beef	Plant	Hybrid	p value
Calm+	0.24 (a)	0.26 (a)	0.2 (a)	0.37
Adventurous+	0.08 (b)	0.17 (ab)	0.14 (a)	0.047
Energetic+	0.16 (a)	0.06 (b)	0.05 (b)	0.001
Pleasant/ Grateful+	0.45 (a)	0.3 (b)	0.29 (b)	0.002
Loving+	0.13 (a)	0.07 (a)	0.06 (a)	0.046
Amazed+	0.09 (a)	0.12 (a)	0.14 (a)	0.329
Hopeful+	0.19 (a)	0.23 (a)	0.21 (a)	0.653
Happy+	0.46 (a)	0.22 (b)	0.25 (b)	<0.0001
Hungry+	0.4 (a)	0.25 (b)	0.27 (b)	0.005
Nostalgic+	0.17 (a)	0.02 (b)	0.03 (b)	<0.0001
Satisfied+	0.56 (a)	0.32 (b)	0.28 (b)	0.0001
Unhappy/ Sad-	0.02 (a)	0.04 (a)	0.06 (a)	0.147
Dissatisfied-	0.06 (b)	0.19 (a)	0.2 (a)	<0.0001
Anxious-	0.01 (b)	0.05 (a)	0.08 (ab)	0.009
Afraid-	0.01 (a)	0.04 (a)	0.06 (a)	0.069
Suspicious-	0.1 (b)	0.19 (ab)	0.18 (a)	0.03
Bored-	0.07 (a)	0.07 (a)	0.13 (a)	0.12
Disappointed-	0.07 (b)	0.17 (a)	0.18 (a)	0.007
Deceived-	0.04 (a)	0.07 (a)	0.08 (a)	0.26
Disgusted-	0.02 (b)	0.03 (a)	0.08 (b)	0.007
Uncertain-	0.1 (b)	0.24 (a)	0.24 (a)	0.001
Curious*	0.11 (b)	0.36 (a)	0.41 (a)	<0.0001
Neutral*	0.21 (a)	0.3 (a)	0.22 (a)	0.112

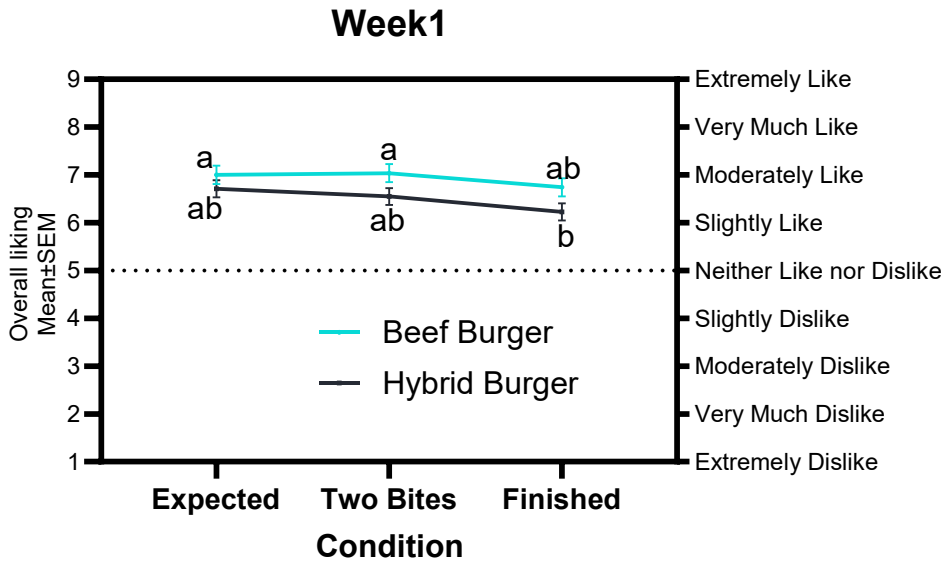
Note: +Positive emotion, -Negative emotion and *Unclassified emotion. a, b, c Frequency of emotional terms with different letter codes is significantly different across the three types of burgers (plant-based, beef, and hybrid).

6.9 Appendix I Chapter 4 Differences in the proportion of sensory attributes towards the product

Attributes	Plant	Hybrid	Beef	P value
Beany Legumes	0.54 (a)	0.31 (b)	0.02 (c)	<0.0001
Meat Flavour	0.09 (c)	0.39 (b)	0.78 (a)	<0.0001
Mushroom Earthy	0.57 (a)	0.49 (a)	0.04 (b)	<0.0001
Savoury	0.36 (a)	0.37 (a)	0.47 (a)	0.082
Cohesive	0.3 (b)	0.44 (a)	0.44 (a)	0.012
Dense Compact	0.18 (b)	0.36 (a)	0.36 (a)	<0.0001
Greasy Oily	0.11 (b)	0.13 (b)	0.41 (a)	<0.0001
Juicy	0.27 (b)	0.29 (b)	0.64 (a)	<0.0001
Soft	0.46 (a)	0.33 (b)	0.22 (b)	<0.0001
Tender	0.3 (a)	0.28 (a)	0.38 (a)	0.114
Fat Flavour	0.05 (c)	0.19 (b)	0.52 (a)	<0.0001
Smoky Grilled	0.17 (b)	0.21 (b)	0.38 (a)	<0.0001
Dry	0.26 (a)	0.26 (a)	0.11 (b)	0.001
Flavourless	0.15 (a)	0.14 (a)	0.04 (b)	0.002
Red Pepper	0.24 (a)	0.17 (a)	0.03 (b)	<0.0001

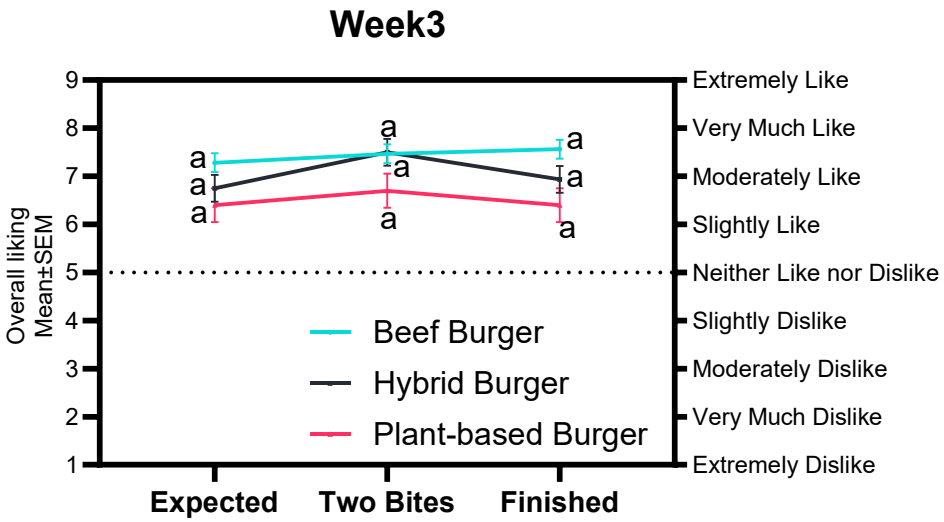
Note: +Positive emotion, -Negative emotion and *Unclassified emotion. a, b, c Frequency of emotional terms with different letter codes is significantly different across the three types of burgers (plant-based, beef, and hybrid).

6.10 Appendix J Chapter 4 Two-way ANOVA for the liking of two burgers across the expected, two-bite, and finished stages in Week 1.



Product fixed impact: $F(1,110)=8.18$, $p=0.005$, $\eta^2=0.068$
Condition fixed impact: $F(2,110)=2.32$, $p=0.10$, $\eta^2=0.04$
Week*Product fixed interaction: $F=(2,110)=0.22$, $p=0.80$, $\eta^2=0.004$
Participants random factor: $F(56, 110)=0.22$, $p<0.0001$, $\eta^2=0.64$

6.11 Appendix K Chapter 4 Two-way ANOVA for the liking of three burgers across the expected, two-bite, and finished stages in Week 3



Product fixed impact: $F(2,110)=8.46$, $p<0.001$, $\eta^2=0.13$
Condition fixed impact: $F(2,110)=1.63$, $p<0.0001$, $\eta^2=0.03$
Week*Product fixed interaction: $F=(4,110)=0.59$, $p<0.66$, $\eta^2=0.02$
Participants random factor: $F(57, 110)=3.16$, $p<0.0001$, $\eta^2=0.61$

Conferences

9th Nursten Symposium, June 2022

Oral: Literature review of self-reported emotional response measurement for food products

Biosciences PGR Symposium, June 2023

Oral: Investigating consumer emotional responses evoked by protein-based products

10th Nursten Symposium, June 2023

Oral: Investigating the impact of sharing environmental information on consumers perception of protein-based products

15th Pangborn Sensory Science Symposium, August 2023

Poster: Understanding consumer responses to protein alternatives and consumer willingness to access environmental information

11th Nursten Symposium, June 2024

Oral: One size doesn't fit all: Consumer liking of protein alternatives is impacted by personal traits

Biosciences PGR Symposium 2024, July 2024

Poster: One size doesn't fit all: Consumer liking of protein alternatives is impacted by personal traits

11th European Conference on Sensory and Consumer Research, September 2024

Poster: One size doesn't fit all: Consumer liking of protein alternatives is impacted by personal traits

12th Nursten Symposium, June 2025

Oral: From taste to choice: How sensory experience and carbon labels influence real-life burger selection

16th Pangborn Sensory Science Symposium, August 2025

Poster: From taste to choice: How sensory experience and carbon labels influence real-life burger selection

Future food symposium, September 2025

Oral: From taste to choice: How sensory experience and carbon labels influence real-life burger selection

Award

03 July 2024: Judges' vote – morning session 2nd place poster winner, Postgraduate Bioscience Research Symposium

Chapter 7. Reference

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