Consumer Emotional Engagement with Plant-Based Meat Alternatives

A thesis presented in partial fulfilment of the
requirements for the degree of

Doctor of Philosophy
in
Food Technology

at Massey University, Manawatū, New Zealand.

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2024

Acknowledgements

Completing this thesis has been an extraordinary journey, filled with many highs and lows. As I reach the end, I am overwhelmed with a mix of relief and gratitude. This accomplishment would not have been possible without the support and encouragement of many incredible people whom I would like to acknowledge now:

First and foremost, I would like to express my deepest gratitude to my supervisors Professor Joanne Hort, Dr Caroline Giezenaar, and Dr Jonathan Godfrey for sharing their expertise and wisdom, and for their unwavering support and guidance throughout this journey. Thank you for helping me to find my voice, my abilities and my self-confidence.

My heartfelt thanks go to all past and present members of the Feast Lab for creating such a friendly and inspiring environment to work. You have all made my time here so memorable, making it so much harder to leave, but I know I've made connections for life. Special thanks to those who assisted with my research studies and alleviated much stress: Caroline, Emily, Joyce, Dianne, Ellie, Simone, Robyn, and Rosie. I would also like to extend my appreciation to the research participants who took part in my studies. Without their willingness to participate, this research would not have been possible.

I would like to acknowledge the financial support of the New Zealand Ministry of Business Innovation and Employment (MBIE) Catalyst Grant, which made this work possible and provided invaluable opportunities to share my research in Wanaka, Sydney, Singapore, and Dublin.

To my parents, Karen and Martin, and my siblings Kathryn and Michael, thank you for always being my biggest cheerleaders and celebrating even the smallest of wins. Your support and motivation throughout my education have been instrumental in my success, and I am grateful for your constant belief in me. To my soon-to-be parents-in-law, Murray and Philippa, thank you for the generosity and understanding you have shown Josh and I as we complete our education. Your kindness and interest in my research have been greatly appreciated.

Finally, to Josh, my best friend for life and fellow meat alternative connoisseur, thank you for your unconditional love, support, and understanding through the highs and lows of my doctoral journey, even as you navigated your own. As we close the VERY long 'university' chapter of our lives, I look forward to what the next chapter has in store for us.

Publications, Presentations and Awards

First Author Publications

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. (2023). Development of a consumer-led emotion lexicon for meat and plant-based burger patties using digitally recreated eating contexts. *Journal of Sensory Studies*, 38(3), e12824. https://doi.org/https://doi.org/10.1111/joss.12824

Collaboration on additional projects as part of the Future Foods Catalyst project leading to publication

Gonzalez-Estanol, K., Orr, R. E., Hort, J., & Stieger, M. (2023). Can flavour and texture defects of plant-based burger patties be mitigated by combining them with a bun and tomato sauce? *Food Quality and Preference*, 109, 104920. https://doi.org/https://doi.org/10.1016/j.foodqual.2023.104920

Giezenaar, C., Orr, R. E., Godfrey, A. J. R., Maggs, R., Foster, M., & Hort, J. (2024). Profiling the novel plant-based meat alternative category: Consumer affective and sensory response in the context of perceived similarity to meat. *Food Research International*, 114465. https://doi.org/https://doi.org/10.1016/j.foodres.2024.114465

Oral Presentations

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. February 2022. 'Emotion Lexicon Development for Plant-based Burger Patties'. 16th NZOZ Sensory and Consumer Science Symposium, Palmerston North, New Zealand (Online).

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. May 2022. 'Consumer Emotional Engagement with Plant-Based Foods'. 1st Consumer Dimensions of Future Food Symposium (Online).

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. February 2023. 'Sensory and Emotional Profiling of Plant-Based Burgers'. 17th NZOZ Sensory and Consumer Science Symposium, Wanaka, New Zealand.

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. December 2023. 'Investigating the Effect of Contextual Variables on Consumer Emotional Response to Plant-Based Meatballs'. Visiting researcher seminar. Agency for Science Technology and Research (A*Star), Singapore.

Oral Presentations (continued)

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. February 2024. 'Investigating the Effect of Contextual Variables on Consumer Emotional Response to Plant-Based Meatballs'. 18th NZOZ Sensory and Consumer Science Symposium, Sydney, Australia.

Orr, R. E., Giezenaar, C., Godfrey, A. J. R., & Hort, J. September 2024. 'Context Matters: How Eating Environment and Meal Context Affect Consumer Evaluation of Liked and Disliked Products'. 11th European Conference on Sensory and Consumer Research, Dublin, Ireland.

Awards

Orr, R. E . February 2024. 1st place winner student presentation competition: 18th NZOZ Sensory and Consumer Science Symposium, Sydney, Australia.

Orr, R. E . June 2024. Claude McCarthy Fellowship: Travel scholarship to attend 11th European Conference on Sensory and Consumer Research, Dublin, Ireland.

Abstract

Plant-based meat alternatives (PBMAs) can support consumers in reducing meat consumption without having to drastically change the way they eat. However, consumer uptake of PBMAs is low highlighting the need for a better understanding of the drivers of PBMA acceptance. The research presented in this thesis aimed to do this by leveraging two innovative techniques in sensory consumer research: measuring emotional response and using digital immersive environments (digital-IEs).

As no emotion lexicon had been published for plant-based patties (PB-patties) or PBMAs in general before this work, an emotional lexicon specific to comparing meat and PB-patties was created. Taking a unique approach, participants were immersed (using digital-IEs) in two relevant burger-eating scenarios to evoke key emotions associated with plant-based patty (PB-patty) consumption in realistic scenarios. Different age and diet groups were included in the lexicon development process to ensure it was inclusive of the range of emotions that could potentially be experienced by end-users. The lexicon included emotions not found in generic lexicons, highlighting the value of a product-specific lexicon for gaining deeper insights. Many emotions were negatively classified, such as ‘deceived’, ‘disappointed’, and ‘anxious’, while others were positively classified, including ‘amazed’ and ‘hopeful’.

The lexicon was applied with meat-eating consumers to emotionally profile a variety of commercially available meat and plant-based patties, alongside measures of liking, sensory attributes, and perceived similarity to a beef patty. Findings revealed that PB-patties closely resembling beef were the most appealing to meat eaters, receiving high liking scores and evoking positive emotional responses, sometimes comparable to those elicited by the beef patty. In contrast, patties that did not mimic meat characteristics were generally disliked and evoked negative emotional responses. These results indicate that PB-patties lacking meat-like characteristics require significant product development to gain acceptance among meat-eating consumers.

The lexicon was also applied to investigate the impact of eating scenarios created using digital-IEs, and accompanying foods, on emotional response, as well as liking, towards plant-based meatball alternatives (PB-meatballs). Serving two PB-meatballs with a well-liked sauce significantly increased both liking and positive emotional response. Additionally, consuming PB-meatballs in an appropriate home environment improved liking for one product and enhanced positive emotional responses toward both. These findings emphasised the importance of considering contextual factors in future research on PBMAs to better understand how they would perform in real-life eating situations.

This research provided an emotion lexicon that researchers and food manufacturers can apply to better understand consumer emotional responses to PBMAs. It identified sensory attributes driving liking and positive emotional responses such as a strong beef flavour and juicy texture, as well as those that drive disliking and negative emotional responses including a beany flavour and pasty/doughy texture, providing a guide for improved PBMA product development. Furthermore, the research demonstrated that consumer acceptance of PBMAs can be improved when served with other meal components and consumed in a contextually appropriate environment, which has implications for how PBMAs are evaluated in the field. Notably, this research showcased the potential of digital-IEs as a tool for gaining insights into consumer responses in settings that are more representative of 'real-life' eating scenarios than traditional sensory testing facilities (i.e. sensory booths).

Preface

This PhD research was one part of Te Rangahua Taha Wheako mō ngā Kai o Āpōpō: The Consumer Dimension of Future Foods (CDFF), one of four projects making up the New Zealand – Singapore Future Foods Catalyst Research Programme, funded by the Ministry of Business, Innovation and Employment (MBIE). The purpose of the CDFF project was to enhance understanding of consumer response to future plant-based foods and thus plant-based meat alternatives (PBMA) were the product focus of this PhD project.

The consumption of PBMAs presents a promising avenue for consumers to reduce their meat intake and contribute to a more sustainable food system. However, despite the potential benefits, uptake of PBMAs has been slow, with recent data indicating a decline in sales (Mridul, 2023; Pierce et al., 2023). If PBMAs are to successfully integrate into mainstream diets a deeper understanding of consumer perception of PBMAs is required. Food choice decisions and the decision to make a dietary change are complicated processes, thus traditional methods of measuring acceptance such as liking or disliking for a product are likely to be insufficient for understanding the intricacies of these decisions.

Emotions play a key role in food choice decision-making (Loewenstein & Lerner, 2003) and experiencing positive emotions is highly relevant to the acceptance of novel (Jiang et al., 2014; Motoki et al., 2021) and plant-based foods (Bryant, 2019; Chen, 2022; Onwezen et al., 2022). Thus, the use of newer methods such as measuring emotional response shows promise for gaining deeper insights into consumer perception of PBMAs. Furthermore, emotional response towards food can be context-dependent, and as such, new approaches such as digital immersive environments can be beneficial for recreating likely eating scenarios to capture emotions that better reflect real-life eating scenarios, while retaining experimental control.

Thesis Structure

This thesis first presents a general introduction and a review of the existing literature on emotional response to foods, consumer acceptance of PBMAs and digital immersive techniques. The literature review concludes with a summary of the identified research gaps in understanding of consumer emotional responses to PBMAs and an overview of the objectives set to address these research gaps (Chapter 1). Six objectives were set and are addressed through chapter 2 to chapter 4. Chapter 2 focuses on developing a novel consumer-led emotion lexicon specific to meat and plant-based burger patties where digital immersive environments are utilised to evoke emotions across relevant eating scenarios. In Chapter 3 the emotion lexicon developed in Chapter 2 is applied to profile a range of meat and plant-based burger patties that vary in sensory characteristics, alongside liking, sensory characteristics, and perceived similarity to a beef patty. In Chapter 4 the impact of contextual variables, including where a food is consumed and how it is consumed, on liking and emotional response is investigated. Finally, chapter 5 provides a summary of the key research findings, limitations, recommendations for future work and the overall conclusions.

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List of abbreviations

ANOVA	Analysis of variance
CATA	Check all that apply
CDFF	The consumer dimension of future foods
CEQ	valence × arousal circumplex-inspired emotion questionnaire
(T-)CLT	(Traditional) central location test
Digital-IEs	Digital immersive environments
DI-Home	Digital immersive home
DI-Concert	Digital immersive concert
GLM	Generalised linear model
HCA	Hierarchical cluster analysis
LMM	Linear mixed effect model
PB-Meatballs	Plant-based alternatives to meatballs
PB-Patty	Plant-based burger patty
PB-Patties	Plant-based burger patties
PBMA	Plant-based meat alternatives
PCA	Principal components analysis
PC	Principal component
RATA	Rate all that apply
SE	Standard error
VR	Virtual reality

Chapter 1: General Introduction and Literature Review

An immense challenge facing humanity is to provide a growing world population with healthy diets from sustainable food systems (Willett & Rockström, 2019). With the world's population estimated to approach 10 billion by 2050 (United Nations, 2017), there will be increased demand for protein and food overall. The challenge of meeting higher protein requirements is compounded by environmental issues such as climate change, biodiversity loss, land use and freshwater use (Willett & Rockström, 2019). Food production is the largest pressure caused by humans to the environment with animal-based protein production having a much greater impact on the environment than plant-based protein production (Aiking, 2011). Compared to plant-based protein sources, animal-based protein sources are associated with more greenhouse gas emissions (Clune et al., 2017), greater land and nitrogen requirements (Davis et al., 2016), and greater impacts on terrestrial and aquatic biodiversity (Willett & Rockström, 2019). Additionally, excess consumption of red and processed meat has been linked to increased risks of diseases, including type 2 diabetes, cancer, and cardiovascular disease (Ekmekcioglu et al., 2018). If current trends in meat consumption persist, these risks to both human health and the environment will worsen. To achieve a more sustainable food system, the EAT-Lancet Commission has recommended a shift towards a predominantly plant-based diet with low amounts of animal-source foods (Willett & Rockström, 2019).

New Zealanders predominantly follow an omnivorous diet, with only 7% of the population estimated to be meat-free (vegan, vegetarian, or pescatarian), and an additional 7% identifying as flexitarian (Realini et al., 2023). However, Kantar (2022) have indicated that as many as 19% of New Zealanders always or mostly maintain a meat-free diet. Nonetheless, a significant dietary shift is still necessary to decrease the country's overall consumption of animal protein. This dietary shift will require consumers to accept new foods. Multiple factors affect consumer acceptance and motivate behaviours towards new foods, but sensory characteristics of foods are consistently rated as the most important motivation underlying acceptance (Martins & Pliner, 2005). However, the adoption of plant-based foods, including PBMAs, has been slow due to

several factors. One major challenge is that many products fail to meet consumer expectations, particularly in terms of sensory properties that do not always replicate those of meat (Elzerman et al., 2015; Elzerman et al., 2013; Hartmann & Siegrist, 2017). Additionally, many PBMAs possess sensory characteristics that are unappealing to consumers, leading to rejection (Chigwedere et al., 2022; Giacalone, Clausen, et al., 2022).

Traditionally, in consumer research, acceptance is measured through hedonic tests, to assess overall liking and degree of liking for individual sensory attributes (Fiorentini et al., 2020). However, sensory acceptability is only one factor driving food choice and consumption decisions and is rarely a strong predictor of marketplace performance (Jaeger & Giacalone, 2021; Thomson & Coates, 2021) or food choice in real life (de Graaf et al., 2005). This has driven sensory and consumer researchers to take a broader perspective on how consumers experience foods. One method employed is measuring emotional associations to food products, recognising the key role emotions play in food-related decision-making (Loewenstein & Lerner, 2003).

Experiencing positive emotions has been suggested to play an important role in acceptance of alternative protein sources (Bryant et al., 2019; Cardello et al., 2022; Motoki et al., 2021; Onwezen et al., 2022). Furthermore, Jiang et al. (2014) indicated that the decision to buy novel foods may be dominated by the emotional connotations of the food. At the commencement of this research, there was a notable lack of research regarding consumer emotional responses to PBMAs. There was a recognised need for broader research into how the extrinsic characteristics, e.g., brand, packaging, and intrinsic characteristics e.g., sensory characteristics, of PBMAs influence consumer emotions. The present research specifically concentrated on investigating the intrinsic characteristics of PBMAs. By gaining a better understanding of consumer emotional response to PBMAs, insights into the consumer experience can be deepened (Jaeger et al., 2020). This knowledge can then be leveraged to inform research and development in the food industry to develop interventions aimed at increasing consumer acceptance of PBMAs.

Emotional response is affected by context (Piqueras-Fiszman & Jaeger, 2014; Schouteten, 2021), where context refers to all of the variables in a particular eating occasion (i.e., where, when, how,

and with whom the food is eaten) (Meiselman et al., 2000). In traditional consumer testing settings, contextual information is often disregarded, however, such testing environments do not represent how consumers experience food in real life (Nijman et al., 2019). In recent years, significant attention has been placed on improving the ecological validity of consumer testing by incorporating contextual factors (Stelick & Dando, 2018). Digital immersion has emerged as a promising approach to achieve this goal, allowing for the recreation of relevant consumption contexts in the laboratory or central location settings using technologies such as video walls, immersive rooms, or augmented/virtual reality headsets.

This literature review firstly outlines what emotion is, and how and why it is measured in consumer and sensory research. Next, factors affecting acceptance of plant-based meat alternatives are discussed and what is already known regarding their acceptance and emotional response. Consideration is then given to what is meant by context and how and why it can be implemented in consumer testing. Subsequently, the chapter concludes with the research gaps identified which led to the aim and objectives for the research presented in this thesis.

1.1 Emotional response to food products

1.1.1 What is emotion?

"*Everyone knows what an emotion is, until asked to give a definition. Then, it seems, no one knows*" (Fehr & Russell, 1984).

While most people can easily list several emotions, defining what an emotion is proves far less straightforward. There is no one definition of emotion with several definitions found in literature according to the field of science or perspective from which it is studied (Panagiotou & Gkatzionis, 2022). For this thesis, emotions are defined as brief episodes whereby a stimulus/event elicits an emotional response (action tendency, automatic reaction, expression, and/or feeling) which is dependent upon an individual's needs, goals, and/or values (Coppin & Sander, 2021). For example, chocolate may elicit an emotional response of feeling guilty if the person's goal is to lose weight. Other definitions emphasise that emotions are experienced with rapid onset, high

intensity and are short-lasting (Cabanac, 2002; Clore et al., 1987; Ferrarini et al., 2010; Gibson, 2006; King & Meiselman, 2010).

Emotions can be distinguished from other affective feelings such as preferences, moods, and attitudes. Preferences are stable evaluative judgments concerning liking or disliking a stimulus, independent of current needs or goals. Moods, on the other hand, may not be in response to a specific stimulus or event, develop more gradually, and last longer. Attitudes refer to enduring beliefs and predispositions towards a stimulus or event (Scherer, 2005).

Emotion classification, or how one emotion can be distinguished from another, has been the subject of extensive debate in emotion research. In particular, emotion theorists have argued over whether emotions are discrete entities or are best described along dimensions of valence and arousal (Harmon-Jones et al., 2017). Basic (or discrete) emotion theory (Darwin, 1872; Ekman, 1994; Izard, 2013; Plutchik, 1980) suggests humans and animals experience discrete categories of emotion, where each emotion is an adaptation to solve an adaptive problem e.g. fear is to avoid danger (Matsumoto & Ekman, 2009). The "big six" basic emotions (also referred to as primary emotions) are typically agreed to be fear, disgust, anger, sadness, happiness and surprise (Prinz, 2004), which according to Matsumoto and Ekman (2009) are universally recognised through distinctive facial expressions. The second approach to defining the structure of emotions is the dimensional approach (Larsen & Diener, 1992; Russell, 1980; Thayer, 1990; Watson et al., 1988) which suggests emotions can be defined by where they lie in two or three dimensions where the dimensions usually include valence, arousal or intensity. The circumplex model of affect, developed by Russell (1980), is a widely accepted framework that suggests an individual can describe their current feelings as a single point on a two-dimensional space called a circumplex (**Figure 1.1**). The two dimensions represent valence (x-axis) and arousal (y-axis), with distance from the origin representing intensity. Valence indicates how pleasant or unpleasant someone feels, while arousal measures how calm or agitated someone feels (Feldman Barrett, 2017). Russell (1980) demonstrated how 28 different terms used to describe feelings/moods/emotions could be mapped to the circumplex in a circular structure.

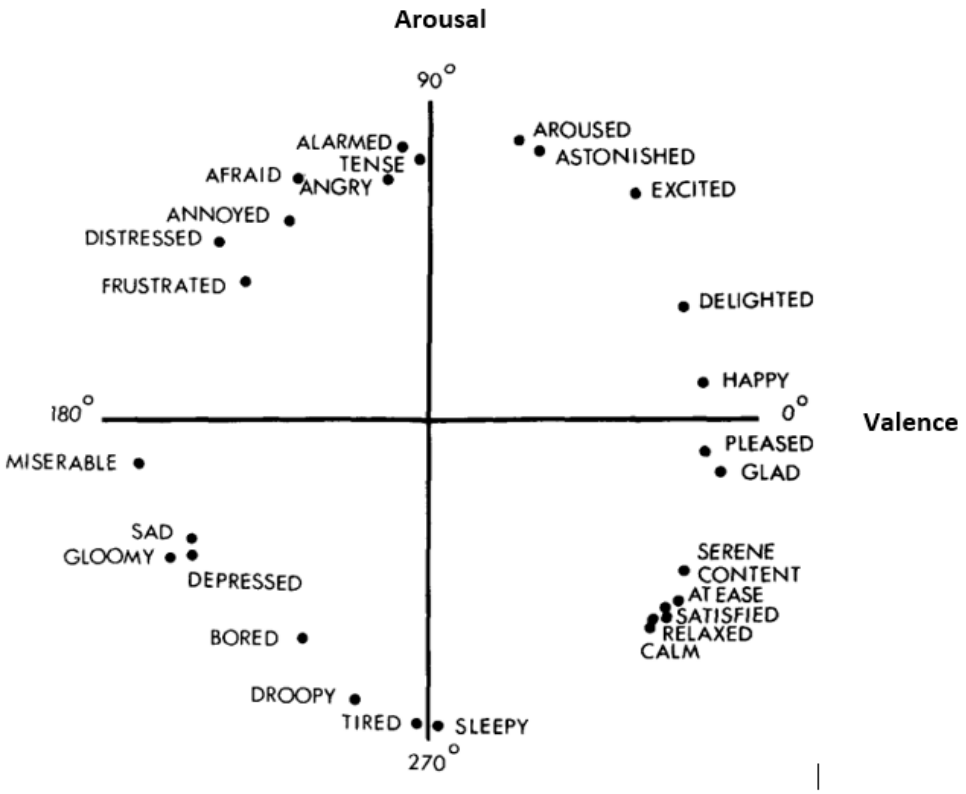

Figure 1.1 Circumplex Model of Affect. Adapted with permission from "A Circumplex Model of Affect" by J. A. Russell, Journal of Personality and Social Psychology, 39(6), p.1168. (https://doi.org/10.1037/h0077714). Copyright © 1980, American Psychological Association.

In this thesis, an explicit approach to understanding consumer emotional responses towards PBMAs was taken (*see* **1.1.3** for a discussion of explicit and implicit measures of emotion). Consequently, a dimensional model viewpoint was adopted, as basic (or discrete) emotion theory would only allow for the assessment of basic emotions, thereby limiting the emotional vocabulary and reducing discrimination.

1.1.2 Why measure emotional response to foods?

In consumer research, acceptance has conventionally been determined using hedonic tests e.g. the 9-point hedonic scale (Peryam & Pilgrim, 1957), to evaluate overall liking and the extent of liking for specific sensory attributes (Fiorentini et al., 2020). However, while sensory acceptability is important, it is only one-factor influencing food choice and consumption decisions and is rarely a strong predictor of marketplace performance (Jaeger & Giacalone, 2021; Thomson & Coates,

2021) or food choice in real life (de Graaf et al., 2005). This has driven sensory and consumer researchers to take a broader perspective on how consumers experience foods. Consequently, over the last decade, there has been significant interest in measuring emotional associations, or conceptualisations, of food products. This interest stems from the key role emotions play in food choice decision-making through both the anticipated emotional consequences associated with purchasing and consuming specific products, and emotions experienced immediately after purchasing or consuming the product (Loewenstein & Lerner, 2003).

Several studies have shown the inclusion of emotional measurements to provide additional information beyond liking. Such information can deepen understanding of consumer product experiences (Jaeger et al., 2020). In some cases, emotional response measures have distinguished products that are equally liked (Bhumiratana et al., 2014; Meiselman, 2017; Mora et al., 2018; Ng et al., 2013). For example, Ng et al. (2013) measured the emotional profiles of different blackcurrant cordials and found for samples with similar liking scores, emotions 'adventurous', 'daring' and 'good-natured' discriminated the liked products and emotions 'tame' and 'disgust' discriminated the disliked samples. Similarly, Bhumiratana et al. (2014) found distinct emotion profiles for brands of coffee that were equally liked. For example, one brand of coffee was associated with positive-high energy emotions e.g., 'active', 'boosted', 'energetic', 'rested', and 'empowering' were generated, whilst another brand was associated with positive-low energy emotions e.g. 'comfortable', 'pleasant', 'warm'. Such information is valuable for product development and marketing strategies (Meiselman, 2015; Thomson et al., 2010).

Furthermore, using a combination of emotional and hedonic liking measures can increase the predictive power of consumer food choice decisions (Dalenberg et al., 2014; Giacalone, Llobell, et al., 2022; Gutjar et al., 2015; Schouteten et al., 2018). For example, Dalenberg et al. (2014) in a study focusing on food-evoked emotions and liking for seven breakfast drinks, successfully predicted 50% of individuals' choice of drink one week after the initial product assessment. This prediction accuracy increased to almost 80% when considering the top two predicted choices.

Products belonging to the same product category but differing in some sensory properties have been found to have different emotional profiles (Spinelli & Jaeger, 2019). For example, in chocolate, Thomson et al. (2010) found bitter to be associated with 'confident', 'adventurous', and 'masculine'; and creamy and sweet with 'fun', 'comforting' and 'easy-going'. Chaya et al. (2015) found that increasing the hoppiness of beer generally increased ratings of negative emotion categories and decreased ratings of positive emotion categories. This is known as a 'sensory-specific effect', the notion that a product's emotional profile relies on its specific sensory properties (Spinelli & Jaeger, 2019). This suggests that the sensory profile of a product may be modified to increase specific positive emotions or to decrease negative emotions (Spinelli & Jaeger, 2019) and used for developing and optimising new products. Other applications include sensory marketing, which is beyond the scope of this project, where the emotional connotations of a product are measured and these messages are aligned with the branding and marketing, e.g., calming, or energising products (Jiang et al., 2014; King & Meiselman, 2010).

1.1.3 How are food-evoked emotions measured?

Significant interest in emotions within the field of sensory and consumer science has led to the development of several instruments for measuring consumer emotional responses to food products. Depending on how emotions are assessed, measures can typically be divided into implicit and explicit methods (Lagast et al., 2017). Implicit methods measure a response evoked indirectly or automatically by the stimulus itself and happens without insight or awareness (unconscious), whereas explicit methods measure a response requiring conscious effort for initiation and associated with some level of insight and awareness (Kaneko et al., 2018). **Table 1.1** provides a summary of implicit and explicit instruments which have been used in the study of food-evoked emotions.

Explicit verbal self-report questionnaires are by far the most commonly used measures for the assessment of food-evoked emotions. Through a systematic literature review of the instruments used to measure food-evoked emotions, Low et al. (2022) identified 193 studies of which 107 exclusively used cognitive explicit instruments in the form of emotion lexicons. A further 33

studies used cognitive explicit instruments in combination with other measures e.g. physiological measures. Of these 140 studies, 26 used non-verbal emotion lexicons, while the remainder used verbal lexicons.

Table 1.1. Instruments used to measure emotional response to food by three levels of measurement level (cognitive, behavioural, physiological) and levels of emotional processing (implicit, explicit) adapted from Lagast et al. (2017); Low et al. (2022).

	Emotional processing level	
Measurement level	**Implicit**	**Explicit**
Cognitive	Reaction tasks	Verbal self-report questionnaires (emotion lexicon) Non-verbal/visual self-report questionnaires (Cartoons, Emoji, Pictures) Free listing/ associations
Behavioural	Amount consumed Rapid forced choice Facial expression analysis Facial EMG Eye tracking Gamification	Buying behaviour Willingness to consume Amount consumed (self-report eating diary)
Physiological	Cardiovascular responses Respiration responses Skin conductance response Brain responses Pupillary responses	Not applicable

Explicit verbal self-report questionnaires have faced criticism due to various limitations. These include respondents experiencing difficulty in articulating emotions, cultural variability in the emotional lexicon, potential interference of verbalising emotions with the food experience itself, and the capture of only conscious, declared opinions and potentially only socially desirable responses (Kaneko et al., 2018). Despite the acknowledged limitations, explicit methods continue to be widely used as they offer several advantages over implicit methods such as facial expression analysis/EMG. Explicit methods (e.g. self-report questionnaires) are easy to implement and are user-friendly for both researchers and participants (Lagast et al., 2017). Additionally, explicit methods are cost-effective, and straightforward to analyse and interpret, as they contain less noise than implicit methods, and allow for rapid data collection from multiple participants simultaneously. Explicit methods also enable the use of a broader emotional vocabulary (Cardello & Jaeger, 2021; Schouteten, 2021) and offer good product discrimination (Dorado et al., 2016).

In contrast, implicit methods offer an indirect and non-self-reported approach, eliminating the need for consumers to consciously reflect on how a product makes them feel (Lagast et al., 2017). Additionally, implicit methods often register data continuously, unlike explicit methods that usually only collect data at specific time points unless utilising temporal techniques (Lagast et al., 2017). However, when applied in a food context, implicit methods can present several limitations depending on the instrument used. The measure of facial reactions has been the most popular implicit method used for emotional response measurement in food research (Schouteten, 2021), however, face reading software focuses on a small number of emotions, primarily negative ones (Meiselman, 2017; Schouteten, 2021). Therefore, questionnaires are better for capturing and distinguishing between positive emotional experiences (Schouteten, 2021). Furthermore, any instrument measuring facial reaction requires participants to adapt their eating behaviour to facilitate accurate registration of facial expressions (Schouteten, 2021). Additionally, facial methods may be subject to noise during chewing and swallowing (Schouteten, 2021). Other limitations include slower data collection as usually only one participant can be assessed at a time, the need for specialised and often expensive equipment, and the invasive use of sensors in the case of physiological measures (Cardello & Jaeger, 2021; Schouteten, 2021; Weerawarna N.R.P et al., 2023).

There is currently no 'gold standard' approach to measuring food-evoked emotions (Kaneko et al., 2018; Low et al., 2022), however, due to the limitations associated with implicit measures, explicit methods e.g. questionnaires are currently recommended as the default approach while implicit measures are better suited as secondary measures (Cardello & Jaeger, 2021; Schouteten, 2021).

1.1.3.1 Explicit methods: self-reporting questionnaires

Explicit methods used for measuring food-evoked emotions are typically either verbal or visual self-report questionnaires (Lagast et al., 2017). Self-report questionnaires are most commonly used to measure food-evoked emotions due to ease of use, cost-effectiveness and discriminative power (Dorado et al., 2016). For verbal self-report measures, consumers are provided with a list

of emotion terms (lexicon) and asked to check or rate the emotions experienced (Dalenberg et al., 2014). Non-verbal self-report measures use animated cartoons (e.g., PrEmo® (Desmet, 2019)), emoji (first used by Jaeger, Vidal, et al. (2017)) or pictures (e.g. Mood Portraits® (Churchill & Behan, 2010)) to depict emotions, instead of emotion terms (Dorado et al., 2016).

An emotion lexicon can be utilised across all food and beverage categories i.e. a generic (food) lexicon (also commonly referred to as a predetermined or standardised lexicon) or developed for a specific product category (product-specific lexicon also referred to as a consumer-led lexicon when developed with consumer input) (Dorado et al., 2016). The EsSense Profile® created by King and Meiselman (2010) was the first generic emotion lexicon developed for consumer research of food products. The EsSense Profile® contains 39 emotion terms, 25 positive, 3 negative and 11 uncategorised. EsSense25 is a reduced version of the EsSense Profile® containing 25 emotion terms (Nestrud et al., 2016). The Geneva Emotions and Odour Scale (GEOS), containing 36 emotion terms, is another example of a generic emotion lexicon, developed to specifically measure the emotions associated with odour (Chrea et al., 2009). More recently, Jaeger et al. (2020) developed the valence x arousal circumplex-inspired emotion questionnaire (CEQ) which consists of 12 pairs of emotions which span the different segments of the valence x arousal circumplex developed by Russell (1980).

The main advantage to using a generic (food) emotion lexicon like the EsSense Profile® is that such lexicons are general and so can be applied to any group of products without the labour-intensive process of developing a product-specific lexicon (Chaya et al., 2015; Spinelli et al., 2014). However, due to the general nature of these lexicons, not all emotion terms are relevant to every product category and emotions that are important can be missing (Ng et al., 2013). The inclusion of irrelevant terms makes the questionnaire longer, which can cause confusion, fatigue, and boredom for the user (Jaeger et al., 2013). Furthermore, generic lexicons like the EsSense Profile®, mainly consist of positive emotion terms as they are aimed at product users who typically like the product so may capture disliking less accurately (Dalenberg et al., 2014). Meiselman (2015) argues that non-users should also be studied to identify characteristics that

work against product adoption, in which case the inclusion of more negative emotions is necessary.

An alternative to using a generic (food) lexicon is developing a product-specific lexicon where consumers generate a lexicon in their own words for a product category of interest. The development of a product-specific lexicon is a time-consuming process but has the advantage of only including relevant emotion terms better-capturing emotions specific to the product category thereby increasing its discrimination ability (Ng et al., 2013). A product-specific lexicon can also provide deeper information on emotions underlining the consumption experience (Bhumiratana et al., 2014). Several product-specific lexicons have been developed, including chocolate (Gunaratne et al., 2019; Thomson et al., 2010); blackcurrant squashes (Ng et al., 2013); chocolate and hazelnut spreads (Spinelli et al., 2014); coffee (Bhumiratana et al., 2014); beer (Chaya et al., 2015; Mora et al., 2019); wine (Ferrarini et al., 2010; Mora et al., 2020); and milkshakes (Weerawarna N.R.P, 2021). At the time of this research, an emotion lexicon for PBMAs or any form of plant-based products had not been published.

1.1.3.2 Questionnaire format for explicit emotional response assessment

In a systematic review of current literature regarding measuring emotional response to foods, Low et al. (2022) identified various questionnaire formats used for explicit emotional response assessment across 107 studies. Among these, discrete scales were the most popular, used in 39 studies e.g. (Bhumiratana et al., 2014; Cardello et al., 2012; Ferrarini et al., 2010; Gutjar et al., 2015; Spinelli et al., 2014), followed by rapid methodologies e.g. Check-All-That-Apply (CATA) which were used in 33 studies e.g. (Gunaratne et al., 2019; Jaeger, Spinelli, et al., 2018; Ng et al., 2013; Schouteten et al., 2017; Sinesio et al., 2019). Line scales were less popular, used in 13 studies e.g. (Chaya et al., 2015; Dorado et al., 2016; Eaton et al., 2019; Mora et al., 2020; Mora et al., 2018; Nijman et al., 2019), as well as Rate-All-That-Apply (RATA), which was used in eight studies e.g. (Jaeger, Lee, et al., 2018; Low, Lin, et al., 2021; Schouteten et al., 2015; Schouteten et al., 2016).

Originally developed for sensory product characterisation with consumers (Ares & Jaeger, 2023), CATA has emerged as a popular approach for collecting emotional response data. CATA involves respondents checking all relevant emotion attributes from a predefined list (Hollowood et al., 2018). The resulting data is the frequency of attribute selection. The simplicity of selecting terms from a list makes CATA a quick, easy, and intuitive task for consumers that is less cognitively demanding compared to rating methodologies (Adams et al., 2007).

An alternative to CATA is using a rating methodology such as discrete scales and line scales where respondents rate the intensity of each emotion term in relation to the focal product (Seninde & Chambers, 2021). Rating scales can be more cognitively demanding and time-consuming compared to CATA (Seninde & Chambers, 2021), and hence RATA, where only terms considered applicable to the focal product are rated, can be advantageous (Hollowood et al., 2018). However, it is worth noting that rating scales are often anchored at one end with 'not at all' or 'strongly disagree' so respondents can be instructed to select this option instead of rating if the emotion does not apply (Seninde & Chambers, 2021). Rating methodologies (e.g. RATA or intensity scales) are advantageous when sample differences are subtle or only differ in attribute intensity. In such cases, intensity ratings allow for better discrimination among samples (Ares & Jaeger, 2023). Moreover, rating methodologies can provide more nuanced emotional detail, capturing additional emotions at lower intensity levels compared to CATA where respondents typically use a higher threshold to check an emotion (Meiselman, 2016). When comparing a rating (where respondents are asked to rate all terms) and a RATA question format, Seninde and Chambers (2021) found that the rating question format yielded more "apply" responses than the RATA question format. This suggests respondents may also use a higher threshold to rate an emotion when using RATA compared to rating.

1.1.4 Methods of measuring 'in context'

Evaluating food products in real-life environments e.g., a restaurant or at home, is time-consuming, expensive and logistically more complex (Holthuysen et al., 2017). Additionally, the lack of control over external cues in real-life environments makes it difficult to standardize

settings, sample preparation, and presentation across different consumers (Giezenaar & Hort, 2021). Consequently, consumer sensory researchers have explored several strategies to evoke context or recreate realistic consumption scenarios in the laboratory or a central location. This allows researchers to maintain a scientifically controlled environment whilst understanding consumer response to products in more ecologically valid environments (Bangcuyo et al., 2015; Galiñanes Plaza et al., 2019; Giezenaar & Hort, 2021). The main techniques used have included written scenarios where consumers are asked to imagine a situation and think of that situation when evaluating the product. The imagined scenario can be predefined such as imagining oneself eating breakfast (Giménez et al., 2015; Hein et al., 2012; Piqueras-Fiszman & Jaeger, 2014), or defined by the consumers themselves such as imagining the location, time and company for consuming a beer (Dorado et al., 2016; Jaeger, Fiszman, et al., 2017). Nijman et al. (2019) supplemented a written scenario with images and audio, similarly, Andersen et al. (2019) supplemented it with images. Imagined environments have however been found to be cognitively demanding. For instance, Andersen et al. (2019) found that consumers reported difficulties in engaging with a photo-enhanced imagined context compared to a digital simulation. Furthermore, Jaeger, Fiszman, et al. (2017) found, that when consumers were asked to write about a situation they imagined, samples could not be hedonically discriminated, suggesting that evaluating samples under imagined contexts may be distracting consumers away from the tasted samples. Köster (2003) expressed that consumers are lazy and unlikely to direct cognitive effort to context evocation.

More recently, there has been significant interest in the use of digital technologies including video walls, immersive rooms (360-degree projection of images or videos) and virtual reality (VR)/augmented reality headsets to recreate eating contexts, referred hereon in as digital immersive environments (digital-IEs). **Table 1.4** provides a summary of previous studies which have used digital-IEs to recreate eating environments.

These digital-IEs require an expensive initial outlay but once established offer a relatively inexpensive and fast way to achieve any desired context (Giezenaar & Hort, 2021). A greater

number of studies have opted to use virtual or augmented reality headsets, likely attributed to their portability and lower cost compared to the technology required for an immersive room.

Table 1.4. Studies employing digital-IEs to recreate eating environments in the laboratory or central location.

Technique	Reference
Video walls	(Bangcuyo et al., 2015; Delarue et al., 2019; Hathaway & Simons, 2017)
Immersive rooms	(De Wijk et al., 2022; Lichters et al., 2021; Liu et al., 2019; Pennanen et al., 2020; Sinesio et al., 2019; Sinesio et al., 2018; van Bergen et al., 2021; Worch et al., 2020; Zandstra et al., 2020)
Virtual reality (VR)/ augmented reality headsets	(Alba-Martínez et al., 2024; Andersen et al., 2019; Chen et al., 2020; Colla et al., 2023; Kong et al., 2020; Low, Lin, et al., 2021; Man et al., 2023; Picket & Dando, 2019; Schouteten et al., 2024; Sinesio et al., 2019; Song et al., 2022; Stelick et al., 2018; Torrico et al., 2020; Torrico et al., 2021; Worch et al., 2020; Yang et al., 2022)

When immersive rooms are used, the experience can be enhanced through the use of aroma diffusion, audio, and context-specific furniture and/or accessories (Giezenaar & Hort, 2021). For example, in a study by Sinesio et al. (2018) images of a countryside landscape were supplemented with audio recordings of birds chirping and leaves rustling. Additionally, the odour of fresh herbs was introduced through the placement of herbs in a basket on the table as décor. Other table décor such as a tablecloth and carafe of water were also used to further enhance the setting. As expected, the more immersive the context can be made, the closer the consumer response to their response in real life (Stelick & Dando, 2018).

1.2 Plant-based foods, acceptability, and emotional response

To achieve a more sustainable food system, experts have recommended a shift towards a predominantly plant-based diet with low amounts of animal source foods (Willett & Rockström, 2019). A plant-based diet emphasises the consumption of minimally processed foods such as fruits, vegetables, legumes, whole grains, nuts, and seeds while limiting the intake of meat, poultry, fish, seafood, and dairy (Heart Foundation, 2024).

PBMAs have been developed to support consumers in transitioning to a primarily plant-based diet without having to drastically change the way they eat. PBMAs can be categorised into two main groups: those designed to mimic the sensory properties of conventional meat products (e.g., sausages, burger patties, mince), typically made from purified plant proteins including pea, soy, and wheat. These products are herein referred to as 'meat analogues'. Other plant-based products include vegetable-based products that intend to replace meat in a meal but are not specially designed to mimic meat. These products are often made from ingredients including vegetables, grains, legumes, and pulses and undergo less processing compared to meat mimics (Tso et al., 2020) and are herein referred to as 'wholefood' products. Hybrid meat products are a further alternative to meat where a proportion of meat is replaced with plant-based ingredients and is intended as a transition product for consumers who want to lower their meat consumption without compromising on taste, flavour, and texture (Grasso, 2020). The adoption of PBMAs presents a promising avenue for consumers to reduce their meat intake and contribute to a more sustainable food system. However, despite their potential benefits, uptake of PBMAs has been slow, with recent data indicating a decline in sales (Mridul, 2023; Pierce et al., 2023).

1.2.1 Factors affecting acceptance of plant-based meat alternatives

Several person and product-related factors contribute to the acceptance of PBMAs (**Table 1.2)**. *See* Onwezen et al. (2021), Giacalone, Clausen, et al. (2022) and Szenderák et al. (2022) for comprehensive reviews of motivations and barriers to PBMA acceptance.

All factors listed in **Table 1.2** are relevant to PBMA acceptance, for example, previous research suggests that higher-income individuals (Good Food Institute APAC, 2023; International Food Information Council, 2020; Spalding, 2022), and those with a higher level of education (Tertiary qualification and/or University degree) (Hoek et al., 2011; International Food Information Council, 2020; Realini et al., 2023; Van Loo et al., 2020) are more willing to consume PBMAs. However, within the scope of this research, emotional response towards PBMA was the primary focus, while sensory appeal, situational appropriateness, and familiarity were secondary factors explored to understand their impact on liking and emotional response. Moreover, person-related

factors such as diet and age groups were considered to gain insight into the preferences of future potential PBMA consumers.

Table 1.2. Person and product-related factors contributing to the acceptance of PMBAs.

Person related factors	Reference	Product related factors	Reference
Diet	(International Food Information Council, 2020; Slade, 2018; Van Loo et al., 2020)	Sensory appeal	(Chigwedere et al., 2022; Elzerman et al., 2015; Fiorentini et al., 2020; Giacalone, Clausen, et al., 2022; Hartmann & Siegrist, 2017; Hoek et al., 2011; Michel et al., 2021)
Meat attachment	(Broeckhoven et al., 2021; Graça et al., 2015)	Familiarity	(Bryant et al., 2019; Hoek et al., 2011; Michel et al., 2021; Weerawarna N.R.P et al., 2024)
Age/generation	(Alae-Carew et al., 2022; Broeckhoven et al., 2021; Kemper et al., 2023; Neuhofer & Lusk, 2022; Realini et al., 2023; Spalding, 2021)	Perceived healthiness and naturalness	(Hwang et al., 2020; Michel et al., 2021; Noguerol et al., 2021; Onwezen et al., 2021; Tso & Forde, 2021)
Gender	(Bryant et al., 2019; International Food Information Council, 2020; Kemper et al., 2023; Neuhofer & Lusk, 2022; Realini et al., 2023; Van Loo et al., 2020)	Price	(Broeckhoven et al., 2021; Bryant et al., 2019; Bryant, 2019; Michel et al., 2021; Van Loo et al., 2020)
Income	(Bryant et al., 2019; Good Food Institute APAC, 2023; International Food Information Council, 2020; Neuhofer & Lusk, 2022; Spalding, 2022; Weerawarna N.R.P et al., 2024)	Labels	(Demartini et al., 2022; Giezenaar, Godfrey, et al., 2024; Noguerol et al., 2021)
Education	(Hoek et al., 2011; International Food Information Council, 2020; Kemper et al., 2023; Neuhofer & Lusk, 2022; Realini et al., 2023; Van Loo et al., 2020)	Emotional response /conceptual associations	(Cardello et al., 2022; Jiang et al., 2014; Michel et al., 2021; Onwezen et al., 2021; Onwezen et al., 2022; Schouteten et al., 2016; Zandstra et al., 2023)
Political orientation	(Bryant et al., 2019)	Situational appropriateness	(Elzerman et al., 2021; Michel et al., 2021; Motoki et al., 2021)
Culture	(Bryant et al., 2019)		
Food neophobia	(Bryant et al., 2019; De Koning et al., 2020; Hoek et al., 2011; Onwezen et al., 2021)		
Food choice motives (health,	(Giezenaar, Godfrey, et al., 2024; Hoek et al., 2011;		

taste, sustainability, animal welfare)	Onwezen et al., 2021; Rosenfeld & Tomiyama, 2020; Weerawarna N.R.P et al., 2024)

1.2.1.1 Emotional response to plant-based meat alternatives

Experiencing positive emotions is associated with higher acceptance of novel foods (Jiang et al., 2014; Motoki et al., 2021), alternative proteins (Onwezen et al., 2022), and plant-based foods specifically (Bryant et al., 2019; Cardello et al., 2022; Chen, 2022). For example, Onwezen et al. (2022) found experiencing positive emotions to be the most influential factor in determining individuals' intention to consume alternative proteins, surpassing personal norms, food neophobia, and food-choice motives. Furthermore, Cardello et al. (2022) found positive emotions, particularly 'happy', 'comforting' and 'energetic' to be associated with a positive change of more than one scale point in willingness to consume plant-based foods (milk, cheese, meat and fish) whereas negative emotions boring', 'uninspired' and 'dissatisfied' was associated with a negative change in willingness to consume of more than one scale point. Understanding consumer emotional responses towards PBMAs could provide valuable insights for overcoming emotional barriers and facilitating the transition to a plant-based diet. However, there remains a notable gap in understanding of the emotions elicited by actual tasting of PBMAs.

Schouteten et al. (2016) is the only published study (to the researcher's knowledge) to have previously investigated emotional responses to PBMAs where actual products have been tasted. Schouteten et al. (2016) investigated overall liking and emotional response for a meat-based, insect-based, and plant-based (soy and wheat protein) burger patty. The meat-based patty was liked significantly more than the plant-based burger and was most frequently associated with positive emotions e.g. 'content', 'happy', 'glad' and 'pleasant', whereas the plant-based burger was most frequently associated with negative emotions e.g. 'disappointed', 'discontent', 'disgust', 'dissatisfied' and distrust'.

Other studies have investigated anticipated emotions towards PBMAs through surveys. For example, Zandstra et al. (2023) in an online survey with Dutch consumers, measured anticipated

emotional response (13 emotions) to images of a plant-based burger and a meat burger. For the plant-based burger respondents rated significantly higher for expected emotions ‘proud’, ‘cool’ and ‘bored’, whereas the meat burger rated significantly higher for emotions ‘happy’, ‘guilty’ and ‘worried’. Expected liking of the plant-based burger was significantly related to expectations of feeling ‘satisfied’, ‘anxious’ and ‘worried’.

Moussaoui et al. (2023) investigated emotional responses towards images of a plant-based burger. Each image remained consistent except for the information provided regarding the type of plant protein (soy, pea or wheat (seitan)). Emotional response did not change based on the type of plant protein, however, there were notable differences in emotional response among consumer segments with varying attitudes towards meat reduction. Supporters of meat reduction were characterised by higher frequencies of positive emotions e.g. ‘happy’, ‘joyful’, ‘pleasant’, and ‘good’ and lower frequencies of negative emotions e.g. ‘bored’, and ‘disgusted’. Conversely, rejectors of meat reduction displayed the opposite pattern.

The existing literature on emotional response to PBMAs is limited, and anticipated emotional response may not always align with actual experiences. Furthermore, the study by Schouteten et al. (2016) only included one plant-based sample and is several years old. Given the significant advancements in technology over recent years, PBMA quality may have improved. Consequently, Schouten et al’s findings may no longer accurately reflect products currently on the market. Further research into the emotions evoked when tasting PBMAs is needed.

1.2.1.2 Sensory appeal

Low sensory appeal has been identified as a significant barrier to the widespread acceptance of PBMAs (Elzerman et al., 2015; Hartmann & Siegrist, 2017; Hoek et al., 2011; Michel et al., 2021). PBMAs are frequently marketed with direct comparisons to their meat counterparts such as plant-based chicken, leading consumers to have specific sensory expectations (Giacalone, Clausen, et al., 2022). However, conventional meat products possess distinct aroma, textural and flavour characteristics that are challenging to replicate in PBMAs. As a result, the sensory quality of PBMAs often falls short of their meat counterparts (Fiorentini et al., 2020; Giacalone, Clausen,

et al., 2022). Moreover, PBMAs often exhibit inferior sensory properties, including mouth drying, low juiciness, and off-flavours (e.g., beany, earthy and bitter). Many of these defects can be attributed to the high contents of plant ingredients, e.g., legume proteins, which are known to impart unpleasant flavours and mouthfeel (Chigwedere et al., 2022; Giacalone, Clausen, et al., 2022). Improving the sensory quality of PBMAs is critical, given that sensory acceptance consistently ranks as the most crucial factor influencing individual food choices (Martins & Pliner, 2005).

It is a common belief that mimicking conventional meat products may lead to consumer acceptability of meat-eating consumers wanting to add plant-based proteins to their diet, whereas plant-based products that do not mimic meat cater to vegetarians and vegans (Falkeisen et al., 2022; Fiorentini et al., 2020; Hoek et al., 2011). However, previous research has yielded conflicting findings regarding consumer preferences for meat alternatives.

Using focus groups with New Zealand consumers, Kerslake et al. (2022) uncovered mixed attitudes among different dietary groups regarding the realistic sensory aspects of meat alternatives. While most vegans and vegetarians expressed discomfort with meat mimicry, omnivores showed positive sentiments toward realistic meat alternatives. Among German omnivore and flexitarian consumers, Michel et al. (2021) identified a weak preference for meat alternatives to taste like meat. However, an online survey of European consumers by Waehrens et al. (2023) revealed a desire for improvements in plant-based chicken and beef alternatives to resemble the sensory properties of meat more closely, indicating a preference for meat-like taste, texture, and odour. Interestingly, Faber et al. (2022) discovered that a segment of consumers categorised as 'no animal – high plant' displayed significantly more interest in plant-based meat replacers resembling the taste and texture of meat compared to other segments including medium and higher animal consumers. Elzerman et al. (2013) found that while some consumers prefer meat substitutes that resemble meat for ease of preparation, others felt it important that meat alternatives not resemble meat and should have an identity of their own. Collier et al. (2021) found no consensus on whether meat alternatives should mimic meat or not, with some participants

perceiving meat mimicry as strange or dishonest. In a recent study by Weerawarna N.R.P et al. (2024), utilising an online survey to explore motivations and barriers to plant-based product consumption among New Zealand flexitarians, 'tastes good' was identified as the most important criteria for selecting PBMAs outweighing the importance of the product tasting like meat. Lastly, Hoek et al. (2011) observed that consumers who favour meat tend to prefer meat-like alternatives, while those preferring meat alternatives prefer products distinct from meat.

Understanding consumer preference regarding sensory attributes, including preferences for meat-mimicking products or those distinct from meat, is essential for improving PBMA acceptance. The aforementioned studies highlight the complex nature of consumer preferences for meat alternatives. It is likely that segments of consumers with varying preferences exist, which may or may not be related to personal factors such as diet. Pertinently, these studies have primarily utilised online surveys or discussion groups to determine consumer preferences, often neglecting actual product tasting, which is imperative to provide greater insights into the specific sensory attributes consumers prefer in PBMAs.

1.2.1.3 Situational appropriateness

Situational appropriateness, as defined by Cardello and Meiselman (2018), refers to the perceived degree of fit between products and different usage situations. These situational variables can include location (e.g., at home, at a restaurant), a specific place within the location (e.g., at home in front of the TV), occasions (e.g., at a rugby match, at a concert), social surroundings (e.g., for guests, to impress someone), physiological processes (e.g., as a thirst-quencher), and mental processes (e.g., as a treat for myself) (Giacalone et al., 2015).

Previous research has shown that PBMA consumption is considered more appropriate in certain situations than in others. For example, PBMA consumption is considered more appropriate in casual settings such as when consumed alone, with family, friends, or at informal locations like food festivals, cafes, or at home (Michel et al., 2021; Motoki et al., 2021). Conversely, PBMAs are perceived as less appropriate in formal eating situations, such as family Sunday meals, business lunches, or barbecue parties (Michel et al., 2021) as well as when dining with

acquaintances or at pubs or bars (Motoki et al., 2021). Motoki et al. (2021) found a restaurant to be appropriate but the opposite was found by Michel et al. (2021). This difference may be attributed to cultural variations, with one study focusing on German consumers and the other on Japanese consumers, different interpretations of 'restaurant' as the terms could encompass a fast-food restaurant or a fine-dining restaurant, or the lack of a standardised definition for PBMAs in both studies could have led to differing interpretations (i.e. PBMAs might be understood as new generation meat mimics or traditional plant-based products like tofu).

Additionally, Elzerman et al. (2021) compared the appropriateness of minced meat and a meat hamburger with their meat alternative counterparts in various situations. The results indicated that conventional meat was considered significantly more appropriate than meat alternative equivalents in situations such as dining with family, being short on time, cooking for children, and socialising with friends. The meat alternatives were only rated as more appropriate than meat when dining with vegetarians.

These studies highlight the importance of considering the eating environment in PBMA research as product acceptance and emotional response may differ depending on the perceived situational appropriateness of the environment.

1.2.1.4 Familiarity with PBMAs

Unfamiliarity has also been identified as a significant barrier to PBMA acceptance (Michel et al., 2021), and studies have shown that increased familiarity through repeated exposure is linked to higher PBMA acceptance (Bryant et al., 2019; Hoek et al., 2011). Weerawarna N.R.P et al. (2024) identified a subgroup of flexitarians who exhibited greater acceptance of sensory attributes in PBMAs that many find detrimental such as 'beany/legume flavour' and 'pasty texture'. Interestingly 'tasting like meat' was less important to this subgroup than other product characteristics. Notably, this subgroup demonstrated a higher consumption frequency of PBMAs further supporting the notion that increased familiarity is associated with increased acceptability. As this research was conducted through an online survey, whether these findings can be replicated with actual tasting of products to better understand the impact of repeated exposure on sensory

preferences for PBMAs is still unknown. Additionally, the impact of familiarity on emotional response towards PBMAs could provide valuable insights into how consumers perceive these products. For example, are those more familiar with PBMAs more positive in their emotional response?

For food in general, familiarity or previous exposure plays an important role in people's willingness to try new foods (Bäckström et al., 2004; Raudenbush & Frank, 1999; Tuorila et al., 2001). Individuals often form judgments about the sensory quality of unfamiliar foods, and these assessments can greatly impact acceptance. When people become familiar with a product, it can either validate or challenge their preconceived notions about its sensory quality (Tuorila & Hartmann, 2020). When individuals are familiar with a food product, they experience a sense of certainty about its identity, leading to reduced anxiety and suspicion towards it (Aldridge et al., 2009).

1.2.1.5 Dietary groups

Consumers can be categorised into various dietary groups based on their level of meat consumption. These groups include meat eaters/omnivores, flexitarians /meat reducers, and meat excluders (vegan, vegetarian or pescatarian) as outlined in **Table 1.3**. Meat eaters constitute the largest proportion of consumers, followed by flexitarians who account for approximately 23% of global consumers according to Euromonitor International (2022). In contrast, vegetarians and vegans represent a smaller proportion, accounting for 6% and 4% respectively (Euromonitor International, 2020).

Table 1.3. Dietary group definitions.

Diet	Definition
Vegan	Someone who excludes all meat, poultry, fish, seafood, eggs and dairy (Heart Foundation, 2024)
Vegetarian (lacto-Ovo)	Someone who excludes all meat from their diet (including red meat, poultry, fish, seafood and by-products of slaughter) but includes eggs and dairy (Vegetarian Society New Zealand, 2021)
Pescatarian	Someone who excludes meat and poultry from their diet but includes eggs, dairy, fish and seafood (Heart Foundation, 2024)
Flexitarian/ Meat Reducer	The definition of a flexitarian is less clear, and a number of different definitions can be found in literature. To overcome this, the CDFF project has chosen to define a flexitarian as someone who is actively reducing, or has actively reduced, the amount of animal flesh they consume, but is not eliminating it completely from their diet.

Meat Eater/ Omnivore	Someone who eats meat, poultry, fish, seafood, eggs, and dairy, and has not reduced their meat consumption in the past 12 months (Colmar Brunton, 2019)

According to a survey conducted in the USA, a lower percentage of omnivores (44%) have tried plant-based meat alternatives compared with flexitarians (77%), vegetarians (72%) and vegans (76%) (International Food Information Council, 2020). Similarly, Kemper et al. (2023) found in New Zealand meat eaters eat significantly less meat substitutes than meat reducers and occasional meat eaters. Unsurprisingly, meat eaters are more likely to choose a conventional meat option over a PBMA option (Slade, 2018; Van Loo et al., 2020).

Meat eaters and flexitarians have various reasons for preferring to continue to consume meat. The primary motivation for meat eaters is simply enjoying the taste of meat (Cliceri et al., 2018; Kemper et al., 2023), while concerns about the perceived inferior taste and nutrition, higher cost, unfamiliarity, inconvenience, and social stigma of vegetarian diets also play a role (Rosenfeld & Tomiyama, 2020). Similarly, flexitarians often include meat in their diets due to cravings, taste preferences, nutritional beliefs (Kemper, 2020), social situations, and because they cook meat for others in their household (Kemper et al., 2023). However, flexitarians are also motivated to reduce meat intake for several reasons including cost, health, nutrition, animal welfare/ethics, environmental and sustainability concerns, social status, and culture (Realini et al., 2023; Weerawarna N.R.P et al., 2024). Novel PBMAs (i.e. those that replicate meat) are suggested to make the transition to a flexitarian diet easier (Ma & Chang, 2022). Vegetarians on the other hand have made the conscious decision to exclude meat from their diets for various reasons including concerns for animal welfare, health, and environmental sustainability of food systems (Rosenfeld & Tomiyama, 2020), as well as social and cultural factors (Kemper, 2020).

Considering the diverse perspectives and behaviours towards meat consumption among dietary groups it is reasonable to expect each group will have differing emotional responses towards PBMAs. Potentially meat eaters will approach PBMAs with resistance and scepticism due to their attachment to conventional meat products. On the other hand, flexitarian and meat excluders may

exhibit more positive emotional responses such as satisfaction as they are already open to or actively seeking meat alternatives. However, these are only speculation and the emotional responses of different dietary groups towards PBMAs are unknown. Measuring emotional responses to PBMAs among different dietary groups can assist in identifying preferences and dislikes about existing products. These insights could provide valuable guidance for tailoring future product development to better meet the preferences and needs of different dietary groups.

1.2.1.6 Age groups

Millennials (those born 1981 – 1996) currently make up the largest portion of PBMA eaters (Spalding, 2021) and are recognised as a key generation in the adoption of plant-based diets and flexitarianism (Knaapila et al., 2022). Moreover, studies by Bayer (2019), Colmar Brunton (2019), and Hielkema and Lund (2021) indicate that younger individuals are more likely to be vegan or vegetarian or express an intention to reduce meat consumption than older age groups.

However, research by Kemper et al. (2023) suggests that adults aged 25-55 (encompassing both Millennials and Generation X (those born from 1965 to 1980)) are the most inclined to reduce meat intake than both younger and older demographics. Realini et al. (2023) add that individuals aged 18-44 are more likely to eat PBMAs compared to those aged 60 and above. Furthermore, Alae-Carew et al. (2022) found both Millennials and Generation X to have the largest proportions of plant-based foods consumers. Therefore, it is crucial not to overlook the role Generation X can play in meat reduction and PBMA uptake. Conversely, individuals aged 55 and above are less likely to have intentions of reducing meat consumption (Hielkema & Lund, 2021), and are less inclined to consume plant-based meat alternatives due to a lack of interest (International Food Information Council, 2020). Given these trends, targeting younger adults (those under 55 years), who are most receptive to meat reduction and PBMAs, appears to be a more effective strategy than focusing on older adults who are less interested in dietary change.

1.3 Consumer testing 'in context'

1.3.1 What is context and why is it important?

Context refers to all of the variables in a particular eating occasion (i.e., where, when, how, and with whom the food is eaten) (Meiselman et al., 2000).

In the past, good practice in consumer and sensory science has dictated testing should be conducted in highly controlled settings e.g. white/neutral walls and furniture, an odourless environment and temperature and humidity control, to minimise variation due to external sensory signals (Nijman et al., 2019). Whilst this is still recommended for objective testing, findings collected in the traditional sensory booth may not truly reflect how a product will be accepted in real life (de Graaf et al., 2005; Nijman et al., 2019). Moving consumer research from the sensory booth setting closer to where consumers actually purchase or consume the products being tested may increase a test's ecological validity (Stelick & Dando, 2018).

1.3.2 Effect of digital immersive environments on consumer response

1.3.2.1 Effect of digital immersive environments on hedonic liking

When studying the effect of evoked context on consumer response, the data collected in the evoked context is normally compared to data collected in traditional sensory booths or central locations and sometimes the real-life context. Of the research published, conflicting findings on the impact of digital-IEs (VR headsets, videowalls or immersive rooms) have been reported for hedonic liking with the majority of studies finding no differences in hedonic liking ratings between traditional sensory booth/central location and digital-IEs (Colla et al., 2023; Delarue et al., 2019; Hannum et al., 2019; Kong et al., 2020; Pennanen et al., 2020; Sinesio et al., 2019; Stelick & Dando, 2018; Torrico et al., 2020; Zandstra et al., 2020). However, increased liking ratings for identical products in a digital-IEs compared to sensory booths were reported by (Hathaway & Simons, 2017; Low, Lin, et al., 2021; Sinesio et al., 2018).

Other studies have compared consumer responses in multiple digital-IEs as opposed to comparing to a control setting (i.e. sensory booths or CLT). Commonly the digital-IEs will be congruent/appropriate and incongruent/inappropriate to the focal product. Again, conflicting

findings on the impact of digital-IEs on liking have been found. For instance, Schouteten et al. (2024) found liking for watermelon to be higher in a congruent VR summer environment, whereas liking for chocolate truffles was higher in a congruent VR winter environment. Similarly, Song et al. (2022) found liking of rye bread to be higher in a congruent VR restaurant environment compared to an incongruent VR cinema environment. In contrast, Alba-Martínez et al. (2024) found no difference in visual liking of fives cakes when assessed in a congruent VR dining room compared to an incongruent VR car and van Bergen et al. (2021) found expected liking was higher for congruent food-context combinations (popsicle at the beach, sushi in the sushi restaurant) than for incongruent combinations. However, upon tasting, no differences were found in liking.

1.3.2.2 Effect of digital immersive environments on emotional response

The impact of digital-IEs on emotional response to foods has received less attention than hedonic liking. However, from the studies that have compared digital-IEs to a control environment or to each other, it has been consistently observed that emotional responses are influenced by the consumption context (De Wijk et al., 2022; Giezenaar & Hort, 2021; Kong et al., 2020; Low, Lin, et al., 2021; Pennanen et al., 2020; Torrico et al., 2020; Worch et al., 2020). For instance, Low, Lin, et al. (2021) evaluated tea-break snacks under three contextual settings, including sensory booths, an evoked mixed reality café (HoloLens), and a real café. The mixed-reality café and real café evoked similar emotional responses but responses in the sensory booths were different. Pennanen et al. (2020) investigated emotional response to rye nacho chips and chocolate in digital-IEs under three conditions, a control environment, a sunny day environment and a rain shower environment. For both products rating intensities for positive emotions were higher in the sunny day environment compared to the rain shower environment and negative emotions were higher in the rainy-day environment compared to the sunny environment.

Schouteten et al. (2024) and Colla et al. (2023) are the only studies identified to have not observed differences in emotional response between a control setting and digital-IEs or between multiple digital-IEs. In the case of Schouteten et al. (2024), emotional responses to watermelon, chocolate truffles and crackers did not differ between VR contexts (summer and winter). Colla et al. (2023)

did not observe differences in emotional response (or beverage choice and consumption) to apple juice samples when assessed in sensory booths, an evoked café (using pictures), a VR café, and an actual café. Based on these findings, they concluded that these measurements were consistent across different contexts, suggesting that taking these measurements under immersive or real-life conditions is unnecessary for apple juice.

With few exceptions studies that have compared digital-IEs to each other or a control environment, have shown that emotional responses are influenced by the consumption context and demonstrated the ability of digital-IEs to modify emotional responses. This highlights the potential of using digital-IEs in consumer research to capture emotional responses to food products in contextually relevant environments. This is particularly relevant to PBMAs, whose acceptance has been demonstrated to be contextually sensitive (*see* **section 1.2.1.3**).

1.3.2.3 Effect of digital immersive environments on virtual presence and engagement

In consumer and sensory research, ensuring that participants are engaged during product testing is crucial for obtaining meaningful data. The definition of engagement varies among disciplines but encompasses concepts like involvement, commitment, passion, enthusiasm, absorption, focused effort, zeal, dedication, and energy, and is negatively related to boredom (Alfes et al., 2013). Alternatively, the Merriam-Webster dictionary describes the state of being engaged as 'emotional involvement and commitment' (Merriam-Webster, 2024).

It has been suggested that traditional product testing environments, lacking contextual information, do not promote engagement (Hannum & Simons, 2020). Bangcuyo et al. (2015) suggested that digital-IEs could be leveraged to enhance both ecological validity and consumer engagement during product testing. Bangcuyo et al. (2015) proposed a presence and engagement questionnaire to measure participant engagement in digital-IEs. This questionnaire was adapted from the Presence Questionnaire (Witmer & Singer, 1998) and the User Engagement Scale (O'Brien & Toms, 2010). Several studies have since used this questionnaire and demonstrated that digital-IEs are more engaging than traditional testing environments (i.e. sensory booths) (Bangcuyo et al., 2015; Hathaway & Simons, 2017; Sinesio et al., 2019; Zandstra et al., 2020).

Additionally, the findings of Bangcuyo et al. (2015) and Hathaway and Simons (2017) suggest that product preference data collected in digital-IEs is more discriminating and more reliable due to increased engagement, where reliability was assessed through duplicate testing across sessions.

In the context of virtual environments, immersion is the degree to which the sensory channels (e.g., sight, sound, touch) are engaged by the virtual simulation, and presence is the actual feeling of being situated within the virtual environment (Berkman & Akan, 2019). For virtual environments to be beneficial, people need to experience a sense of presence, however, people experience different levels of presence even when they are immersed in the same virtual environment setting (Martingano et al., 2023). Previous research has demonstrated higher presence and engagement scores in digital-IEs compared to traditional testing environments. However, these studies have typically analysed mean scores for all participants without considering potential consumer segments that experience varying levels of presence and/or engagement. Additionally, if consumer segments exist, it is unknown if they will respond similarly regarding their product assessments in digital-IEs.

1.3.3 Use of context in plant-based meat alternative research

As outlined in **section 1.2.1.3** consumption of PBMAs is perceived to be more appropriate in casual settings compared to formal settings (Michel et al., 2021; Motoki et al., 2021). Despite these findings, only one study has been identified where the eating environment is considered in consumer testing of PBMAs. Gonzalez-Estanol et al. (2023), with this thesis' author as a contributor, used a digitally recreated burger restaurant setting, complete with room décor and burger boxes, to replicate a typical consumption environment for burgers. This study utilised the restaurant setting but not a control setting, leaving a further opportunity for research comparing responses in digital-IEs against a control to identify the importance of the eating environment in consumer response to PBMAs.

While the eating environment has been neglected in PBMA consumer research, more attention has been given to the meal context or 'how' PBMAs are prepared. Consuming PBMAs in combination with other food components can influence acceptance. For instance, Elzerman et al.

(2011) demonstrated that consuming PBMAs in a meal context can increase liking from when tasted alone. When two PBMAs, similar in composition but differing in appearance (mince vs. pieces), were tasted individually, the pieces were preferred over the mince. However, when incorporated into various dishes, the pieces were still liked better than mince in a rice dish and a salad but were liked similarly in spaghetti and soup. Similarly, Cordelle et al. (2022) showed that liking for specific PBMAs varied depending on the dish in which they were prepared. For example, a soy-based PBMA was liked more when prepared in a lasagna compared to in a white sauce or chop suey. Gonzalez-Estanol et al. (2023) observed that adding a bun and sauce to soy and hemp-based patties reduced off-flavour and texture defects to some extent but did not affect overall liking. This is likely due to differences in product types i.e. a patty constitutes a larger proportion of a dish making it harder to 'mask' compared to mince. Additionally, Niimi et al. (2022) found overall liking and texture liking did not significantly differ between PBMA and beef mince prepared in a Bolognaise sauce, highlighting that the preparation of PBMAs can help to bridge the liking gap between conventional meat and PBMAs.

These studies collectively demonstrate that the dish in which PBMAs are prepared can significantly alter liking, although the extent of this impact may vary depending on the specific dish. These studies concentrated on assessing liking, leaving the influence of meal context on emotional responses toward PBMAs unexplored.

1.4 Research gaps

Experiencing positive emotions was identified as a key driver for the consumption of PBMAs. However, literature on emotional response to PBMA consumption is notably scarce, with only one study addressing this topic at the outset of this research. Consequently, key emotions associated with PBMA consumption are largely unknown. To measure emotional response to PBMAs effectively, the development of an emotion lexicon specific to PBMA consumption is necessary. While generic lexicons exist, they may not capture the unique emotions associated with PBMA consumption, which could include more negative emotions.

Younger adults, including Millennials and Generation X, are most likely to adopt a plant-based diet and were selected as the focus age groups for this research. Furthermore, meat eaters, including flexitarians, make up the largest proportion of consumers. Therefore, understanding the sensory preferences of these consumers is crucial for PBMAs to become more appealing and encourage meat reduction. Through profiling a range of PBMA products for sensory attributes, liking, and emotional response, sensory attributes driving positive emotions and liking can be identified. Ambiguous findings from previous research suggest that meat-eating consumers may have differing preferences regarding whether PBMAs should replicate meat or have an identity of their own, indicating potential segments with varying sensory preferences. As such, consideration should be given to the potential existence of consumer segments with different liking and emotional response patterns.

Acceptance of PBMAs is context-dependent, with previous research identifying situationally appropriate settings for their consumption, albeit these situations had been identified through surveys. Over the past decade, digital-IEs have been used in consumer testing to increase ecological validity by replicating real-life eating scenarios within a laboratory setting. Several studies have demonstrated changes in liking and emotional responses towards an identical product when evaluated in traditional testing environments compared to a digitally recreated one or across various digital-IEs, although PBMAs have not been a focal product in such research. The use of digital-IEs could therefore be beneficial in consumer testing towards PBMAs to measure consumer response in relevant eating environments. An opportunity to fill a gap in the existing literature by investigating the influence of digital-IEs on consumer response to PBMAs was also identified. Furthermore, while the impact of meal context (how a PBMA is prepared) on liking for PBMA consumption has been explored, its effect on emotional response remains unexplored.

Finally, previous research demonstrated higher presence and engagement scores in digital-IEs compared to traditional testing environments. However, these studies have typically analysed mean scores for all participants without considering potential consumer segments that may

experience varying levels of presence and/or engagement. Additionally, if segments exist, it is currently unknown whether they would respond similarly in digital-IEs.

1.5 Research aims and objectives

The overall aim of this thesis was to develop a new understanding of consumer emotional engagement with plant-based meat alternatives. Based on advances and gaps identified in the literature the following research objectives, summarised in **Figure 1.2** were established:

1a. Develop a consumer-led emotion lexicon specific to meat and plant-based patties to identify the key emotions associated with plant-based meat alternatives **(Chapter 2)**

1b. Utilise digital immersive environments in the emotion lexicon development process to evoke emotions relevant to different eating scenarios **(Chapter 2)**

2. Profile a range of burger patties (meat and plant-based) for liking, emotional response, sensory attributes, and perceived similarity to meat to identify sensory attributes driving liking and positive emotional response in plant-based burger patties **(Chapter 3)**

3. Determine if consumers can be segmented based on their preferences (liking and emotional response) for meat and plant-based burger patties and determine if the consumer profile for these segments varies according to diet, age group or frequency of PBMA consumption **(Chapter 3)**

4. Validate the developed emotion lexicon for its ability to discriminate across a range of plant-based burger patties that vary in sensory properties **(Chapter 3)**

5. Explore how consumption setting and meal context influence liking and emotional response to plant-based alternatives to meatballs **(Chapter 4)**

6. Compare participant engagement between a central location test and digital immersive environments, and assess if consumers can be segmented based on their level of engagement with the testing environments **(Chapter 4)**

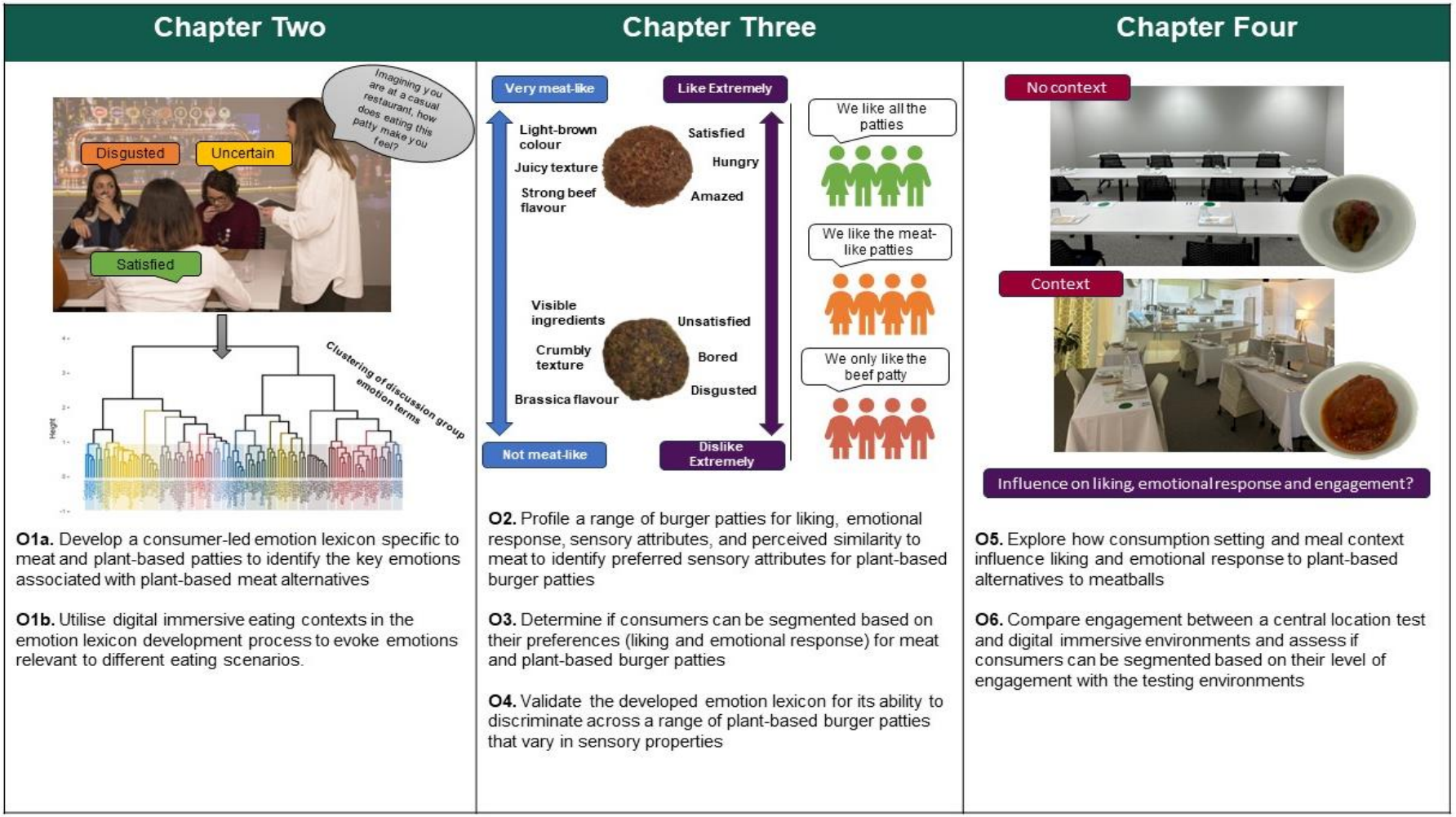

Figure 1.2. Summary of research objectives

Chapter 2: Development of a Consumer-led Emotion Lexicon for Meat and Plant-Based Burger Patties using Digitally Recreated Eating Environments (Study 1)

The study presented in this chapter was published in the *Journal of Sensory Science* in February 2023. The Statement of Originality form - DRC-16 is attached at the end of this chapter. The contents of this chapter reflect the original manuscript, with the exception of the introduction, which was revised to prevent overlap with Chapter 1 and to provide additional background information on the lexicon development process. Additionally, some terminology has been changed to align with the rest of the thesis.

2.1 Introduction

In consumer testing, product acceptance is typically assessed using liking measures like the 9-point hedonic scale (Peryam & Pilgrim, 1957) (Fiorentini et al., 2020). However, recent years have seen increased interest in including additional measures, particularly food-evoked emotions, to gain a deeper understanding of the consumer experience (Jaeger et al., 2023; Jaeger et al., 2020). Emotions play a key role in decision-making (Damasio, 2006; Loewenstein & Lerner, 2003) and measuring emotional responses towards food products can provide insights beyond liking (Ng et al., 2013). For instance, understanding whether a product is disliked due to disgust or uncertainty due to first exposure can offer more nuanced feedback.

Both implicit (unconscious) and explicit (conscious) methods have been used to measure food-evoked emotions (Kaneko et al., 2018; Low et al., 2022). In product testing, explicit methods such as verbal self-report questionnaires are widely used due to their ease of use, cost-effectiveness, and discriminative power, as well as their allowance for the use of a broader emotional vocabulary (Cardello & Jaeger, 2021; Dorado et al., 2016; Schouteten, 2021). Verbal self-report questionnaires, typically involve consumers checking or rating applicable emotions from a provided list (Dalenberg et al., 2014). Emotion lexicons can be general/generic for use with all foods e.g. the EsSense Profile (King & Meiselman, 2010) or the valence × arousal circumplex-

inspired emotion questionnaire (CEQ) (Jaeger et al., 2020), or product-specific (Dorado et al., 2016). While general lexicons are versatile and less labour-intensive to develop than a product lexicon (Chaya et al., 2015; Spinelli et al., 2014), product-specific lexicons may better capture emotions unique to a product category, improving discrimination (Ng et al., 2013) and can provide deeper information on emotions underlining the consumption experience (Bhumiratana et al., 2014). To date, no emotion lexicon specific to PBMA products has been published.

Positive emotions are key drivers of acceptance for novel and plant-based foods (Bryant, 2019; Chen, 2022; Jiang et al., 2014; Motoki et al., 2021; Onwezen et al., 2022). Measuring emotional response towards PBMAs could be useful for gaining deeper insights into consumer perception of PBMAs, however, the literature on emotional response to PBMA consumption is notably scarce, with only one study (Schouteten et al., 2016) addressing this topic at the outset of this research. Consequently, the key emotions associated with PBMA consumption are largely unknown and it is uncertain if generic lexicons encompass all the emotions associated with consumption of PBMAs. To measure emotional response to PBMAs effectively, the development of an emotion lexicon specific to PBMA consumption was necessary.

Emotional responses to food are influenced by the eating context, where eating context refers to all of the variables in a particular eating occasion including where, when, how, and with whom the food is eaten (Meiselman et al., 2000; Piqueras-Fiszman & Jaeger, 2014). Conducting product testing "in context" can capture more realistic emotional responses (Piqueras-Fiszman & Jaeger, 2014). The use of digital-IEs including video walls, immersive rooms and virtual/augmented reality headsets, has become popular for introducing context while maintaining experimental control (Galiñanes Plaza et al., 2019; Giezenaar & Hort, 2021). Previous research has observed emotional responses towards the same food product to differ when responses collected in digital-IEs are compared to a control environment, or each other (Giezenaar & Hort, 2021; Kong et al., 2020; Low, Lin, et al., 2021; Pennanen et al., 2020; Torrico et al., 2020; Worch et al., 2020). Therefore, using digital-IEs to immerse consumers in intended product consumption scenarios

during emotion term generation for lexicon development could help evoke more relevant emotional terms.

2.1.1 Process for developing a verbal product-specific emotion lexicon

The process of developing a product-specific emotions lexicon typically involves several stages: 1) product selection; 2) emotion term generation; 3) reduction of terms; 4) grouping of similar terms; and 5) validation of the lexicon. However, the methods used at each stage of this process have varied significantly across different studies, as outlined in the following sections.

2.1.1.1 Product selection

Products that span the most relevant sensory variation within the product category of interest should be selected as the stimuli for emotion generation. This is important for ensuring the lexicon will be discriminating across the product category (Mora et al., 2019). The number of products used varies between studies. For instance, in the development of emotion lexicons for their respective product categories, Spinelli et al. (2014) used six different chocolate hazelnut spreads, while Ng et al. (2013) used 11 different blackcurrant squashes. Sometimes, researchers may require more samples to cover the desired variation. For instance, Ng et al. (2013) aimed to investigate both added sugar and no-added sugar squashes, as well as different market segments (Economy, Standards, and Niche).

2.1.1.2 Emotion term generation

One-on-one interviews (Ng et al., 2013; Spinelli et al., 2014); or small group discussions (Bhumiratana et al., 2014; Chaya et al., 2015; Mora et al., 2020; Weerawarna N.R.P, 2021)) are commonly used methods to generate a list of emotion terms in response to the selected range of products. Ng et al. (2013) recommended the use of small group discussions as a more efficient process to one-on-one interviews. The number of participants used for the term generation stage has varied significantly between studies: 17 (Chaya et al., 2015), 20 (Bhumiratana et al., 2014), 29 (Ng et al., 2013), 75 (Spinelli et al., 2014) and 99 (Mora et al., 2020).

A number of methods have been used for emotion term generation. Triadic elicitation has been a popular method used for emotion term generation in various studies (Chaya et al., 2015; Mora et

al., 2020; Ng et al., 2013; Spinelli et al., 2014; Weerawarna N.R.P, 2021). During this activity, participants assess triads of samples and describe 'in what way two samples are similar but different from the third in terms of the emotional response they elicited'.

Another method, as demonstrated by Gunaratne et al. (2019), in their development of an emotion lexicon for chocolate, involved providing participants with a list of 64 emotion terms and instructing them to use CATA while tasting chocolate. Of these 64 emotions, 31 were obtained from EsSense Profile®, 28 from focus group discussions, and five from previous research related to emotion-based studies. Participants were also allowed to express emotions in their own words using an open-ended question. The terms from the focus groups were generated by presenting participants with an image board containing a collection of images, which fall into the six segments of the NeedScope model™ (boldness, distinction, discernment, comfort, harmony, and vitality). Participants were then asked to state all emotion terms related to each segment.

In developing a coffee emotion lexicon, Bhumiratana et al. (2014), took a different approach by not providing samples to participants. Instead, participants were asked to reflect on their experiences of drinking coffee in different locations where consumers typically enjoy coffee beverages: coffee shop/restaurant, home, office/work, or on-the-go. The moderator prompted each participant to describe drinking experiences at each location, including good, bad, most enjoyable, and worst experiences to capture all of the possible emotions triggered by various coffee types, situations, and experiences.

In some studies, participants are provided with lists of emotion terms to assist them in expressing their emotions. Spinelli et al. (2014) suggested future studies could be conducted first without a list and, immediately after, with the help of the list, to verify if additional information can be added. In Spinelli et al. (2014) a list of 22 positive and negative emotion terms derived from both food related and general emotions research was provided. Ng et al. (2013) similarly suggested a hybrid method, using a list partly defined by consumers and partly selected from the literature. This avoids influencing the participants initially but also prevents important emotion terms from being ignored. Weerawarna N.R.P (2021) used this recommended approach and provided

participants with a list of 66 emotion terms after they had generated emotion terms in their own words. The emotional terms were taken from various sources including Eaton et al. (2019); King and Meiselman (2010); Ng et al. (2013) and a list sometimes used by a commercial dairy manufacturer (unpublished).

In most cases, term generation is conducted in a standard sensory laboratory or central location. However, in the case of Bhumiratana et al. (2014), small group discussions were held in a local coffee shop. To the researcher's knowledge, this is the only study that has introduced contextual cues into the lexicon development process.

2.1.1.3 Reduction of terms

A large number of terms can emerge from the emotion generation stage, however, these may not all be emotion terms or very relevant to the product category. To remove non-emotion terms, the generated list of emotions can be compared to published lists of emotions such as Clore et al. (1987) and Laros and Steenkamp (2005) which contain 564 and 50 emotion terms, respectively. Terms on the generated list which are not found on the published lists are removed as recommended by van Zyl and Meiselman (2015).

Regarding removing emotion terms that are irrelevant to the product category, Ng et al. (2013) had 29 participants rate the generated terms against a set of samples, and only those terms selected by 5 or more participants were included in the final lexicon. Chaya et al. (2015) had participants rate terms for relevance using a line scale anchored from absolutely irrelevant to absolutely relevant. Terms with a mean 'relevance' score of less than 33% were excluded as being evaluated as not very relevant to beer. Bhumiratana et al. (2014) had 48 coffee drinkers CATA relevant terms that described the emotions related to coffee drinking whilst drinking 2 coffee samples. Terms selected less than 10 times were eliminated except for terms belonging to the EsSense Profile.

2.1.1.4 Grouping of similar terms

Sometimes researchers have combined synonyms or grouped similar emotion terms into categories. This further reduces the length of the lexicon making it easier for consumers to use,

but also removes double-ups in emotions that mean the same/similar thing to consumers. For example, Ng et al. (2013) combined emotion terms with similar meanings (e.g. ‘trust’, ‘confidence’ and ‘reassurance’) using the understanding of the researchers and a thesaurus. Weerawarna N.R.P (2021) had participants individually sort cards (each containing an emotion term) into groups of synonyms or closely related terms. From the sorted groups they selected the 10 most discriminating emotion terms with respect to the sample they had assessed. The 12 most cited emotion groups across all participants were selected for the final lexicon. Chaya et al. (2015) assessed 10 beer samples using 54 emotion terms on an intensity scale from 'very low' to 'very high'. Multivariate statistical techniques, including factor analysis, principal components analysis, and hierarchical cluster analysis (HCA), were employed to analyse mean sample ratings for each emotion term. While all three techniques revealed similar data patterns, HCA was selected as the most practical method, offering researchers control over determining the optimal number of clusters. The resulting lexicon contained 12 emotion terms.

Mora et al. (2020) applied the method used by Chaya et al. (2015) to wine samples (conventional approach) and compared the resulting emotion lexicon to one developed using a rapid-method approach. For the rapid approach, a sorting task methodology was used, and consumers were asked to sort emotions into categories using the criteria of joining emotions with similar meanings. The conventional approach resulted in 13 emotion categories and the rapid approach resulted in 15 emotion categories. Both lexicons were found to be similar in discriminating emotional responses elicited by different types of wines.

An issue in the study of product emotions is whether to use small or large numbers of emotions. For verbal emotion lexicon, list lengths have varied from 3 to 66 emotion terms (Low et al., 2022). There is no set number of terms a list should contain, but there are advantages and disadvantages to both shorter lists and longer lists. For example, a shorter list makes for a quicker and easier task, but consumers may use all the available terms thereby decreasing discrimination between the samples. A longer emotion list can mean better characterisation but consumers may give less consideration to each term (Ares & Jaeger, 2023). A balance between the two is required

(Meiselman, 2015). Chaya et al. (2015) cautioned against over-reducing a lexicon as this risks missing out on valuable emotional data. Ares, Antúnez, et al. (2015) compared a short list of 12 attributes to a long list of 20 attributes when using CATA and found no apparent risk in using the longer list if the inclusion of more attributes is useful e.g. to describe the subtle nuanced differences between samples.

2.1.1.5 Validation of emotion lexicon

Once the final list of emotion terms has been decided, the emotion lexicon is typically "tested" for its ability to discriminate across samples from the product category of interest. An emotional profile for individual products is generated using consumers then significant differences in emotion scores between products are identified (Chaya et al., 2015). This chapter describes the development of an emotion lexicon until the grouping of similar terms stage. The validation of the emotion lexicon developed in this chapter is included in **Chapter 3.**

2.1.2 Research focus

Plant-based patties (PB-patties) were selected as the focal product type as patties make up the largest proportion of PBMA products in New Zealand (Mintel, 2021) and globally (Kaczorowski, 2021).

The primary objectives of the study presented in this chapter were to:

1a. Develop a consumer-led emotion lexicon specific to meat and plant-based patties to identify the key emotions associated with plant-based meat alternatives.

1b. Utilise digital immersive environments in the emotion lexicon development process to evoke emotions relevant to different eating scenarios.

2.2 Materials and methods

Emotion lexicon development took place over three stages. In stage one, 12 discussion groups generated emotion terms in response to five patty samples varying in sensory characteristics in relevant digital-IEs. Stage two involved reducing the list of terms by removing irrelevant and non-emotion terms. Stage three encompassed further term reduction via an online task where

consumers sorted the remaining emotion terms into categories based on similar meanings. This study was considered and assessed as low risk following the Massey University Human Ethics Committee process (human ethics notification number: 000024400). Written informed consent was obtained from all participants. Participants who took part in the discussion groups and online activity were offered an NZD40 shopping voucher as compensation for their time. Participants who took part in the online activity only were offered a NZD15 shopping voucher.

2.2.1 Stage one: Emotion term generation discussion groups

2.2.1.1 Participants

Forty-four participants were recruited from the Food Experience and Sensory Testing (Feast) Lab consumer database, Massey University internal emails, and flyer distribution around Palmerston North, NZ. To ensure a range of users and non-users of plant-based meat alternatives contributed to the lexicon, participants (**Table 2.1**) from two age groups (Millennials: born 1980 – 1996; and Generation X: 1965 - born 1981) and three diet groups (meat eater, flexitarians, meat excluder (vegan, vegetarian and pescatarian)) were recruited. Participants were required to be able to communicate effectively in English and be regular patty consumers (at least once a month). Participants included both users (fortnightly or more, 43%) and non-users of meat alternatives (once a month or less, 57%), and all participants were willing to try meat alternatives as part of the study.

Table 2.1. Participant demographics for discussion groups.

Diet Group	n	Age Group	n	Gender	n
Meat Excluders	12	Millennials	7	Male	1
				Female	6
		Generation X	5	Male	0
				Female	5
Flexitarians	16	Millennials	9	Male	2
				Female	7
		Generation X	7	Male	1
				Female	6
Meat Eaters	16	Millennials	8	Male	2
				Female	6
		Generation X	8	Male	3
				Female	5

Participants were split into twelve discussion groups (up to 5 participants per group) and attended one discussion group (~75 min) with participants from the same diet group and age group.

Participants were grouped in this way so as not to discourage participants from sharing their true emotions based on the assumption that different consumer groups (e.g., vegetarians and meat eaters) may experience contrasting emotions towards the samples.

2.2.1.2 Samples

Five patties were evaluated (**Table 2.2**). Four were plant-based, and one was animal-based (beef). The PB-patties were selected to represent variation across the New Zealand PB-patty market in terms of sensory characteristics, and main protein source. Two of the PB-patties were selected to resemble meat (meat analogues), and the other two patties were selected not to resemble meat (wholefood). The animal-based sample was a high-end beef patty selected to represent a good quality meat patty. The beef patty was included so that the lexicon was representative of meat products in addition to plant-based products and the lexicon could be used for studies that include meat products in addition to plant-based products if required. Four samples were commercially available in New Zealand, and one was formed from a commercially available vegetable 'mince' mix specifically aimed at being made into patties.

Samples were cooked in a frying pan (Daily Cook Frypan, Tefal, France) in one tablespoon of olive oil per patty (100% Pure Olive Oil, Pams, New Zealand). All commercial samples were prepared according to the manufacturer's instructions on the packaging. The Vince Plant-based Vegetable Mix came as a dehydrated mix and was rehydrated with boiling water using instructions provided by the manufacturer, then formed into similar-sized patties. Once cooked, each patty was cut into six pieces (14-19g) and individual pieces were wrapped in aluminium foil (Catering Foil, Rota, New Zealand). Samples were held in a food warmer (E84 Food Warmer, Bakbar, New Zealand) heated to 45 ± 5 °C until served (20 - 60 minutes). Samples were served blind (labelled with three-digit random codes) directly from the food warmer.

Table 2.2. Description of the patty products used for the discussion groups.

Product Name	Ingredients	Classification	Manufacturer
Bean Supreme Hemp Burgers	Green Peas (43%), Onion, Chickpeas (15%), Vegetable Oil, Hemp (6%), Spinach (4%), Kale (2%), Coriander, Methylcellulose, Locust Bean Gum, Carrageenan, Sweetcorn, Salt, Potato Fibre, Lemon Juice Concentrate, Parsley, Paprika, Garlic, Cumin, Black Pepper.	Wholefood	Life Health Foods NZ Ltd, Auckland, New Zealand
Vince Plant-Based Vegetable Mince Classic Kiwi Style	Tomatoes, cauliflower, onion, carrot, peanuts, Tamari, celery, tomato paste, potato starch, apple cider vinegar, nutritional yeast, garlic, coconut sugar, thyme, garlic powder, salt, onion powder, pepper.	Wholefood	Olive and Ash Ltd, Whangarei, New Zealand
Gardein Beefless Burgers	Water, Textured Vegetable Protein (Soy Protein Concentrate, Caramel Colour), Soy Protein Concentrate, Vital Wheat Gluten, Expeller Pressed Canola Oil, Onions, Soy Protein Isolate, Emulsifier (Methylcellulose E461), Yeast Extract, Onion Powder, Black Malted Barley Extract(for colour) Garlic Powder, Dehydrated Garlic, Organic Ancient Grain Flour (KAMUT® Khorasan Wheat, Amaranth, Millet, Quinoa), Natural Flavours (from plant sources), Cane Sugar, Potato Starch, Sea Salt, Salt, White Distilled Vinegar, Spices (Celery Seeds), Organic Cane Sugar, Smoke Flavour, Spice Extractives, Pea Protein, Molasses Powder (Molasses, Wheat Starch, Soy Lecithin), Carrot Fibre, Sugar Beet Fiber.	Meat Analogue	Conagra Brands Inc, Chicago, Illinois, United States
Beyond Meat Beyond Burgers	Water, pea protein (16%), canola oil, coconut oil, rice protein, flavouring, stabilizer (methylcellulose), potato starch, apple extract, colour (beetroot red), maltodextrin, pomegranate extract, salt, potassium salt, concentrated lemon juice, maize vinegar, carrot powder, emulsifier (sunflower lecithin).	Meat analogue	Beyond Meats Inc, El Segundo, California, United States
First-light Wagu Beef Burgers	Wagyu Beef (88%), Water, Potato Starch, Grainy Mustard, White Miso Paste (Soy Beans), Pea Fibre, Salt, Dehydrated Vegetables (Onion, Garlic), Herbs, Spice, Preservative (223), Herb Extract, Spice Extract.	Animal protein	First Light Foods Ltd, Havelock North, New Zealand

The plant-based samples were served in a fixed order within a discussion group so that participants could assess and discuss the same sample. Between the different discussion groups, the presentation order was based on a balanced Williams Latin square design (Wakeling & MacFie, 1995). The beef patty sample was excluded from the design and always served in the 5th position as it was not assessed by non-meat-eating participants. Participants were not required to consume the whole sample, but enough to assess how it made them feel. Unsalted water crackers (Water crackers original, Arnott's, Australia) and filtered water were provided as palate cleansers.

2.2.1.3 Digital Immersive Environments

Two digital-IEs were used for emotion term generation discussion groups to elicit terms that were relevant to real-life consumption, not to compare the emotions generated between the two digital-IEs. The environments used were a meal at home and a meal out at a gastropub. Both environments were set up in the "Immersive Space" in the FEAST laboratory at Massey University. The Immersive Space is a 50m^2 room with blank white walls and fitted with Igloo immersive technology (Igloo Vision Ltd., Australia) which allows for 360° image/video projection and surround sound. To create the digital-IEs, 360-degree images of the kitchen and living area of a home (https://www.shutterstock.com/image-photo/minsk-belarus-august-2013-interior-modern-1742773139) (**Figure 2.1A**) and the inside of a gastropub (https://www.shutterstock.com/image-photo/grodno-belarus-november-2018-full-spherical-1375917515) (**Figure 2.1B**) were projected on the walls of the evaluation room. In the home context, audio of an evening current events TV show was played as background noise (recording created by the researcher). In the bar context, audio of bar ambience (https://www.youtube.com/watch?v=ZSrVznkaMEM) including chatter and jazz music (https://www.youtube.com/watch?v=_sI_Ps7JSEk&t=116s) was played as background noise. Participants were spread out and seated at their own tables to adhere to social distancing requirements due to the Covid-19 pandemic.

In addition to image projection and audio, a brief written scenario (**Table 2.3**) was read to participants to provide clarity on how to interpret the images. The written scenarios were broad

as making them too specific may have prevented participants from imagining themselves in the specific scenario. For the home context it was considered that emotional response to a meal may differ depending on who has prepared it. It could also differ depending on who is being cooked e.g., family or visitors. The written scenario also enabled clarification that the patties were purchased from the supermarket and cooked at home not purchased from a takeaway which would result in different expectations.

For the gastropub, it was important to clarify that the participants were out for a casual meal with friends. As they were paying for the meal, expectations would likely be higher than at home and it was expected that this would stimulate a different range of emotions.

Table 2.3. Written scenarios provided to participants during discussion groups.

Eating Environment	Written Scenario	Subsequent Samples
Home	I want you to imagine you are at home with your family and/or flatmates and you're having burgers for dinner. You have purchased burger patties from the supermarket and cooked them for dinner. This is the patty you have prepared [referring to sample in front of participant].	I want you to keep imagining you are at home with your family and/or flatmates having burgers for dinner. But now this is the patty you have prepared.
Gastropub	I want you to imagine you are at the pub with friends having dinner and a few drinks. You have ordered a burger for dinner. This is the patty that arrives in your burger [referring to sample in front of participant].	I want you to keep imagining you are at the pub with friends having dinner and a few drinks. But now this is the patty that arrives in your burger.

A

B

Figure 2.1. A) Digitally recreated home eating environment; B) Digitally recreated gastropub eating environment.

2.2.1.4 Discussion Group Procedure

All discussion groups were led by the same moderator who used a discussion guide (**Appendix A**) to facilitate the discussion and ensure all groups followed the same pattern of discussion.

Each session started with an icebreaker activity where participants introduced themselves and spoke about their favourite burgers. This was followed by an explanation of the purpose of the session: *to come up with a list of emotion terms in response to how you feel when eating different burger patties*, and a short explanation of what was meant by an emotion term and how this differs from other affective feelings such as mood. This was based on the definition of an emotion as being in response to a specific event, rapid, intense and short-lasting (Ferrarini et al., 2010; Meiselman, 2015), and a mood not being in response to a specific event, building up more gradually and lasting longer (Beedie et al., 2011). Participants were instructed that *"We are interested to discuss how these patties make you feel in the moment you are eating them (emotional response). We are not interested in how you are generally feeling today. These longer-term feelings are your mood and are not in response to the burger patty".*

Two warm-up activities verified participants understood what the moderator meant by an emotion term and stimulated emotion elicitation. The first required participants to choose from a selection of images and describe how the image made them feel following Ng et al. (2013). For the second warm-up activity, participants focussed on emotions specific to burger eating. They were asked to think of positive and negative emotion terms to describe how eating their favourite burger, and a less preferred burger, would make them feel. These terms were not included in the formation of the lexicon.

Following the warm-up activities, emotion term generation commenced. All five (four for non-meat-eating groups) samples were first assessed in the digital home context.

Participants received the samples one at a time and were instructed to assess the sample by looking at it, eating it, and then writing down how the sample made them feel. Participants assessed the samples individually, and after every two samples shared and discussed their terms. Each new

emotion term was recorded by the moderator in a table projected onto the wall so participants could see an overview of terms already suggested. The table was split into three classifications: positive, negative, or neither positive nor negative (unclassified). Participants were asked to specify in which category the emotion term belonged if it was unclear to the moderator. After all samples were assessed in the home context, the process was repeated in the gastropub context but with samples presented in a different order.

After participants had generated their terms, they were presented with the emotion terms from the EsSense Profile® (King & Meiselman, 2010) and asked to consider if any of those also explained how they felt towards any of the samples in either of the contexts. This step was included to check that terms often used for assessing food and beverage had not been articulated/missed. Participants completed this activity individually and then shared and discussed it as a group. Relevant new terms from the EsSense Profile® were added to the table for the home context, gastropub context, or both.

Finally, participants were presented with all the emotion terms their group had generated and were asked to reconsider if all the emotion terms were relevant to burger eating and were terms they would use in their everyday lives. If most participants within a discussion group agreed a term was irrelevant, the emotion term was removed.

2.2.2 Stage two: Filtering of terms

Emotion terms from all the discussion groups (not including terms from the warm-up activities) were compiled into an initial list which was further refined by the researcher by removing non-emotion terms (e.g. ‘unhealthy’, ‘opinionated’), or emotions that did not relate to how the patty samples made the participants feel (e.g. feeling ‘offended’ being served a less preferred sample in the digital immersive gastropub).

To verify the terms were generally regarded as emotions, the list was checked following van Zyl and Meiselman (2015). Each term was compared with published lists of emotions by Clore et al. (1987) and Laros and Steenkamp (2005), containing 564 and 50 terms respectively. If a term was

not included on one of the lists or in the EsSense Profile®, it was removed. In instances where a term was not included in published lists, but a synonym was and the word had been suggested by more than one discussion group, the term was not removed as it was regarded as a more common or relatable way for consumers to express that emotion. Finally, for consistency, all terms were formulated to be an adjective (if not already) to fit into the sentence "I feel…"

2.2.3 Stage three: Online sorting-task

An online sorting task was used to group the refined emotion list from stage two into emotion categories based on similar meanings. The purpose of this stage was to use a consumer-led approach to reduce the overall number of terms to remove overrepresented emotions and synonyms and make the final lexicon more efficient to use. The approach used was adapted from the rapid method for grouping terms into emotional categories used by Mora et al. (2020).

2.2.3.1 Participants

Participants (n=115) were recruited from the Feast Lab consumer database, Massey University internal emails, advertisements on community social media pages and flyer distribution around Palmerston North, NZ. Of the 115 participants, 42 had also attended a discussion group. Participants were balanced across the same age groups and diet groups as the discussion groups (**Table 2.4**). Participants were not screened for gender. Additionally, participants were required to be able to communicate effectively in English. All new participants to the study (i.e., did not attend a discussion group) provided informed consent within the online activity.

Table 2.4. Participant demographics sorting-task.

Diet Group	n	Age Group	n
Meat Excluders	36	Millennials	19
		Generation X	17
Flexitarian	42	Millennials	24
		Generation X	18
Meat Eaters	37	Millennials	19
		Generation X	18

2.2.3.2 Online sorting-task procedure

A sorting task activity was created in Compusense® Cloud (Compusense Inc., Ontario Canada). Participants were invited to complete the sorting task activity in their own time using their own laptop or desktop computer using a link sent by email. Participants were instructed to organise

emotion terms into categories they thought shared a similar meaning and to choose one emotion term from each category to be the title term (i.e., the term that best represented all the other terms in the category). Participants were informed that the emotion terms had been generated in response to meat and plant-based patties.

Participants could propose as many categories as they considered necessary and did not have to categorise all the terms. However, to set expectations, they were informed that typically 10-20 categories would be made (based on the pilot study).

A pilot study was completed by five researchers from the Feast laboratory who completed the activity on their own devices in their own time as per the study protocol. All emotion terms were presented in a randomised order (i.e., positive, negative, and neutral terms randomised), but feedback indicated it was difficult to complete the activity with >100 terms randomised. It was suggested terms should be grouped into positive, negative, and neutral subgroups so participants would generally only have to look through a proportion of the terms each time they created a category. Therefore, in the actual study, emotion terms were presented in a fixed order of positive, negative, and then unclassified emotions, in alphabetical order within each subgroup. This classification of each emotion term was determined based on the most frequently indicated classification by participants during the discussion groups.

2.2.4 Data analysis

Statistical analyses were performed using R version 4.1.3 (R Core Team, 2022) through R Studio software version 1.4.1717 (R Studio Team, 2021). Package `factoextra` (Kassambara & Mundt, 2020) was used for hierarchical cluster analysis (HCA).

2.2.4.1 Identifying frequently mentioned emotion terms from discussion groups

Across the 12 discussion groups, there were 24 opportunities for an emotion term to be recorded as, although each term was only recorded once, it could be recorded for each context. The frequency with which each emotion term was mentioned across the 12 discussion groups was determined.

2.2.4.2 Clustering of emotion terms to determine emotion categories

The sorting-task data was arranged in a dissimilarity matrix, where each of the emotions was listed along the first row and top column. Each cell recorded the frequency at which each pair of emotions was not co-sorted into the same category. HCA was then performed on the dissimilarity matrix using the R package `factoextra` (Kassambara & Mundt, 2020) to group similar emotions into categories. Emotions were grouped using Euclidean distance and the Complete Linkage criterion. The appropriate number of clusters was determined using the elbow method, which determines the optimal number of clusters for a relatively low within-cluster sum of squares.

2.2.4.3 Identification of inconsistently understood emotion terms

To ensure the final lexicon was familiar and easily interpreted by end users regardless of consumer group, the grouping of emotion terms for each of the consumer groups was compared to the groupings of the total sample.

To achieve this, a *standardised* dissimilarity matrix was created to present the level of agreement of the grouping of emotional terms between consumer groups. In the *standardised* dissimilarity matrix, the frequency at which each pair of emotions was not co-sorted in the original dissimilarity matrix was divided by the square root of the total variance (standard deviation). Here, variance presented the difference between the proportion of each consumer group and the proportion of the total consumer group that did not co-sort a pair of emotions into the same category. The total variance for each of the emotions pairs was calculated by summing the variance of each of the six consumer groups. Pairs of emotions with a low total variance indicated consistency in understanding the similarity of emotions *a* and *b* between the six consumer groups. HCA was performed on the *standardised* dissimilarity matrix in the same manner as the *original* dissimilarity matrix.

The clustering solution for the *original* dissimilarity matrix was compared to the clustering solutions for the *standardised* dissimilarity matrix. Emotion terms that shifted clusters between the *original* and *standardised* matrix (indicating that these terms were understood differently

between consumer groups) were identified and classified as inconsistently understood emotion terms. These emotion terms were subsequently excluded from the emotion categories and hence the final lexicon.

2.2.4.4 Title terms for emotion categories for final lexicon

The frequency each emotion term was denoted as a title term during the sorting-task stage was determined. The emotion within a category most frequently selected as a title term was assigned as the category title term.

2.3 Results

2.3.1 Emotion term generation

Twelve group discussions generated an initial list of 158 different terms (**Table 2.5**) to describe how a range of PB-patties and a meat patty made participants feel when consumed across two different eating contexts.

At stage 2, the initial list of terms was reduced to 119 by the removal of 31 non-emotion terms and eight irrelevant emotion terms. Included in this refined list were 10 terms not present on published lists by Clore et al. (1987) and Laros and Steenkamp (2005), but were suggested by more than one discussion group, and were retained as synonyms to existing emotion terms, e.g., ‘intrigued’, ‘underwhelmed’, and ‘deceived’ were kept as another way to express ‘interested’, ‘disappointed’ and ‘cheated’, respectively.

Similar numbers of positive and negative emotions were experienced. Of the 119 emotion terms 64 were classified as positive terms, 58 as negative terms, and 22 as unclassified. In some instances, a term was classified by the participants as more than one category e.g., accepting, curious, and surprised were classified as positive, negative, and unclassified.

Table 2.5. complete list of terms generated during discussion groups including classification of positive, negative, or unclassified (neither positive nor negative) as determined by discussion group participants.

Terms generated during discussion groups			
Acceptance (+ - /)	Eager (+)	Peaceful (+)	Removed Terms:
Active (+)	Embarrassed (-)	Pleasant (+)	Compulsive† (+)
Adventurous (+)	Energetic (+)	Pleased (+)	Conflicted† (/)
Affectionate (+)	Enjoyment (+)	Polite (+ /)	Confrontational† (-)
Afraid (-)	Enthusiastic (+)	Proud (+ /)	Dubious† (-)
Agitated (-)	Excited (+)	Put-off§ (-)	Diet/restricted† (-)
Alert (+)	Expectant (+)	Reassured (+ /)	Familiar† (+)
Amazed (+)	Fearful (-)	Regretful (-)	Flat† (-)
Ambivalent (/)	Friendly (+)	Relaxed (+)	Full† (+)
Angry (-)	Frustrated (-)	Relieved (+ /)	Healthy† (+)
Annoyed (-)	Fulfilled (+)	Sad (-)	Heavy† (-)
Anticipation (+)	Glad (+)	Satisfised (+ /)	Invigorated† (+)
Anxious (-)	Glum (-)	Scared (-)	Indecisive† (-)
Apprehensive (-)	Good (+)	Sceptical§ (- /)	Insatiable† (+)
At-ease (+)	Grateful (+)	Secure (+ /)	Judgemental† (-)
Attracted (+)	Greedy (+)	Surprised (+ - /)	Let-down† (-)
Avoidant (-)	Grumpy (-)	Suspicious (- /)	Opinionated† (-)
Bliss (+)	Guilty (-)	Tame (- /)	Repulsed† (-)
Bored (- /)	Happy (+)	Tender (+)	Reserved† (-)
Brave (+ /)	Hopeful (+ /)	Thoughtful (+)	Resistant† (-)
Calm (+)	Hungry (+ -)	Tired (- /)	Rewarded† (+)
Cared-for§ (+)	Impatient (+ -)	Uncertain (-)	Satiated† (+)
Cautious (-)	Impressed (+)	Uncomfortable (-)	Social† (+)
Cheated (-)	Indifference (/)	Underwhelmed§ (-)	Spoilt† (+)
Cheerful (+)	Insecure (-)	Uneasy (-)	Strange† (-)
Comfortable (+)	Inspired (+)	Unfulfilled (-)	Stressed† (-)
Concerned (-)	Interested (+ /)	Unhappy (-)	Tempted† (+)
Confident (+)	Intrigued§ (+ -)	Unimpressed§ (-)	Trapped† (-)
Confused (- /)	Irritated (-)	Uninspired (-)	Tricked† (-)
Content (+)	Joyful (+)	Uninterested (- /)	Unhealthy† (-)
Courageous (+)	Keen§ (+)	Unsure§ (-)	Unenthusiastic† (-)
Critical (-)	Lively (+)	Upset (-)	Wasteful† (-)
Curious (+ - /)	Loving (+)	Wanting more (Want)	Appreciative‡ (+)
Daring (+)	Mad (-)	(+)	Awful‡ (-)
Deceived§ (-)	Merry (+)	Warm (+)	Lucky‡ (+)
Deflated (- /)	Mild (/)	Whole (+)	Offended‡ (-)
Delighted (+)	Nauseous (-)	Wonder (+)	Sorry‡ (-)
Disappointed (-)	Nervous (-)	Worried (-)	Shame‡ (-)
Disgusted (-)	Neutral§ (/)		Terrible‡ (-)
Dissatisfied (-)	Nostalgic (+)		Thankful‡ (+)
Doubtful (-)	Overwhelmed (-)		

†Removed, not an emotion terms according to published lists of emotions by Clore et al. (1987) and Laros and Steenkamp (2005) or not included on the EsSense Profile®; ‡ Removed, not in response to product; § Kept, not an emotion term according to published lists but a synonym term to an emotion mentioned more than once. + positive emotion, - negative emotion, / unclassified emotion as classified by discussion group participants.

Emotions could be recorded a maximum of 24 times (numbers in parentheses indicate citation frequency across groups/contexts). Positive emotions 'happy' (20), 'interested' (20), 'pleased' (19), 'satisfied' (19), 'relaxed' (18), and 'curious' (17) were experienced most frequently across the discussion groups as well as negative emotions 'disappointed' (23), 'dissatisfied' (17), 'annoyed' (14), and 'disgusted' (14). For unclassified emotion terms, 'curious' (12), 'neutral' (11), and 'mild' (9) were mentioned most frequently.

In the home context, 109 emotions terms were articulated and 101 were generated in the gastropub context. Eighteen were only generated in the home context while 10 terms were only generated in the gastropub context (**Table 2.6**).

Table 2.6. Emotion terms mentioned exclusively in each eating context.

Home Only	**Gastropub only**
Afraid	Agitated
Alert	Bliss
Attracted	Cheated
Cheerful	Confident
Concerned	Deflated
Courageous	Grateful
Glum	Impatient
Greedy	Inspired
Grumpy	Mad
Insecure	Reassured
Lively	
Loving	
Scared	
Thoughtful	
Uncertain	
Unfulfilled	
Wanting more	
Wonder	

2.3.2 Emotion categories

Consumers grouped the 119 emotion terms into a mean of 15 (SD = 7) categories, and a mean of 102 (SD = 27) emotion terms were used in the categories, i.e., some terms were left as single-term categories.

In the cluster analysis, beyond 25 clusters there was a minimal drop in the within-cluster sum of square and so additional clusters did not model the data much better. Also, from a practical point of view, it was important to capture the key emotion categories but also keep the lexicon concise for ease of use and to avoid redundant emotion categories.

The 25 cluster solution using the original dissimilarity matrix (**Table 2.7,** *see* **Appendix B** for cluster dendrogram) and the standardised dissimilarity matrix (**Table 2.8,** *see* **Appendix C** for cluster dendrogram) were compared. Terms consistently clustered together in both clustering solutions were adopted in the final emotion categories (**Table 2.9**). Twenty-nine emotion terms with inconsistent cluster membership between solutions were identified. These were removed from the clustering solutions because their interpretation in relation to the other terms was apparently different between consumers. However, as an exception, the terms 'satisfied' and 'disgusted' were not removed and assigned their own categories as they have been repeatedly reported as important emotions in previous research. Disgust is the negative emotion most often studied in emotion research related to food and consumer products (Meiselman et al., 2022), and 'satisfied' features in a number of lexicon for other product categories (Bhumiratana et al., 2014; King & Meiselman, 2010; Mora et al., 2020; Ng et al., 2013). 'Satisfied' and 'disgusted' were also among the most frequently mentioned emotion terms during the discussion groups.

Table 2.7. Original dissimilarity matrix hierarchical clustering analysis solution for 25 clusters.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9
Accepting	Active	Adventurous	Affectionate	Amazed	Anticipation	Blissful	Cared-for†	Curious
At-ease	Alert	Brave	Attracted	Impressed	Expectant	Cheerful	Good†	Interested
Calm	Eager	Confident	Friendly	Inspired†	Hopeful	Delighted	Grateful	Intrigued
Comfortable	Energetic	Courageous	Loving	Surprised		Enjoyment	Pleasant	Wonder
Content	Enthusiastic	Daring	Tender			Glad	Pleased	
Peaceful	Excited		Warm†			Happy		
Reassured†	Keen					Joyful		
Relaxed	Lively					Merry		
Secure†								
Relieved†								
Cluster 10	Cluster 11	Cluster 12	Cluster 13	Cluster 14	Cluster 15	Cluster 16	Cluster 17	Cluster 18
Fulfilled†	Greedy	Nostalgic	Afraid	Agitated†	Bored	Cheated	Critical†	Deflated
Proud†	Hungry	Polite	Anxious	Angry	Tired	Deceived	Sceptical	Disappointed
Satisfied†	Impatient	Thoughtful†	Apprehensive	Annoyed	Uninterested†		Suspicious	
Whole†	Wanting-more		Avoidant	Frustrated				
			Cautious	Grumpy				
			Concerned	Irritated				
			Fearful†	Mad†				
			Insecure					
			Nervous					
			Scared†					
			Worried					
Cluster 19	Cluster 20	Cluster 21	Cluster 22	Cluster 23	Cluster 24	Cluster 25		
Disgusted†	Doubtful†	Embarrassed†	Glum	Overwhelmed†	Tame†	Underwhelmed†		
Nauseous†	Uncertain	Guilty†	Sad	Uncomfortable	Ambivalent	Unfulfilled†		
Put-off†	Confused	Regretful†	Unhappy	Uneasy	Indifferent	Unimpressed		
	Unsure		Upset		Mild	Uninspired		
					Neutral	Dissatisfied		

† Emotion terms removed from the emotion lexicon due to shifting clusters between the original and standardised clustering solutions.

Table 2.8. Standardised dissimilarity matrix hierarchical clustering analysis solution for 25 clusters.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9
Accepting	Active	Affectionate	Amazed	Anticipation	Blissful	Cared-for†	Curious	Fulfilled†
At-ease	Adventurous	Attracted	Impressed	Expectant	Cheerful	Proud†	Inspired†	Reassured†
Calm	Alert	Friendly	Surprised	Hopeful	Delighted	Whole†	Interested	Secure†
Comfortable	Brave	Loving			Enjoyment		Intrigued	Warm†
Content	Confident	Tender			Glad		Thoughtful†	
Good†	Courageous				Happy		Wonder	
Peaceful	Daring				Joyful			
Relaxed	Eager				Merry			
Satisfied†	Energetic							
	Enthusiastic							
	Excited							
	Keen							
	Lively							

Cluster 10	Cluster 11	Cluster 12	Cluster 13	Cluster 14	Cluster 15	Cluster 16	Cluster 17	Cluster 18
Grateful	Greedy	Nostalgic	Afraid	Agitated†	Angry	Anxious	Avoidant	Bored
Pleasant	Hungry	Polite	Cautious	Fearful†	Annoyed	Apprehensive	Doubtful†	Tired
Pleased	Impatient	Tame†	Concerned	Guilty†	Frustrated	Embarrassed†	Insecure	
Relieved†	Wanting-more		Uncomfortable	Overwhelmed†	Grumpy	Nauseous†	Sceptical	
			Uneasy	Regretful†	Irritated	Nervous	Suspicious	
				Scared†			Worried	

Cluster 19	Cluster 20	Cluster 21	Cluster 22	Cluster 23	Cluster 24	Cluster 25
Cheated	Critical†	Deflated	Glum	Uncertain	Unimpressed	Ambivalent
Deceived	Disgusted†	Disappointed	Put-off†	Confused	Uninspired	Indifferent
Mad†		Underwhelmed†	Sad	Unsure	Uninterested†	Mild
		Unfulfilled†	Unhappy		Unsatisfied	Neutral
			Upset			

†Emotion terms removed from the emotion lexicon due to shifting clusters between the original and standardised clustering solutions

A key difference between the two clustering solutions was that when the original dissimilarity matrix was used for clustering, the terms 'afraid', '**anxious'**, 'apprehensive', 'avoidant', 'cautious', 'concerned', 'fearful', 'insecure', 'nervous', 'scared' and 'worried' were one cluster. However, when the standardised matrix was used this cluster split into three clusters: '**afraid'**, 'cautious' and 'concerned' (joined with 'uncomfortable' and 'uneasy'); '**anxious'**, 'apprehensive' and 'nervous'; 'avoidant', 'insecure' and 'worried' (joined with 'sceptical' and '**suspicious'**). Bolded terms are those that would be assigned as the title term for that category. It was decided to keep the three separate clusters as 'afraid' and 'anxious' are not viewed as interchangeable terms (National Alliance on Mental Illness, 2021).

Another key difference was that in the clustering solution for the original dissimilarity matrix the terms 'active', 'alert', 'eager', '**energetic'**, 'enthusiastic', 'excited', 'keen' and 'lively' were one cluster, and '**adventurous'**, 'brave', 'confident', 'courageous' and 'daring' were another cluster. However, in the standardised matrix these two cluster were joined as one. It was decided to keep these as two separate emotion categories as the two clusters represented distinct meanings. 'Adventurous' indicates someone willing to try new or difficult things (Cambridge University Press, 2022a) which is highly relevant to the consumption of new and novel foods, while 'energetic' means having or involving a lot of energy (Cambridge University Press, 2022c) or wanting very much to do or have something (eager) (Cambridge University Press, 2022b).

The frequency of each emotion term selected as a title term during the sorting-task is listed in **Table 2.9**. The term within a category most frequently selected as a title term was assigned as the title term for each respective category. In the case of cluster four, 'pleasant' and 'grateful' were both assigned as the title term as they were selected an equal number of times. The same situation occurred in cluster 11 where 'unhappy' and 'sad' were both selected an equal number of times.

Table 2.9. Final 24 emotion categories with their assigned title terms.

Adventurous	Afraid	Amazed	Angry	Anxious
Adventurous (27) Brave (21) Confident (15) Courageous (8) Daring (7)	Afraid (15) Cautious (11) Concerned (11) Uncomfortable (10) Uneasy (11)	Amazed (19) Impressed (17) Surprised (14)	Angry (41) Annoyed (11) Frustrated (9) Grumpy (5) Irritated (13)	Anxious (19) Apprehensive (8) Nervous (7)
Bored	**Calm**	**Curious**	**Deceived**	**Disappointed**
Bored (21) Tired (5)	Accepting (16) At-ease (7) Calm (27) Comfortable (18) Content (20) Peaceful (12) Relaxed (19)	Curious (28) Interested (22) Intrigued (5) Wonder (7)	Cheated (12) Deceived (23)	Deflated (4) Disappointed (37)
Disgusted	**Dissatisfied**	**Energetic**	**Happy**	**Hopeful**
Disgusted (14)	Unimpressed (9) Uninspired (6) Dissatisfied (20)	Active (18) Alert (8) Eager (16) Energetic (25) Enthusiastic (11) Excited (21) Keen (5) Lively (8)	Blissful (4) Cheerful (5) Delighted (10) Enjoyment (10) Glad (2) Happy (62) Joyful (8) Merry (2)	Anticipation (6) Expectant (11) Hopeful (16)
Hungry	**Loving**	**Neutral**	**Nostalgic**	**Pleasant/Grateful**
Greedy (19) Hungry (23) Impatient (10) Wanting-more (9)	Affectionate (16) Attracted (5) Friendly (15) Loving (25) Tender (4)	Ambivalent (13) Indifferent (12) Mild (9) Neutral (26)	Nostalgic (16) Polite (10)	Grateful (12) Pleasant (12) Pleased (6)
Satisfied	**Suspicious**	**Uncertain**	**Disgusted**	**Unhappy/Sad**
Satisfied (22)	Sceptical (6) Suspicious (13) Avoidant (7) Worried (12)	Uncertain (16) Confused (12) Unsure (13)	Disgusted (14)	Glum (3) Sad (36) Unhappy (36) Upset (14)

Numbers in parenthesis reflect the frequency at which the term was selected as a title term. Title terms were the terms within a cluster that had the highest frequency of being selected as a title.

The final lexicon for meat and plant-based patties included 24 emotion categories, 11 positive, 11 negative, and two unclassified (**Table 2.10**). The classification of positive, negative, and unclassified was based on the title terms most frequent classification during the discussion groups. For example, 'Hungry' was classified as positive nine times and negative two times, and so was classified as positive in the final lexicon. 'Curious' did not clearly fit into one category as it was classified as positive 17 times, negative seven times, and unclassified 12 times, and so was

unclassified. The emotion terms within a category not assigned as the title term can be provided to end users to give further clarification as to the meaning of an emotion category.

Table 2.10. Emotion lexicon for meat and plant-based patties containing 24 emotion categories.

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

(EP) indicates emotion terms included on the EsSense Profile®; (C) indicates emotion terms included on the CEQ.

Table 2.10 also highlights that ten of the 24 emotion categories are shared with the EsSense Profile® and five terms ('unhappy' and 'dissatisfied', and 'happy' and 'satisfied' are paired together in the CEQ) are shared with the valence × arousal circumplex-inspired emotion questionnaire (CEQ) (Jaeger et al., 2020). Additional synonym terms are shared between this lexicon and the EsSense Profile® and CEQ. 'aggressive' from the EsSense Profile® and 'tense/ bothered' from the CEQ share a similar meaning to 'angry'. From the CEQ 'jittery/nervous' is similar to 'anxious'.

2.4 Discussion

This study developed an emotional lexicon for meat and plant-based patties. It used discussion groups in digital-IEs and then a sorting task to group emotion terms with similar meanings and reduce the lexicon size while remaining inclusive of the relevant emotion space. The final emotional lexicon included 24 emotion categories of which 11 were positive, 11 were negative and two were unclassified.

2.4.1 Comparison of the developed emotion lexicon to generic emotion lexicon

Developing a consumer-led emotion lexicon enables the lexicon to be tailored to a product category unlike, for example, the EsSense Profile® which is general to all foods (King & Meiselman, 2010). Notably, ten of 24 emotion categories in the final lexicon here are also present

in the EsSense Profile® which is one of the most popular emotion lexicons in the field of consumer science (Cardello & Jaeger, 2016). A key difference between this lexicon and the EsSense Profile® is the inclusion of more negative emotion terms, which has also been found with other consumer-led lexicons e.g., (Bhumiratana et al., 2014; Chaya et al., 2015; Mora et al., 2019; Ng et al., 2013). The EsSense Profile® includes only three negative emotion terms while this lexicon includes 11. The EsSense Profile®, mainly consists of positive emotion terms as it is designed for use with product users who typically like the product (Dalenberg et al., 2014). However, Meiselman (2015) argues that non-users should also be studied to identify characteristics that work against product adoption. The inclusion of non-product users in the development of this lexicon likely contributed to the high number of negative terms. The inclusion of these negative terms gives the lexicon the potential to capture aversion more accurately which is particularly important for novel products like PB-patties where acceptance is relatively low.

In addition to a better balance of positive and negative terms, the developed lexicon covers a broad range of the valence x arousal space as recommended by Jaeger, Spinelli, et al. (2018) and Prescott (2017). The valence × arousal circumplex-inspired emotion questionnaire (CEQ) (Jaeger et al., 2020) consists of 12 pairs of emotions which span the different circumplex segments. The lexicon developed in the current work directly shared five emotions (‘calm’, ‘energetic’, ‘bored’, ‘happy’/ ‘satisfied’, ‘unhappy’/ ‘dissatisfied’), and two synonym emotions (‘angry’ and ‘anxious’), with the CEQ pairs of emotions. These seven emotions are spread over the circumplex model spanning both the valence and arousal dimensions. Other terms from the developed lexicon are not directly used in the CEQ but would further cover the 12 segments of the circumplex model if mapped out based on the placement assigned to these emotions in Jaeger, Spinelli, et al. (2018). The developed lexicon therefore covers a broad range of the valence x arousal space but using terms specific to meat and plant-based patties.

2.4.2 Specific emotions associated with novel foods

The emotion categories ‘deceived’, ‘anxious’, ‘afraid’, ‘uncertain’ and ‘suspicious’ were notably present but absent on the EsSense Profile® or the CEQ (apart from ‘jittery’/ ‘nervous’ which is

similar to ‘anxious’). Although emotion terms were collected as a list, rather than by sample, the researcher noticed that these terms were mentioned when consumers were exposed to the two plant-based samples that intended to resemble meat (meat analogues). Terms indicating deception or suspicion may be particularly relevant inclusions for lexicons used to evaluate products, like meat analogues, that are attempting to mimic other products.

Collier et al. (2021) found that in Swedish consumers ‘uncertainty’ and ‘scepticism’ around the contents and composition of meat alternatives, especially those that visually resemble meat, were two main barriers to purchase and consumption. Terms indicating deception or suspicion are strongly associated with neophobia, a human trait that manifests in anxiety towards novel foods (Jiang et al., 2014) that is responsible for some consumers’ failure to engage with new, often innovative, foods (Barrena & Sánchez, 2013; Jiang et al., 2014). In the present study, it is postulated that the inclusion of non-product users of meat analogues proved advantageous for lexicon development by revealing feelings such as ‘anxious’, and ‘uncertain’ and their synonym terms which were frequently mentioned at the term generation stage. By contrast, feeling ‘amazed’ likely captured the exceedance of expectations for a product for which consumers had preconceived negative sensory perceptions (Michel et al., 2021). This demonstrates the importance of the development and use of product category specific emotion lexicon to better capture the emotions experienced when evaluating novel foods.

2.4.3 Consideration of consumer language

‘Neutral’ and ‘deceived’ are terms not included on the published lists of emotions by Clore et al. (1987) and Laros and Steenkamp (2005) but were not excluded when filtering terms, as they were suggested by more than one discussion group and were synonyms to terms included on the published emotion lists, ‘indifferent’ and ‘cheated’, respectively. ‘Indifferent’ and ‘cheated’ were included in the emotion list used in the grouping task but participants selected the terms ‘neutral’ and ‘deceived’ as the title term for their respective groups. This highlights that published lists may not always include the go-to terms used by consumers to convey such feelings and highlights another advantage of a consumer-led lexicon.

2.4.4 Effect of immersive environments on emotional response

Of the initial 119 emotion terms, 18 were unique to the home context and 10 to the gastropub context. The greater number of unique terms in the home context is likely due to all participants assessing the samples in the home context first. There were positive and negative terms evoked uniquely in each context. However, notably terms such as 'afraid', 'concerned', 'insecure', 'scared' and 'uncertain' were only mentioned in the home context. Previous research has shown liking of a product can increase or decrease with repeat exposure (Köster et al., 2003). Mere Exposure Theory (Pliner, 1982; Zajonc, 1968) suggests experience with a product can lead to increased liking due to the dissipation of neophobia. While this theory applies to liking, it could explain why the negative terms mentioned previously were only mentioned in the home context as these negative emotions could have dissipated by the second time participants were exposed to the sample.

Comparing emotions generated in the different contexts was not an aim in this study, different contexts were used to widen the relevance of the lexicon across use case scenarios. However, the results suggested that, as unique emotions were perceived across different context, digital-IEs provided an efficient and useful tool to evoke and capture emotions that were representative across different real-life eating scenarios. Future research is needed to investigate the effect of using different digital-IEs on emotion lexicon generation using a balanced design and including a control condition (no digital context).

2.4.5 Applicability of lexicon to other plant-based products

This emotion lexicon was developed using a variety of patties including meat analogues, wholefood patties, and a beef patty. There is potential that the lexicon can be a better substitute than a generic lexicon for studies investigating emotional responses to PBMAs beyond patties. However, if this emotion lexicon were to be used with other plant-based/ meat analogue products outside the scope of patties it is recommended the lexicon be tested first in a preliminary study (e.g., discussion groups) to ensure there are no missing emotion categories relevant to the new product set.

2.4.6 Limitations and recommendation for future work

This is the first study to develop an emotion lexicon for meat and plant-based patties but had some limitations. First of all, the developed emotion lexicon had not yet been validated for its ability to discriminate across a range of PB-patties, but it was investigated in **Chapter 3**.

Discussion groups participants were screened to fit in different age and diet consumer groups. This study did not balance for gender, and only two men took part in the discussion groups. Even though some studies justify this imbalance by noting that women are more adept with emotional language (Eaton et al., 2019), other studies have shown differences in emotional responses between genders (Chaya et al., 2015; Mora et al., 2018) and so the inclusion of more men may have contributed additional emotional terms to this lexicon. Gender information was not collected for the sorting-task activity and so the gender balance for this portion of the lexicon development is unknown. For the discussion groups, participants attended with other members of the same age and diet groups. Separating the participants by age could have prevented intergeneration discussion which may have triggered additional emotion terms. Furthermore, despite recruiting participants to meet quotas based on diet groups and age groups, the emotion terms generated during the discussion groups were pooled together, and differences in the emotion terms generated by the various groups were not assessed. In hindsight, this represents a missed opportunity to gain insights into the specific emotions experienced by different diets and age groups towards PB-patties.

Ideally, to avoid attention bias towards terms at the top of the list in the sorting task, the positive terms (and negative terms) would be presented together but in a randomised order i.e., participant one would receive the positive terms in a different order to participant two, however, this was not possible within the functionality of the software. When all words were randomised together during the pilot (i.e., positive terms mixed with negative terms), the activity was discerned to be too confusing for participants. Furthermore, participants fed back that 119 terms was a challenging number to sort into groups which in some cases may have led to “lazy” grouping. If

using this approach, it is recommended to reduce the list of emotion terms prior to this stage if possible.

It is acknowledged that patties are not usually consumed on their own but as part of a meal (burger bun, sauce, lettuce etc.). When consumed as part of a meal emotional response to the patties could change. However, this study aimed to focus on collecting emotions related to patties that differed in main protein source avoiding any impact of other foods.

The lexicon presented here was developed with English speakers in New Zealand. van Zyl and Meiselman (2015), have demonstrated that cross-cultural differences in emotion expression exist within the same language as well as across languages. Therefore, caution is warranted regarding the direct use of this list of emotions in other languages or cultures as different emotions may need to be represented or emotions may be better represented with a different term. Preliminary checks in such cultures and languages are recommended

Lastly, employing a balanced design for the presentation order of digital-IEs and including a control condition (no digital context) would have provided stronger evidence for digital-IEs as an effective tool for generating emotion terms unique to different eating situations.

Future research should prioritise validating the developed emotion lexicon for its ability to discriminate across a range of PB-patties. Furthermore, the relevance of the emotion lexicon for use with other PBMA products beyond patties should be investigated. Additional research should explore the effect of different immersive environments on emotion lexicon generation, using balanced designs and including a control condition (no digital context). Finally, future research should investigate whether applying the developed lexicon reveals differences in emotional responses to the same product when assessed in different immersive environments.

2.5 Conclusions

This was the first study to determine an emotional lexicon for meat and plant-based burger patties. The final emotional lexicon consisted of 24 emotion categories: 11 positive, 11 negative, and two unclassified. It provides an important tool for further research on the links between sensory and emotional drivers of PB-patty consumption across different types of patty consumers and has the potential to be adopted for a wider product set. Measuring emotion with a consumer-led lexicon, as opposed to a generic one, has the potential to facilitate increased success in determining potential engagement with PBMAs. Although not specific research objectives, the approach taken also highlighted the importance of using different use case scenarios and potential end users in the development of a consumer-led lexicon. The next chapter presents validation of the generated lexicon to differentiate a wide range of patty products.

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STATEMENT OF CONTRIBUTION DOCTORATE WITH PUBLICATIONS/MANUSCRIPTS

We, the student and the student's main supervisor, certify that all co-authors have consented to their work being included in the thesis and they have accepted the student's contribution as indicated below in the Statement of Originality.

Student name:	Rebekah Orr
Name and title of main supervisor:	Professor Joanne Hort
In which chapter is the manuscript/published work?	Chapter 2
What percentage of the manuscript/published work was contributed by the student?	80%

Describe the contribution that the student has made to the manuscript/published work:
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Chapter 3: Consumer Sensory, Emotional and Liking Responses to Meat and Plant-Based Burger Patties (Study 2)

3.1 Introduction

Substituting conventional animal protein for PBMAs is one-way consumers can reduce their meat intake and contribute to a more sustainable food system (Willett & Rockström, 2019). However, uptake of PBMAs has been slow, with recent data indicating a decline in sales (Mridul, 2023; Pierce et al., 2023). As discussed in **section 1.2.1** several factors can affect acceptance of PBMAs but low sensory appeal has been identified as a main barrier to acceptance (Elzerman et al., 2015; Hartmann & Siegrist, 2017; Hoek et al., 2011; Michel et al., 2021). PBMA often exhibit inferior sensory quality compared to their meat counterparts (Fiorentini et al., 2020; Giacalone, Clausen, et al., 2022) and possess undesirable sensory attributes including mouth drying, low juiciness, and off-flavours (e.g., beany, earthy and bitter). Many of these defects can be attributed to the high contents of plant ingredients used in PBMAs, e.g., legume proteins, which are known to impart unpleasant flavours and mouthfeel (Chigwedere et al., 2022; Giacalone, Clausen, et al., 2022). Improving the sensory quality of PBMAs is critical, given that sensory acceptance consistently ranks as the most crucial factor influencing individual food choices (Martins & Pliner, 2005).

The aforementioned studies have focused on understanding consumer acceptance of PBMAs which mimic meat, whereas research focusing on consumer acceptance of plant-based products that do not intend to mimic meat (i.e. 'wholefood' products) has been neglected. It is a common belief that mimicking conventional meat products may lead to consumer acceptability of meat-eating consumers wanting to add plant-based proteins to their diet, whereas plant-based products that do not mimic meat cater to vegetarians and vegans (Falkeisen et al., 2022; Fiorentini et al., 2020; Hoek et al., 2011). However, previous research (Collier et al., 2021; Elzerman et al., 2013; Faber et al., 2022; Hoek et al., 2011; Kerslake et al., 2022; Michel et al., 2021; Waehrens et al., 2023; Weerawarna N.R.P et al., 2024) has yielded conflicting findings regarding the preferences of consumers regarding PBMAs and it is likely that segments of consumers with varying preferences exist, which may or may not be related to personal related factors such as diet or

frequency of PBMA consumption, as previously discussed in **section 1.2.1.2**. Moreover, these studies have primarily utilised online surveys or discussion groups to determine consumer preferences, often neglecting actual product tasting, which could provide greater insights into the specific sensory attributes consumers prefer in PBMAs. Understanding consumer preferences regarding sensory attributes, including whether they prefer meat-mimicking products or those distinct from meat, is essential for improving acceptance of PBMAs.

In addition to liking, measuring emotional response shows promise for gaining deeper insights into consumer perception of PBMAs. Emotions play a key role in food choice decision-making (Loewenstein & Lerner, 2003) and experiencing positive emotions is highly relevant to the acceptance of novel (Jiang et al., 2014; Motoki et al., 2021) and plant-based foods (Bryant, 2019; Chen, 2022; Onwezen et al., 2022). However, the existing literature on the emotional response to PBMAs is limited and Schouteten et al. (2016) is the only study to have previously investigated emotional response to PBMAs where actual products have been tasted and only included one PB-patty. Other studies (Collier et al., 2021; Moussaoui et al., 2023; Zandstra et al., 2023) have investigated anticipated emotional responses through online surveys, but these may not always align with actual experiences. Findings from these studies have been discussed in detail in **section 1.2.1.1.**

Measuring emotional responses to products made from a range of plant-based ingredients, and that vary in sensory characteristics from meat-like to not-so-meat-like, could offer valuable insights for industry. Such information can identify sensory attributes that resonate most positively with consumers, aiding the development of products that align with consumer preferences. Additionally, studying emotional responses can broaden insights into consumers' general feelings towards PBMAs. The emotion lexicon developed in **Chapter 2** can assist in measuring consumer emotional responses using highly relevant emotion terms. As the emotion lexicon was developed using burger patties, patties were also used as the focus product in this study enabling validation of the emotion lexicon for its ability to discriminate across a range of plant-based burger patties varying in their sensory properties.

Flexitarians and meat eaters were selected as the focal consumers for this study as they constitute the largest consumer groups for meat reduction. Investigating their preferences and dislikes regarding existing PBMAs should provide valuable insights for guiding future PBMA product development ultimately leading to increased PBMA acceptance and consumption among meat eaters and flexitarians, potentially resulting in reduced overall meat consumption or a continued decrease in meat consumption among flexitarians. Furthermore, Millennial and Generation X consumers were recruited for this study as the most likely to adopt a plant-based diet (Kemper et al., 2023; Realini et al., 2023).

3.1.1 Research focus

The main objectives of the study presented in this chapter were to:

1. Profile a range of burger patties (meat and plant-based) for liking, emotional response, sensory attributes, and perceived similarity to meat to identify sensory attributes driving liking and positive emotional response in plant-based burger patties (PB-patties)
2. Determine if consumers can be segmented based on their preferences (liking and emotional response) for meat and plant-based burger patties and determine if the consumer profile for these segments varies according to diet, age group or frequency of PBMA consumption
3. Validate the developed emotion lexicon for its ability to discriminate across a range of PB-patties that vary in sensory properties.

Materials and methods

A quantitative consumer study was used to determine consumer sensory assessment, liking, and emotional response to burger patties across a wide range of sensory properties and ingredients including meat analogues, wholefood patties, a hybrid beef-vegetable patty and a beef patty.

3.1.2 Participants

The study was considered and assessed as low risk following the Massey University Human Ethics Committee process (human ethics notification number: 4000026606). Informed consent was obtained from all participants at the commencement of the study. Participants were compensated for their time with a NZD40 shopping voucher after completing the study.

Participants were recruited via the Food Experience and Sensory Testing (Feast) Laboratory consumer database, Massey University, internal emails, and flyer distribution around Palmerston North, NZ. Inclusion criteria required participants to: (1) be aged between 25 and 55 years, (2) include meat in their diet, (3) be regular burger patty consumers (at least once a month), (4) be able to communicate effectively in English, (5) not be allergic or intolerant to the sample ingredients, (6) not be pregnant nor lactating, and (7) be willing to try plant-based meat alternatives. Eligibility was assessed through a self-reported recruitment screening questionnaire. To further characterise the participants, the recruitment screening questionnaire also collected information on diet (flexitarian or omnivore), and frequency of PBMA consumption (consumption of any products that would replace meat in a meal) where the options were '2-3 times a week', 'once a week', 'once a fortnight', 'once a month', 'less than once a month' and 'never'. PBMA consumption groups were recategorized into groups to form similar group sizes and to aid data handling: High-user (2-3 times a week/once a week), low/medium-user (once a fortnight/once a month), non-users (less than once a month/ never).

One hundred and ten participants were recruited for the study. When employing the CATA method for sensory characterisation, Ares et al. (2014) found that 60 to 80 consumers are typically sufficient when dealing with noticeably different samples. However, when CATA questions are used alongside overall liking questions, it's essential to consider the number of consumers required for hedonic tests as well. In such cases, a range of 100 to 120 consumers is considered appropriate, as noted by Hough et al. (2006). Furthermore, when considering consumer segments, the number of clusters in the data is unknown before data analysis. However, for robustness and relevance, Castura et al. (2022) recommend only interpreting clusters with approximately 50 or more consumers and hence at least 100 consumers are required if data is to be segmented.

3.1.3 Samples

Twelve burger patty samples were included in this study **(Table 3.1)**. Ten samples were commercially available in New Zealand supermarkets, and two samples, a beef-vegetable hybrid, and Quorn were made by the researcher.

Samples were selected to represent variations in sensory characteristics and raw ingredients across the New Zealand plant-based burger patty market. Wholefood patties were selected to differ in their vegetable-based ingredients and meat analogue samples were selected to include different common plant-based proteins (pea, soy, wheat, mycoprotein), blends of plant-based proteins, and to vary in similarity to a meat patty (as judged by the researcher). A beef patty was included as a benchmark for comparison to the meat analogue patties.

To include a hybrid vegetable-beef product a patty containing approximately 40% plant-based ingredients and 40% beef mince was created by combining a commercially available vegetable 'mince' with beef mince (*see* **Appendix D** for formulation). Commercial Quorn™ burgers were not available in New Zealand so a patty was made from Quorn™ mince (*see* **Appendix E** for formulation) as Quorn™ is a popular meat substitute brand both in New Zealand and globally.

Table 3.1. Description of patty products.

Product Name	Abbreviated Name in Chapter	Ingredients	Classification	Manufacture	Product Image
Silver Fern Farms: Pure Beef Burger with Short Rib	Beef	Beef 97% (Boneless Short Rib 20%), Bovine Collagen (2%), Salt, Pepper	Animal protein	*Silver Fern Farm Limited, Dunedin, New Zealand*	 
Pams: Plant-Based Falafel Burgers	Pams	Chickpeas (37%) (chickpeas, water), batter (water, wheat flour, maize starch, salt, thickeners (401, 464)), breadcrumbs (wheat flour, glucose, salt, yeast, colour (100)), vegetables (onion, dehydrated red pepper), water, seasoning (rice flour, spices, salt, sugar, starch (tapioca, potato), vegetable fibre, sunflower oil, thickener (415) (contains soy), spice extract), palm oil, canola oil, pregelatinised maize starch, thickener (1412).	Wholefood	*Foodstuffs Own Brands Limited, Auckland, New Zealand*	 
Bean Supreme: Quinoa and Mushroom Burgers	Bean Supreme_1	Mushroom (23%), Black Beans, Onion, Borlotti Beans (14%), Kumara (6%), Quinoa (5%), Vegetable Oil, Methylcellulose, Carrageenan, Locust Bean Gum), Potato Fibre, Parsley (1.5%), Soy Sauce, Salt, Yeast Extract, Garlic, Lemon Juice Concentrate, Smoked Paprika, Black Pepper.	Wholefood	*Life Health Foods NZ Ltd, Auckland, New Zealand*	 

Table 3.1. Description of patty products (continued).

Product Name	Abbreviated Name in Chapter	Ingredients	Classification	Manufacture	Product Image
Bean Supreme: Veggie Good Supreme Burgers	Bean Supreme_2	Potato, Carrot, Onion, Tomato, Pumpkin, Lentils, Quinoa, Vegetable oil, Pumpkin seed, Rolled Oats, Sunflower Seed, Methylcellulose, Locust Bean Gum, Potato Fibre, Spices, Salt, Soy sauce, Garlic, Yeast Extract, Coconut Sugar, Food Acid (Citric).	Wholefood	*Life Health Foods NZ Ltd, Auckland, New Zealand*	
Food Nation: Cauliflower, Turmeric and Ginger	Food Nation_1	Vegetables (54%) (Mushroom, Cauliflower, Onion, Kumara, Chickpeas, Ginger, Garlic), Water, Vegetable Protein (Faba Bean, Pea), Vegetable Oil, Vegetable Gums (Methylcellulose, Xanthan, Locust Bean, Guar), Rice Flour, Modified Starch (1412), Spices, Pea Fibre, Salt, Dehydrated Vegetables.	Wholefood	*Food Nation Ltd, Christchurch, New Zealand*	
Food Nation: Beetroot, Kumara and Quinoa	Food Nation_2	Vegetables (59%) (Mushrooms, Chickpeas, Beetroot, Kumara, Red Onion, Garlic), Vegetable Oil, Kiwi Quinoa, Vegetable Protein (Faba Bean, Pea), Vegetable Gums (Methylcellulose, Xanthan, Locust Bean, Guar), Rice Flour, Modified Starch (1412), Pea Fibre, Salt, Molasses, Spices.	Wholefood	*Food Nation Ltd, Christchurch, New Zealand*	

Table 3.1. Description of patty products (continued).

Product Name	Abbreviated Name in Chapter	Ingredients	Classification	Manufacture	Product Image
Vegie Delights: Smoky BBQ Burgers	Vegie Delights	Water, Vegetable Protein (20%) (Soy, Wheat), Vegetable Oils (Sunflower, Canola), Oats, Onion, Wheat Flour, Wheat Bran, Seasoning (Soy, Wheat, Barley), Starch (Potato, Tapioca), Yeast Extract, Flavour (Soy, Gum Arabic), Carrageenan Gum, Garlic, Minerals (Zinc, Iron), Vitamin (B12), Spices.	Meat analogue	*Sanitarium Health Food Company, Auckland, New Zealand*	
Beyond Meats: Beyond Burgers	Beyond Meats	Water, pea protein (16%), canola oil, coconut oil, rice protein, flavouring, stabilizer (methylcellulose), potato starch, apple extract, colour (beetroot red), maltodextrin, pomegranate extract, salt, potassium salt, concentrated lemon juice, maize vinegar, carrot powder, emulsifier (sunflower lecithin).	Meat analogue	*Beyond Meats Inc, El Segundo, California, United States*	
Birds Eye: Plant-Based Burgers	Birds Eye	Water, plant based proteins (24%) [wheat, soy, pea, colours (caramel III, caramel IV)], canola oil, thickeners (461, guar gum, xanthan gum), flavour, yeast extracts, maize starch, yeast, maltodextrin (maize), salt, vegetable fibres, sugar, hydrolysed vegetable protein (maize), vegetables (onion, garlic), smoke flavour, food acid (tartaric), pepper, mineral (zinc), vitamin (B12).	Meat analogue	*Simplot Australia Pty Ltd, Auckland, New Zealand*	

Table 3.1. Description of patty products (continued).

Product Name	Abbreviated Name in Chapter	Ingredients	Classification	Manufacture	Product Image
Impossible Foods: Impossible Burger	Impossible Foods	Water, Soy Protein Concentrate (21%), Sunflower Oil, Coconut Oil, Thickener (INS 461), Glutamic Acid, Natural Flavours, Cultured Dextrose, Modified Starch, Yeast Extract, Soy Leghemoglobin (genetically modified), Salt, Antioxidant (INS 307b), Soy Protein Isolate, Vitamins and Minerals (Zinc Gluconate, Niacin (Vitamin B3), Thiamine Hydrochloride (Vitamin B1), Pyridoxine Hydrochloride (Vitamin B6), Riboflavin (Vitamin B2), Vitamin B12).	Meat analogue	*Impossible Foods Inc. Redwood City, California, United States*	
Quorn Mince	Quorn	Mycoprotein (94%), rehydrated free range egg white, caramelised sugar, barley malt extract, acidity regulator (calcium acetate), firming agent (calcium chloride).	Meat analogue	*Quorn Foods, North Yorkshire, United Kingdom*	
Beef Mince and Vince Plant-Based Vegetable Mince Classic Kiwi Style	Hybrid	<u>Beef mice:</u> Beef (100%) <u>Vegetable mince:</u> Tomatoes, cauliflower, onion, carrot, peanuts, Tamari, celery, tomato paste, potato starch, apple cider vinegar, nutritional yeast, garlic, coconut sugar, thyme, garlic powder, salt, onion powder, pepper.	50:50 Hybrid of animal protein and plant-based protein	*Olive and Ash Ltd, Whangarei, New Zealand*	

3.1.4 Sample preparation

Patties were brushed on both sides with Olive Oil (Countdown, New Zealand) and then cooked between a top and bottom plate on a commercial grill set at 180°C (Grill Station, Roband, Australia) for the times indicated in **Table 3.2.** Cooking times varied from the manufacturer's instructions as the grill was kept at a fixed temperature and the patties were heated on both sides at the same time. A cooking trial prior to the study was used to determine the time required to reach an internal temperature of 75°C. Cooked patties were cut into eighths (weights listed in **Table 3.2**) and individually wrapped in aluminium foil. Two pieces of each patty were placed into a ceramic dish coded with a random three-digit code. All samples were cooked prior to the session and held in a food warmer (E84 Food Warmer, Bakbar, New Zealand) heated to 50 ± 5 °C for a maximum of 45 minutes.

Table 3.2. Cook times and weights of each product (where weight is approximately one-eighth of a patty).

Product	Cook Time (mins)	Weights (g) Mean ± SD
Bean Supreme_1	5	9.5 ± 0.6
Bean Supreme_2	5	14.7 ± 0.6
Food Nation_1	5	9.9 ± 0.7
Food Nation_2	5	10.1 ± 0.7
Pams	6	10.0 ± 0.8
Vegie Delights	6	8.4 ± 0.7
Beyond Meats	5	9.9 ± 0.8
Impossible Foods	5	12.0 ± 0.8
Birds Eye	6	8.4 ± 0.7
Quorn	6	11.4 ± 0.7
Beef	9	10.2 ± 0.9
Hybrid	6	12.1 ± 0.8

3.1.5 Sensory attribute selection

Sensory attributes identified from the literature (Carvalho et al., 2015; Coetzee, 2022; De Angelis et al., 2020; Grasso et al., 2022; Grasso et al., 2019; Neville et al., 2017) to describe beef and plant-based burgers and hybrid meat and meat analogue products were compiled into a list. This list included 49 different attributes covering appearance (15), texture/mouthfeel (15), taste (5) and flavour (14) modalities.

Three focus groups (n=22, 6-8 participants per group) were held to determine if all sensory attributes from the compiled list were relevant to the 12 patty products selected for the consumer

study and if any key sensory attributes were missing. Focus group participants included staff and students associated with the Feast Lab as well as members of the public recruited through the Feast consumer database. From an ethical perspective, to avoid exceeding 25% of an average adult female's recommended daily intake for fat (70g), sugar (90 g), sodium (2300mg) and energy (8700 KJ), only eight of the 12 products were assessed in each focus group, but all products appeared at least twice across the groups. Participants assessed each sample monadically against the list of sensory attributes using a CATA approach, participants were also encouraged to write down any new relevant sensory attributes they perceived. After each sample, the group discussed new attributes to expand on the list of attributes.

Terms selected less than 20% of the time across all samples were deemed irrelevant and removed. This removed the terms 'bitter' taste, 'astringent' mouthfeel and 'off-flavour' which have been previously reported as undesirable characteristics in PBMA's but were only used 6% 'bitter' taste, 3% 'astringent' mouthfeel, and 3% 'off-flavour' of the time during the focus groups.

New attributes frequently suggested were added to the attribute list and included, for example: inconsistent texture, visible ingredients, and fried outer coating. In some cases, attributes were reworded to be more relevant to the products e.g., bleeds like meat was changed to pink/red centre. Or a new attribute was combined with an existing one e.g., 'dense' was combined with 'hard', and 'doughy' was combined with 'pasty' as these attributes had a similar meaning to the participants. For the vegetable-based samples, participants mentioned several different vegetables and spices. Instead of listing each separately, they were combined into groups based on similar classifications e.g., 'root vegetables' and 'aromatic spices'.

Attributes identified from the literature were generally found to cover the meat analogue samples. The wholefood patties were less represented, and their sensory attributes made up most of the new attributes added.

The final list included 51 attributes (**Table 3.3**) covering appearance (15), texture/ mouthfeel (16), and taste/flavour (20) modalities. A large number of sensory attributes was required due to sample

diversity. Many of the attributes were self-explanatory but to reduce ambiguity, a definition for each attribute was developed by the researcher. Definitions were based on information gathered through the discussion groups e.g., aromatic spices were the flavours participants suggested, and based on the researcher's knowledge of the samples.

Table 3.3. Final attribute list and definitions used for sensory evaluation.

Modality	Attribute	Definition/ Cue
Appearance	Browning on outside	The sample has caramel-like browning on the surface
	Fried crumb coating	The sample has a golden-yellow outer coating
	Dark brown colour	The sample is a dark brown colour
	Light brown colour	The sample is a light brown colour
	Green colour	The sample is a green colour
	Orange colour	The sample is an orange colour
	Greasy/ oily	The sample has an oily or greasy surface
	Dry	The sample looks dry/ lacks moisture
	Pink/red centre	The sample has a pink or red centre similar to raw meat
	Moist	The sample looks wet/ moist
	Fibrous	The sample looks fibrous e.g., visible muscle fibres/ thin thread-like structures
	Hard/ Dense	The sample looks like it would be difficult to break or take a lot of force to bite and chew
	Crumbly	The sample looks like it would easily fall apart
	Chunky	The sample is made up of thick or lumpy pieces
	Visible ingredients	The sample has visible ingredients e.g., pieces of vegetables, chickpeas, seeds, quinoa, herbs
Texture/ Mouthfeel	Dry	The sample is lacking moisture
	Moist	The sample is wet/ moist
	Juicy	Moisture/juice is released from the sample during chewing
	Chewy/ Rubbery	The sample needs to be chewed hard or for some time before swallowing
	Cohesive	The sample sticks together and does not fall apart easily
	Crumbly	The sample breaks into pieces easily
	Greasy/ Oily	The sample leaves an oily or greasy coating in the mouth
	Grainy/ Granular	The sample contains small course particles
	Hard/ Dense	The sample is difficult to break/ takes a lot of force to bite and chew
	Soft	The sample is easy to bite/break
	Pasty/ Doughy	The sample creates a paste that may sticks to the teeth/ mouth when chewed
	Springy	The sample recovers to original form after being compressed
	Tender	The sample is easy to bite into
	Chunky	The sample has thick or lumpy pieces
	Inconsistent	The sample has an inconsistent texture due to the presence of minimally processed ingredients e.g., vegetables, seeds, quinoa
	Crunchy	The sample is hard but crisp and makes a loud crunching noise when fractured e.g., fried food, crackers
Flavour/ Taste	Smoky/ Grilled	The flavour of smoke e.g., ashy/ woody/ burnt
	Strong beef	Strong beef flavour
	Weak beef	Weak beef flavour
	Metallic/ Blood	The flavour of metal or blood
	Breadcrumbs/ Wheat	The flavour of bread
	Fat	The flavour of animal fat
	Black pepper	The flavour of black pepper

Table 3.3. Final attribute list and definitions used for sensory evaluation (continued).

Modality	Attribute	Definition/ Cue
Flavour/ Taste	Salty	The flavour of salt
	Savoury/ Umami	The flavour of glutamate (MSG) e.g., soy sauce, miso
	Mixed herbs	The flavour of herbs e.g., Rosemary, oregano, coriander, basil
	Beany	The flavour of beans e.g., Soybean
	Nutty	The flavour of nuts
	Garlic/Onion	The flavour of garlic and/or onion
	Root vegetables	The flavour of potato, carrot, pumpkin, kumara (sweet potato), Beetroot or similar
	Brassicas	The flavour of cauliflower, cabbage, broccoli, leafy greens or similar
	Tomato	The flavour of crushed tomatoes
	Mushroom/ Earthy	The flavour of mushroom or soil
	Hot spices (spicy)	The flavour of hot spices e.g., Chilli, black pepper, ginger
	Aromatic spices	The flavour of aromatic spices e.g., cloves, cumin, fennel, cinnamon, nutmeg, allspice, Paprika, coriander seed

3.1.6 Emotion lexicon

The emotion lexicon developed in **Chapter 2** was used. As the emotion lexicon was reduced to emotion, all terms within a category were presented (**Appendix F**) and participants were instructed to read all the terms associated with each emotion category and to rate their feeling of the underlying emotion that the words were describing as suggested by Eaton et al. (2019). Going forward, for simplicity, 'category' will be dropped, and emotion categories will be referred to by their names. For example, the calm emotion category will simply be referred to as 'calm' and emotion categories will be referred to as 'emotions'.

3.1.7 Experimental design

Participants assessed 12 products for affective response (liking and emotion), sensory attributes, and likeness to a beef patty using a questionnaire hosted through Compusense Cloud® Software (Compusense Inc., Ontario, Canada). Due to the high number of samples, and an ethical need to not exceed more than 25% of an average female adult's recommended daily intake for fat (70g), sugar (90 g), sodium (2300mg) and energy (8700 KJ), samples were assessed over two sessions according to an incomplete block design. To assist with the logistics of cooking the samples, products were split into two blocks (**Table 3.4**) and one block was assessed per session. Each block contained a combination of both meat analogues and wholefood patties to maintain variation in samples across a block to avoid comparison within a product type. Beef and Food Nation_1 were assessed in both blocks to determine participant re-test reliability. To account for

order effects, the order in which participants assessed each block was balanced across the participants.

Table 3.4. sample blocks where one block was assessed per session.

Block A	Block B
Beef	Beef
Food Nation_1	Food Nation_1
Beyond Meats	Impossible Foods
Vegie Delights	Birds Eye
Hybrid	Quorn
Bean Supreme_1	Food Nation_2
Bean Supreme_2	Pams

Within a session, samples were presented monadically following a balanced Williams' Latin square design (Kemp et al., 2009; Wakeling & MacFie, 1995). Samples were served wrapped in aluminium foil on small white ceramic dishes labelled with random 3-digit codes. For the replicated samples, different 3-digit codes were used in each block. Participants were provided with two pieces of each sample and instructed when to taste each piece to pace sample consumption. Participants were instructed to use one piece for the affective response questions and the other for sensory attributes assessment. Participants were not required to consume the whole sample but were encouraged to consume as much as they could to fairly assess each sample.

Unsalted water crackers (Countdown, Australia) and filtered water were provided as palate cleansers. A 30-second minimum break was enforced between the emotion assessment and sensory assessment and a two-minute break was enforced between samples to allow participants time to cleanse their palate to minimise carry-over effects.

3.1.8 Questionnaire

Data collection took place in ISO standard (ISO 8589:2007) sensory booths under white light (**Figure 3.1**). Data was collected using Compusense Cloud® Software (Compusense Inc., Ontario, Canada) via iPads. When presented with a sample, participants first assessed the sample for overall liking, appearance-liking, texture-liking, and flavour-liking using a 9-point hedonic scale (Peryam & Pilgrim, 1957), labelled from 1 = 'dislike extremely' to 9 = 'like extremely'. Participants then assessed their emotional response to the sample followed by the sensory

attributes using CATA. Participants were forced to make at least one selection for each of the CATA questions. When making their emotional response assessment, participants were instructed to *"select the words that best describe how the sample makes you feel"*. For sensory product characterisation participants were instructed to *"Select the words that describe the appearance [or texture or flavour] of the sample"*. Lastly, participants rated how much the sample resembled a beef patty using a 5-point fully labelled box scale, 1 = 'not at all meat like', 2 = 'not very meat-like', 3 = 'somewhat meat-like', 4 = 'very meat-like', 5 = 'extremely meat-like'.

Attribute presentation order for the CATA questions (emotion and sensory) was balanced between participants. However, for each participant, the order of the attributes was fixed for all samples across the two sessions as recommended by Meyners and Castura (2016). CATA attributes were presented in the questionnaire as a 'grid' across two columns as described by (Hollowood, Hort, & Kemp, 2018). Due to the large number of sensory attributes, a separate page was used to present the attributes for appearance, texture, and flavour, in that order. At the start of each session, participants were provided with the lists and definitions of sensory and emotion attributes to refer to throughout the session, and a short presentation was given on the order of assessment and how to answer each question type.

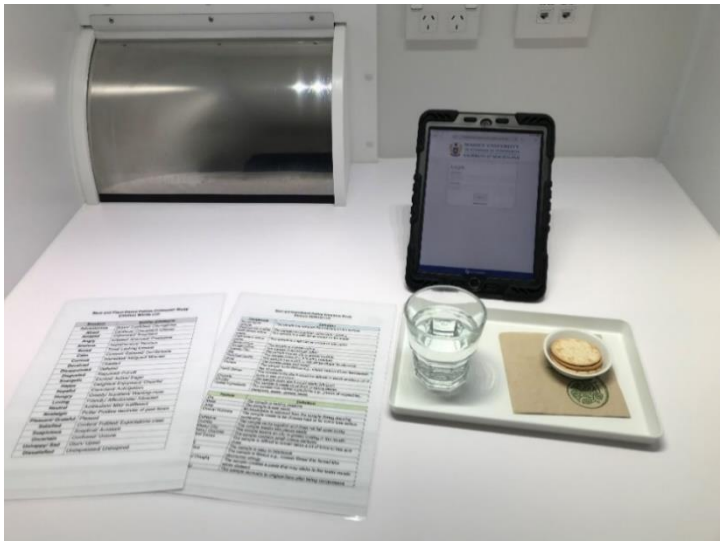


Figure 3.1. Participants assessed samples in ISO-standard sensory booths under white light. Product assessments were made on an iPad. Filtered water and plain water crackers were provided as palate cleansers.

3.1.9 Data analysis

All statistical analyses were performed in R version 4.1.3 (R Core Team, 2022) using R Studio software version 2022.12.0.353. Commonly used packages included `dplyr` (Wickham et al., 2023) for data manipulation, `ggplot2` (Wickham, 2016) for data visualisation, `lme4` (Bates et al., 2015) for linear mixed effect models, and `emmeans` (Lenth, 2023) for multiple paired comparisons. Any additional packages are specified in the text where relevant. An α level of 0.05 was considered statistically significant and mean ± standard error (SE) values are reported throughout the chapter.

3.1.9.1 Liking ratings

To determine whether liking ratings differed between products, linear mixed effect models (LMM), with each liking modality (overall liking, appearance, texture, or flavour) as a response variable, were used. *Product* and *visit* were set as a fixed effect and *participant* was set as a random effect. Analysis of variance (ANOVA) was applied to determine which fixed effects were significant. When a significant main effect of *product* or *visit* was identified, post hoc pairwise comparison tests with Tukey adjustments for multiple comparisons were conducted.

Participant re-test reliability was assessed by comparing the overall liking ratings for the two products assessed in both sessions using Cohen's kappa statistic (McHugh, 2012) (`psych` (Meyer et al., 2008; Revelle, 2023)).

3.1.9.2 Perceived similarity to a meat patty of the samples and relationship to liking

To investigate how similar patties were perceived to resemble a meat patty, participant proportions selecting each option on the 5-point Likert scale were determined and visualised in a stacked bar plot. Correlations between perceived similarity to a meat patty and liking ratings (separate analyses were run for each liking modality) were investigated using Spearman correlation coefficients (ρ).

3.1.9.3 Product differentiation: sensory and emotion CATA

To determine if participants were consistent in their sensory and emotion CATA assessments, Spearman correlation coefficients (ρ) were calculated between the citation proportions from

CATA data collected in sessions 1 and 2 for the two samples assessed in both sessions (Beef and Food Nation_1).

Citation proportions for all attributes (sensory and emotion) were calculated by dividing attribute citation frequency by the total number of participants. To visualise attribute-product relationships, principal components analysis (PCA) was conducted on mean citation proportions. Separate biplots (`factoextra` (Kassambara & Mundt, 2020)) were created for sensory and emotion attributes. Attributes with a correlation to a PC (r) of >0.6 or <-0.6 were considered important. Liking ratings (overall, texture, appearance, and flavour), and similarity to meat were projected as supplementary variables.

To determine if attribute citation proportion differences existed between products, a generalised linear model (GLM) (binomial family) was performed for each attribute (Agresti, 2018; Bi & Kuesten, 2022). For both sensory attributes and emotion attributes, the binary scores were used as the response variable, and *product*, *visit* and *participant* were set as fixed effects. Analysis of deviance (Agresti, 2018) was used to determine which fixed effects were significant. When a significant main effect of *product* or *visit* was identified, post hoc pairwise comparison tests with Tukey adjustments for multiple comparisons were conducted.

3.1.9.4 Sensory predictors of overall liking

To identify which sensory attributes were predictors of overall liking, an ordinal logistic regression model (`ordinal` package (Christensen, 2022)) with overall liking as the response variable and the 51 sensory attributes as fixed factors was used. The contribution of each sensory attributes to liking was determined by the regression coefficient and analysis of deviance was used to determine if the contribution of the sensory attributes was significant.

3.1.9.5 Clustering consumers

K-means clustering was applied to determine if segments of consumers with different overall liking responses existed. K-means clustering (Euclidian distance) was performed on the individual participant data using their overall liking ratings for each product; 103 rows (consumers) x 12 columns (overall liking x 12 products). The optimal number of clusters in each

situation was determined using the elbow and silhouette methods (`factoextra` package (Kassambara & Mundt, 2020)). To determine if overall liking of the products differed between clusters, a linear mixed effect model (LMM) was used with overall liking as the response variable. *Cluster adherence* and *product* were set as fixed effects, and interactions were allowed between *product* and *cluster adherence*, *participant* was set as a random effect. Analysis of variance was used to determine which main effects and interaction effects were significant. For a significant interaction effect of *cluster adherence* and *product*, post hoc tests with Tukey adjustments for multiple comparisons were conducted to determine for which products the clusters differed in their mean overall liking ratings.

Sensory drivers of liking for the liking clusters were determined as described in **section 3.2.8.4.**

Emotional responses were clustered similarly to overall liking where k-means clustering was performed on individuals' binary outcomes for each emotion attribute by product; 103 rows (consumers) x 288 columns (24 emotions x 12 products). To determine if product emotion citation proportions differed between consumer clusters, a generalised linear model (GLM) (Binomial family) was performed for each emotion. Binary scores were used as the response variable, and *product*, *cluster adherence* and *panellist* were set as fixed effects, and interactions were allowed between *product* and *cluster adherence*. Analysis of deviance was used to determine which main effects and interaction effects were significant. For a significant interaction effect of *cluster adherence* and *product*, post hoc tests with Tukey adjustments for multiple comparisons were conducted to determine for which products the clusters had different emotion citation proportions.

For both liking and emotion clusters, a Chi-Square Goodness of Fit Test was used to determine if differences in proportions of age group, gender, diet group and PBMA consumption existed between each cluster. A Chi-Square Goodness of Fit Test was also used to determine if differences in proportions of emotion clusters existed between liking clusters.

3.2 Results

One hundred and three participants completed the study (mean ± SD age: 36.9 ± 9.5 years; 77 women and 26 males) **(Table 3.5)**. Participants self-reported as either flexitarians (n = 54) or omnivores (n = 49) and included non-users (n=43), low/medium users (n=36) and high-users (n=24) of PBMA.

Table 3.5. Participant demographics.

Demographic	Categories	Total (n)	Percentage
Gender	Male	26	25%
	Female	77	75%
Age	Millennial	70	68%
	Generation X	33	32%
Diet	Flexitarian	54	52%
	Omnivore	49	48%
PBMA consumption frequency	High user	24	23%
	Low/medium user	36	35%
	Non-user	43	42%

3.2.1 Perceived similarity of the products to a meat patty

The proportions of participants selecting each option on the 5-point Likert scale for perceived similarity to a meat patty for each product are shown in **Figure 3.2**. Clearly, Beef was perceived to be most meat-like with the majority of participants (98%) rating it as either *extremely or very meat-like (*median = 5 on 5-point Likert scale*)*. Of the meat analogue patties, Impossible Foods was observed to be the most meat-like with the majority of participants rating it either *very* (42%) or somewhat (32%) meat-like (median = 4). Similarly, Beyond Meats was rated *very meat-like* (36%) and *somewhat meat-like* (41%) (median = 3). For Birds Eye and Vegie Delights, the largest proportion of ratings were for *somewhat meat-like* (55% and 45%, respectively, median = 3). Quorn was reported as the least meat-like of the analogue patties with most participants rating it either *somewhat* (32%) or *not very meat-like* (36%) (median = 2). Interestingly, despite containing 40% beef mince, the largest proportion of ratings were for *somewhat* (36%) and *not very meat-like* (31%) (median = 2) for the Hybrid patty. For the wholefood patties over 50% of participants selected *not at all meat-like* (all median = 1).

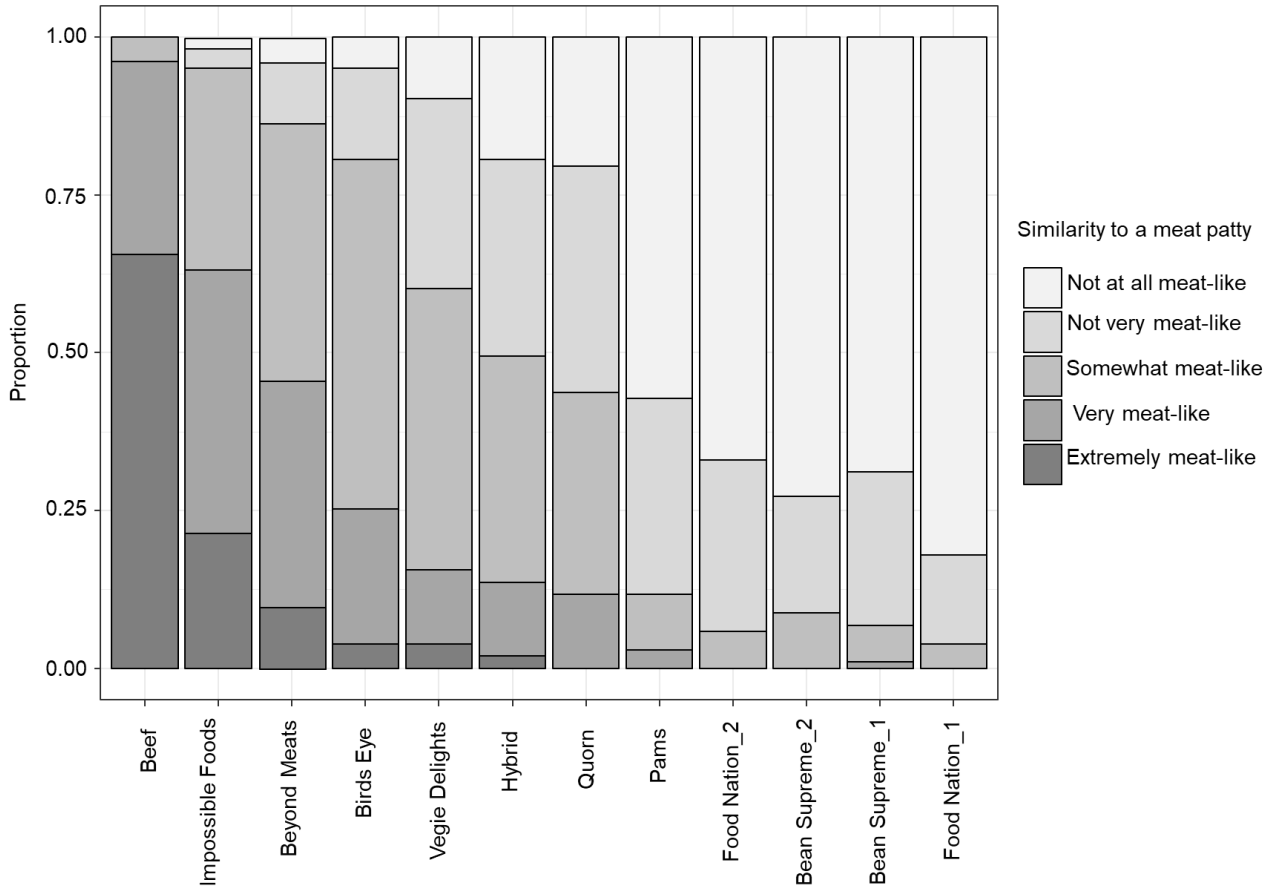


Figure 3.2. The proportion of participants selecting each option on the 5-point Likert scale for perceived similarity to a meat patty for each product.

3.2.2 Product liking

Mean overall liking ratings from the first visit for the two products assessed in both sessions (data not shown) showed strong agreement ($\kappa = 0.72$) with the second visit data. indicating participants were consistent in their liking ratings, at least for these two products. Additionally, from the LMM analysis of variance, no significant *visit* effects were observed for any of the liking modalities (all, $p>0.05$, **Table 3.6)**. A significant effect of *product* was observed for all liking modalities (overall, appearance, texture, and flavour) (all $p<0.001$, **Table 3.6**).

Table 3.6. Summary of F values and p-values from ANOVA of linear mixed effect models on ratings for each liking modality.

Liking Category	Product (DF=11)		Visit (DF=1)	
	F	p	F	p
Overall	6.3646	<0.001***	0.88	0.35
Appearance	11.2011	<0.001***	1.83	0.17
Texture	5.5899	<0.001***	0.05	0.82
Flavour	5.6214	<0.001***	0.06	0.80

Significant effects indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)

Product mean (±SE) liking ratings (overall, appearance, texture, and flavour) are presented in **Table 3.7**.

Table 3.7. Mean (±SE) liking ratings per product and post hoc comparisons.

Product	Overall liking	Appearance liking	Texture liking	Flavour liking
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Beef	6.9^{a} ± 0.1	6.9^{a} ± 0.1	6.6^{ab} ± 0.2	6.9^{a} ± 0.1
Impossible Foods	6.7^{ab} ± 0.1	7.0^{a} ± 0.1	6.9^{a} ± 0.1	6.6^{ab} ± 0.1
Beyond Meats	6.4^{abc} ± 0.2	6.8^{ab} ± 0.1	6.5^{ab} ± 0.1	6.3^{bc} ± 0.2
Birds Eye	6.1^{bc} ± 0.2	6.5^{ab} ± 0.1	6.0^{bc} ± 0.2	6.1^{bc} ± 0.2
Pams	5.9^{cd} ± 0.2	6.4^{ab} ± 0.2	5.5^{cd} ± 0.2	6.1^{bc} ± 0.2
Vegie Delights	5.8^{cd} ± 0.2	6.2^{bc} ± 0.2	5.6^{c} ± 0.2	5.9^{c} ± 0.2
Hybrid	5.2^{de} ± 0.2	5.7^{c} ± 0.2	4.9^{de} ± 0.2	5.6^{cd} ± 0.2
Quorn	5.0^{e} ± 0.2	5.7^{c} ± 0.2	4.7^{e} ± 0.2	5.1^{de} ± 0.2
Bean Supreme_2	4.7^{ef} ± 0.2	5.0^{d} ± 0.2	4.3^{ef} ± 0.2	4.8^{ef} ± 0.2
Food Nation_2	4.3^{fg} ± 0.2	4.2^{e} ± 0.2	4.2^{ef} ± 0.2	4.5^{ef} ± 0.2
Food Nation_1	4.1^{fg} ± 0.2	3.9^{e} ± 0.2	4.0^{f} ± 0.2	4.6^{ef} ± 0.2
Bean Supreme_1	4.0^{g} ± 0.2	4.1^{e} ± 0.2	4.0^{f} ± 0.2	4.2^{f} ± 0.2

abcdefg Different letters by column indicate significant differences between means across products (post hoc tests with Tukey adjustments for multiple comparisons).

Mean overall liking ratings ranged from 4.0 ± 0.2 (Bean Supreme_1) to 6.9 ± 0.1 (Beef). Similar ranges were also observed for appearance liking (3.9 ±0.2 to 7.0 ±0.1), texture liking (4.0 ± 0.2 to 6.9 ± 0.1) and flavour liking (4.2 ± 0.2 to 6.9 ± 0.1). Post hoc tests showed overlap but identified a subgroup of four products (Food Nation_1, Bean Supreme_1, Bean Supreme_2, Food Nation_2) with low overall liking ratings (less than 'five' - neither like nor dislike) and a subgroup of four products (Beef, Beyond Meats, Impossible Foods, Birds Eye) with higher overall liking ratings (above 'six', - 'like slightly'). Products receiving the lowest overall liking rating all belonged to

the wholefood classification whereas the liked products included Beef and three meat analogue samples. A moderate positive correlation (ρ>0.54, **Table 3.8**) was observed between perceived similarity to meat and all liking modalities.

With a few exceptions, similar subgroups were observed for the other liking modalities. Exceptions were that Vegie Delights and Pams were included in the higher liking subgroup for appearance liking, Quorn and Hybrid were included in the lower liking subgroup for texture liking, and Pams was included in the higher liking subgroup for flavour liking. The relative lack of sample fluctuation between liking subgroups is probably due to the strong positive correlation observed between overall liking and texture liking (Spearman correlation (ρ) =0.86, **Table 3.8**), and flavour liking (ρ = 0.92). The correlation between overall liking and appearance liking was less strong (ρ = 0.69). This was likely due to greater differences between appearance and overall liking for some products, particularly noticeable for Quorn, Hybrid and Pams patties, suggesting that for these samples expectations set by appearance were not fully met when the sample was tasted.

Table 3.8. Spearman correlations (ρ) of each liking modality to each other and perceived similarity.

	Appearance liking	**Flavour liking**	**Texture liking**	**Overall liking**	**Perceived similarity to meat**
Appearance liking	NA	0.62	0.66	0.69	0.55
Flavour liking		NA	0.75	0.92	0.54
Texture liking			NA	0.86	0.57
Overall liking				NA	0.58
Perceived similarity to meat					NA

3.2.3 Differential emotional response to the patties

Citation proportions (data not shown) for the two products assessed in both sessions showed a high correlation (ρ = 0.88) indicating a consistent participant emotional response, at least for these two products across the two sessions. Additionally, from the GLM analysis of deviance, no effect of *visit* was observed for any of the emotions (**Appendix G**). A significant main effect of *product* was observed for all emotion categories except ‘neutral’ and ‘anxious’. Mean product emotion citation proportions are reported in **Table 3.9**.

Table 3.9. Average emotion citation proportions across all products and emotion citation proportions for each product with results from post hoc tests with Tukey adjustments for multiple comparisons.

Emotion Category	Average citation across all products (±SE)	Beef	Hybrid	Beyond Meats	Impossible Foods	Vegie Delights	Birds Eye	Quorn	Pams	Food Nation_1	Food Nation_2	Bean Supreme_1	Bean Supreme_2
Adventurous	0.13±0.01	0.13 ab	0.10 ab	0.19 a	0.15 ab	0.17 ab	0.06 b	0.15 ab	0.18 ab	0.13 ab	0.14 ab	0.11 ab	0.11 ab
Afraid	0.03±0.01	0.01 b	0.03 ab	0.01 ab	0.00 b	0.02 ab	0.02 ab	0.02 ab	0.01 b	0.09 a	0.11 a	0.04 ab	0.03 ab
Amazed	0.09±0.01	0.15 ab	0.06 abcd	0.18 ab	0.19 a	0.11 abcd	0.12 abc	0.04 bcd	0.09 abcd	0.02 d	0.06 abcd	0.04 cd	0.07 abcd
Angry	0.02±0.01	0.01 b	0.05 ab	0.00 b	0.00 b	0.00 b	0.02 ab	0.02 ab	0.00 b	0.04 ab	0.03 ab	0.09 a	0.04 ab
Anxious	0.04±0.01	0.02 a	0.06 a	0.04 a	0.02 a	0.02 a	0.01 a	0.02 a	0.03 a	0.07 a	0.06 a	0.08 a	0.05 a
Bored	0.10±0.02	0.02 c	0.06 bc	0.05 bc	0.06 abc	0.11 abc	0.07 abc	0.12 abc	0.09 abc	0.09 bc	0.17 ab	0.23 a	0.15 ab
Calm	0.15±0.01	0.19 ab	0.17 ab	0.14 ab	0.20 ab	0.11 b	0.27 a	0.15 ab	0.17 ab	0.11 b	0.07 b	0.09 b	0.18 ab
Curious	0.30±0.02	0.17 c	0.33 ab	0.43 a	0.24 abc	0.32 abc	0.38 ab	0.32 abc	0.41 ab	0.22 bc	0.22 bc	0.23 ab	0.28 abc
Deceived	0.09±0.01	0.00 b	0.15 a	0.07 ab	0.07 ab	0.08 ab	0.06 ab	0.13 a	0.07 ab	0.09 ab	0.12 a	0.15 a	0.09 ab
Disappointed	0.22±0.03	0.09 fg	0.24 abcdef	0.06 g	0.11 defg	0.18 cdefg	0.10 efg	0.33 abc	0.16 bcdefg	0.38 ab	0.27 abcd	0.43 a	0.27 abcde
Disgusted	0.10±0.02	0.03 c	0.13 abc	0.02 c	0.03 c	0.05 c	0.03 c	0.06 c	0.04 c	0.24 a	0.23 ab	0.26 a	0.09 bc
Dissatisfied	0.22±0.03	0.10 d	0.25 abc	0.10 cd	0.11 cd	0.16 cd	0.14 cd	0.27 cd	0.16 cd	0.36 ab	0.36 ab	0.38 a	0.27 bcd
Energetic	0.12±0.02	0.22 ab	0.11 bcd	0.25 a	0.21 ab	0.12 abcd	0.08 cd	0.07 cd	0.12 abcd	0.04 d	0.06 cd	0.04 d	0.09 bcd

Table 3.9. Average emotion citation proportions across all products and emotion citation proportions for each product with results from post hoc tests with Tukey adjustments for multiple comparisons (continued).

Emotion Category	Average citation across all products (±SE)	Beef	Hybrid	Beyond Meats	Impossible Foods	Vegie Delights	Birds Eye	Quorn	Pams	Food Nation_1	Food Nation_2	Bean Supreme_1	Bean Supreme_2
Happy	0.25±0.03	0.45 a	0.21 de	0.44 ab	0.44 ab	0.29 abc	0.27 bc	0.16 cde	0.30 abc	0.07 e	0.15 cde	0.09 de	0.18 cd
Hopeful	0.15±0.01	0.15 ab	0.15 ab	0.17 ab	0.20 a	0.17 ab	0.20 a	0.17 ab	0.20 b	0.09 b	0.06 b	0.06 b	0.09 b
Hungry	0.12±0.02	0.29 a	0.15 abc	0.18 ab	0.21 ab	0.12 bcd	0.11 bcd	0.13 bcd	0.12 bcd	0.05 cd	0.04 cd	0.00 d	0.06 bcd
Loving	0.09±0.01	0.15 a	0.10 abc	0.16 a	0.15 a	0.09 abc	0.15 a	0.08 abc	0.10 abc	0.02 c	0.05 abc	0.01 bc	0.06 abc
Neutral	0.18±0.01	0.15 a	0.20 a	0.13 a	0.16 a	0.20 a	0.26 a	0.16 a	0.17 a	0.14 a	0.20 a	0.18 a	0.20 a
Nostalgic	0.07±0.01	0.13 a	0.07 ab	0.09 ab	0.08 ab	0.09 ab	0.12 ab	0.05 ab	0.05 ab	0.04 b	0.05 ab	0.02 ab	0.06 ab
Pleasant/ Grateful	0.27±0.04	0.38 ab	0.22 bcd	0.45 a	0.47 a	0.23 bcd	0.41 ab	0.16 d	0.38 abc	0.12 d	0.10 d	0.10 d	0.18 cd
Satisfied	0.27±0.04	0.51 a	0.25 bcd	0.39 ab	0.43 ab	0.30 bc	0.32 bc	0.18 cdef	0.33 bc	0.09 f	0.11 def	0.07 f	0.22 bcde
Suspicious	0.15±0.02	0.07 c	0.15 abc	0.15 abc	0.07 bc	0.11 bc	0.09 bc	0.13 bc	0.11 bc	0.26 a	0.28 a	0.18 ab	0.16 abc
Uncertain	0.23±0.02	0.12 c	0.22 abc	0.23 abc	0.11 bc	0.24 abc	0.18 abc	0.27 ab	0.20 abc	0.28 ab	0.36 a	0.29 ab	0.28 ab
Unhappy/Sad	0.13±0.02	0.04 e	0.17 abcd	0.02 e	0.06 de	0.08 cde	0.05 de	0.11 bcde	0.10 cde	0.24 ab	0.21 abc	0.31 a	0.13 bcde

[abcdefg]Different lowercase letters by row indicate significant differences between means across products obtained from post hoc tests with Tukey adjustments for multiple comparisons.

‘Curious’ was the most frequently cited emotion, followed by ‘satisfied’, ‘pleasant/grateful’, ‘uncertain’, ‘disappointed’, and ‘dissatisfied’ (average across products all > 20%). In contrast, emotion categories ‘anxious’, ‘afraid’, and ‘angry’ received low average citation proportions across the products (<5%).

Figure 3.3 presents a PCA biplot showing the relationship between each emotion and products, the first two principal components accounted for 78.3% of the variation in the data. Correlation coefficients of important emotion attributes to PC1 and PC2 are presented in **Appendix H.**

PC1 (67.7%) differentiated emotions based on positive and negative valence. PC1 was highly positively correlated (all r>0.76, **Appendix H**) with all 11 negative emotions (‘afraid’, ‘angry’, ‘anxious’, ‘bored’, ‘deceived’, ‘disappointed’, ‘disgusted’, ‘dissatisfied’, ‘suspicious’, ‘uncertain’’, unhappy’), and was highly negatively correlated (all r>-0.67) with ten positive emotions (‘calm’, ‘amazed’, ‘energetic’, ‘happy’, ‘hopeful’, ‘hungry’, ‘loving’, ‘nostalgic’, ‘pleasant’, ‘satisfied’). PC2, only accounting for 10.5% of the variation, differentiated products based on arousal, and was highly positively correlated (r=0.76) with ‘adventurous’ and negatively correlated) with ‘calm’(r=-0.63) and ‘neutral’(r=-0.88). ‘Energetic’ was moderately positively correlated with PC2 (r=0.43).

‘Curious’ was highly positively correlated with PC3 (r=0.73) (not shown, accounting for 7.4% of variance). The valence of each emotion had been classified during the lexicon development stage and was confirmed by the positioning of the emotions on the PCA biplot. The ‘curious’ emotion was unclassified but was somewhat positioned in the direction of the positive emotions on the biplot.

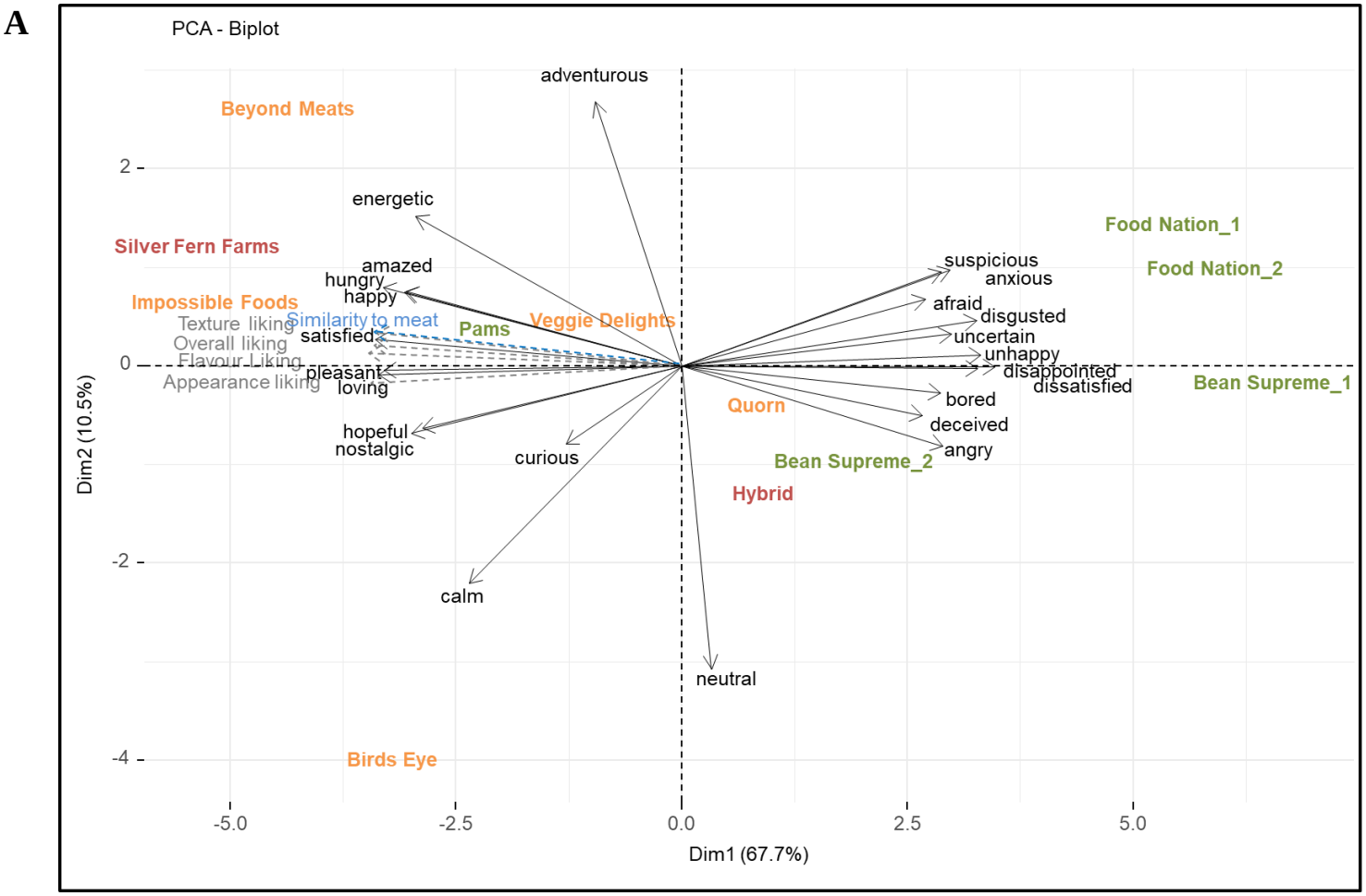


Figure 3.3. A) PCA biplot of the relationship between emotion categories and products for PC1 and PC2. Products shown in green = wholefood patties, orange = meat analogue patties and red = beef patty and hybrid patty. Liking modalities and perceived similarity to meat are projected as supplementary variables.

B

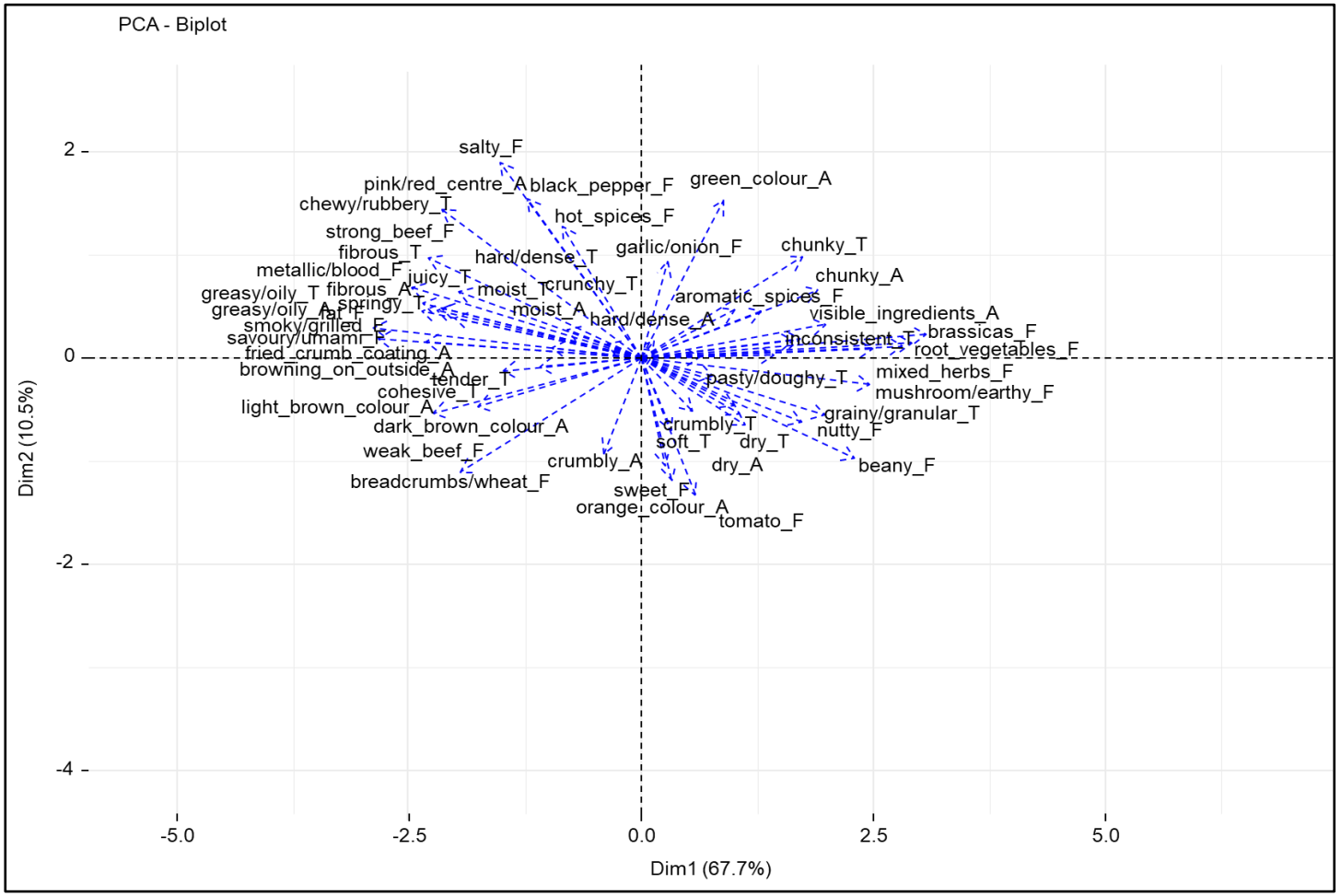


Figure 3.3. B) Sensory attributes projected (supplementary variables) on Emotion PC1 and PC2 biplot.

The general positioning of the products on the PCA biplot shows Beef, Beyond Meats, and Impossible Foods, and to a lesser extent Birds Eye, Pams and Vegie Delights projected highly negatively on PC1, associating with positive emotions. In contrast, Food Nation_1, Food Nation_2, Bean Supreme_1, and to a lesser extent Bean Supreme_2, Quorn, and Hybrid were projected positively on PC1, therefore associating with negative emotions. The projection of products on PC1 was in keeping with the liking ratings, with more liked products projected in the negative direction towards positive emotions and less liked products projected in the positive direction towards negative emotions. The projection of liking ratings (overall, texture, appearance, and flavour), and perceived similarity to meat, as supplementary variables were also highly negatively correlated with PC1 (all $\rho>0.86$, **Appendix H**) in the direction of emotions 'satisfied', 'pleasant/grateful' and 'loving'. Patties falling mid-range for liking (e.g. Vegie Delights, Quorn, Pams, Hybrid) were positioned more centrally on PC1.

Beyond Meats was projected highly positively on PC2, showing an association with higher arousal and received the highest citation proportion for 'adventurous'. Beef, Food Nation_2, and Food Nation_1 were projected somewhat positively on PC2 but not as much as Beyond Meats. Birds Eye was projected highly negatively on PC2, showing an association with lower arousal emotions, likely due to its high citation proportion for 'calm' and low citation proportion for 'adventurous'. Hybrid and Bean Supreme_2 were also positioned somewhat negatively on PC2. The other patties did not load particularly in either direction of PC2. The 'neutral' emotion was also highly negatively correlated with PC2 but did not discriminate between the patties according to GLM analysis of deviance **(Appendix G**). Pams, Quorn, and Beyond Meats were projected highly positively on PC3, indicating a strong positive association with the emotion 'Curious.' In contrast, Beef was projected highly negatively on PC3. This aligns with the citation proportions, as Beef received the lowest citation proportion for 'Curious,' while Beyond and Pams received the highest citation proportions for this emotion.

3.2.3.1 Distinguishing emotions between similarly liked products

Significant differences in citation proportions for some emotions were found for products that did not significantly differ in overall liking (**Table 3.10**). These emotions represented both valence (e.g. 'happy') and arousal (e.g. 'calm', 'energetic') as well as 'curious'. For example, Beef, and Beyond Meats did not significantly differ in overall liking, however, the citation proportion for 'curious' was significantly higher for Beyond Meats compared to Beef. Food Nation_1 received significantly higher citation proportions compared to Bean Supreme_2 for the emotion 'disgusted' and Bean Supreme_2 received higher citation proportions for emotions 'happy' and 'satisfied' compared to Food Nation_1.

Table 3.10. Significant differences in emotion citation proportion for similarly liked products.

Emotion	Product Comparison	Emotion Citation proportion	Overall Liking Rating
Curious	Beyond Meats vs. Beef	0.43^{a} vs. 0.17^{c}	6.4 ± 0.2^{ABC} vs. 6.9 ± 0.1^{ABC}
Pleasant/grateful	Beyond Meats vs. Vegie Delights	0.45^{a} vs. 0.23^{bcd}	6.4 ± 0.2^{ABC} vs. 5.8 ± 0.2^{CD}
Calm	Birds Eye vs. Vegie Delights	0.27^{a} vs. 0.11^{b}	6.1 ± 0.2^{BC} vs. 5.8 ± 0.2^{CD}
Energetic	Beyond Meats vs. Birds Eye	0.25^{a} vs. 0.08^{d}	6.4 ± 0.2^{ABC} vs. 6.1 ± 0.2^{BC}
Energetic	Impossible Foods vs. Birds Eye	0.21^{ab} vs. 0.08^{d}	6.7 ± 0.1^{AB} vs. 6.1 ± 0.2^{BC}
Happy	Bean Supreme_2 vs. Food Nation_1	0.18^{cd} vs. 0.07^{e}	4.7 ± 0.2^{EF} vs. 4.1 ± 0.2^{FG}
Satisfied	Bean Supreme_2 vs. Food Nation_1	0.23^{bcde} vs. 0.09^{f}	4.7 ± 0.2^{EF} vs. 4.1 ± 0.2^{FG}
Disgusted	Food Nation_1 vs. Bean Supreme_2	0.24^{a} vs. 0.09^{bc}	4.1 ± 0.2^{FG} vs. 4.7 ± 0.2^{EF}
Bored	Bean Supreme_1 vs. Food Nation_1	0.23^{a} vs. 0.09^{bc}	4.0 ± 0.2^{G} vs. 4.1 ± 0.2^{FG}

^{abcde}Different lowercase letters by row indicate significant differences between mean emotion citation proportions across products. ^{ABCDEF}different uppercase letters by row indicate significant differences between overall liking ratings across products obtained from post hoc tests with Tukey adjustments for multiple comparisons.

3.2.4 Product sensory differentiation

Citation proportions (data not shown) for the two products assessed in both sessions showed high correlation ($\rho = 0.97$) indicating participants were consistent in their sensory assessments for these two products. Additionally, from GLM analysis of deviance, a significant effect of *visit* was only observed for two sensory attributes ('visible ingredients' appearance ($p=0.052$) and 'hard/dense' texture ($p=0.016$)) **(Appendix I).** A significant main effect of *product* was found for all sensory attributes (all $p<0.001$) **(Appendix I)**. Sensory attributes citation proportions for each product are presented in **Table 3.11**.

Table 3.11. Sensory attributes citation proportions for the twelve patty products and post hoc groups following Tukey adjustments for multiple comparisons.

Modality	Attribute	Beef	Hybrid	Beyond Meats	Impossible Foods	Vegie Delights	Birds Eye	Quorn	Pams	Food Nation_1	Food Nation_2	Bean Supreme_1	Bean Supreme_2
Appearance	Browning on outside	0.84 abc	0.72 bcde	0.89 a	0.85 abc	0.80 abcd	0.84 abc	0.76 abcd	0.24 f	0.69 de	0.57 e	0.72 bcde	0.68 cde
	Fried crumb coating	0.17 cd	0.28 bc	0.17 cd	0.07 de	0.39 b	0.10 de	0.12 cd	0.93 a	0.03 e	0.05 de	0.08 de	0.08 de
	Dark brown colour	0.16 bc	0.04 cd	0.02 cd	0.27 ab	0.12 bc	0.16 abc	0.15 abc	0.01 cd	0.02 d	0.09 cd	0.34 a	0.02 cd
	Light brown colour	0.50 bcde	0.46 de	0.71 ab	0.63 abc	0.66 abc	0.73 a	0.70 a	0.15 g	0.03 h	0.36 def	0.19 fg	0.15 g
	Green colour	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.00 d	0.13 bc	0.93 a	0.17 b	0.05 cd	0.11 bc
	Orange colour	0.00 d	0.65 ab	0.16 cd	0.02 d	0.16 cd	0.15 cd	0.14 cd	0.59 a	0.05 d	0.19 bc	0.01 d	0.79 a
	Greasy/oily	0.47 a	0.50 a	0.50 a	0.50 a	0.35 ab	0.52 a	0.24 bc	0.42 ab	0.49 a	0.36 ab	0.07 d	0.08 cd
	Dry	0.19 cd	0.06 de	0.08 de	0.11 cd	0.30 bc	0.08 cde	0.44 ab	0.11 cd	0.01 e	0.01 de	0.63 a	0.60 a
	Pink/red centre	0.45 a	0.09 c	0.17 bc	0.12 c	0.12 bc	0.01 c	0.03 c	0.02 c	0.00 c	0.29 ab	0.00 c	0.05 c
	Moist	0.30 b	0.64 a	0.59 a	0.48 a	0.29 b	0.60 a	0.24 b	0.47 a	0.62 a	0.60 a	0.01 c	0.03 c
	Fibrous	0.36 ab	0.09 de	0.40 a	0.33 abc	0.21 bcd	0.31 abc	0.12 de	0.04 e	0.12 de	0.10 de	0.18 bcde	0.14 cde
	Hard/dense	0.45 a	0.01 b	0.11 b	0.21 b	0.13 b	0.15 b	0.08 b	0.10 b	0.15 b	0.13 b	0.57 a	0.40 a
	Crumbly	0.06 fg	0.46 ab	0.21 def	0.12 cdefg	0.29 cdef	0.08 bcde	0.67 a	0.23 bcd	0.02 g	0.05 efg	0.22 de	0.42 abc

Table 3.11. Sensory attributes citation proportions for the twelve patty products and post hoc groups following Tukey adjustments for multiple comparisons (continued).

Modality	Attribute	Beef	Hybrid	Beyond Meats	Impossible Foods	Vegie Delights	Birds Eye	Quorn	Pams	Food Nation_1	Food Nation_2	Bean Supreme_1	Bean Supreme_2
Texture/ Mouthfeel	Chunky	0.31 c	0.16 cde	0.23 cde	0.22 cde	0.13 de	0.14 e	0.19 cde	0.14 e	0.21 cde	0.35 bcd	0.52 ab	0.60 a
	Visible ingredients	0.12 ef	0.47 c	0.12 def	0.03 f	0.14 de	0.12 ef	0.33 d	0.77 bc	0.82 b	0.88 ab	0.85 ab	0.92 a
	Dry	0.17 bc	0.01 d	0.07 cd	0.18 bc	0.23 bc	0.03 d	0.47 a	0.12 cd	0.01 d	0.00 d	0.59 a	0.61 a
	Moist	0.34 de	0.77 ab	0.58 abc	0.51 bcd	0.37 de	0.65 abc	0.30 ef	0.48 cde	0.73 a	0.72 a	0.07 g	0.14 fg
	Juicy	0.33 a	0.31 a	0.37 a	0.22 a	0.03 d	0.21 ab	0.07 bcd	0.05 cd	0.08 cd	0.18 abc	0.01 d	0.00 d
	Chewy/rubbery	0.62 a	0.05 de	0.34 b	0.35 b	0.21 bc	0.18 bcd	0.04 e	0.18 bcd	0.17 cde	0.19 bc	0.15 cde	0.18 bcde
	Cohesive	0.21 bcd	0.13 cde	0.21 bcde	0.23 bcd	0.27 bc	0.34 b	0.07 e	0.32 bc	0.25 bc	0.17 cde	0.09 de	0.15 bcde
	Greasy/oily	0.48 a	0.37 ab	0.39 ab	0.41 ab	0.25 bc	0.40 ab	0.12 cd	0.38 ab	0.34 b	0.25 bc	0.07 d	0.04 d
	Grainy	0.14 de	0.27 bc	0.18 bcd	0.17 cde	0.20 bcd	0.12 de	0.36 b	0.20 bcde	0.08 e	0.33 bc	0.65 a	0.65 a
	Hard/dense	0.33 a	0.010 bc	0.06 bc	0.05 bc	0.10 b	0.02 c	0.01 c	0.01 c	0.02 c	0.01 c	0.29 a	0.29 a
	Soft	0.09 d	0.78 a	0.44 c	0.42 c	0.50 bc	0.69 ab	0.66 ab	0.68 ab	0.77 a	0.73 a	0.15 d	0.14 d
	Pasty/ doughy	0.01 f	0.30 bc	0.08 def	0.08 def	0.38 b	0.27 bcd	0.11 cde	0.68 a	0.42 b	0.39 b	0.12 de	0.07 def
	Springy	0.30 ab	0.09 def	0.37 ab	0.28 abc	0.15 cdef	0.38 a	0.05 ef	0.20 bcd	0.29 ab	0.16 bcde	0.02 f	0.04 ef

Table 3.11. Sensory attributes citation proportions for the twelve patty products and post hoc groups following Tukey adjustments for multiple comparisons (continued).

Modality	Attribute	Beef	Hybrid	Beyond Meats	Impossible Foods	Vegie Delight	Birds Ey	Quorn	Pams	Food Nation_1	Food Nation_2	Bean Supreme_1	Bean Supreme_2
Texture/ Mouthfeel	Tender	0.29 c	0.45 abc	0.51 ab	0.56 a	0.32 bc	0.60 a	0.30 bc	0.31 bc	0.47 ab	0.42 abc	0.12 c	0.09 c
	Chunky	0.34 c	0.14 def	0.20 cdef	0.24 cde	0.14 def	0.08 f	0.13 ef	0.08 f	0.14 ef	0.34 bcd	0.49 ab	0.53 a
	Fibrous	0.35 a	0.15 cde	0.33 ab	0.29 abc	0.21 abcde	0.21 abcd	0.10 de	0.06 e	0.10 de	0.07 de	0.17 bcde	0.13 cde
	Inconsistent	0.11 d	0.22 cd	0.13 cd	0.10 cd	0.16 cd	0.09 cd	0.15 bcd	0.18 bcd	0.26 bc	0.48 a	0.41 ab	0.48 a
	Crunchy	0.07 abc	0.00 c	0.06 bc	0.03 abc	0.13 ab	0.01 abc	0.02 abc	0.10 ab	0.01 c	0.03 abc	0.10 abc	0.22 a
	Crumbly	0.05 ef	0.35 bc	0.22 cde	0.15 cdef	0.24 cd	0.04 ef	0.74 a	0.12 cdef	0.03 f	0.07 def	0.47 ab	0.57 a
Flavour/ Taste	Smoky/ Grilled	0.52 ab	0.26 bc	0.65 a	0.51 ab	0.48 ab	0.49 ab	0.26 c	0.11 d	0.09 d	0.14 cd	0.17 cd	0.19 cd
	Strong beef	0.83 a	0.06 de	0.24 bc	0.30 bc	0.09 de	0.10 de	0.03 e	0.01 e	0.00 e	0.00 e	0.01 e	0.00 e
	Weak beef	0.11 c	0.38 a	0.38 a	0.56 a	0.33 ab	0.49 a	0.41 a	0.06 c	0.07 c	0.10 bc	0.07 c	0.11 bc
	Metallic/ blood	0.15 a	0.05 bc	0.05 bc	0.11 ab	0.00 c	0.05 bc	0.04 bc	0.00 c	0.02 c	0.03 bc	0.00 c	0.02 bc
	Breadcrumbs/wheat	0.04 d	0.23 b	0.10 bcd	0.17 bc	0.21 b	0.23 b	0.25 b	0.67 a	0.06 cd	0.14 bcd	0.16 bc	0.20 b
	Fat	0.50 a	0.14 bcde	0.25 bc	0.35 b	0.20 bcd	0.30 b	0.08 de	0.13 cde	0.10 de	0.08 de	0.03 e	0.01 e
	Black pepper	0.70 a	0.06 d	0.11 cd	0.11 cd	0.44 b	0.08 d	0.10 cd	0.24 cd	0.38 b	0.13 cd	0.12 cd	0.13 cd

Table 3.11. Sensory attributes citation proportions for the twelve patty products and post hoc groups following Tukey adjustments for multiple comparisons (continued).

Modality	Attribute	Beef	Hybrid	Beyond Meats	Impossible Foods	Vegie Delight	Birds Ey	Quorn	Pams	Food Nation_1	Food Nation_2	Bean Supreme_1	Bean Supreme_2
Flavour/ Taste	Salty	0.47 ab	0.32 bc	0.45 abc	0.40 abc	0.50 a	0.31 c	0.31 c	0.36 abc	0.39 abc	0.30 c	0.38 abc	0.28 c
	Savoury/ umami	0.37 b	0.35 b	0.55 a	0.47 ab	0.41 ab	0.48 ab	0.38 ab	0.40 ab	0.34 b	0.35 b	0.37 b	0.34 b
	Sweet	0.01 e	0.30 a	0.12 bcd	0.09 abcde	0.07 bcde	0.16 abcd	0.09 abcde	0.22 ab	0.07 cde	0.22 ab	0.03 de	0.19 abc
	Mixed herbs	0.16 de	0.46 bc	0.16 de	0.11 e	0.43 bc	0.15 de	0.53 b	0.63 b	0.56 b	0.28 cd	0.24 de	0.46 bc
	Beany	0.00 c	0.20 bc	0.29 bc	0.18 c	0.27 bc	0.36 bc	0.28 bc	0.22 bc	0.33 b	0.37 b	0.60 a	0.66 a
	Nutty	0.02 e	0.07 bcde	0.19 bc	0.09 cde	0.18 bcd	0.15 bcd	0.15 bcd	0.13 bcd	0.05 de	0.26 ab	0.51 a	0.61 a
	Garlic/ onion	0.21 ef	0.42 abc	0.29 cdef	0.17 f	0.48 ab	0.22 ef	0.42 bcd	0.57 a	0.55 a	0.26 def	0.27 cdef	0.33 bcde
	Root vegetables	0.01 g	0.39 bc	0.06 fg	0.04 fg	0.14 def	0.09 efg	0.10 efg	0.35 bcd	0.38 bc	0.78 a	0.26 cde	0.49 a
	Brassicas	0.01 e	0.10 bcde	0.02 de	0.01 e	0.05 cde	0.06 cde	0.10 bcd	0.10 bcd	0.30 a	0.21 ab	0.15 bc	0.17 abc
	Tomato	0.01 f	0.69 c	0.07 cdef	0.03 cdef	0.19 abc	0.14 abcde	0.16 ab	0.12 abcde	0.03 ef	0.17 abc	0.06 cdef	0.28 bc
	Mushroom/ earthy	0.02 e	0.19 cd	0.21 cd	0.20 bc	0.17 cd	0.26 abc	0.21 bc	0.04 de	0.24 c	0.43 ab	0.58 a	0.15 cd
	Hot spices	0.13 b	0.03 b	0.02 b	0.01 b	0.39 a	0.00 b	0.07 b	0.46 a	0.38 a	0.08 b	0.03 b	0.09 b
	Aromatic Spices	0.15 g	0.35 bcdef	0.18 efg	0.13 g	0.42 bc	0.20 efg	0.37 bcdef	0.43 cd	0.63 a	0.23 defg	0.24 bcdefg	0.37 ced

[abcdef]Different lowercase letters across rows indicate significant differences between means across products obtained from post hoc tests with Tukey adjustments for multiple comparisons ($p<0.05$)

In general, the most frequently used sensory attributes were; 'browning on outside' appearance, 'soft' texture, 'visible ingredients' appearance, 'moist' texture and appearance, 'light brown colour' appearance, and 'savoury/umami' flavour. In contrast, other attributes were highly specific to one or two products e.g., 'fried crumb coating' appearance (Pams), 'green colour' appearance (Food Nation_1), 'tomato' flavour (Hybrid), 'strong beef' flavour (Beef), and 'nutty' flavour (Bean Supreme_1 and Bean Supreme_2).

For meat analogue patties, the most frequently cited sensory attributes were; 'browning on outside' appearance, 'light brown colour' appearance, 'soft' texture', 'moist' texture, 'weak beef' flavour, 'smoky/grilled' flavour, 'savoury/umami' flavour, and 'tender' texture. Most frequently cited sensory attributes for wholefood patties included 'visible ingredients' appearance, 'inconsistent' texture, 'root vegetable' flavour, and 'beany' flavour. These attributes were also commonly detected in Hybrid.

Beef had a significantly higher citation proportion for 'strong beef' flavour compared to the other patties. A 'weak beef' flavour was more prominent for the Hybrid and meat analogue patties. Impossible Foods had the highest citation proportion for 'weak beef' flavour but was not significantly different to the other meat analogue patties and the Hybrid. The citation proportions for 'fat' flavour, 'pink/red centre' appearance 'black pepper' flavour and 'chewy rubbery' texture were significantly higher for Beef compared to all of the other patties. Beef also had a significantly higher citation proportion for 'hard/dense' texture compared to the Hybrid and meat analogue patties. In contrast, the Hybrid and meat analogues were significantly higher for 'soft' texture compared to Beef. Citation proportions of 'smoky/grilled' flavour were not significantly different between Beef and the meat analogue patties, except for Quorn which had a lower citation proportion. Of note, a 'mushroom/earthy' flavour and 'beany' flavour was detected by approximately 20-30% of respondents in Hybrid and all of the meat analogue patties but not in Beef.

PCA biplots were produced showing the relationship between sensory attributes and product. The first four principal components of the PCA accounted for 78.5% of the variance. **Figure 3.4A**

shows the PCA biplot for PC1 versus PC2 and **Figure 3.4B** shows the PCA biplot for PC3 versus PC4. Correlations of important sensory attributes from PC1 to PC4 are presented in **Appendix J.**

PC1 (33.4%) was positively correlated with appearance attributes 'light brown colour', 'greasy/oily', and 'fibrous', flavour attributes 'fat', 'smoky/grilled', 'metallic/blood', 'strong beef', 'weak beef', and 'savoury/umami', and texture attributes 'greasy/oily', 'springy', 'juicy', 'fibrous', 'tender', and 'chewy/rubbery'. In contrast, PC1 was negatively correlated with appearance attributes 'visible ingredients', 'dry', and 'chunky', flavour attributes 'beany', 'nutty', 'brassica', 'root vegetable', and 'mixed herbs', and texture attributes 'inconsistent', 'grainy/granular', 'dry', and 'crumbly'. PC1 differentiated the products based on sensory similarity to a beef patty. The Beef and meat analogue patties, except for Quorn and Hybrid, were projected positively on PC1. In contrast, the wholefood patties were positioned negatively on PC1. Quorn was positioned closer to the wholefood patties, while the Hybrid was positioned in the centre. The projection of all liking modalities (overall, texture, appearance, and flavour) as supplementary variables were highly positively correlated with PC1 (all $\rho>0.75$, **Appendix J**) in the direction of sensory attributes 'weak beef' flavour, 'light brown colour' appearance and 'juicy' texture. The projection of perceived similarity to meat as a supplementary variable was also highly positively correlated with PC1 ($\rho=0.88$) but was positioned closer to flavour attributes 'smoky/grilled', 'strong beef' and 'metallic/blood'.

PC2 (24.6%) differentiated the products mainly based on their appearance and textural properties. PC2 was positively correlated with 'moist' appearance, 'soft', 'pasty/doughy' and 'moist' texture, and 'garlic/onion', 'aromatic spices', and 'mixed herbs' flavour. PC2 was negatively correlated with appearance attributes 'hard/dense', 'chunky', 'dry' and 'dark brown colour' and texture attributes 'hard/dense', 'chunky' and 'dry'. The wholefood patties were clearly separated by PC2 with Pams, Food Nation_1, and Food Nation_2 positioned in the positive direction, and Bean Supreme_1 and Bean Supreme_2 positioned in the negative direction. The Beef and meat analogue patties, Beyond Meats, Impossible Foods, and Beef were positioned in the negative

A

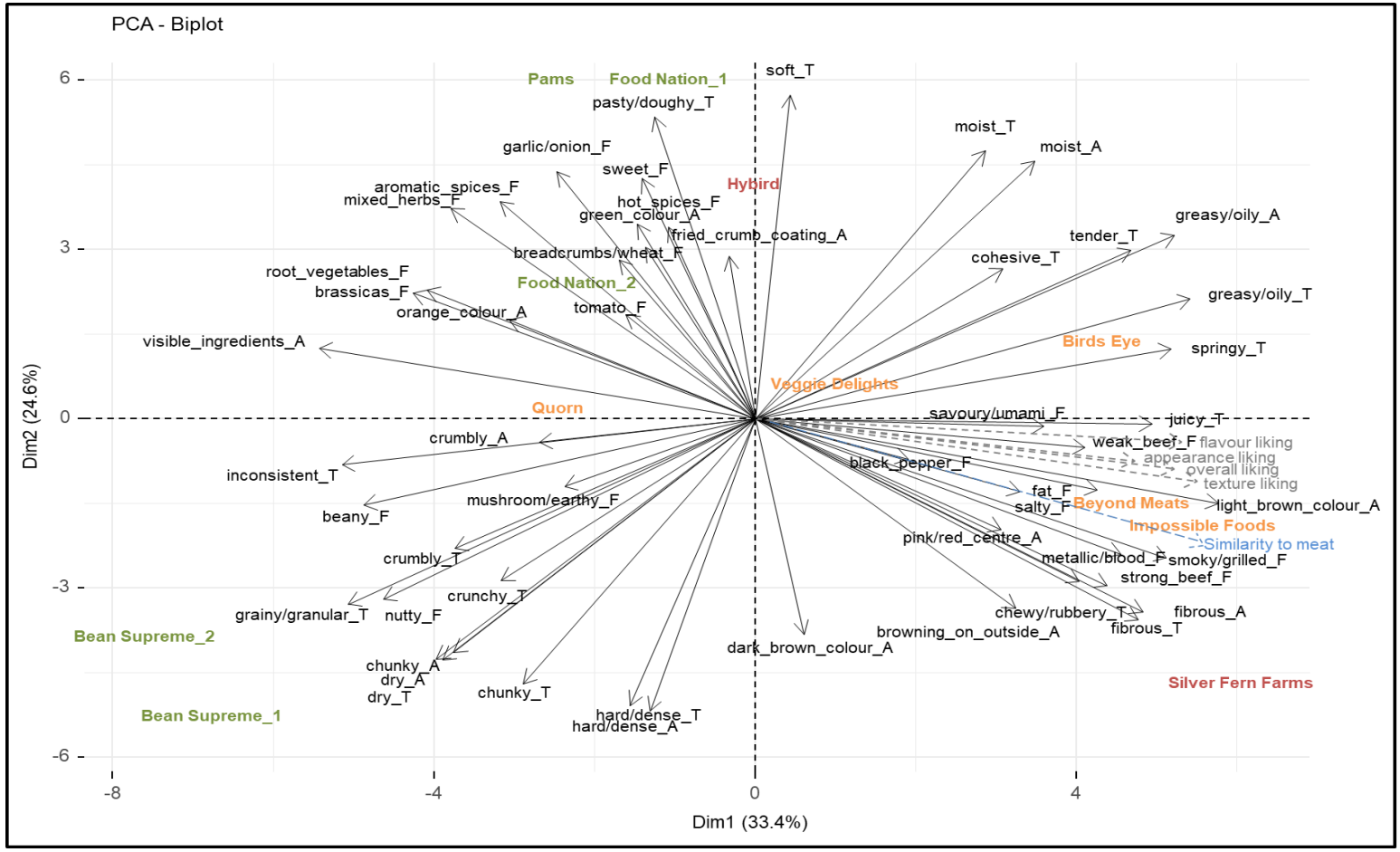


Figure 3.4. A) PCA biplot visualising the relationship between sensory attributes and products for PC1 and PC2 Products shown in green = wholefood patties, orange = meat analogue patties and red = beef patty and hybrid patty. Liking modalities and perceived similarity to meat are projected as supplementary variables. _F denotes flavour attributes, _A appearance attributes and _T texture attributes.

B

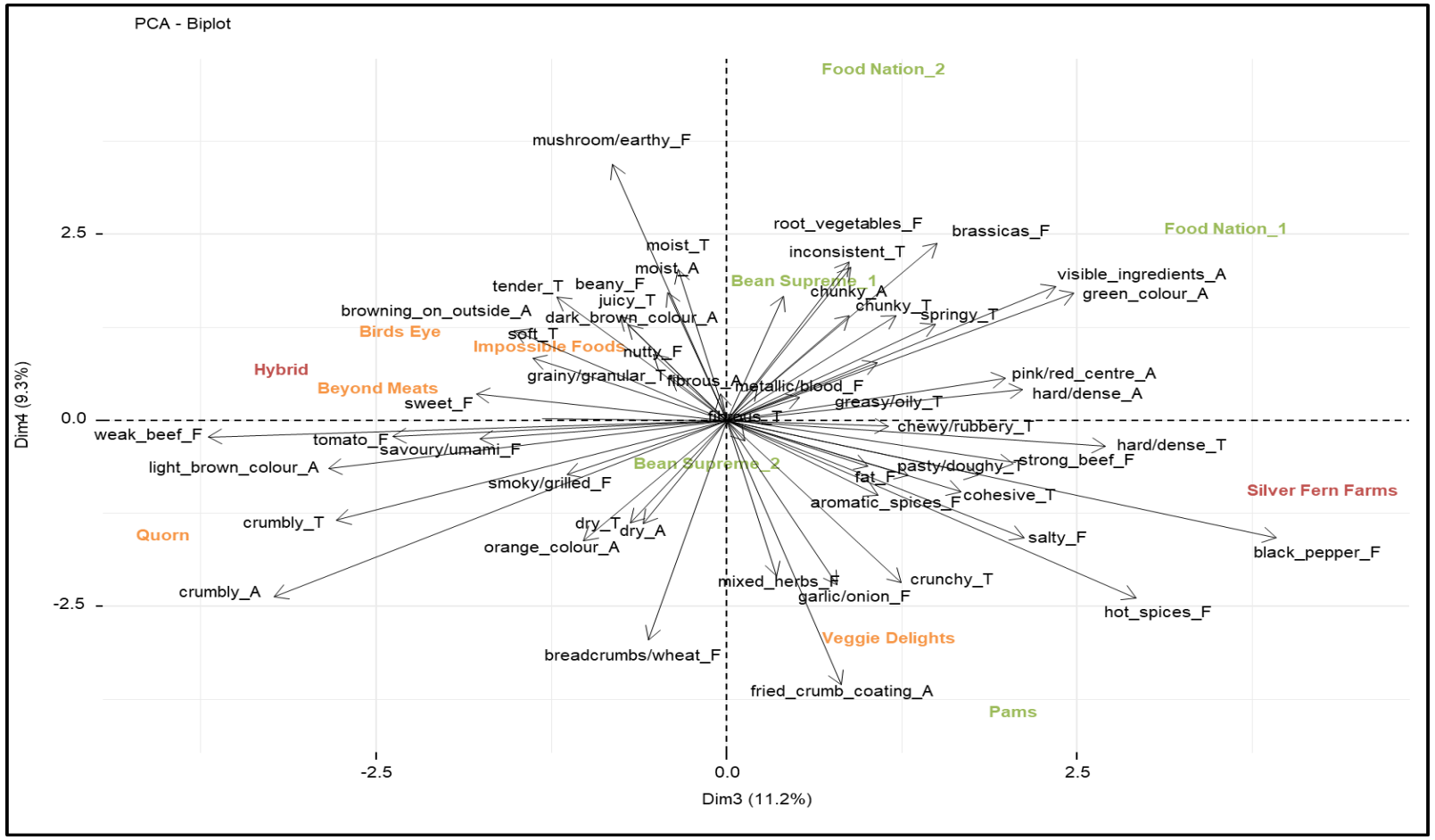


Figure 3.4.B) PCA biplot visualising the relationship between sensory attributes and products for PC3 and PC4. Products shown in green = wholefood patties, orange = meat analogue patties and red = beef patty and hybrid patty. Liking modalities and perceived similarity to meat are projected as supplementary variables. _F denotes flavour attributes, _A appearance attributes and _T texture attributes (continued).

direction and Hybrid and Birds Eye were positioned in the positive direction. Quorn and Vegie Delights were positioned close to the centre.

PC3 (11.2%) and PC4 (9.3%) further differentiated the products. Attributes 'hot spices' flavour and 'black pepper' flavour were positively correlated to PC3. The wholefood patties (except Bean Supreme_2), Beef, and Vegie Delights were positioned in the positive direction on PC3. Attributes 'crumbly' appearance and 'weak beef' flavour were most negatively correlated with PC3. The meat analogue patties (except for Vegie Delights), and to a lesser extent Bean Supreme_2, were positioned negatively on PC3. Quorn was positioned closely to 'crumbly' appearance and texture, 'weak beef' flavour and 'light brown colour' appearance, while Birds Eye, Impossible Foods, Beyond Meats and Hybrid were positioned closest to 'weak beef flavour'. Attribute 'mushroom/earthy' flavour was positively correlated with PC4. Food Nation_2 was positioned highly positively on PC4. Attributes 'breadcrumb/wheat' flavour, and 'fried crumb coating' appearance were most negatively correlated with PC4. Vegie Delights and Pams were positioned highly negatively on PC4.

3.2.5 Sensory predictors of overall liking

Thirty of the 51 sensory attributes were identified as significant predictors of overall liking, of which 13 were flavour attributes (**Table 3.12**). For ordinal logistic regression a positive regression coefficient indicates the presence of an attribute increases the odds of a product being liked i.e., rating in higher liking categories is more likely. Indicated by the highest regression coefficient, a 'strong beef' flavour was identified as the top predictor of liking (RC=1.73) followed by 'juicy' texture (RC=0.64). Other attributes identified as significant predictors of liking included 'fried crumb coating', 'light brown colour', and 'moist' appearance; 'weak beef', 'smoky/grilled' 'mixed herbs', 'savoury/umami', 'garlic and onion', 'breadcrumb/wheat', 'salty', and 'fat' flavour; and 'tender', 'cohesive', 'moist', and 'crunchy' texture. Not surprisingly, these drivers align with the projection of liking rating as a supplementary variable on the sensory PCA biplot (**Figure 3.4A**).

'Green colour' appearance was identified as the top predictor of disliking (RC= -1.23) followed by 'pasty/doughy' texture (RC= -0.76). Other attributes identified as significant predictors of disliking included 'hard/dense', 'crumbly', and 'dry' appearance, 'root vegetable', 'beany', 'brassica', and 'metallic/blood' flavour, 'hard/dense', 'chewy/rubbery', 'inconsistent', and 'dry' texture.

Table 3.12. Regression coefficients and associated p-values for all sensory attributes as determined by ordinal logistic regression model for predicting overall liking.

Modality	Attribute	Regression coefficient	p-value
Appearance	Green colour	-1.23	<0.001***
	Fried crumb coating	0.35	0.007**
	Fibrous	0.29	0.131
	Crumbly	-0.22	0.013*
	Dark brown colour	0.19	0.145
	Hard/ Dense	-0.17	<0.001***
	Light brown colour	0.14	0.003**
	Moist	0.13	<0.001***
	Orange colour	-0.07	0.596
	Pink/red centre	0.06	0.338
	Visible ingredients	0.03	0.648
	Dry	-0.02	<0.001***
	Browning on outside	0.02	0.952
	Greasy/ Oily	0.006	0.065
Texture	Pasty/ Doughy	-0.76	<0.001***
	Juicy	0.64	<0.001***
	Hard/ Dense	-0.59	0.001***
	Tender	0.40	<0.001***
	Chewy/ Rubbery	-0.37	<0.001***
	Cohesive	0.36	<0.001***
	Crunchy	0.36	0.039*
	Dry	-0.34	0.007**
	Inconsistent	-0.34	0.010**
	Crumbly	-0.21	0.111
	Moist	0.12	0.007**
	Springy	0.09	0.551
	Chunky	0.05	0.743
	Greasy/ Oily	-0.04	0.712
	Soft	-0.04	0.865
	Grainy/ Granular	-0.01	0.891
Flavour/Taste	Strong beef	1.73	<0.001***
	Weak beef	0.58	<0.001***
	Smoky/ Grilled	0.43	<0.001***
	Mixed herbs	0.43	0.004**
	Savoury/ Umami	0.39	<0.001***
	Metallic/ Blood	-0.38	0.035*
	Hot Spices (spicy)	0.33	0.464
	Garlic and Onion	0.26	0.027*
	Black Pepper	0.23	0.233
	Root Vegetables	-0.21	0.001***
	Sweet	0.19	0.199
	Beany	-0.18	<0.001***
	Aromatic spices	0.17	0.643
	Tomato	-0.16	0.493

Table 3.12. Regression coefficients and associated p-values for all sensory attributes as determined by ordinal logistic regression model for predicting overall liking (continued).

Modality	Attribute	Regression coefficient	p-value
Flavour/Taste	Nutty	0.15	0.971
	Breadcrumbs/ Wheat	0.10	0.022*
	Salty	0.10	0.014*
	Fat	0.08	0.028*
	Brassicas	-0.07	0.009**
	Mushroom/ Earthy	-0.05	0.315

p-values presented as *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)

3.2.5.1 Relationship between sensory attributes and emotional response

The projection of sensory attributes as supplementary variables on the emotion PCA biplot (**Figure 3.3B**) further emphasised that the division between positive and negative emotions is related to meat-like and non-meat-like sensory attributes. As PC1 was related to positive and negative valence, those sensory attributes most highly correlated with PC1 in the positive and negative direction were the same sensory attributes identified as drivers of (dis)liking. For example, meat-like attributes such as 'strong beef' flavour, 'fibrous' texture, 'juicy' texture, were positioned closely to positive emotions 'happy', 'hungry', and 'amazed' and attributes 'smoky/grilled' flavour and 'savoury/umami' flavour were positioned closely to positive emotions 'pleasant/grateful' and 'satisfied'. Sensory attributes 'fried crumb coating' appearance, 'hot spices' flavour, 'breadcrumb/wheat' flavour, which were most cited for the Pams patty, were also positioned in the direction of positive emotions. In the opposite direction, non-meat related sensory attributes such as 'brassicas' flavour, 'root vegetable' flavour, 'visible ingredients' appearance, 'inconsistent' texture and 'mushroom/earthy' flavour were positioned closely to negative emotions 'uncertain', 'unhappy', 'disappointed', and 'dissatisfied'. None of the supplementary sensory attributes were highly correlated with PC2 of the emotion biplot, hence, it is difficult to make conclusions regarding the relationship between sensory attributes and arousing emotions. However, 'salty' flavour (r=0.54) was most positively correlated with PC2 and other intense flavours such as 'black pepper' (r=0.36) and 'hot spices'(r=0.27) were positioned positively on PC2. In contrast, 'tomato' flavour was most negatively correlated with PC2 (r=-0.38) and other less intense flavour attributes including 'sweet'(-0.34), 'weak beef'

(r=0.31) and 'beany' (r=-0.28) were positioned negatively on PC2, suggesting a possible relationship between spicy and other flavours and arousal.

3.2.6 Clustering of consumers based on overall liking to individual products

Consumers were clustered based on their overall liking ratings for individual products. Three consumer clusters were determined for overall liking ratings, **Table 3.13.** presents the mean overall liking ratings of the products for each consumer cluster.

Analysis of variance on LMM of overall liking revealed a significant effect of liking *cluster adherence* ($p<0.001$) and interaction of *product* and liking *cluster adherence* ($p<0.001$). Cluster one (n = 35), deemed the 'beef and meat analogue patty enthusiasts', scored above the neutral point (mean greater than 'five' - neither like nor dislike - on the 9-point hedonic scale) for the overall liking of all meat analogue patties, the Hybrid, and Beef. Cluster two (n = 30), deemed the 'plant-based patty enthusiasts', scored above the neutral point (mean greater than 'five' - neither like nor dislike - on the 9-point hedonic scale) for overall liking of all patties. Whereas cluster three (n=38), deemed the 'plant-based patty sceptics', scored below the neutral point (mean less than 'five' - neither like nor dislike - on the 9-point hedonic scale) for the overall liking of Vegie Delights, Hybrid, Quorn, and all Wholefood patties (except Pams). Furthermore, for the 'plant-based patty sceptics' cluster, when a patty was scored above the neutral point, in most cases the score was significantly lower than the other two clusters. Of note, the highest overall liking score for the 'plant-based patty enthusiasts' cluster was for Impossible Foods followed by Beyond Meats, whereas the other two clusters rated Beef most highly.

Liking clusters had similar gender ratios ($X^2 = 0.280$, $p = 0.869$), diet ratios ($X^2 = 2.717$, $p = 0.257$) and PBMA consumption ratios ($X^2= 5.507$, $p = 0.239$), but for age groups ($X^2 = 6.37$, $p = 0.041$) the "plant-based patty enthusiasts" cluster had more Generation X participants (n=15, 50%) compared to the "beef and meat analogue patty enthusiasts" cluster (n=8, 23%) and "plant-based patty sceptics" cluster (n=10, 27%).

Table 3.13. Overall liking cluster characteristics and cluster mean (± SE) liking ratings by product.

		Cluster 1 Beef and meat analogue patty enthusiasts (n = 35)	**Cluster 2 Plant-based patty enthusiasts (n = 30)**	**Cluster 3 Plant-based patty sceptics (n = 38)**
Gender	Male	9 (26%)	7 (23%)	11 (29%)
	Female	26 (74%)	23 (77%)	27 (71%)
Diet	Omnivore	20 (57%)	11 (37%)	18 (47%)
	Flexitarian	15 (43%)	19 (63%)	20 (53%)
Age group	Millennial	27 (77%)	15 (50%)	28 (74%)
	Generation X	8 (23%)	15 (50%)	10 (26%)
PBMA consumption frequency	High	11 (31%)	6 (20%)	7(19%)
	Low	8 (23%)	10 (33%)	18(47%)
	None	16 (46%)	14 (47%)	13 (34%)
Product	Beef	$7.30^{a} \pm 0.19$	$6.50^{b} \pm 0.30$	$6.60^{b} \pm 0.25$
	Impossible Foods	$6.91^{a} \pm 0.17$	$7.23^{a} \pm 0.25$	$6.03^{b} \pm 0.23$
	Beyond Meats	$6.83^{a} \pm 0.24$	$7.07^{a} \pm 0.27$	$5.39^{b} \pm 0.24$
	Birds Eye	$6.71^{a} \pm 0.19$	$6.50^{a} \pm 0.28$	$5.21^{b} \pm 0.27$
	Vegie Delights	$6.17^{a} \pm 0.16$	$6.57^{a} \pm 0.34$	$4.87^{b} \pm 0.29$
	Hybrid	$6.11^{a} \pm 0.23$	$6.23^{a} \pm 0.32$	$3.63^{b} \pm 0.21$
	Quorn	$5.63^{a} \pm 0.24$	$5.97^{a} \pm 0.28$	$3.68^{b} \pm 0.25$
	Pams	$5.60^{b} \pm 0.26$	$6.80^{a} \pm 0.26$	$5.50^{b} \pm 0.30$
	Bean Supreme_2	$5.00^{b} \pm 0.25$	$5.97^{a} \pm 0.25$	$3.39^{c} \pm 0.25$
	Food Nation_2	$4.00^{b} \pm 0.31$	$5.93^{a} \pm 0.26$	$3.21^{c} \pm 0.23$
	Food Nation_1	$3.34^{b} \pm 0.21$	$6.30^{a} \pm 0.22$	$3.15^{b} \pm 0.26$
	Bean Supreme_1	$3.80^{b} \pm 0.26$	$5.20^{a} \pm 0.36$	$3.10^{b} \pm 0.22$

[abcdef]Different lowercase letters across rows indicate significant differences between means across products obtained from post hoc tests with Tukey adjustments for multiple comparisons ($p<0.05$).

3.2.6.1 Consumer liking clusters sensory predictors of liking

Sensory predictors of overall liking were determined for each of the three liking clusters. For each cluster, similar numbers of sensory attributes (8-9 attributes) were identified as significant predictors of overall liking. The presence of a 'strong beef' flavour was identified as the strongest predictor of overall liking for all three liking clusters as identified by the highest regression coefficients (**Table 3.14**). A 'weak beef' flavour 'smoky/grilled' flavour and 'juicy' texture were also significant predictors of liking for all three clusters highlighting a preference for meat-like sensory attributes.

Other significant predictors of liking varied among the liking clusters. For the "beef and meat analogue patty enthusiasts" cluster (cluster 1) unsurprisingly sensory attributes with higher citation proportions among the beef and meat analogue patties were identified as significant

predictors of overall liking including ‘tender’ texture, ‘salty’ flavour, ‘fibrous’ appearance, ‘greasy/oily’ appearance, and ‘light brown’ colour appearance. Whereas for the “plant-based patty enthusiasts” cluster (cluster 2) other significant predictor attributes included ‘moist’ appearance, ‘garlic/onion’ flavour, ‘mixed herb’ flavour, ‘cohesive’ texture and ‘dry’ appearance which are attributes with similar citation proportions among meat analogues and wholefood patties. For the “plant-based patty sceptics” cluster (cluster 3) other significant predictors of liking were attributes common among the Beef and meat analogue patties e.g. ‘chunky’ appearance, ‘tender’ texture, and ‘savoury/ umami’ flavour as well as ‘fried crumb coating’ appearance.

For liking clusters 1 and 3 the presence of a ‘green colour’ appearance was the strongest predictor of disliking, as identified by the lowest regression coefficients (**Table 3.14**). For cluster 2 the presence of a ‘pasty/doughy’ texture was identified as the strongest predictor of disliking. A ‘pasty/doughy’ texture was also identified as a predictor of disliking for cluster 1. Other similarities between the clusters included ‘brassica’ flavour, and dry appearance as predictors of disliking for clusters 1 and 3, while clusters 2 and 3 shared a ‘hard/dense’ appearance as a predictor of disliking.

Otherwise, the attributes driving disliking varied among the clusters. For cluster 1 the presence of attributes, ‘chunky’ appearance, and ‘mushroom/earthy’ flavour were also significant predictors of disliking. For cluster 2 ‘browning on outside’ appearance and ‘metallic/blood’ flavour were identified as predictors of disliking. A higher number of attributes were identified as significant predictors of disliking for cluster 3, including ‘root vegetable’ flavour, ‘dry’ texture, ‘beany’ flavour, ‘inconsistent’ texture, ‘aromatic spices’ flavour, ‘tomato’ flavour and ‘crumbly’ appearance.

Table 3.14. Regression coefficients and p-values for 51 sensory attributes as determined by ordinal logistic regression model for predicting overall liking where separate regression models were used for each liking cluster.

Modality	Attribute	Cluster 1 Beef and meat analogue patty enthusiasts		Cluster 2 Plant-based patty enthusiasts		Cluster 3 Plant-based patty sceptics	
		Regression Coefficient	p-value	Regression Coefficient	p-value	Regression Coefficient	p-value
Appearance	Browning on outside	-0.251	0.102	-0.377	0.047*	0.410	0.059
	Fried crumb coating	-0.104	0.520	0.405	0.100	0.878	0.001**
	Dark brown colour	0.042	0.701	-0.109	0.852	0.263	0.343
	Light brown colour	0.177	0.029*	-0.136	0.591	-0.023	0.136
	Orange colour	0.567	0.116	-0.183	0.179	-0.271	0.793
	Green colour	-1.856	<0.001***	-0.900	0.069	-1.329	<0.001***
	Greasy/oily	0.268	0.017*	0.086	0.217	-0.250	0.987
	Dry	-0.268	0.002**	0.402	0.035*	-0.141	0.001**
	Pink/red centre	-0.129	0.544	0.053	0.280	-0.547	0.101
	Moist	0.108	0.108	0.320	<0.001***	-0.303	0.957
	Fibrous	0.372	0.022*	-0.055	0.562	-0.051	0.732
	Hard/dense	-0.287	0.054	-0.654	<0.001***	-0.259	0.041*
	Crumbly	-0.377	0.345	-0.038	0.555	-0.600	<0.001***
	Chunky	-0.612	0.014*	-0.102	0.198	0.711	0.023*
	Visible ingredients	-0.263	0.242	-0.054	0.767	-0.113	0.197
Texture/ Mouthfeel	Greasy/oily	0.113	0.415	0.035	0.904	-0.380	0.246
	Moist	0.076	0.576	0.232	0.051	0.041	0.103
	Juicy	0.750	<0.001***	0.747	0.001**	0.509	0.021*
	Chewy/rubbery	-0.318	0.113	-0.424	0.057	0.049	0.852
	Cohesive	0.272	0.252	0.567	0.005**	0.219	0.188
	Grainy/granular	-0.010	0.750	0.041	0.935	0.321	0.241
	Hard/dense	-0.552	0.147	-0.476	0.204	-0.122	0.385

Table 3.14. Regression coefficients and p-values for 51 sensory attributes as determined by ordinal logistic regression model for predicting overall liking where separate regression models were used for each liking cluster (continued).

Modality	Attribute	Cluster 1 Beef and meat analogue patty enthusiasts		Cluster 2 Plant-based patty enthusiasts		Cluster 3 Plant-based patty sceptics	
		Regression Coefficient	p-value	Regression Coefficient	p-value	Regression Coefficient	p-value
Texture/ Mouthfeel	Soft	-0.233	0.138	0.266	0.277	0.233	0.093
	Pasty/doughy	-0.861	<0.001***	-0.752	0.004**	-0.408	0.127
	Springy	0.110	0.759	0.361	0.141	0.273	0.172
	Tender	0.427	0.028*	0.319	0.095	0.667	<0.001***
	Fibrous	0.117	0.612	-0.064	0.850	-0.139	0.636
	Chunky	0.354	0.161	0.050	0.852	-0.439	0.098
	Inconsistent	-0.292	0.197	-0.111	0.682	-0.486	0.033
	Crunchy	0.551	0.173	0.233	0.517	0.458	0.118
	Crumbly	0.126	0.717	-0.111	0.668	-0.368	0.081
	Dry	-0.265	0.400	-0.182	0.592	-0.577	0.031*
Flavour/Taste	Smoky/grilled	0.387	<0.001***	0.645	<0.001***	0.389	<0.001***
	Strong beef	2.112	<0.001***	1.340	<0.001***	1.992	<0.001***
	Weak beef	0.547	<0.001***	0.488	0.018*	0.755	<0.001***
	Metallic/blood	-0.620	0.327	-0.159	0.025*	-0.238	0.339
	Breadcrumbs/wheat	0.150	0.023	0.052	0.586	-0.172	0.282
	Fat	0.056	0.912	-0.057	0.128	-0.043	0.166
	Black pepper	0.599	0.143	-0.012	0.990	0.525	0.520
	Salty	0.424	0.023*	0.076	0.012*	-0.113	0.961
	Savoury/ umami	0.137	0.286	0.566	0.055	0.487	0.003**
	Sweet	-0.007	0.667	0.189	0.803	0.647	0.144

Table 3.14. Regression coefficients and p-values for 51 sensory attributes as determined by ordinal logistic regression model for predicting overall liking where separate regression models were used for each liking cluster (continued).

Modality	Attribute	Cluster 1 Beef and meat analogue patty enthusiasts		Cluster 2 Plant-based patty enthusiasts		Cluster 3 Plant-based patty sceptics	
		Regression Coefficient	p-value	Regression Coefficient	p-value	Regression Coefficient	p-value
Flavour/Taste	Mixed herbs	0.248	0.651	0.622	<0.001***	0.104	0.136
	Beany	-0.130	0.234	-0.162	0.056	-0.488	<0.001***
	Nutty	0.089	0.923	0.376	0.910	0.154	0.852
	Garlic/onion	-0.027	0.260	0.452	0.007**	0.273	0.701
	Root vegetable	-0.232	0.054	-0.030	0.889	-0.695	<0.001***
	Brassicas	-0.427	<0.001***	0.049	0.926	-0.692	<0.001***
	Tomato	-0.119	0.291	-0.156	0.923	-0.539	0.008**
	Mushroom/earthy	-0.289	0.036*	-0.012	0.814	0.085	0.850
	Hot spices	0.358	0.766	0.436	0.465	0.342	0.442
	Aromatic spices	-0.105	0.157	0.416	0.160	-0.265	0.042*

p-values presented as *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)

3.2.7 Clustering consumers based on emotional response to individual products

Two consumer clusters were identified in terms of emotional response. Emotion citation proportions for each product by consumer cluster are shown in **Appendix K.** Clusters were not significantly different in terms of gender ratios ($X^2 = 0.305$, $p = 0.581$), diet group ratios ($X^2 = 0.257$, $p = 0.612$), PBMA consumption frequency ratios ($X^2 = 0.478$, $p = 0.787$), and age group ratios ($X^2 = 0.176$, $p = 0.675$).

Analysis of deviance of GLMs found a significant effect of *emotion cluster adherence* for emotions 'adventurous', 'amazed', 'bored', 'calm', 'curious', 'disappointed', 'disgusted', 'dissatisfied', 'energetic', 'happy', 'hopeful', 'hungry', 'loving', 'neutral', 'nostalgic', 'pleasant/grateful', 'satisfied' and 'suspicious' (all $p<0.05$, **Appendix G**). For all emotions except 'disappointed', 'disgusted', 'satisfied', and 'suspicious', citation proportions were significantly higher for cluster 2 (n=39) compared to cluster 1 (n=64). In contrast, cluster 1 showed higher citation proportions for 'disappointed', 'disgusted', 'satisfied', and 'suspicious' than cluster 2. This suggests that, in general, the smaller cluster, cluster 2, had a more positive and less negative emotional response towards the samples compared to cluster 1 (**Figure 3.5**).

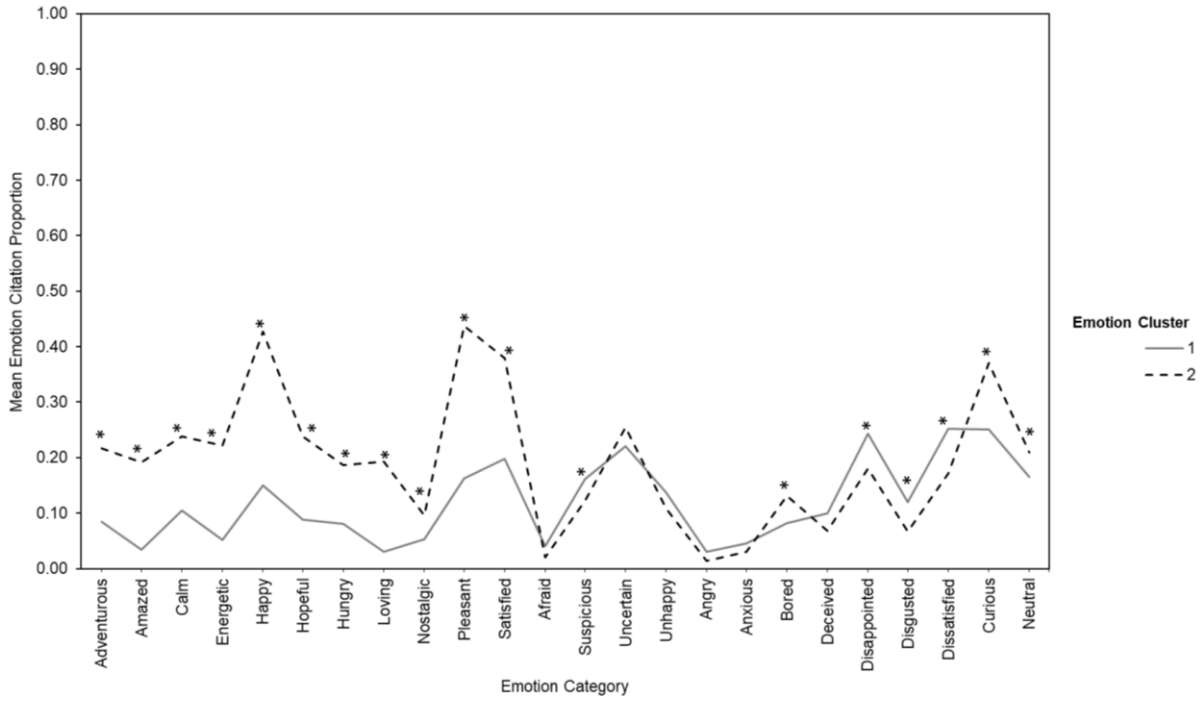


Figure 3.5. Mean emotion citation proportion by emotion cluster (averaged over products). Significant differences are indicated by * ($p < 0.05$).

A significant interaction of *product* and *emotion cluster adherence* was found for emotions 'happy', 'loving', 'pleasant/grateful', 'satisfied', 'disappointed', 'suspicious', 'uncertain', and 'dissatisfied'(all $p<0.05$, **Appendix G**), where cluster 2, in comparison to cluster 1, had significantly higher citation proportions for emotions 'happy' and 'pleasant/grateful' towards products Beef, Hybrid, all meat analogues, Food Nation_2 and Bean Supreme_2. Furthermore, cluster 2 had significantly higher citation proportions for 'loving' towards Beef, Hybrid, Beyond Meats, Impossible Foods, Birds Eye and Quorn and higher citation proportions for 'satisfied' towards Silver Ferns Farms, all meat analogues, and Food Nation_2. In contrast, cluster 1, in comparison to cluster 2, had significantly higher citation proportions for 'suspicious' and 'uncertain' towards Beyond Meats, 'dissatisfied' towards Birds Eye and Impossible and 'disappointed' towards Vegie Delight and Quorn (**Figure 3.6**). With a few exceptions, the significant differences in emotion citation proportions between the two clusters involved Beef, Hybrid and the meat analogue patties, and hence emotional response towards the wholefood patties was similar between the two emotion clusters.

A relationship between emotion cluster membership and liking cluster membership was identified ($X^2 = 23.492$, $p < 0.001$). **Table 3.15** shows the number of consumers belonging to each emotion cluster by liking cluster.

Table 3.15 Relationship between liking clusters and emotion clusters.

	Liking Cluster 1: Beef and meat analogue patty enthusiasts	**Liking Cluster 2: Plant-based patty enthusiasts**	**Liking Cluster 3: Plant-based patty sceptics**	**Total (n)**
Emotion Cluster 1	17 (49%)	12 (40%)	35 (92%)	64
Emotion Cluster 2	18 (51%)	18 (60%)	3 (8%)	39
Total (n)	35	30	38	103

A majority of the 'plant-based patty sceptics' cluster belonged to emotion cluster 1 (n=35, 92%), while the 'plant-based patty enthusiasts' had a higher proportion of emotion cluster 2 (n=18, 60%), compared to emotion cluster 1. The 'beef and meat analogue patty enthusiasts' cluster was characterised by an even proportion of emotion cluster 1 (n=17, 49%) and emotion cluster 2 (n=18, 51%).

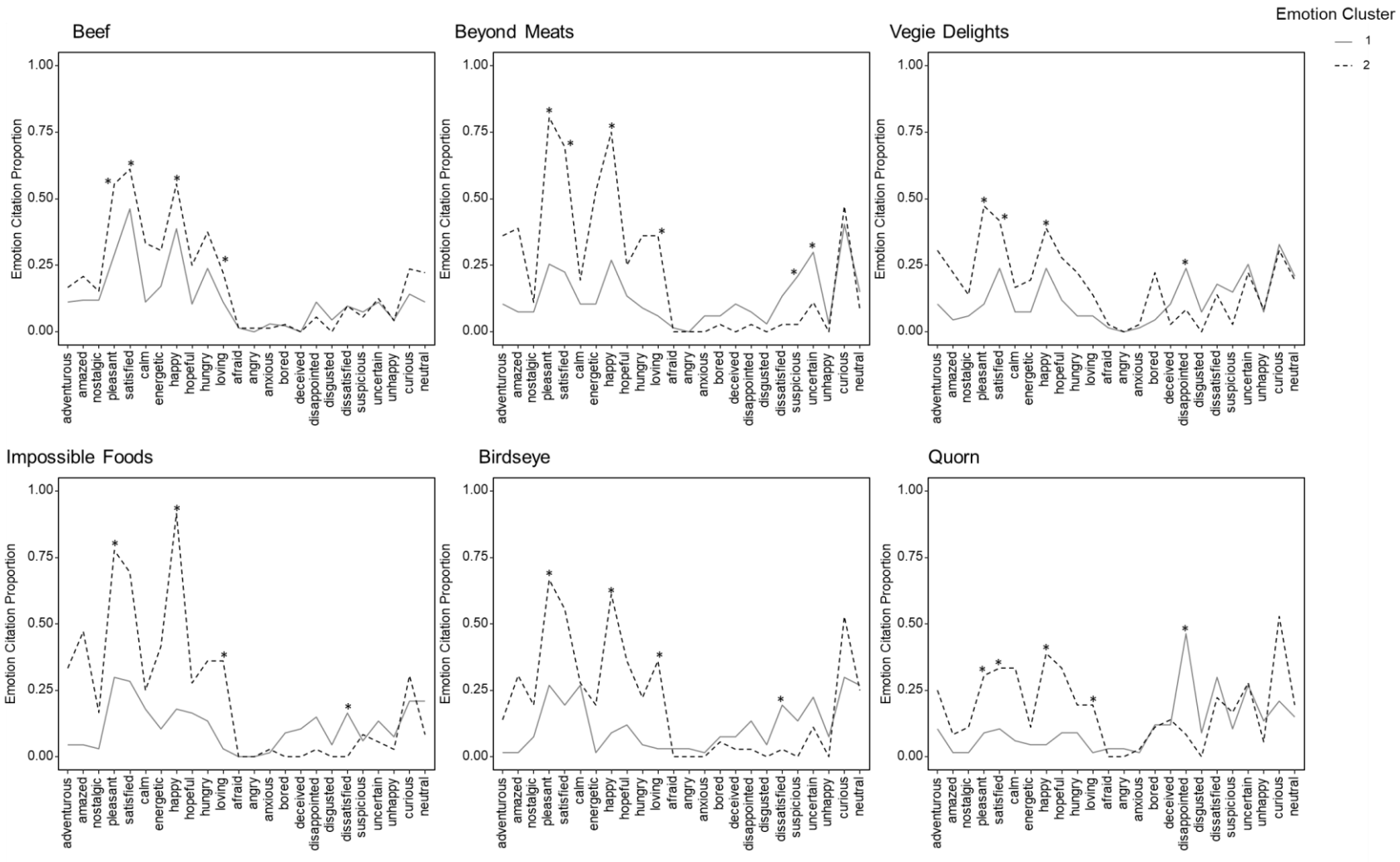


Figure 3.6. Product emotion citation proportions by emotion cluster. Significant differences in citation proportions are indicated by * ($p < 0.05$).

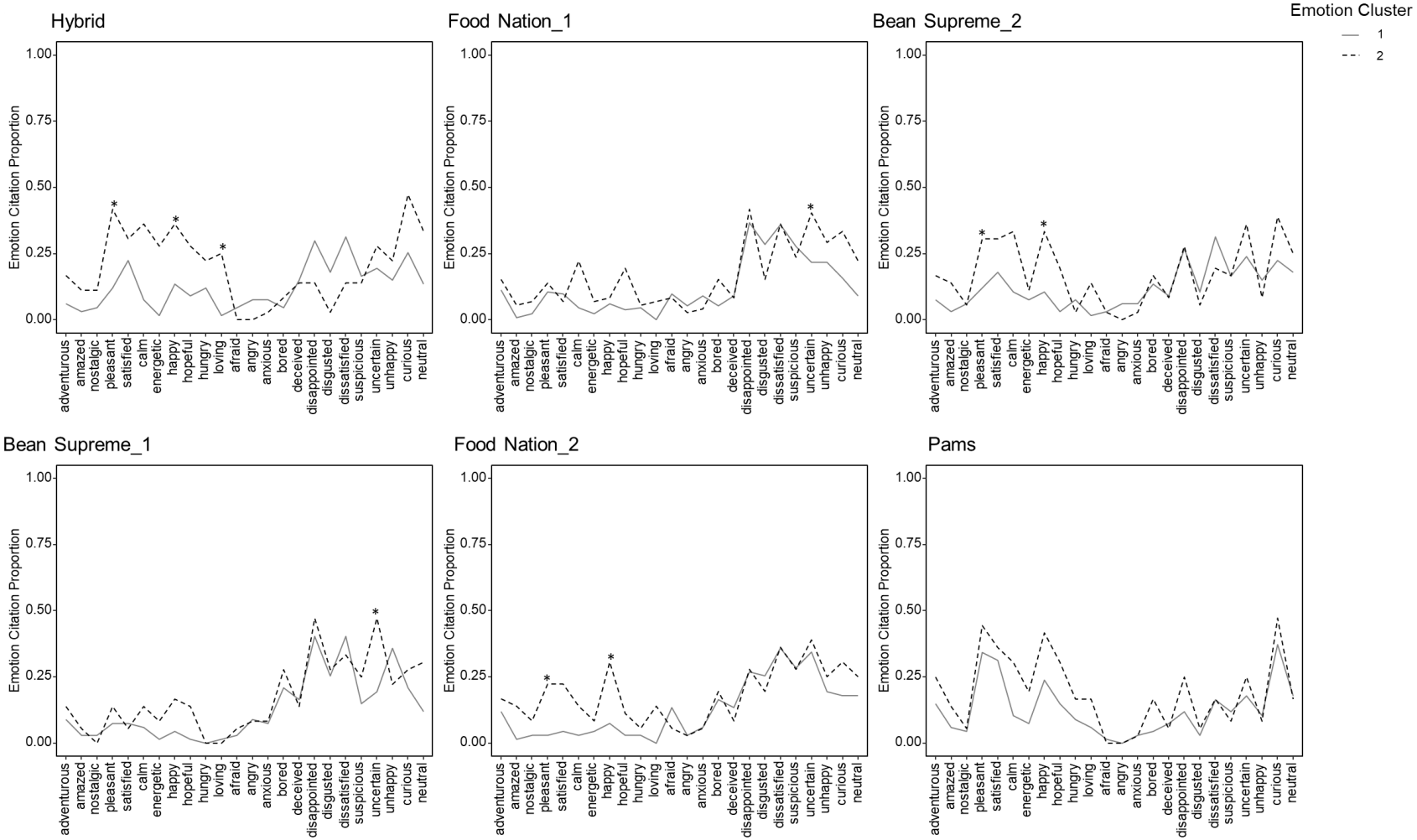


Figure 3.6. Product emotion citation proportions by emotion cluster. Significant differences in citation proportions are indicated by * ($p < 0.05$) (continued).

3.3 Discussion

This was the first study to measure emotional response to PB-patties that both varied in their similarity to meat and included PB-patties made from wholefoods that had no meat-like characteristics. Ten commercially available plant-based burger patties (wholefood and meat analogues), one beef patty and one hybrid beef-vegetable patty were profiled for their perceived similarity to a beef patty, sensory attributes, consumer liking and emotional response by flexitarians and omnivores. This study showed that commercially available PB-patties vary widely in their perceived similarity to a beef patty ranging from not at all meat-like to very meat-like. Patties perceived to be most similar to meat received the highest liking ratings and highest citation proportions for positive emotions. The beef patty was the most liked sample but was not significantly different in overall liking to Impossible Foods and Beyond Meats patties contradicting previous research that inferior sensory quality of *all* PBMAs compared to their meat counterparts is a barrier to acceptance (Fiorentini et al., 2020; Giacalone, Clausen, et al., 2022; Onwezen et al., 2021). A 'strong beef' flavour was identified as the top predictor of overall liking followed by several other meat-related sensory attributes. The wholefood patties received the lowest liking ratings and highest citation proportions for negative emotions. A 'green colour' appearance was identified as the top predictor of overall disliking, as well as other sensory attributes common among the wholefood patties including 'pasty/doughy' texture and 'visible ingredients' appearance. Three consumer segments with different liking preferences for meat and PB-patties were identified, however, a preference for meat and meat analogue patties was still prominent across the consumer segments. Furthermore, when consumers were clustered based on emotional responses two segments were identified; a smaller segment that generally had more positive emotional responses, particularly towards the meat and meat analogue samples, and a larger segment with more negative emotional responses particularly towards the meat analogue samples.

3.3.1 Strong preference for meat and meat analogue patties over wholefood patties

Meat and meat analogue patties were preferred over wholefood patties. This preference was reflected in both the liking ratings and emotional responses. In regards to liking, Gonzalez-Estanol et al. (2023) found a similar pattern of preference with a beef patty being most liked followed by a 'meat-like' soy-based patty, while a hemp patty with no meat-like characteristics received the lowest liking score. Giezenaar, Orr, et al. (2024) also found a strong preference for products resembling meat when a range of PBMAs (e.g. burger patties, sausages, chicken alternatives, meatball alternatives) were assessed.

Given consumer preference for products resembling meat, it was unsurprising that the presence of a 'strong beef' flavour was the top predictor of overall liking. Other attributes identified as predictors of liking were common sensory descriptors for beef patties e.g. 'brown' colour, 'meat' flavour, 'fat' flavour, 'salty' flavour, 'tender' texture, and 'juicy' texture (Carvalho et al., 2015). A preference for meat-like sensory attributes in PB-patties aligns with the findings of Neville et al. (2017) who found a meaty flavour to be the biggest driver of liking in PB-patties, and (Elzerman et al., 2013; Hoek et al., 2011; Kerslake et al., 2022; Waehrens et al., 2023) who found participants or subgroups of participants who prefer meat substitutes to be similar to meat.

Most of the sensory attributes identified as predictors of liking were attributes common to both meat and meat analogue patties. The beef patty did however receive significantly higher citation proportions for attributes 'strong beef' flavour, and 'fat' flavour suggesting improvements could be made to meat analogues for these attributes. That said, the Impossible Foods and Beyond Meats samples did not differ from the meat patty for overall liking ratings and several positive emotions despite not matching the beef patty for these attributes, indicating that perfect replication of the sensory attributes of a meat patty was not essential for acceptance and positive emotional response. Inferior sensory quality of PBMAs compared to meat counterparts has previously been reported as a barrier to acceptance (Fiorentini et al., 2020; Giacalone, Clausen, et al., 2022; Onwezen et al., 2021), this blanket statement was disproven here, albeit only for two of the ten PB-patties investigated.

Despite containing 40% beef mince, liking of the Hybrid patty was low compared to the beef patty and some meat analogue patties, and was perceived to be *not very meat-like*. The vegetable mince ingredients appeared to have dominated the sensory profile of the Hybrid patty and masked the meat-like properties with an 'orange colour' appearance, 'tomato' flavour, 'moist' appearance and texture, and 'soft' texture being the most prominent sensory attributes. Contradictory to this finding, Neville et al. (2017) found two hybrid formulations both with 37% beef to not differ significantly in liking from a beef burger and share similar sensory properties, however, the ingredients used to replace the beef were not disclosed. Furthermore, Grasso et al. (2022) found a 60% beef and 40% vegetable hybrid patty to be significantly more liked than a beef patty. In the present study, the particular choice of vegetable mince, or quantity used, may account for the inconsistency across studies and other meat replacers may have provided a different acceptance outcome for a hybrid patty.

A small number of sensory attributes were identified as drivers of liking that are not typically meat-related. These included a 'fried crumb-coating' appearance, 'crunchy' texture, 'mixed herbs' flavour and 'garlic/onion' flavour. Potentially the fried coating provided a more favourable crunchy texture compared to the undesirable textures of the other wholefood patties. Unfortunately, fried foods are perceived by consumers as harmful to well-being (Ares, de Saldamando, et al., 2015) and consumption should be limited (Ministry of Health, 2020), so frying patties to improve the texture would likely not appeal to those looking to reduce their meat consumption for health reasons. Nonetheless, incorporating mixed herb flavours and/or garlic/onion flavours into patty formulations could potentially enhance product acceptance.

The wholefood patties were perceived by most consumers to be *not at all meat like,* this was not surprising as these products do not aim to mimic meat. A 'green colour' appearance was the top predictor of disliking. Other predictors of disliking included several textural attributes commonly associated with the wholefood patties including 'pasty/doughy texture', 'inconsistent' texture, and 'dry' texture. Notably, texture liking ratings were the lowest of the liking modalities for the wholefood patties. Similarly, Gonzalez-Estanol et al. (2023) found the texture liking of a hemp

patty to be lower than a 'meat-like' soy patty and beef patty. Addressing textural issues is critical for improving consumer acceptance of patties made from wholefoods. The presence of flavours 'beany', 'root vegetable' and 'brassicas' were also found to be significant predictors of disliking. These flavours were most prominent among the wholefood patties, however, a 'beany' flavour was also detected in all other products except for the Beef patty. A beany flavour is a common defect among PBMAs due to the high content of plant-derived ingredients (Chigwedere et al., 2022; Giacalone, Clausen, et al., 2022) and was also identified as a driver of disliking by Gonzalez-Estanol et al. (2023). Masking these unfavourable flavours is important for improving consumer acceptance of PB-patties made from wholefoods.

3.3.2 Emotional response and link with sensory attributes

The majority of the variation in emotional responses between products was explained by PC1 of the emotion biplot (**Figure 3.3A**), which separates emotions based on positive and negative valence (Jaeger et al., 2020; Russell, 1980). Patties resembling beef and receiving the highest liking ratings (e.g., Beef, Impossible Foods, Beyond Meats) had higher citation proportions for positive emotions like 'satisfied,' 'happy,' and 'hungry.' Conversely, patties dissimilar to beef and with the lowest liking ratings (e.g., wholefood patties) had higher citation proportions for negative emotions like 'suspicious,' 'disappointed,' and 'dissatisfied.' Products with mid-range liking (e.g., Vegie Delights, Quorn, Pams, Hybrid) tended towards the centre of PC1, indicating divided consumer emotional responses. The projection of sensory attributes as supplementary variables on the emotion PCA biplot (**Figure 3.3B**) further highlighted that the division between positive and negative emotions was related to beef-like versus non-beef-like sensory attributes.

A small percentage of variation in emotional response between the products was explained by PC2 of the emotion biplot (**Figure 3.3A**), which separates emotions based on arousal (Jaeger et al., 2020; Russell, 1980). This may indicate that most of the variance between samples was caused by the valence of emotions and relatively less by arousal. However, this is not uncommon, for example, when measuring emotional response to a range of PBMA products Giezenaar, Orr, et al. (2024) found PC2 accounted for 6.5% of the variation and with plant-based milk, Weerawarna

N.R.P et al. (2023) and Moss et al. (2022), found PC2 to account for 14.6% and 16.9% of the variation, respectively.

The relationship between sensory attributes and arousing emotions (PC2) was less clear than for PC1 but a possible relationship between trigeminal sensations linked to intense flavours (e.g. spicy) (Cayeux et al., 2023) and arousal was identified. Such links have been found in other studies for example, Giezenaar, Orr, et al. (2024) also observed a relationship between intense flavours such as 'salty' and 'hot spices' and activated emotions like 'adventurous' and 'energetic' in PBMAs. Similarly, Jaeger, Spinelli, et al. (2018) found that in flavoured peanuts, flavours such as 'spicy', 'peppery', and 'salty' were associated with activation, while 'bland' was associated with deactivation. In the present study, the beef and meat analogue patties accounted for the most variation across PC2 and in a few cases, PC2 differentiated meat analogues that were similarly liked. For example, Birds Eye had a significantly higher citation proportion than Vegie Delights for the low arousal 'calm' emotion. Vegie Delights patty received significantly higher citation proportions for 'hot spices', and 'salty' flavours compared to Birds Eye which supports the potential relationship identified between more intense flavours and higher arousal. Beyond Meats and Impossible Foods had a significantly higher citation proportion than Birds Eye for the high arousal 'energetic' emotion. In this situation the three products only significantly differed in citation proportions for texture attributes 'dry', 'soft', and 'pasty/doughy', and so the link between flavour intensity and higher arousal was not evident in this case. Further investigation is required to better understand the relationship between flavours linked to trigeminal sensations and evoking arousing emotions in PBMAs, and the impact this has on acceptance.

Emotional response towards plant-based meat analogues has not been well investigated previously and this was the first study to measure emotional response to PB-patties made from wholefoods. One study by Schouteten et al. (2016) found under blind conditions a plant-based patty (meat analogue) was associated with negative emotions 'disappointed', 'discontent', 'disgust', 'dissatisfied', and 'distrust'. This contrasts with the findings of the present research, which found consumers to be generally positive in their emotional response towards meat

analogues. However, in the eight years since that study was published, improvements have likely been made to the sensory characteristics of PB-patties. The findings of this research are in line with those of Zandstra et al. (2023) who determined through an online survey that when asked to rate expected feelings towards a plant-based burger that looked like meat consumers rated higher for positive emotions e.g. 'happy', 'satisfied', 'relaxed' compared to negative emotions e.g. 'anxious', 'disgust', 'disappointed'.

3.3.3 Segmenting consumers based on overall liking

Clustering consumers based on overall liking ratings indicated preferences for PB-patties are not homogenous. The 'plant-based patty enthusiasts' cluster which made up approximately one-third of consumers showed a consumer segment who were accepting of all patty types. Interestingly this cluster had a higher ratio of Generation X consumers compared to the other two liking clusters which suggests a link between this age group and higher acceptance of wholefood patties could exist but would require further investigation. The 'plant-based patty enthusiasts' cluster in combination with the 'beef and meat analogue patty enthusiasts' cluster demonstrated a high proportion of consumers were accepting of meat analogue patties. On the other hand, the 'plant-based patty sceptics' showed approximately a third of consumers were less accepting of PB-patties regardless of whether they mimicked meat or not.

Previous research (Collier et al., 2021; Elzerman et al., 2013; Kerslake et al., 2022) has suggested subgroups of consumers exist who would prefer meat substitutes to not mimic the sensory properties of meat. In the present research, the 'plant-based patty enthusiasts' cluster had higher mean overall liking ratings for the wholefood patties compared to the other two clusters, however, overall liking ratings for the meat analogues patties were still higher than those for the wholefood patties. Furthermore, a 'strong beef' flavour was the top driver of overall liking for all three liking clusters. Thus, a cluster of consumers who preferred PB-patties that did not mimic meat was not observed. This research, however, only included consumers who identified as omnivores or flexitarians who keep meat in their diet, possibly because they enjoy the taste of meat and have cravings for meat (Kemper, 2020). Kerslake et al. (2022) found through focus group discussions

that most vegans and vegetarians participants felt uncomfortable about meat alternatives mimicking meat. Therefore, if meat-excluding consumers (e.g. vegetarian or vegan) had been investigated in the present research different patterns of preference could have been observed. However, the focus of this study was intentionally to understand the preferences of meat-eating consumers.

3.3.4 Segmenting consumers based on emotional response and relationship with overall liking segments

Clustering consumers based on emotional responses to the products identified two segments. Both clusters showed similar emotional responses to the wholefood patties but differed significantly in their reactions to the beef and meat analogue patties. Cluster 2 (n=39) had higher citation proportions for several positive emotions towards the beef, hybrid, and meat analogue patties, and sometimes specific wholefood patties. Conversely, cluster 1 (n=64) exhibited more negative emotions towards the meat analogue patties. This clustering was useful for revealing that, despite the meat analogue patties receiving higher liking ratings and citation proportions for positive emotions compared to the wholefood patties, a significantly sized segment of consumers still expressed negative emotions like 'suspicion' and 'disappointment' towards some meat analogue products.

Emotion cluster adherence was not found to be related to any of the variables investigated (gender, diet, age group, PBMA consumption) thus the information collected on the consumers was insufficient for developing a demographic consumer profile for the identified segments. Piqueras-Fiszman and Jaeger (2016) found behavioural and psychographic variables to be more effective than demographic and socio-economic variables for characterising two emotion segments, where the segments exhibited different emotional patterns towards recalled meals. For example, the more positive emotion segment was more likely to be enthusiastic about planning an evening meal and preparing food whereas the less positive segment seemed generally uninterested in food or meal-related activities. Additionally, the less positive segment were more likely to self-report having difficulty in describing their feelings. Jaeger et al. (2022) also found higher food

neophobia to be possibly associated with higher negative valance and higher arousal and higher private body consciousness was positively associated with higher arousal.

Clustering based on emotional response was not as effective as clustering based on overall liking ratings for identifying segments of consumers with varying preferences for PB-patties. However, this is understandable, as clustering based on overall liking involves far fewer variables (overall liking ratings for 12 products), whereas clustering based on emotional response is more complex, involving binary scores for 24 emotions across 12 products. Consequently, it would be more straightforward for the clustering to identify patterns from overall liking compared to emotional response. If other dietary groups, such as vegetarians or vegans, had been included, more variation in emotional response may have been observed, potentially segmenting the consumers further.

A relationship was observed between liking cluster adherence and emotion cluster adherence. Most 'plant-based patty sceptics' belonged to emotion cluster 1, aligning with lower citation proportions for positive emotions and a more negative response towards meat analogue patties compared to cluster 2. In contrast, the 'plant-based patty enthusiasts' had a higher proportion of emotion cluster 2, compared to emotion cluster 1, while the 'beef and meat analogue patty enthusiasts' cluster was characterised by an even proportion of emotion cluster 1 and emotion cluster 2. This was surprising as cluster 2 had expressed higher citation proportions for negative emotions towards some meat analogue patties. This suggests consumers providing similar liking ratings may not necessarily experience or express the same emotional response. This linked back to the point made earlier that individual differences (e.g., food neophobia, private body consciousness, and articulation of emotion, to name a few) can influence food-evoked emotions (Jaeger et al., 2022; Piqueras-Fiszman & Jaeger, 2016).

3.3.5 Reflection on the effectiveness of the developed emotion lexicon

Products were differentiated for 21 of 24 emotion categories from the emotion lexicon developed specifically for meat and plant-based burger patties. Emotions 'neutral' and 'anxious' did not discriminate across the patties, indicating these emotions were used similarly across all products. The 'neutral' emotion did not discriminate across the products indicating all products evoked an

emotional response as there were no specific products that made consumers feel more neutral. The ‘anxious’ emotion received low citation proportions across all products suggesting this emotion is redundant for this group of consumers and the tested products.

An advantage of a product-specific emotion lexicon over a generic emotion lexicon is the inclusion of more relevant emotion terms (Ng et al., 2013). In chapter two several emotions including ‘amazed’, ‘hopeful’, ‘hungry’, ‘angry’, ‘anxious’, ‘afraid’, ‘suspicious’, ‘disappointed’, ‘deceived’, ‘uncertain’, ‘curious’, and ‘neutral’ were highlighted to be present in the developed lexicon but absent on generic emotion lexicon such as the EsSense Profile® (King & Meiselman, 2010) or the valence × arousal circumplex-inspired emotion questionnaire CEQ (Jaeger et al., 2020). For the most part, the inclusion of these emotions proved useful for revealing insights into the consumer experience that may have been missed if a generic emotion lexicon had been used. For example, many of these emotions were negative and their inclusion was advantageous for differentiating the less preferred wholefood patties from the meat and meat analogue patties.

Furthermore, negative emotions ‘deceived’, ‘anxious’, ‘afraid’’, ‘uncertain, and ‘suspicious’, were expected to be particularly relevant to PB-patties due to their association with food neophobia (a human trait that manifests in anxiety towards novel foods) (Jiang et al., 2014) that is responsible for some consumers’ failure to engage with new, often innovative, foods (Barrena & Sánchez, 2013; Jiang et al., 2014). Notably, ‘uncertain’ was the most frequently cited negative emotion. Collier et al. (2021) identified uncertainty around the contents and composition of meat alternatives as a barrier to purchase and consumption, especially those that visually resemble meat. In the present study citations proportions for ‘uncertain’ were lowest amongst the products that most closely resembled meat (Beef and Impossible Foods), and were not significantly different across the remaining products, indicating consumers felt ‘uncertain’ towards both patties that were and were not trying to resemble meat. The ‘deceived’ emotion was most frequently cited for Hybrid and Quorn, which of the meat and meat analogue patties, were perceived to be most dissimilar to meat. It is likely that from the appearance of these patties consumers expected a meat-like patty, however, their expectations were not met. The ‘suspicious’ emotion was most

frequently cited for Food Nation_1 and Food Nation_2. These two products received the lowest appearance liking ratings, their unappealing appearance could have left participants suspicious of what to expect from eating the product.

Negative emotions, 'afraid', 'anxious', and 'angry', received the lowest average citation proportions <5%. This is likely an indication these emotions were not relevant for explaining emotional response to PB-patties in the present study. The study was advertised as a meat and PB-patty study. Since participants have to volunteer to take part in a consumer study (Lawless & Heymann, 2010), the recruited group of participants was likely open to trying PB-patties. As a result, feelings of fear or anxiety towards these products could be less prominent. Additionally, with a CATA methodology, consumers use a higher threshold to check an emotion word thereby producing fewer checked emotions than when asked to rate emotions (Meiselman, 2016). The intensity to which consumers experienced these emotions may not have been strong enough to exceed this 'threshold'. Furthermore, when the emotion lexicon was developed, participants were asked to imagine how they would feel eating PB-patties in digital-IEs. Without contextual information certain emotions could be less relevant e.g., eating a disliked product in sensory booths may not make you feel 'angry' but if you were paying for the patty the emotion may be more relevant.

Positive emotion terms 'hopeful', 'amazed', and 'hungry' were also specific to the developed emotion lexicon. Consumers felt more 'hopeful' towards the meat analogue patties compared to the wholefood patties, and so likely had higher expectations of the meat analogue patties. Consumers felt most 'amazed' by Impossible Foods and Beyond Meats indicating a possible exceedance of expectations by these patties. Moreover, consumers felt most 'hungry' towards the most liked patties Beef, Impossible Foods and Beyond Meats. Finally, the 'curious' emotion received the highest average citation proportion of all the emotions. Interestingly, Beef received the lowest citation proportion for 'curious', highlighting a general sense of curiosity about PB-patties among consumers.

The developed lexicon was effective in discriminating between meat and plant-based patties and at revealing deeper insights into how consumers experience these products beyond liking. Greater separation of the products along the arousal dimension was expected but highlights that most of the variance between samples was caused by the valence of emotions, and relatively less by the arousal. The lexicon could potentially be refined by removal of emotion terms with low citation proportions, however, further investigation using a rating methodology and measuring emotional response in more relevant eating contexts should be conducted before making such decisions. Further, the application of the lexicon with PBMAs beyond burger patties would further validate the usefulness of the emotion lexicon for understanding consumer response to plant-based foods.

3.3.6 Limitations and future research

While this research was successful in profiling a range of meat and plant-based burger patties for liking, emotional response, sensory attributes and similarity to meat, several limitations to the research can be acknowledged. First, only burger patties were used in this study, which could limit the generalisability of the findings to other PBMA products. Second, while an even distribution of meat eaters and flexitarians was recruited, the participant sample was overrepresented by females, Millennials, and non-users of PBMAs. This could have affected the characterisation of the liking and emotion consumer segments. Third, the intensity to which sensory attributes were experienced was not assessed, preventing the determination of the preferred intensity for sensory attributes identified as drivers of liking. Similarly, using CATA for emotional response assessment only indicated the presence or absence of the feeling of an emotion and did not indicate its intensity. The use of rating scales or "just about right" scales (for sensory attributes) could have provided these insights but were deemed impractical given the large number of sensory attributes and samples investigated. Additionally, using a static measure of emotion means it is unknown at which stage in consumption (before, during or after) the emotions were experienced. Fourth, the products were evaluated in isolation, without considering the potential impact of contextual information such as the situational (Michel et al., 2021; Motoki et al., 2021) or meal context (Cordelle et al., 2022; Elzerman et al., 2011) on acceptance or

perception of sensory attributes (Gonzalez-Estanol et al., 2023). Additionally, the samples were assessed in a blind test, however, product information such as packaging could have influenced the results (Demartini et al., 2022; Giezenaar, Godfrey, et al., 2024; Noguerol et al., 2021). Lastly, the information collected on the participants, such as age group and diet group, was insufficient for building a comprehensive consumer profile for the liking or emotional response of such consumer segments.

Using the identified drivers of liking, future research should seek to determine the intensity to which sensory attributes are preferred using manipulated samples to better inform the research and development of PBMA products. Future research should also further explore the impact of demographic variables and other personal related factors e.g. meat attachment, food neophobia, and food choice motives, on preference and emotional response towards PBMAs to gain greater insights into how consumer characteristics impact PBMA acceptance. Finally, testing PBMAs in more contextually relevant situations such as inappropriate eating environments or with other food components could enhance the relevance of the findings to real-world scenarios.

3.4 Conclusions

In summary, this study observed significant variations in liking, emotional response, sensory attributes, and perceived similarity to meat across ten commercially available plant-based burger patties (including both wholefood and meat analogues), along with one beef patty, and one hybrid beef-vegetable patty. The beef patty and two PB-patties, which were perceived to be most similar to a beef patty, received the highest liking ratings and highest citation proportions for positive emotions. In accordance with a preference for beef-like patties a "strong beef" flavour was identified as the top predictor of overall liking, along with several other meat-related sensory attributes. The wholefood patties, which were perceived not to resemble a beef-patty, were generally disliked, receiving the lowest liking ratings and highest citation proportions of negative emotions. A ‘green colour’ appearance was identified as the top predictor of overall disliking, as well as other sensory attributes common among the wholefood patties including ‘pasty/doughy’ texture and ‘visible ingredients’ appearance. Participants were clustered based on their overall

liking ratings revealing three consumer segments with different preferences for PB-patties. This indicates a preference for plant-based burger patties is not homogenous among meat-eating consumers. All three segments, however, preferred meat and/or meat analogue patties over wholefood patties, highlighting the importance of focusing efforts on producing meat-like plant-based products to maximise acceptance among meat-eating consumers. The "plant-based patty enthusiasts" consumer segment was characterised by a higher ratio of Generation X consumers compared to Millennial consumers, with no other distinguishing characteristics observed among the segments. Clustering consumers based on their emotional responses was less effective than clustering based on overall liking ratings for identifying segments with varying preferences for PB-patties. However, it did discriminate consumers based on their emotional responses to the meat analogue patties and highlighted that those who provide similar liking ratings may not necessarily experience or express the same emotional responses. Lastly, the emotion lexicon developed in **Chapter 2** successfully discriminated across the samples for 22 of 24 emotion categories. The next chapter (**Chapter 4**) investigates the impact on liking and emotional response of consuming PBMAs in more contextually relevant situations.

Chapter 4: Investigating the Effect of Contextual Variables on Consumer Response to Plant-based Meatball Alternatives (Study 3)

4.1 Introduction

Contextual factors play an important role in shaping consumer preferences and emotional responses to products (Cardello & Meiselman, 2018). Incorporating these relevant contextual factors into consumer testing can create environments that better simulate real-life eating situations compared to traditional setups (Schöniger, 2022). This approach allows for a more accurate understanding of how consumers would typically experience and evaluate a product in their everyday lives.

Meal context, or the dish in which PBMAs are prepared, can significantly impact their acceptance, although the extent of this impact can vary depending on the specific dish and the type of PBMA. The impact of the meal context is likely dependent on product type, for example, a patty which makes up a larger proportion of a dish would be harder to 'mask' compared to a mince alternative, and the congruency of the PBMA to the dish. While previous studies have primarily focused on how meal context affects liking (Elzerman et al., 2011; Cordelle et al.,2022; Niimi et al., 2022; Gonzalez-Estanol et al., 2023), the influence of meal context on emotional responses toward PBMAs remains largely unexplored. Combining PBMAs with other meal components likely influences the perception of their sensory properties, which can, in turn, affect acceptance. Research into composite foods has found condiments/sauces can decrease flavour intensities of the paired food (Gonzalez-Estanol et al., 2023; Meinert et al., 2011; van Eck et al., 2019). Thus, combining PBMAs with other meal components could be a particularly useful strategy for improving consumer response towards PBMAs by reducing the intensity of unfavourable sensory attributes. Additionally, introducing a potentially unfamiliar food item alongside a familiar meal component can enhance consumer acceptance (Stallberg-White & Pliner, 1999), which is particularly relevant given that unfamiliarity poses a significant barrier to PBMA acceptance (Michel et al., 2021).

Previous research has shown that PBMA consumption is perceived to be more appropriate in casual settings, such as when eating alone, with family (Michel et al., 2021; Motoki et al., 2021) with friends, at food festivals, cafes, and in the home (Motoki et al., 2021). Whereas situations like during a family Sunday meal, for a business lunch, at a barbecue party (Michel et al., 2021), with an acquaintance, and at a pub or bar (Motoki et al., 2021) are considered less appropriate. The appropriateness of consuming PBMAs in restaurants has shown mixed results, with some studies finding it appropriate (Motoki et al., 2021) and others not (Michel et al., 2021). These less appropriate situations include more formal dining situations, where a high-quality meal, like a meat roast, may be preferred over processed foods like PBMAs (Michel et al., 2021) as well as settings where individuals may wish to avoid drawing attention to their food choices due to concerns about judgment, such as at a bar or pub, (e.g., vegetarianism (non-meat eating) is considered less masculine (Kemper et al., 2023)).

While these studies have identified hypothetical appropriate situations for PBMA consumption through online surveys, there is limited research on how actually consuming PBMAs in these contexts affects consumer acceptance and emotional responses. This presents an opportunity to leverage digital-IEs such as video walls to recreate eating environments in laboratory settings while maintaining a scientifically controlled environment (Bangcuyo et al., 2015; Galiñanes Plaza et al., 2019; Giezenaar & Hort, 2021). The study by Gonzalez-Estanol et al. (2023), is the only one identified that considers the eating environment in consumer testing of PBMAs, using a digitally recreated casual restaurant setting complete with room décor and burger boxes. However, this study did not include a control setting, leaving a further opportunity for research comparing responses in a digitally recreated typical eating environment against a control setting to identify the significance of eating environment in consumer response to PBMAs. Furthermore, the effect of digital-IEs on emotional response to food products is sparse in comparison to studies focusing on liking, thus presenting an opportunity to make a valuable contribution to the literature on this topic.

The use of digital-IEs in consumer testing not only improves ecological validity but also improves participant engagement (Bangcuyo et al., 2015). Traditional test environments lack context which can potentially decrease participant attention, focus and motivation, thereby compromising the quality of data collected during product evaluation (Hannum & Simons, 2020). Facilitating improved engagement during product testing could improve the quality of data provided as engagement is closely related to interest and motivation (Hannum & Simons, 2020). Bangcuyo et al. (2015) developed an engagement and presence questionnaire adapted from the Presence Questionnaire (Witmer & Singer, 1998) and the User Engagement Scale (O'Brien & Toms, 2010). This questionnaire has been used in several subsequent studies (Bangcuyo et al., 2015; Hathaway & Simons, 2017; Sinesio et al., 2019; Zandstra et al., 2020) demonstrating that digital-IEs are more engaging than traditional test set-ups.

Previous studies have typically only considered mean engagement and presence scores for all participants. However, it is important to recognise that individuals experience varying levels of presence even when immersed in the same virtual environment setting (Martingano et al., 2023), where presence refers to the actual feeling of being situated within the virtual environment (Berkman & Akan, 2019). Thus, it is plausible that segments of consumers exist who differ in their engagement and presence in digital-IEs. It was hypothesised that participants with higher levels of engagement and presence are more influenced by digital-IEs compared to those with lower levels of engagement, which could impact their product evaluations in digital-IEs. Understanding these differences in engagement and presence and their impact on consumer responses in digital-IEs could provide valuable insights for improving the effectiveness of consumer testing methods..

4.1.1 Research focus

The main objectives of the study presented in this chapter were to:

1. identify an appropriate and inappropriate eating environment for the consumption of plant-based alternatives to meatballs (PB-meatballs).
2. determine if liking and emotional response to PB-meatballs differed between a traditional central location test setting and an appropriate and inappropriate eating environment recreated using digital-IEs.
3. ascertain whether liking and emotional response to PB-meatballs differed when assessed on their own versus with a tomato sauce (meal context).
4. assess whether the impact of eating environment and/or meal context differs between a well-liked PB meatball and a less-liked PB meatball
5. a) determine if engagement differed between test environments and if consumers could be segmented based on level of engagement with the test environments.
   b) establish, if consumer segments existed, whether segments responded to the samples similarly regarding liking and emotional response in the digital-IEs.

4.2 Survey to determine (in)appropriate eating environment for plant-based alternatives to meatballs (Study 3: Part A)

An online survey was used to determine an appropriate and inappropriate eating environment for PB-meatballs. This survey was considered and assessed as low risk following the Massey University Human Ethics Committee process (human ethics notification number: 4000027628). Informed consent was obtained from all participants at the commencement of the survey. Participants were not compensated for their time but had the option to enter a prize draw for one of two 40NZD supermarket gift cards.

4.2.1 Materials and methods

4.2.1.1 Participants

Participants were recruited from the Food Experience and Sensory Testing (Feast) Laboratory consumer database. Inclusion criteria required participants to: (1) be aged 18 years or older; (2)

have access to a desktop, laptop, or tablet to complete the survey; (3) be somewhat familiar with the dish spaghetti and meatballs (or spaghetti Bolognese as this is a very similar dish that would be consumed in the same context). Familiarity with spaghetti and meatballs or spaghetti Bolognese was assessed at the start of the survey. Respondents were asked to rate their familiarity with the dish on a 5-point scale where 1 corresponded to *"never heard of it or eaten it"*, 2 - *"unfamiliar I've heard of it but haven't eaten it*", 3- *"somewhat familiar – I've heard of it and eaten it a few times",* 4 – *"familiar I would eat it occasionally"* and 5 -*"very familiar I eat it often".* This check ensured participants could reliably imagine where they would like to consume the dish/where it is most appropriate to consume. Therefore, if a respondent selected a 1 or 2 on the scale their responses were excluded.

4.2.1.2 Eating environment selection

Eight eating environments were selected for inclusion in the survey. *At home, a restaurant, a café/canteen,* and *a pub* were included as potentially appropriate environments based on previous research (Michel et al., 2021; Motoki et al., 2021). *A beach, a concert, a park,* and *a car* were included as potentially inappropriate environments to select environments not normally associated with hot meal consumption as determined by the researcher.

The intention was to recreate physical environments using digital-IEs. Therefore, while other situational variables can affect food choice and acceptance, e.g., social surroundings, for practicality, these factors were not included in this study. For the inappropriate environments, while these may be more subtle in reality, extreme examples were chosen to test the hypothesis that the appropriateness of digital-IEs affects liking and emotional response.

4.2.1.3 Protocol

A link to the online survey was emailed to potential research participants from the Feast Consumer Database. The survey was hosted using Compusense Cloud® Software (Compusense Inc., Ontario, Canada) and was completed by respondents in their own time, using their own personal devices.

Respondents were asked to select in which eating environments they were most likely, and unlikely, to eat spaghetti with PB-meatballs. Using the environments selected, respondents then ranked where they were most *likely* and *unlikely* to be eating. If respondents did not normally consume PBMAs, they were asked to select where they would be willing to try them.

4.2.1.4 Data analysis

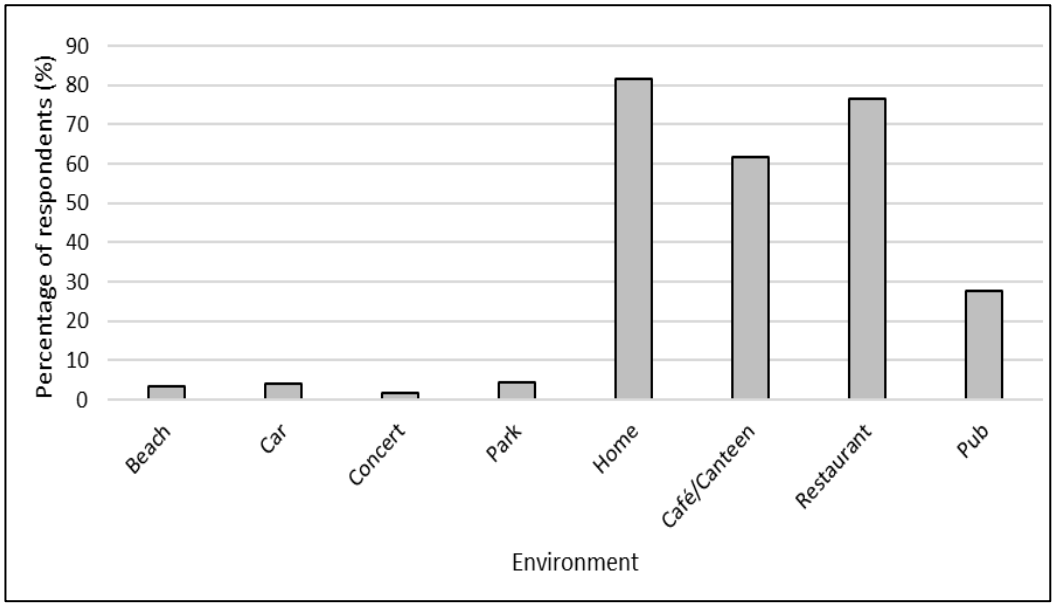
All statistical analyses were performed in R version 4.1.3 (R Core Team, 2022) using R Studio software version 2023.06.1. The percentage of respondents who selected each environment as likely or unlikely for consuming PB-meatballs was determined. The ranking data was modelled using a Plackett-Luce model (`PlackettLuce` (Turner et al., 2023)) to determine the worth parameter for each environment as determined by the coefficient for the model. Worth parameters are constrained to sum to one and represent the probability that the corresponding environment comes first in a ranking of all items (Turner et al., 2020).

4.2.2 Survey outcomes

One-hundred and eighty-three (183) survey responses were received. Three responses were excluded as the respondents scored 2 (*unfamiliar, I've heard of it but never eaten it)* or less for familiarity with spaghetti and meatballs/bolognaise. The remaining 180 responses had a mean familiarity score of 4 corresponding to *familiar I would eat it occasionally.*

The percentage of respondents who selected an environment as likely or unlikely for consuming PB-meatballs is shown in **Figure 4.1**. The home was selected by the highest percentage of respondents as a likely environment for consuming PB-meatballs (82%), followed by a restaurant (77%). A concert was selected by the highest percentage of respondents as an unlikely environment for consuming PB-meatballs (92%), followed by the beach (85%).

A



B

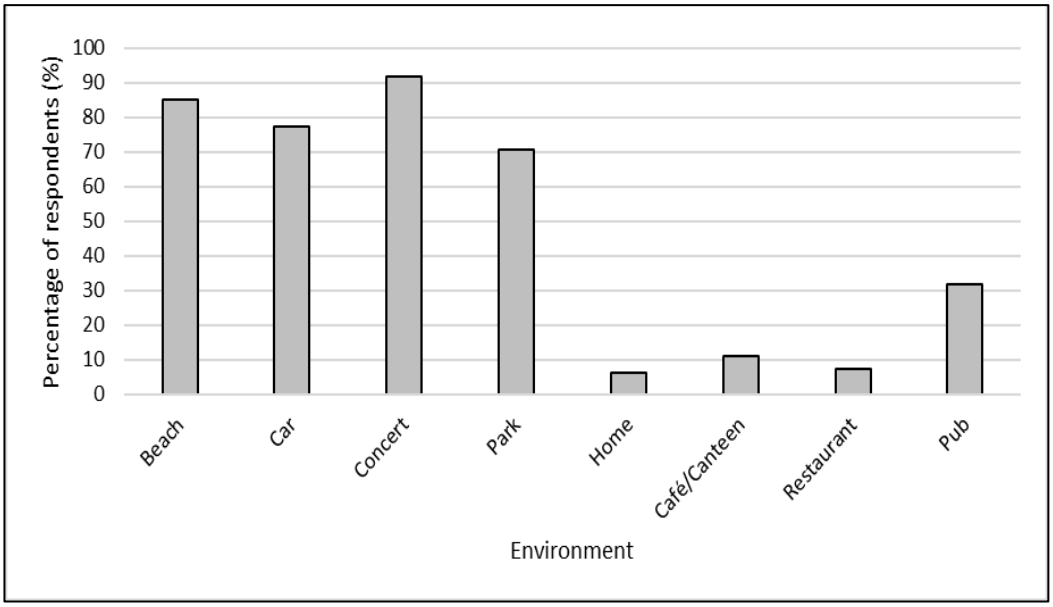


Figure 4.1. Percentage of respondents who selected an environment as a likely (A) or unlikely (B) environment for consuming PB-meatballs.

As indicated by the highest worth parameters determined by Plackett-Luce models (**Table 4.1**) the home was confirmed to be the most likely environment (of the options given) for respondents to consume/be willing to consume PB-meatballs, a restaurant was also a likely environment. As indicated by the lowest worth parameters, a concert was confirmed to be the most unlikely environment (of the options given) for PB-meatballs consumption, a beach was also an unlikely environment.

Table 4.1. Worth parameters as determined by Plackett-Luce models for rankings of most likely and unlikely eating environments for consuming PB-meatballs. (Worth parameters, constrained to sum to one, represent probability environment is ranked first).

Environment	Worth parameters for likely environments	Worth parameters for unlikely environments
Home	0.35	0.02
Restaurant	0.29	0.04
Café/Canteen	0.17	0.008
Pub	0.11	0.06
Park	0.03	0.09
Beach	0.04	0.29
Concert	0.01	0.32
Car	0.004	0.17

4.3 Consumer study to determine effect of eating environment and sauce addition on consumer response (Study 3: Part B)

A quantitative study was conducted to assess consumer emotional response and liking to two PB-meatballs, with and without a tomato sauce, in the appropriate and inappropriate environments selected via experiment one. This study was considered and assessed as low risk according to the Massey University Human Ethics Committee process (human ethics notification number: 4000027702). Informed consent was obtained from all participants at the commencement of the study. Participants were compensated for their time with a NZD60 shopping voucher at study completion.

4.3.1 Materials and methods

4.3.1.1 Participants

Participants were recruited from the Food Experience and Sensory Testing (Feast) Laboratory consumer database, and flyer distribution around Palmerston North, NZ. Inclusion criteria required participants to: (1) be aged between 25 and 55 years, the age range used in the previous chapters to capture Millennial and Generation X consumers, (2) be familiar with the dish spaghetti and meatballs (3) be able to communicate effectively in English, (4) not be allergic or intolerant to the sample ingredients, (5) not be pregnant nor lactating, (6) be willing to try PBMAs, (7) agree that ‘the home’ is an appropriate environment and a ‘music concert’ is an inappropriate environment for consuming PBMAs. All products used were vegan, gluten-free, Halal and Kosher, therefore participants were not excluded on this basis. Eligibility was assessed through a self-reported recruitment screening questionnaire.

4.3.1.2 Samples

To imitate meatballs in tomato sauce (i.e. as you would have in spaghetti and meatballs), two PB-meatball samples (**Table 4.2**) and one tomato sauce were selected. The PB-meatballs were 'meatball' versions of patties included in a previous study and were selected as they represented products with a low and high hedonic rating (**Chapter 3**). The 'Beyond-Meat Balls' were formed from Beyond patties, whereas Food Nation Beetroot, Kumara and Quinoa Amaze Balls ('Veggie Balls') were commercially available as pre-rolled balls. The tomato sauce was selected based on bulk availability and being a well-known quality brand.

Table 4.2. Description of PB-meatballs and tomato sauce.

Product Name	Ingredients	Manufacture	Product Image
Food Nation Beetroot, kumara, and Quinoa Amaze balls	Vegetables (59%) (Mushrooms, Chickpeas, Beetroot, Kumara, Red Onion, Garlic), Vegetable Oil, Kiwi Quinoa, Vegetable Protein (Faba Bean, Pea), Vegetable Gums (Methylcellulose, Xanthan, Locust Bean, Guar), Rice Flour, Modified Starch (1412), Pea Fibre, Salt, Molasses, Spices.	*Food Nation Ltd, Christchurch, New Zealand*	
Beyond Burger	Water, pea protein (16%), canola oil, coconut oil, rice protein, flavouring, stabilizer (methylcellulose), potato starch, apple extract, colour (beetroot red), maltodextrin, pomegranate extract, salt, potassium salt, concentrated lemon juice, maize vinegar, carrot powder, emulsifier (sunflower lecithin).	*Beyond Meats Inc, El Segundo, California, United States*	
Buitoni Sugo Per Pasta Sauce	Tomato Puree (88%)(Water, Tomato Paste), Onions, Sugar, Sunflower Oil, Salt, Herbs & Spices, Food Acid (Citric).	*Buitoni Food Company, Sansepolcro, Italy*	

4.3.1.3 Sample preparation

Beyond patties were divided into 16.1±0.2g portions, rolled into balls, and then frozen until the time of cooking. Three disposable foil dishes (Castaway, New Zealand) were each filled with 200g of tomato sauce, covered with aluminium foil, and heated in an oven (Fisher and Paykel, New Zealand) at 180°C fan force for 15-minutes. The PB-meatballs were separately pan-fried on an induction cooktop (CI604CTB1, Fisher and Paykel, New Zealand) in two tablespoons (approximately 30g) of canola oil (Harvest NZ, New Zealand) per 24 meatballs. The PB-meatballs were cooked from frozen until an internal temperature of 75°C was reached (approximately 10-minutes). After the trays of tomato sauce were heated for 15-minutes in the oven, half of the cooked PB-meatballs were combined with the sauce and heated in the oven for a further 15-minutes (one tray for just the sauce, one tray for Veggie Balls, one tray for the Beyond-Meat Balls). The remaining PB-meatballs were portioned into ceramic dishes, covered with aluminium foil, and kept warm in a food warmer (E84 Food Warmer, Bakbar, New Zealand) at 60 °C. The same procedure was followed for the PB-meatballs that had been combined with the sauce, and the sauce on its own, once they had been in the oven for 15-minutes. Samples (**Table 4.3**) were kept in the food warmer for no longer than one-hour. All samples were served in small white ceramic dishes covered in aluminium foil and labelled with random 3-digit codes. Different 3-digit codes were used in each eating environment. Participants were not required to consume the whole sample but were encouraged to consume as much as they could to fairly assess each sample.

Table 4.3. Sample names and images.

Individual Components	Combined Components
1. Veggie Balls 	4. Veggie Balls + Tomato sauce 
2. Beyond-Meat Balls 	5. Beyond-Meat Balls + Tomato sauce 
3. Tomato sauce 	

4.3.1.4 Test environments

Three test environments were used; A traditional central location test (T-CLT), and two digital-IEs. All three environments were set up in the "Immersive Space" in the Feast laboratory at Massey University (**Figure 4.2**).

Figure 4.2. Test Environments: A. Traditional-CLT set-up (no immersion); B. Digital immersive home environment set-up; C. Digital immersive classical music concert set-up.

For the T-CLT environment (**Figure 4.2A**), no contextual information was given. Tables were arranged to accommodate 12 participants, with all participants facing the same blank wall. Each participant received a white tray, water glass, napkin, plastic spork (spoon-fork), and dish of water crackers.

To create the digital immersive home (DI-Home) (**Figure 4.2B**), a 360° image of the kitchen and dining area of a home created using an Insta360 Pro 2 (https://www.insta360.com/product/insta360-pro2), was projected on the walls of the evaluation room using Igloo immersive technology (Igloo Vision Ltd., Australia). Six tables were set up with white tablecloths and each participant received a placemat, white bowl, water glass, stainless steel fork and spoon, and water crackers. Two participants were seated at each table, accommodating up to 12 participants per session. Props, including a floor lamp, pot plant, and entertainment unit with TV, were placed around the room. The TV was playing current event news stories from the New Zealand Herald YouTube channel https://www.youtube.com/@nzheraldtv. The intention of

having the TV playing was to replicate watching the evening news as well as introduce sound into the experience to reduce the confounding effects of sound across the two immersive environments. At the start of the evaluation participants were given the following context statement: "*When assessing the samples, I would like you to imagine you are having a mid-week dinner at home. You are sitting at the dining table, you could be alone, or with your family or your flatmates (whoever you usually eat dinner with). The TV is playing in the background. This environment may not look like your home but use it to help imagine how you would be feeling if eating at home."* Then for each question participants were instructed *"imagine you are eating dinner at home, [rate how much…]"*

To create the digital immersive classical music concert (DI-Concert) (**Figure 4.2C**), a 360° image of an opera house (https://www.unrealengine.com/marketplace/en-US/product/opera-house-kit) (Unreal Engine, Epic Games INC., USA) was projected on the walls of the evaluation room using Igloo immersive technology (Igloo Vision Ltd., Australia). A video of a classical music concert was also projected on the wall and positioned as if the video was playing on the stage. The classical music concert video was made by joining two YouTube videos; Beethoven: Symphony No. 7 | Bernard Haitink & the Royal Concertgebouw Orchestra (2009)(https://www.youtube.com/watch?v=Rd0HnxWm5CY), and Wolfgang Amadeus Mozart: Flute Concerto no. 1 in G-Major, K. 313 https://www.youtube.com/watch?v=1syDCEn_XOw). Chairs with red seat covers were arranged to mimic consumers sitting in the concert audience. Small tables were set-up between participants and each participant received a white bowl, water glass, stainless steel fork and spoon and water crackers. The small tables were not characteristic of a typical concert but were required to give participants space to rest their iPads and water glasses. At the start of the evaluation participants read the following context statement: "*When assessing the samples, I would like you to imagine you are eating during a classical music performance. You are seated, the lights are dimmed, the audience is quiet and attentively watching the orchestra on stage. Please rest the iPad on the table and eat with the bowl on your lap."* Then for each question participants were instructed *"Imagining you are at a classical music*

concert, [rate how much…]". For the digital-IEs, the lights were dimmed to optimise the projected images. Dim lighting was also necessary for setting the atmosphere in the DI-Concert setting.

4.3.1.5 Experimental design

To assess the effect on liking and emotional response of sauce addition, within a session, the individual components were assessed first and presented monadically following a Williams' Latin square design (Wakeling & MacFie, 1995). Following this, the combined components were assessed and presented monadically following a balanced design. Unsalted water crackers (Original Water Crackers, Arnott's, Australia) and filtered water were provided as palate cleansers. A two-minute minimum break was enforced between samples to allow participants time to cleanse their palate to minimise carry-over effects.

Participants assessed the five samples for expected overall liking, liking (overall, appearance, flavour, and texture) and emotional response in three different eating environments (T-CLT, DI-Home and DI-Concert). Participants also assessed the appropriateness of the eating environment to each sample. Samples were assessed in each eating environment over three separate visits, with one week between visits. All participants assessed the samples in the T-CLT during their first visit to establish a baseline before the introduction of the digital-IEs. Following this baseline assessment, the order of exposure to the digital-IEs (DI-Home and DI-Concert) was balanced across participants during their second and third visits. At the end of each session, participants completed a questionnaire to assess their engagement and sense of presence in each test environment (Bangcuyo et al., 2015).

4.3.1.6 Questionnaire

Data was collected using Compusense Cloud® Software (Compusense Inc., Ontario, Canada) via iPads. At each session start, a short presentation was given on the order of assessment and how to answer each question type. Instructions were also built into the test. When presented with a sample, participants first assessed it for expected liking, followed by overall liking, appearance-liking, texture-liking, and flavour-liking. All liking questions were assessed using a continuous

line scale (0-100) labelled '*dislike extremely'* (0), '*neither dislike nor like'* (50) and '*like extremely'* (100). Participants then assessed their emotional response to the sample using the lexicon developed in **Chapter 2** on continuous line scales (0-100), labelled '*not at all'(0),* '*moderately*' (50) and '*extremely*'(100). When making their emotional response, participants were instructed to *"rate the words that best describe how the sample makes you feel. If you do not feel an emotion rate it as zero"*. The presentation order of the attributes for emotion ratings was balanced between participants, however, for each participant the order of the attributes was fixed for all samples across the two sessions as recommended by Meyners and Castura (2016).

A rating method was employed to measure emotional response for this study to investigate if the emotions observed to have a low average citation proportion (<5%) in **Chapter 3** are irrelevant to PBMAs, or if they are relevant but only experienced at lower intensity levels. Rating may provide finer levels of emotional detail (additional emotions and at lower intensity levels) compared to a CATA task, where consumers use a higher threshold to check an emotion (Meiselman, 2016). A rating method is also advantageous over CATA when differences between samples are more subtle/only differ in the intensity of attributes (Ares & Jaeger, 2023). A rating method was therefore more appropriate for this portion of research where the meatball alternatives were being compared with and without the sauce and differences were likely to be subtle.

Participants also rated their perceived appropriateness of sample consumption in the specific eating environment on a continuous line scale (0-100) anchored from never appropriate to always appropriate. In the digital-IEs, participants were asked "*how appropriate is it to eat this sample for dinner at home?*" or *"how appropriate is it to eat this sample at a classical music concert?* For the T-CLT set-up participants were asked "*how appropriate is it to eat this sample in a product test environment?"*

At the end of each visit, participants completed an engagement and presence questionnaire developed by Bangcuyo et al. (2015) which covers eight dimensions of engagement including Usability, Novelty, Environmental Aesthetics, Involvement, Sensory Awareness, Immersion, Realism, Distraction (**Table 4.4**). Small modifications were made to the original questionnaire,

including replacing "*I felt like I was in a coffee house*" with "*I felt like I was in a home*" and "*I felt like I was at a classical music concert*". The question "*How much did the olfactory aspects of the test environment involve you"* was excluded as aroma was not used in this study. 5-point Likert scales used in the original questionnaire were replaced with continuous line scales (-50 to 50) labelled "*strongly disagree*" "*neither disagree nor agree*" (0) "*strongly agree*" (50) and 7-point Likert scales were replaced with continuous line (-50 to 50) scales labelled '*not at all'*(-50), '*moderately*' (0) and '*very'* (50). This change was made to keep the scale type consistent throughout the evaluation and for ease of data modelling.

Table 4.4. The engagement and presence questionnaire developed by Bangcuyo et al. (2015).

Dimension	Statement/Question	Anchor Points
Usability	The test environment assisted in my evaluations of the samples	Strongly disagree - strongly agree
Environmental Aesthetics	The test environment was appealing	Strongly disagree - strongly agree
	The test environment engaged my senses	
Novelty	The test environment made me feel curious	Strongly disagree - strongly agree
	The test environment distracted me	
	The test experience was boring*	Strongly disagree - strongly agree
Involvement	The test experience was fun	
	I was engaged in the sensory task I performed	
Sensory Awareness	How completely were all your senses engaged by the test environment?	Not at all - very
	How much did the visual aspects of the test environment involve you?	
	How much did the sound aspects of the test environment involve you?	
Immersion	a. I felt like I was in a home	Strongly disagree - strongly agree
	b. I felt like I was at a classical music concert	
	I lost track of time.	
Realism	How disconnected did you feel from the test environment? *	Not at all - very
	How much did your experiences in the test environment seem consistent with your real-world experiences?	
	How completely did you feel immersed in the test environment?	
	How involved were you in the test environment experience?	
Distraction	How aware were you of events occurring in the real world around you? *	Not at all - very
	How quickly did you adjust to the test environment experience?	
	How much did the test environment interfere or distract you from performing your sensory evaluation? *	

* Reverse-coded item. Due to the negatively worded question format, values are reversed scored (strongly disagree (50) – strongly agree (-50); Not at all (50) – Very (-50)).

4.3.2 Data analysis

All statistical analyses were performed in R version 4.1.3 (R Core Team, 2022) through R Studio software version 2023.06.1. R packages used included `dplyr` (Wickham et al., 2023) for data manipulation, `ggplot2` (Wickham, 2016) for data visualisation, `lme4` (Bates et al., 2015) for linear mixed effect models, and `emmeans` (Lenth, 2023) for multiple paired comparisons. An α level of 0.05 was considered statistically significant and mean ± standard error (SE) values are reported throughout the chapter.

4.3.2.1 Situational appropriateness, liking and emotional response ratings

Situational appropriateness, liking and emotional response ratings were all handled similarly. Mean intensity ratings and standard errors (SE) for all situational appropriateness ratings, liking ratings and emotion ratings were determined for each product (Veggie Balls or Beyond-Meat Balls), in the presence and absence of sauce, under each environment condition (T-CLT, DI-Home and DI-Concert).

To determine if situational appropriateness, liking and emotional response ratings differed between the samples or between the environments, linear mixed effect models (LMM) were used. Situational appropriateness ratings, liking ratings or emotional response ratings were set as the response variable, *session order* (order of environments in which samples were assessed i.e. T-CLT|DI-Home|DI-Concert or T-CLT|DI-Concert|DI-Home) *product* (Veggie Balls or Beyond-Meat Balls), *sauce* (present or absent), *eating environment* (T-CLT, DI-Home, DI-Concert) and the two-way and three-way interactions of *product*, *sauce* and *environment* were set as fixed factors and *participant* as a random factor. Post hoc pairwise comparison tests with Tukey adjustments for multiple comparisons were conducted when significant main and interaction effects were identified.

To determine the magnitude of change in liking caused by sauce addition, product liking ratings when tasted on their own were subtracted from those when tasted with sauce. A two-sample paired t-test was then performed on the difference values to determine if any modification to liking with and without sauce differed between the two products.

Note: due to human error the question on situational appropriateness did not appear for every sample in the questionnaire. Instead, this question only appeared at the end of each section i.e., for the sample in the third position for the individual components, and the sample in the second position for the combined components. For the DI-Home 66 participants were affected and the DI-Concert 12 participants were affected. Missing data points were treated as not available (NA) values in the analysis.

4.3.2.2 Engagement and presence questionnaire

For each test environment an average dimension score (Usability, Novelty, Environmental Aesthetics, Involvement, Sensory Awareness, Immersion, Realism, Distraction) was calculated, dimension scores were then linearly summed to generate the total engagement score following Bangcuyo et al. (2015). Reverse-coded questions were reverse-scored. With eight dimensions the total engagement score had a theoretical range of -400 (not engaged at all) to 400 (very engaged). To determine whether the dimension scores and the total engagement score differed between the three environments, linear mixed effect models were performed for each of the dimensions as well as the total engagement score. In all cases *environment* was set as a fixed factor, and *participant* as a random factor. Post hoc pairwise comparison tests with Tukey adjustments for multiple comparisons were conducted when significant effects were identified.

4.3.2.3 Clustering of participants based on engagement and presence questionnaire

To determine whether consumers could be segmented based on their responses to the engagement and presence questionnaire, k-means clustering (Euclidian distance) was performed on the responses to each questionnaire item in the two digital-IEs (42 columns (21 questions x 2 environments), by 109 rows (consumers)). The optimal cluster number was determined using the elbow and silhouette methods (`factoextra` (Kassambara & Mundt, 2020)).

To determine if consumer segments responded differently regarding their liking and emotional response towards the samples, *cluster adherence* was added to the linear mixed effect models for liking and emotion response as a main effect and was allowed to interact with *product*, *sauce* and e*nvironment.*

4.4 Results

4.4.1 Consumer demographics

One-hundred and nine consumers (75.2% female) aged between 25 and 55 years old (mean = 38.6±7.9 years old) participated; 55% were omnivores, 30.3% flexitarian, 9.2% vegetarian, 1.8% pescatarian, 0.9% vegan and 2.8% other diets.

4.4.2 Situational appropriateness

A significant main effect of *environment* ($p<0.001$) was found for situational appropriateness ratings. "For dinner at home" was rated most appropriate for the consumption of the samples (mean=76.5*)* compared to "At a classical music concert" (mean=34.4, $p<0.001$) and "In a product testing environment" (mean=49.7, $p<0.001$) (**Figure 4.3**), confirming that participants considered the selected environments (in)appropriate for the focus products.

A significant *environment*product* interaction ($p=0.001$) was also found for situational appropriateness ratings. In the T-CLT consumption of Beyond-Meat Balls was rated more appropriate than the Veggie Balls ($p<0.001$). Differences in product appropriateness in the other two environments were not observed (Home $p=0.469$, Concert $p=0.754$) (**Figure 4.3**). The effect of *session order* ($p=0.265$), *sauce* ($p=0.359$), or interactions of *sauce* and *environment* ($p=0.307$), and *sauce* and *product* ($p=0.916$) on situational appropriateness ratings were not significant.

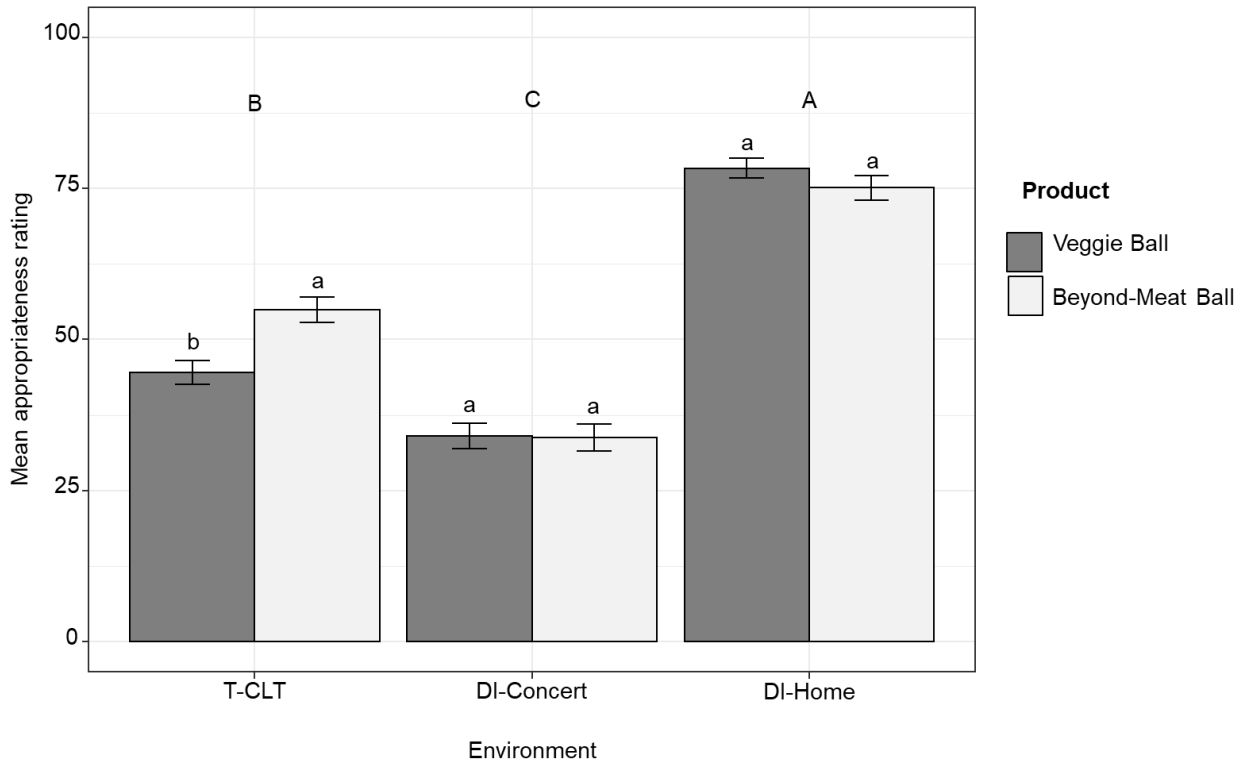


Figure 4.3. Mean (±SE) Perceived situational appropriateness ratings by product in each environment (averaged across sauce); ^{ABC}different uppercase letters indicate significant differences between means across environments. ^{ab}different lowercase letters within an environment indicate significant differences between means across products obtained from post hoc tests with Tukey adjustments for multiple comparisons ($p<0.05$).

4.4.3 Product liking

Expected, appearance, flavour, texture and overall liking product scores and their combination with sauce are summarised in **Appendix L** and F-values and p-values for main and interaction effects derived from linear mixed effect models for each liking modality are presented in **Table 4.5**. The effect of *session order* was not significant for any of the liking modalities indicating the order of the environments in which the samples were assessed did not have a significant impact on the liking ratings.

Table 4.5. F-values and p-values for the main effects of session order, product, sauce and environment, and all 2-way and 3-way interactions derived from linear mixed effect models for each liking modality.

Liking Modality		Session Order (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Product* Sauce (DF=1)	Environment* Product (DF=2)	Environment* Sauce (DF=2)	Environment* Product*Sauce (DF=2)
Expected liking	F	0.524	97.506	148.625	5.563	40.605	3.122	3.940	0.357
	p	0.471	<0.001***	<0.001***	0.004**	<0.001***	0.044*	0.020*	0.700
Overall liking	F	0.875	784.364	18.323	1.970	0.285	2.023	0.614	0.062
	p	0.372	<0.001***	<0.001***	0.140	0.594	0.133	0.541	0.940
Appearance liking	F	0.139	106.887	133.664	9.251	33.567	4.482	5.250	0.353
	p	0.709	<0.001***	<0.001***	<0.001***	<0.001***	0.011*	0.005**	0.703
Flavour liking	F	1.050	657.061	24.262	0.932	2.967	2.155	0.395	0.040
	p	0.308	<0.001***	<0.001***	0.394	0.085	0.116	0.674	0.961
Texture liking	F	0.590	795.795	13.971	3.625	0.524	3.243	0.043	0.143
	p	0.444	<0.001***	<0.001***	0.027*	0.469	0.0394*	0.958	0.867

Significant effects are indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$

4.4.3.1 Influence of product on liking

A significant main effect of *product* was found for all liking modalities (all p<0.001, **Table 4.5**), indicating significant differences in liking ratings between the Veggie Balls and Beyond-Meat Balls when averaged across sauce (absent/present) and environment. Post hoc tests showed for all liking modalities the Beyond-Meat Balls were rated significantly higher than the Veggie Balls (all p<0.001) (**Figure 4.4**).

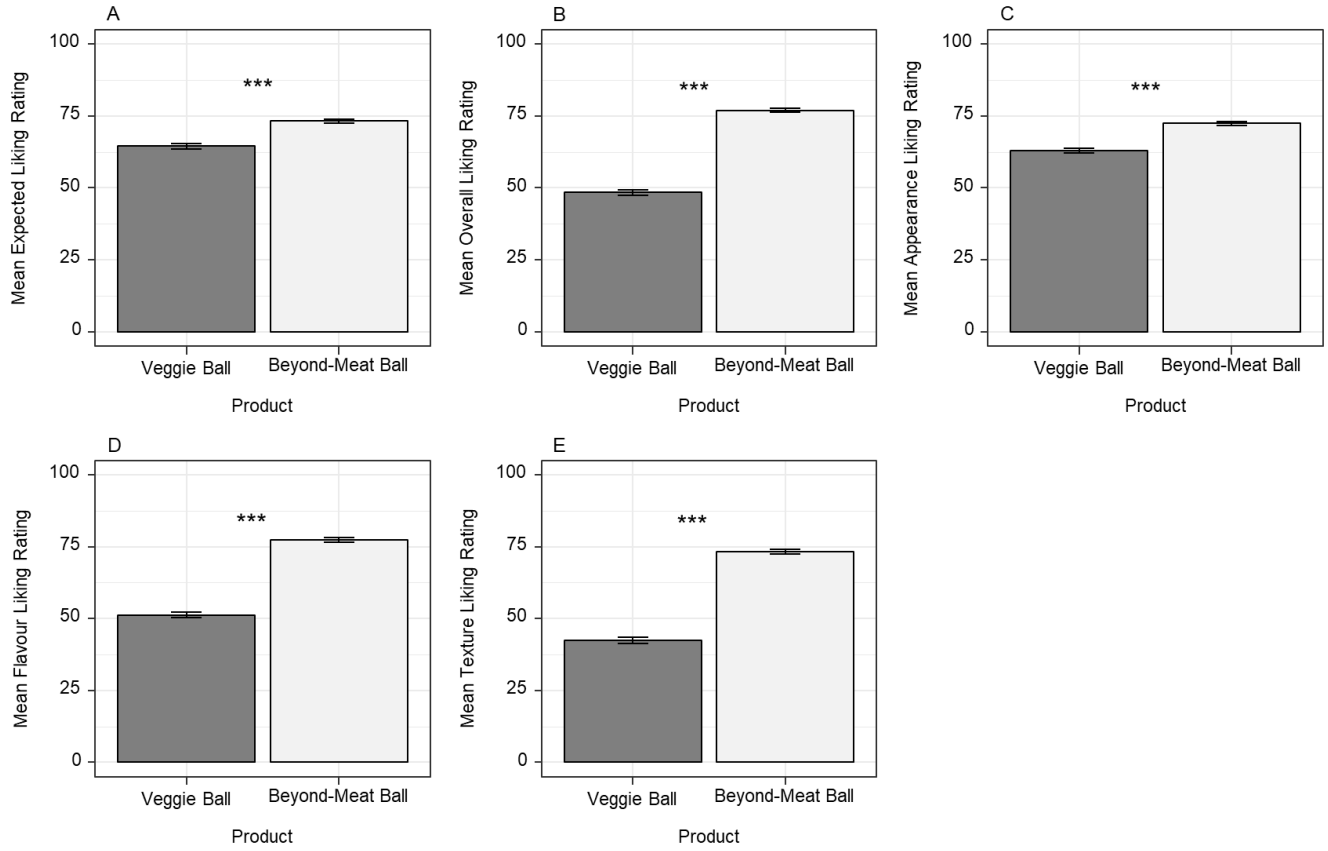


Figure 4.4 A-E. Mean (±SE) liking ratings by product (averaged across sauce and environment); Significant differences are indicated by *** ($p < 0.001$). A) expected liking; B) overall liking; C) appearance liking; D) flavour liking; E) texture liking.

4.4.3.2 Influence of sauce addition on product liking

When tasted on its own the tomato sauce was well-liked with a pooled (across eating environments) mean overall liking of 73.81 ± 1.90 on the 100-point scale.

A significant main effect of *sauce* was found for all modalities of liking (all p<0.001) indicating differences in liking between sauce absent and present when liking ratings were averaged across

products and environments. Post hoc tests showed that for all modalities of liking, ratings were significantly higher when the sauce was present as opposed to absent (all p<0.001) (**Figure 4.5**).

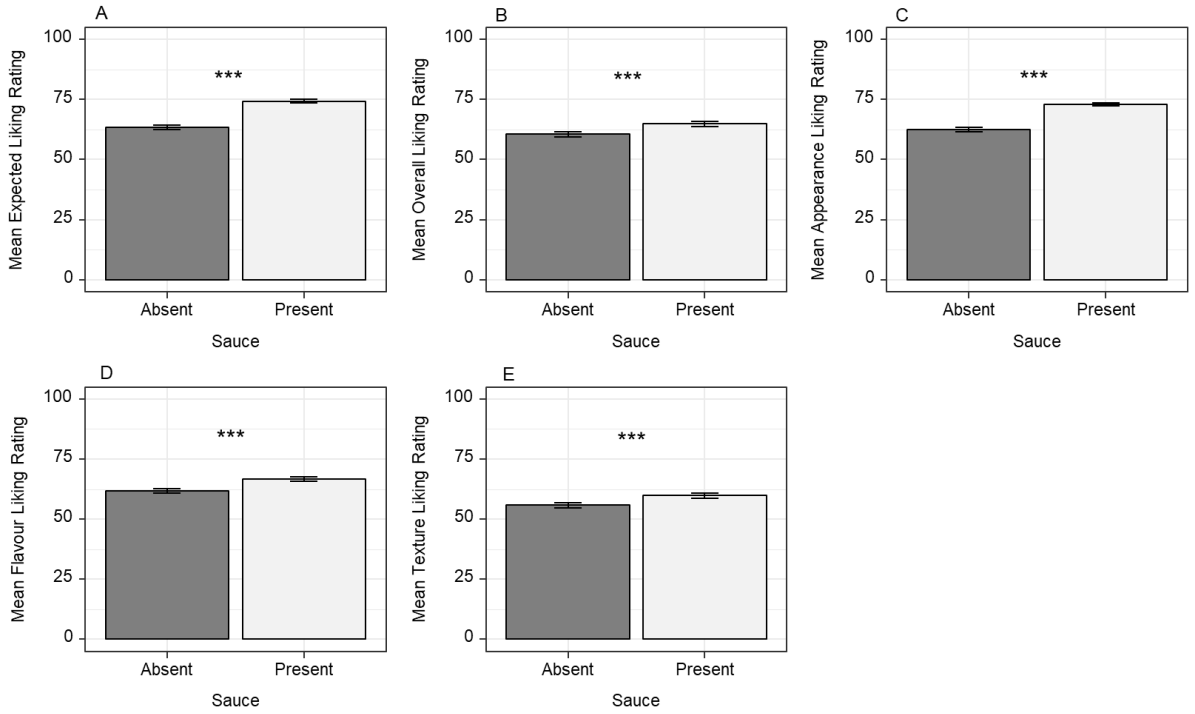


Figure 4.5. Mean (±SE) liking ratings in the absence and presence of sauce (averaged across product and environment); Significant differences are indicated by *** ($p < 0.001$). A) expected liking; B) overall liking; C) appearance liking; D) flavour liking; E) texture liking.

A significant *product*sauce* interaction was observed for appearance (p<0.001) and expected liking (p<0.001) indicating the sauce's impact on liking was dependent on the product. Sauce addition caused a greater increase in appearance liking (t=5.61, p <0.001) and expected liking (t=6.28, p <0.001) for the Veggie Balls than for the Beyond-Meat Balls. The *product*sauce* interaction for flavour liking approached significance (p=0.085), sauce addition caused a greater increase in flavour liking (t=2.28, p =0.023) for the Veggie Balls than for the Beyond-Meat Balls (**Figure 4.6**).

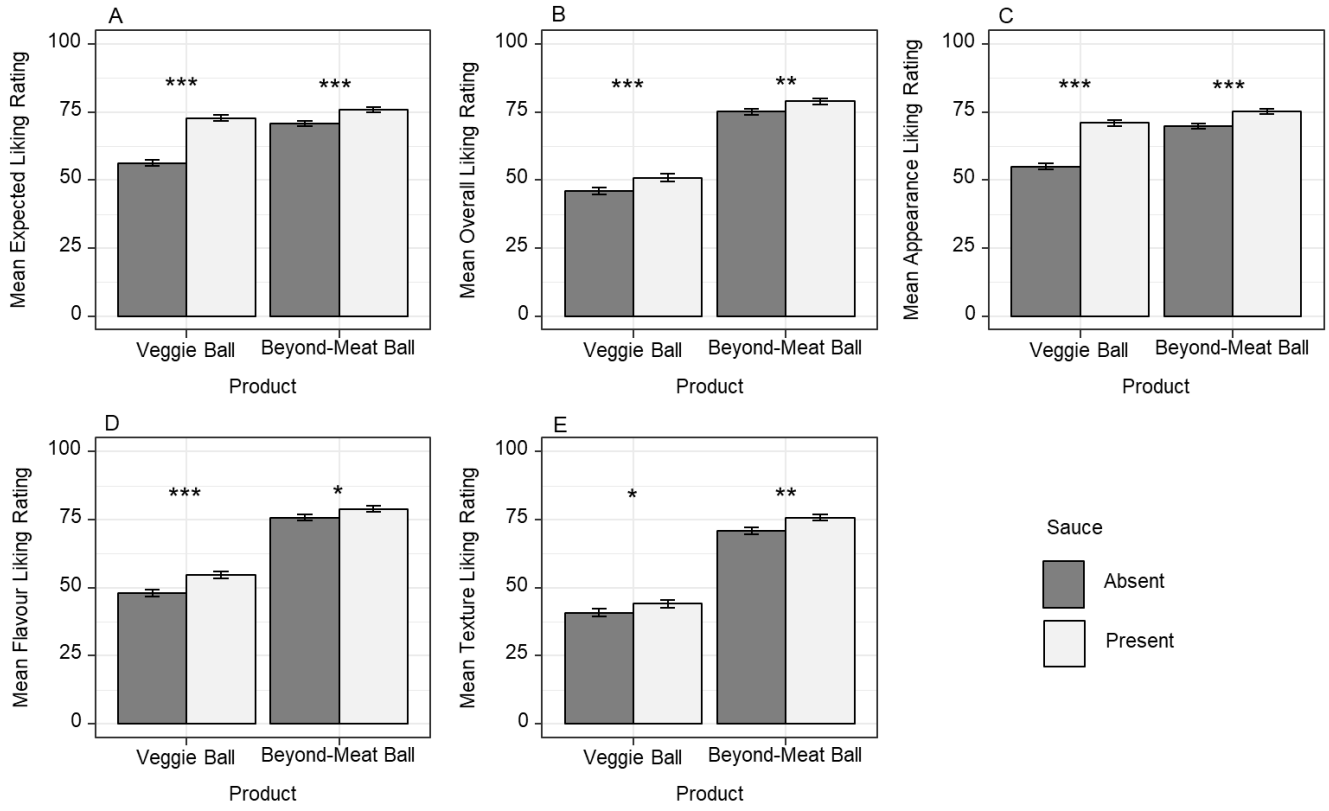


Figure 4.6. Mean (±SE) liking ratings per product in the absence and presence of sauce (averaged across environment); Significant differences are indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$). A) expected liking; B) overall liking; C) appearance liking; D) flavour liking; E) texture liking.

4.4.3.3 Influence of environment on product liking

A significant main effect of *environment* was found for appearance ($p<0.001$), expected ($p=0.004$) and texture liking ($p=0.027$), indicating average ratings for these liking modalities differed according to the environment in which they were assessed. Post hoc tests showed appearance liking was significantly higher in the DI-Home compared to the DI-Concert ($p<0.001$) and T-CLT ($p=0.002$). Similarly expected liking was also significantly higher in the DI-Home compared to the DI-Concert ($p=0.004$) and T-CLT ($p=0.042$). Texture liking was significantly higher in the DI-Home compared to the T-CLT ($p=0.020$).

Furthermore, a significant *product*environment* interaction was found for appearance ($p=0.011$), expected ($p=0.044$), and texture ($p=0.039$) liking indicating the impact of environment was product-dependent. Post hoc tests revealed such ratings for the Veggie Balls (averaged combined liking over sauce absent/present) were significantly greater in the DI-Home compared to the DI-Concert (appearance liking p=<0.001; expected liking p=0.012; texture liking p=0.023) and T-CLT (appearance

liking p=<0.001; expected liking p=0.002; texture liking p=0.005). Appearance liking of the Beyond-Meat Balls was significantly greater in the DI-Home compared to the DI-Concert (p=0.052). Expected and texture liking of the Beyond-Meat Balls did not differ between environments (p>0.05) (**Figure 4.7**).

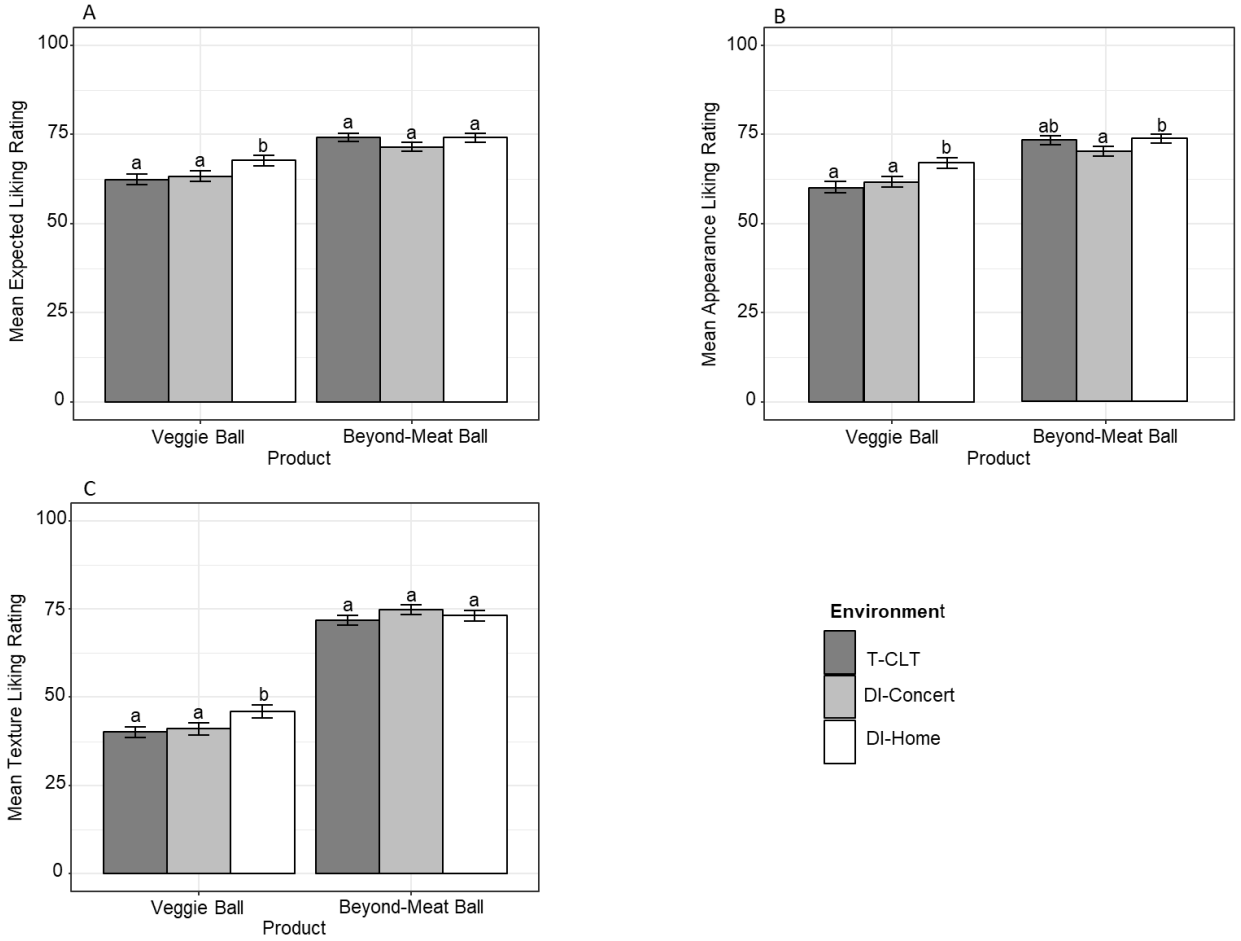


Figure 4.7. Mean (±SE) liking ratings by product in each environment (averaged across sauce); [ab]different lowercase letters within a product indicate significant differences between means across environments obtained from post hoc tests with Tukey adjustments for multiple comparisons (p<0.05). A) expected liking; B) appearance liking; C) texture liking.

A significant *sauce*environment* interaction was found for appearance (p=0.005) and expected (p=0.020) liking. Post hoc tests showed that in the absence of sauce (average combined liking over the two products), appearance and expected liking were significantly higher in the DI-Home compared to the DI-Concert (appearance liking p=0.003; expected liking p=0.040) and T-CLT (appearance liking p=<0.001; expected liking p=0.001). When sauce was present (average combined liking over the two products) appearance liking in the DI-Home was higher than in the DI-Concert (0.045) but not the T-CLT, and expected liking was the same across the environments.

4.4.4 Emotional response

Mean emotion ratings and standard error for each sample in the three eating environments are presented in **Appendix M.** F-values and p-values for main and interaction effects derived from linear mixed effect models for each emotion are presented in **Table 4.6**. The effect of *session order* was significant only for the emotion 'adventurous'. Participants who assessed the samples in the DI-Concert environment during their second session rated 'adventurous' higher (when averaged over product, sauce, and environment) compared to participants who assessed the samples in the DI-Home during their second session.

Table 4.6. F-values and p-values for the main effects of session order, product, sauce and environment and all 2-way and 3-way interactions derived from linear mixed effect models for each emotion category.

Emotion Category		Session Order (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Product* Sauce (DF=1)	Environment* Product (DF=2)	Environment* Sauce (DF=2)	Environment* Product*Sauce (DF=2)
Adventurous	F	4.346	170.938	4.891	3.112	0.664	1.851	3.071	0.238
	p	0.039*	<0.001***	0.0272*	0.045*	0.415	0.158	0.047*	0.789
Afraid	F	0.977	39.011	0.086	0.605	0.049	1.953	2.971	0.393
	p	0.325	<0.001***	0.770	0.546	0.825	0.142	0.052	0.675
Amazed	F	1.926	359.335	10.325	0.793	0.007	1.947	0.352	0.739
	p	0.168	<0.001***	0.001**	0.453	0.934	0.143	0.704	0.478
Angry	F	0.167	87.432	0.684	0.493	0.532	1.695	0.496	0.090
	p	0.684	<0.001***	0.409	0.612	0.466	0.184	0.609	0.914
Anxious	F	0.998	65.176	3.874	4.004	0.001	1.146	1.719	0.152
	p	0.320	<0.001***	0.049*	0.018*	0.980	0.318	0.180	0.859
Bored	F	0.175	241.004	0.018	0.166	0.318	0.985	5.018	2.869
	p	0.676	<0.001***	0.895	0.847	0.573	0.374	0.007**	0.057.

Table 4.6. F-values and p-values for the main effects of session order, product, sauce and environment and all 2-way and 3-way interactions derived from linear mixed effect models for each emotion category (continued).

Emotion Category		Session Order (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Product* Sauce (DF=1)	Environment* Product (DF=2)	Environment* Sauce (DF=2)	Environment* Product*Sauce (DF=2)
Calm	F	0.423	137.494	0.011	31.132	0.872	0.225	0.230	0.190
	p	0.517	<0.001***	0.916	<0.001***	0.351	0.798	0.795	0.827
Curious	F	0.890	132.411	0.380	6.460	0.036	0.881	2.203	0.670
	p	0.347	<0.001***	0.538	0.002**	0.849	0.415	0.041*	0.512
Deceived	F	0.722	210.773	1.291	0.330	0.362	0.268	0.555	0.110
	p	0.397	<0.001***	0.256	0.719	0.548	0.765	0.574	0.896
Disappointed	F	0.586	410.240	0.132	0.691	0.205	3.183	0.699	0.308
	p	0.446	<0.001***	0.717	0.501	0.650	0.042*	0.497	0.735
Disgusted	F	0.074	186.524	0.013	0.001	0.412	0.187	2.603	0.014
	p	0.787	<0.001***	0.910	0.999	0.521	0.830	0.074	0.986
Dissatisfied	F	0.348	391.806	2.118	0.895	0.506	2.078	1.963	0.020
	p	0.556	<0.001***	0.146	0.409	0.477	0.126	0.141	0.981
Energetic	F	1.824	338.022	12.200	8.245	0.061	1.509	1.110	0.370
	p	0.180	<0.001***	<0.001***	<0.001***	0.805	0.222	0.330	0.691
Happy	F	1.136	474.407	4.938	8.754	0.235	2.526	0.377	0.009
	p	0.289	<0.001***	0.026*	<0.001***	0.628	0.080	0.686	0.991
Hopeful	F	0.635	281.426	5.066	6.440	0.155	0.150	1.331	0.052
	p	0.427	<0.001***	0.025*	0.0016*	0.694	0.861	0.265	0.950
Hungry	F	0.378	344.018	8.263	10.865	0.934	3.410	1.082	0.810
	p	0.540	<0.001***	0.004**	<0.001***	0.334	0.033*	0.339	0.445

Table 4.6. F-values and p-values for the main effects of session order, product, sauce and environment and all 2-way and 3-way interactions derived from linear mixed effect models for each emotion category (continued).

Emotion Category		Session Order (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Product* Sauce (DF=1)	Environment* Product (DF=2)	Environment* Sauce (DF=2)	Environment* Product*Sauce (DF=2)
Loving	F	1.814	270.481	15.365	35.045	0.000	0.149	0.467	0.175
	p	0.181	<0.001***	<0.001***	<0.001***	0.992	0.862	0.627	0.839
Neutral	F	0.005	35.154	7.515	0.137	2.360	2.421	1.628	1.123
	p	0.941	<0.001***	0.006**	0.872	0.125	0.089	0.197	0.326
Nostalgic	F	0.115	178.175	20.627	17.725	0.436	0.637	1.251	0.782
	p	0.735	<0.001***	<0.001***	<0.001***	0.509	0.529	0.287	0.458
Pleasant/ grateful	F	2.815	465.350	7.694	7.526	0.255	0.268	0.482	0.209
	p	0.096	<0.001***	0.006**	<0.001***	0.613	0.765	0.618	0.812
Satisfied	F	0.844	521.563	2.965	3.951	0.141	2.566	0.200	0.049
	p	0.360	<0.001***	0.085	0.195*	0.708	0.077	0.819	0.952
Suspicious	F	0.006	121.671	0.089	0.504	0.439	0.142	1.321	0.449
	p	0.936	<0.001***	0.766	0.605	0.508	0.868	0.267	0.639
Uncertain	F	1.345	156.568	0.402	1.920	0.754	1.658	1.264	0.524
	p	0.248	<0.001***	0.526	0.147	0.385	0.191	0.283	0.592
Unhappy/ sad	F	0.138	188.083	0.033	0.100	0.576	1.669	2.268	0.789
	p	0.711	<0.001***	0.857	0.905	0.448	0.189	0.104	0.455

Significant effects are indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)

4.4.4.1 Product effects on emotional response

A significant *product* effect was found for all emotions ($p<0.001$, **Table 4.6**), indicating significant differences in emotional response towards the two products when ratings were averaged over sauce (absent/present) and environment. Post hoc tests showed ratings for all positive emotions were significantly higher for the Beyond-Meat Balls compared to the Veggie Balls and ratings for all negative emotions were higher for the Veggie Balls compared to the Beyond-Meat Balls (all $p<0.001$). Ratings for the unclassified emotion 'curious' were higher for the Beyond-Meat Balls compared to the Veggie Balls ($p<0.001$) whereas ratings for the unclassified emotion 'neutral' were higher for the Veggie Balls ($p<0.001$) (**Figure 4.8**). In general, intensity ratings for positive emotions were higher (>25 on 100-point scale) than intensity ratings for negative emotions (<25 on 100-point scale) except for 'disappointed', 'dissatisfied' and 'uncertain' which were >25 on 100-point scale for the Veggie Balls.

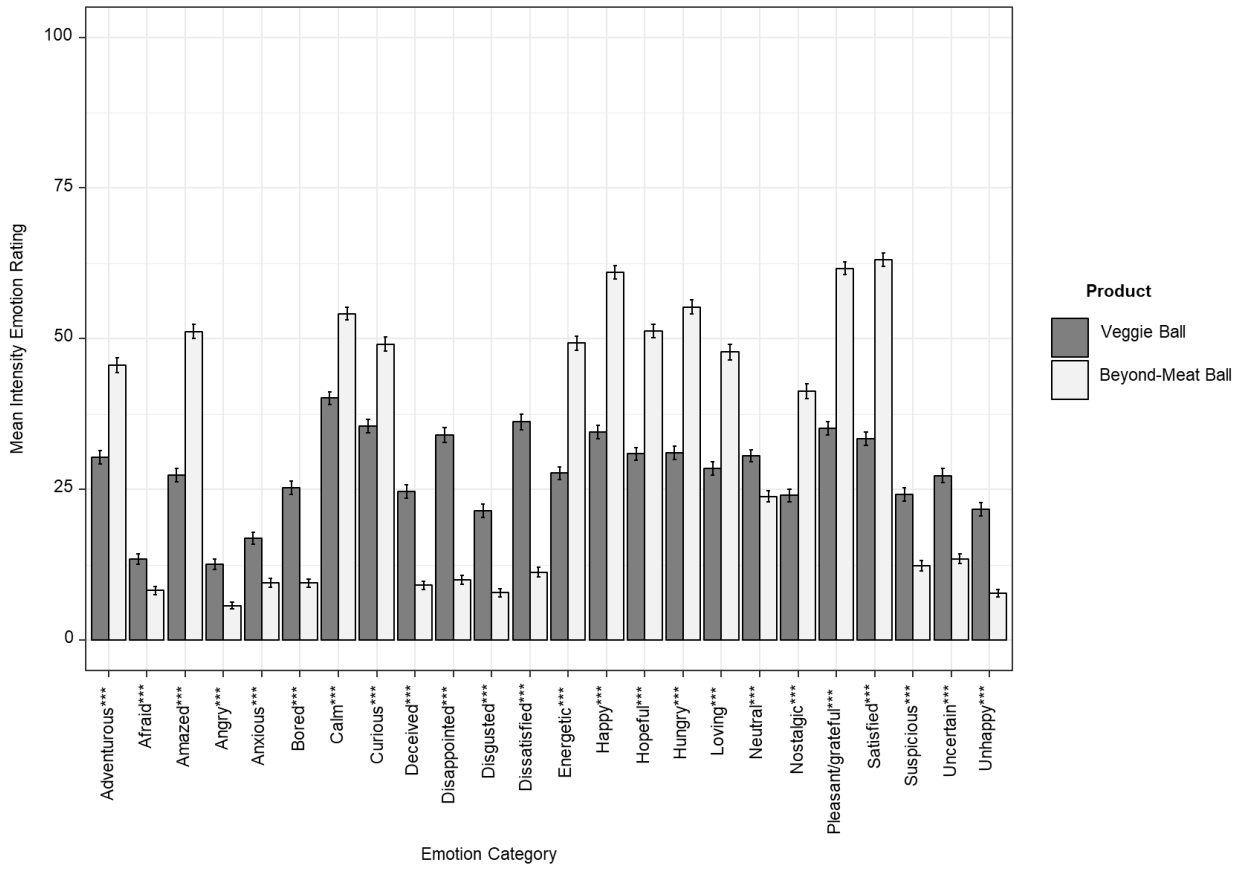


Figure 4.8. Mean (±SE) intensity emotion ratings per product (averaged over sauce and environment); Significant differences are indicated by *** ($p < 0.001$).

4.4.4.2 Influence of sauce on emotional response

A significant *sauce* effect was found for emotions 'adventurous', 'amazed', 'energetic', 'happy', 'hungry', 'hopeful', 'loving', 'nostalgic', 'pleasant', 'anxious', and 'neutral' ($p<0.05$, **Table 4.6**). Ratings for the 'neutral' emotion decreased when the sauce was present, whereas ratings for the other emotions increased when the sauce was present (**Figure 4.9**). Sauce addition increased feelings of several positive emotions towards the products. However, it also elicited an increase in feelings of 'anxiousness', although the intensity rating remained relatively low at 14.09 on a 100-point scale. The sauce was not sufficient to decrease feelings of negative emotions. The *product*sauce* interaction was not significant for any emotions.

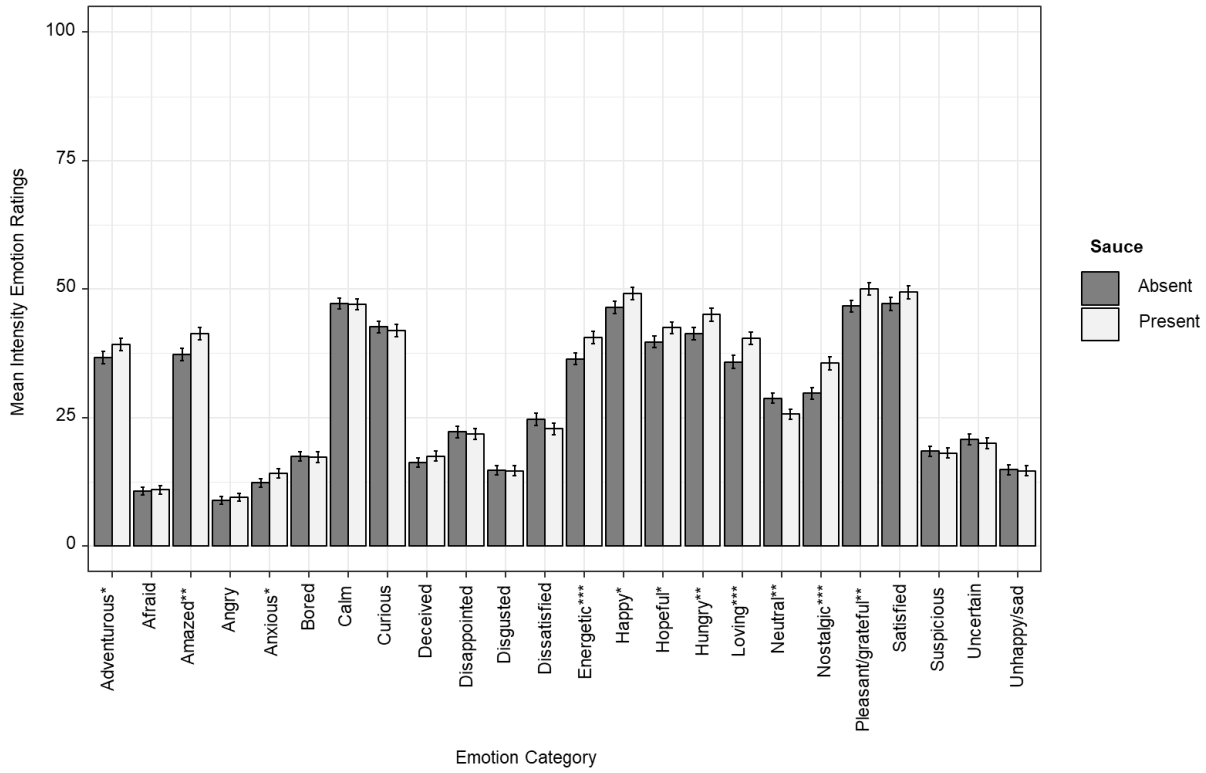


Figure 4.9. Mean (±SE) intensity emotion ratings in the absence and presence of sauce (averaged over product and environment); Significant differences are indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$).

4.4.4.3 Influence of environment on emotional response

A significant effect of *environment* (all $p<0.001$, **Table 4.6**) was found for emotions 'calm', 'adventurous', 'energetic', 'pleasant/grateful', 'loving', 'hopeful', 'happy', 'nostalgic', 'hungry', 'satisfied', 'anxious', and 'curious'. This indicates, that for these emotions, the average combined ratings for all samples differed according to the environment in which they were evaluated.

Figure 4.10 shows the mean rating (averaged over samples) for each emotion in each environment.

Post hoc tests revealed that, in the DI-Home environment, having consumed the samples, participants felt significantly more 'calm' ($p<0.001$), 'loving' ($p<0.001$), 'nostalgic' ($p<0.001$), 'pleasant' ($p<0.001$), 'hopeful' ($p=0.001$), 'happy' ($p<0.001$), energetic ($p=0.002$) and 'hungry' ($p<0.001$) compared to when they consumed the samples in the T-CLT, and significantly more 'calm' ($p<0.001$), 'loving' ($p<0.001$), 'nostalgic' ($p=0.025$), 'satisfied'($p=0.022$) 'and 'hungry'($p=0.005$) compared to when eating in the DI-Concert. In the DI-Concert, the samples made participants feel significantly more 'anxious' ($p=0.013$) and 'energetic'($p<0.001$) compared to the T-CLT. Finally, participants felt significantly more 'curious' towards the samples in the T-CLT compared to the DI-Home ($p=0.011$) and DI-Concert ($p=0.003$).

Significant *product*environment* interactions were detected for 'hungry' ($p=0.033$) and 'disappointed' ($p=0.042$). For Veggie Balls participants felt more 'hungry' having eaten the samples in the DI-Home ($p<0.001$) and DI-Concert ($p=0.029$) compared to the T-CLT, and felt less 'disappointed' by the Veggie Balls in the DI-Home compared to the DI-Concert ($p=0.053$). A significant *sauce*environment* interaction was evident for 'adventurous' ($p=0.047$), 'bored'($p=0.007$), and 'curious'($p=0.041$). When the sauce was absent, participants felt more 'adventurous' towards the samples in the DI-Concert compared to the T-CLT ($p=0.013$) and participants felt more 'curious' towards the samples in the T-CLT compared to the DI-Home ($p<0.001$) and DI-Concert ($p=0.026$). When sauce was present participants felt more 'bored' by the samples in the DI-Home compared to the T-CLT ($p=0.027$).

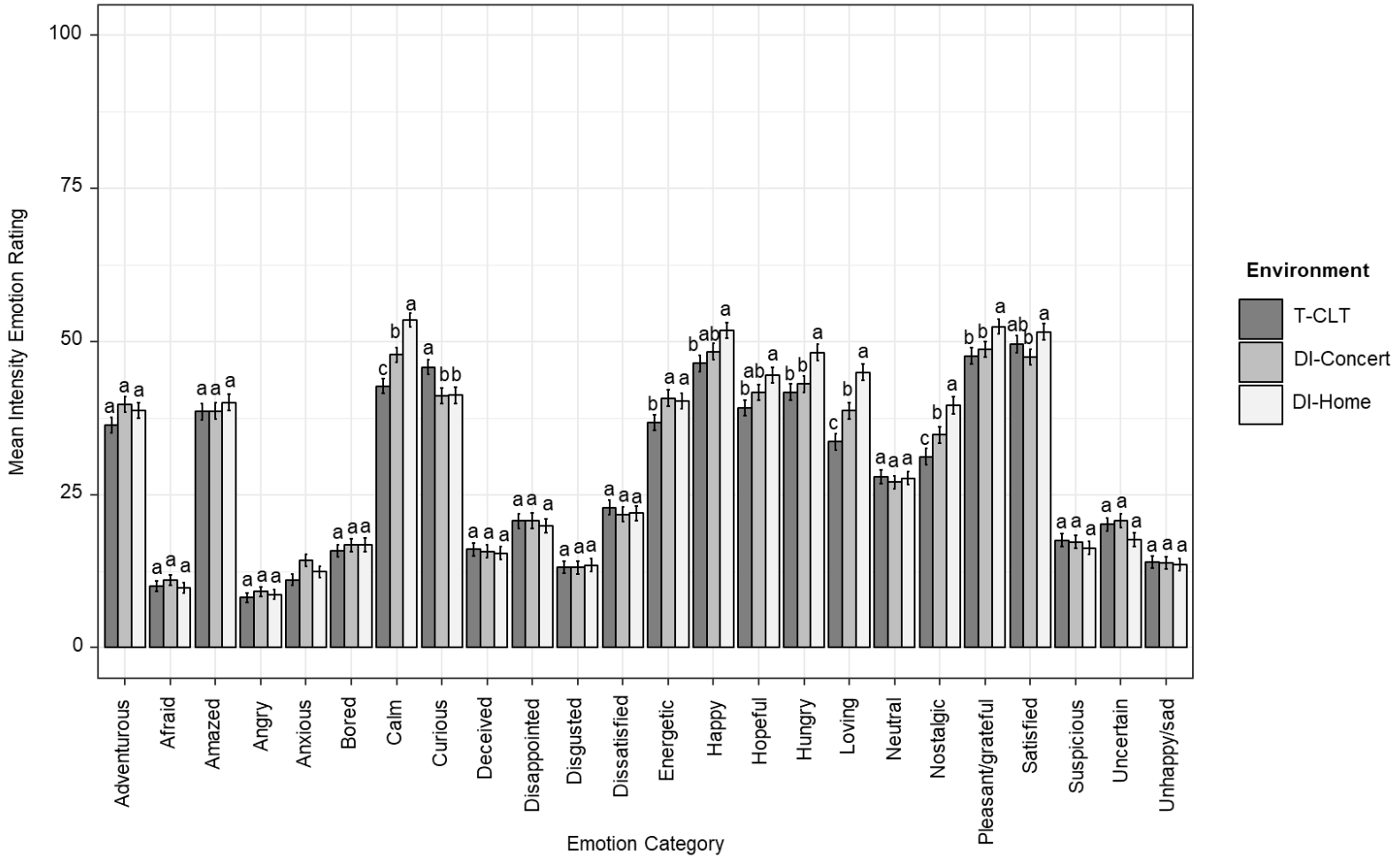


Figure 4.10. Mean ratings per emotion category per eating environment, where means are averaged over product and sauce. [a bc]different lowercase letters within emotion categories indicate significant differences between means across environments obtained from post hoc tests with Tukey adjustments for multiple comparisons ($p<0.05$).

4.4.5 Engagement and presence questionnaire

Mean scores and SE for each dimension of the engagement and presence questionnaire by environment are shown in **Table 4.7**. Mean scores (± SE) for each question on the engagement and presence questionnaire by environment are presented in **Appendix N.**

Table 4.7. Mean scores (±SE) per dimension and total engagement and presence score by environment. Each dimension had a theoretical range of -50 to 50. Total engagement and presence score is the sum of dimension scores (range -400 (not engaging at all) to 400 (very engaging)).

Dimension	T-CLT	DI-Home	DI-Concert
	Mean ± SE	Mean ± SE	Mean ± SE
Usability	7.4±2.4[b]	21.7±2.2[a]	9.1±2.8[b]
Novelty	-14.4±2.9[b]	6.8±2.7[a]	6.3±2.8[a]
Environmental Aesthetics	-3.1±2.7[b]	26.6±1.8[a]	22.6±2.4[a]
Involvement	19.6±2.4[b]	28.2±2.0[a]	30.9±2.2[a]
Sensory Awareness	-7.6±3.1[b]	23.8±2.0[a]	23.7±2.2[a]
Immersion	-29.1±2.5[c]	8.8±3.2[b]	19.1±3.5[a]
Realism	-0.5±3.1[b]	21.6±2.2[a]	17.2±2.6[a]
Distraction	21.2±2.6[a]	12.2±2.7[b]	17.6±2.4[a]
Total Engagement and Presence Score	-6.5±7.7[b]	150.2±6.8[a]	146.4±7.4[a]

[ab] Different lowercase letters across rows indicate significant differences ($p < 0.05$) between the test environments.

The DI-Home and DI-Concert environments received almost identical total engagement/presence scores, which were significantly higher than the T-CLT. DI-Concert and DI-Home did not differ in their mean scores for dimensions ‘Novelty’, ‘Environmental Aesthetics’, ‘Involvement’, ‘Sensory Awareness’ and ‘Realism’ and these dimensions were scored significantly higher in the digital-IEs than for the T-CLT. The DI-Home and DI-concert differed for ‘Usability’, ‘Immersion’ and ‘Distraction’ dimensions. The DI-Home scored significantly higher for the ‘Usability’ dimension compared to the other environments, indicating this environment proved better in assisting the participants in the evaluation of the samples, whereas for the ‘Immersion’ dimension DI-Concert scored significantly higher than the other two environments suggesting DI-Concert was more effective for making participants feel like they were at a real concert then DI-Home was at making them feel like they were in a home. For the ‘Distraction’ dimension the DI-Home scored significantly lower than the other two environments suggesting this environment was more distracting (reverse scored).

4.4.5.1 Clustering of consumers based on engagement questionnaire responses

k-means cluster analysis on individual responses to the engagement and presence questionnaire in the digital-IEs identified a two-cluster solution with 60 and 49 consumers across clusters 1 and 2 respectively. The mean and SE for each dimension by environment and by cluster are shown in **Table 4.8**. Mean scores (± SE) for each question on the engagement and presence questionnaire by environment and by cluster are presented in **Appendix O.**

Table 4.8. Mean scores (±SE) by consumer segment per dimension and total engagement/ presence scores in each environment.

Dimension	T-CLT		DI-Home		DI-Concert	
	Cluster 1 Mean±SE	**Cluster 2** Mean±SE	**Cluster 1** Mean±SE	**Cluster 2** Mean±SE	**Cluster 1** Mean±SE	**Cluster 2** Mean±SE
Usability	9.2±3.5[a]	5.1±3.2[a]	29.8±2.5[a]	11.7±3.4[b]	19.9±3.3[a]	-4.1±3.9[b]
Novelty	-12.0±3.9[a]	-17.3±4.2[a]	7.6±3.7[a]	5.8±3.7[b]	10.2±3.5[a]	1.6±3.7[b]
Environmental Aesthetics	1.4±3.7[a]	-8.7±3.6[b]	33.1±2.0[a]	18.7±2.8[b]	34.7±2.5[a]	7.9±3.4[b]
Involvement	25.0±3.1[a]	13.0±3.6[b]	36.0±2.4[a]	18.7±2.9[b]	40.8±1.7[a]	18.7±3.2[b]
Sensory awareness	-4.2±4.4[a]	-11.7±4.2[b]	31.0±2.4[a]	15.1±2.9[b]	36.7±1.9[a]	7.7±3.0[b]
Immersion	-27.3±3.7[a]	-31.3±3.4[a]	13.9±4.7[a]	2.5±4.2[b]	27.4±4.9[a]	8.9±4.7[b]
Realism	6.1±4.3[a]	-8.5±4.3[b]	30.6±2.4[a]	10.5±3.2[b]	28.8±3.0[a]	2.9±3.4[b]
Distraction	21.2±3.8[a]	21.2±3.5[a]	17.0±3.9[a]	7.4±3.5[b]	22.9±3.4[a]	11.0±3.2[b]
Total Engagement/ Presence Score	19.5±10.8[a]	-38.3±10.7[b]	199.0±8.9[a]	90.4±9.5[b]	221.5±9.0[a]	54.5±10.2[b]

[abc]different lowercase letters within environments indicate significant differences between means across engagement clusters obtained from post hoc tests with Tukey adjustments for multiple comparisons ($p<0.05$).

For all three environments, cluster 1 gave significantly higher total engagement and presence scores compared to cluster 2. However, differences in total scores between the clusters were notably smaller in the T-CLT (difference = 57.8) compared to in the DI-Home (108.6) and DI-Concert (167.0). When immersed in the DI-Home and DI-Concert cluster 1 scored significantly higher for all dimensions compared to cluster 2. In the T-CLT cluster 1 scored significantly higher than cluster 2 for dimensions 'Environmental Aesthetics', 'Involvement', 'Sensory Awareness' and 'Realism', but not for 'Usability', 'Novelty', 'Immersion', and 'Distraction'.

4.4.5.2 Effect of engagement/presence clusters on liking and emotional response

There was a significant main effect of *engagement and presence cluster adherence* for all liking modalities (all $p<0.001$, **Appendix P**), and emotion 'amazed' ($p=0.005$), 'calm'($p=0.030$), 'happy' ($p=0.003$), 'hopeful'($p=0.002$), 'hungry' ($p<0.001$), 'loving'(=0.051), 'nostalgic'($p=0.004$), 'pleasant/grateful'($p=0.004$), 'satisfied'($p=0.001$), 'curious'($p=0.004$),

'afraid' (p=0.015), 'angry'(p=0.005), 'bored'(p=0.016), 'deceived' (p=0.036), 'disgusted' (p=0.005), 'unhappy/sad' (p=0.028), 'dissatisfied' (p=0.036) and 'neutral' (p=0.018) (**Appendix Q)**.

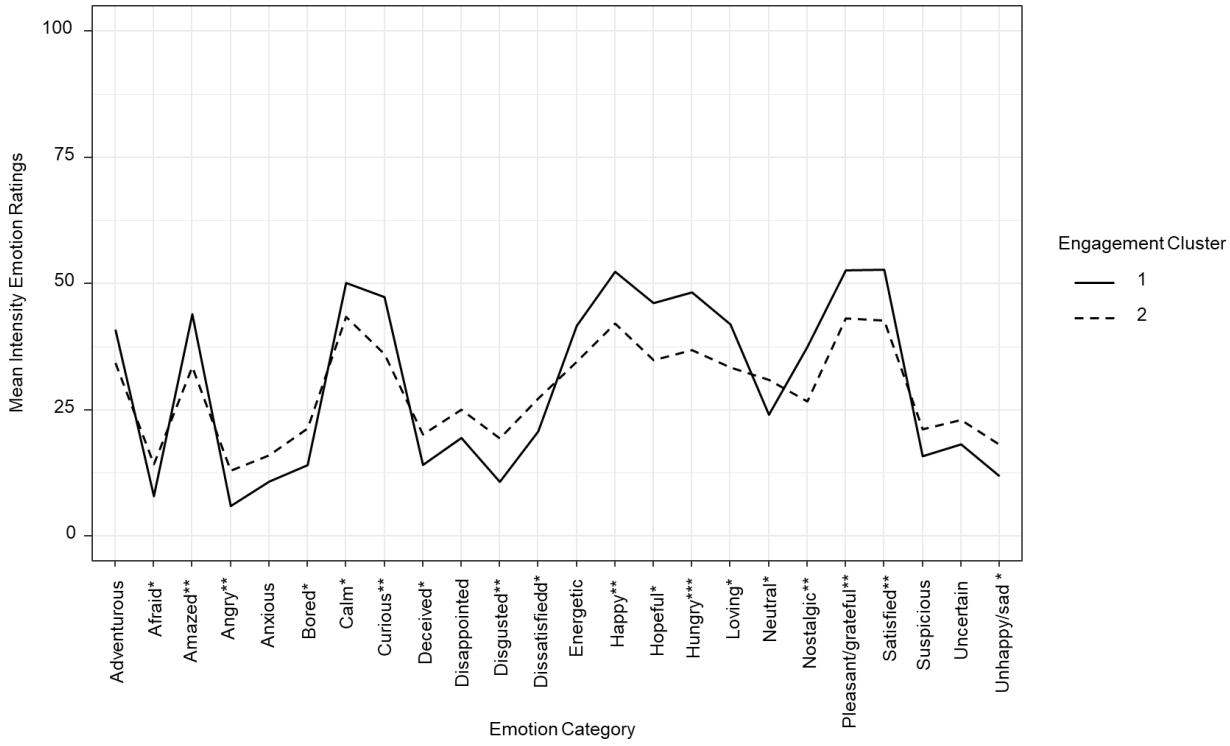


Figure 4.11. Mean intensity emotion ratings per engagement cluster (averaged over product, sauce, and environment). Significant differences are indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$).

Cluster 1 rated significantly higher than cluster 2 for all liking modalities as shown in **Figure 4.11.** Cluster 1 rated significantly higher than cluster 2 for emotions 'amazed', 'calm', 'happy', 'hopeful', 'hungry', 'loving', 'nostalgic', 'pleasant/grateful', 'satisfied', and 'curious'. Cluster 2, however, rated significantly higher than cluster 1 for emotions 'afraid, 'angry', 'bored', 'deceived', 'disgusted', 'unhappy/sad', 'dissatisfied', and 'neutral'.

A significant *cluster*product* interaction was observed for overall (p=0.001), flavour (p=0.018) and texture liking (p<0.001) as well as emotions 'adventurous' (p<0.001), 'amazed'(p<0.001), 'calm' (p<0.001), 'energetic' (p<0.001), 'happy'(p<0.001), 'hopeful'(p<0.001), 'hungry'(p<0.001), 'loving' (p<0.001), 'nostalgic' (p<0.001), 'pleasant'/grateful (p<0.001), 'satisfied'(p<0.001), 'uncertain' (p<0.001) 'suspicious' (p=0.006), 'deceived' (p=0.049) and 'curious' (p=0.001), where cluster 1 rated significantly higher than cluster 2 for the Beyond-Meat

Balls except for emotions ‘suspicious’, ‘uncertain’, ‘neutral’, and ‘deceived’ which were rated higher by cluster 2 than cluster 1 for the Beyond-Meat Balls.

For appearance ($p<0.001$) and expected liking ($p=0.005$), a significant *cluster*sauce* interaction was observed. For appearance liking cluster 1 rated higher than cluster 2 when the sauce was both absent ($p=0.016$) and present ($p<0.001$), however, the difference was greater when the sauce was present (differences of 5.35 versus 12.42). Similarly, for expected liking cluster 1 rated higher than cluster 2 when the sauce was both absent ($p<0.001$) and present ($p<0.001$), with the difference being greater when the sauce is present (differences of 7.96 versus 13.00). The interaction of *cluster*sauce* was also significant for emotions ‘amazed’($p=0.013$) and ‘nostalgic’($p=0.003$). For both emotions, when sauce was present ratings were higher for cluster 1 than cluster 2 (amazed $p<0.001$, nostalgic $p<0.001$).

The interaction of *cluster*environment* was not significant ($p>0.05$) for any liking modalities indicating the differences in liking ratings between the two clusters were not dependent on the environment. Similarly, differences in emotional response ratings between the clusters were consistent across the environments except for a significant *cluster*environment* interaction for emotions ‘adventurous’ ($p=0.001$), ‘calm’($p=0.001$) and ‘curious’($p=0.002$). For these emotions, cluster 1 rated significantly higher than cluster 2 in the DI-Home (adventurous $p=0.020$, calm $p=0.005$, curious $p=0.001$) and DI-Concert (adventurous $p=0.051$, calm $p=0.006$, curious $p<0.001$) environments whereas ratings were not different between clusters in the T-CLT (all $p>0.05$).

4.5 Discussion

Research findings emphasised the importance of considering contextual variables in consumer research, specifically, where a food is eaten and how the food is eaten. Combining PB-meatballs with tomato sauce significantly increased liking (overall, appearance, texture, flavour and expected) of both products. The sauce addition had a greater impact on appearance, flavour and expected liking for the less preferred Veggie Balls compared to the Beyond-Meat Balls. In addition to increasing liking, ratings for several positive emotions increased when the sauce was

present (main effect of sauce). Liking of the Veggie Balls was also significantly impacted by the environment in which the sample was consumed where appearance, expected and texture liking were higher for the Veggie Balls when consumed in the DI-Home compared to the DI-Concert and T-CLT. Emotions were experienced differently between the environments regardless of sample (main effect environment) and ratings for several positive emotions were higher in the DI-Home compared to the other two environments. Total mean engagement and presence scores were similar between the digital-IEs and these scores were higher than the T-CLT. Consumers were segmented into two clusters based on their engagement and presence scores. Cluster 1 consistently showed significantly higher total engagement and presence scores compared to cluster 2 across all three environments. However, the difference was less pronounced in the T-CLT compared to the digital-IEs. Furthermore, cluster 1 consistently rated the samples higher for liking across all modalities and exhibited higher intensity positive and lower intensity negative emotional responses. This trend remained consistent across both the traditional and digital-IEs.

4.5.1 Impact of meal context on liking and emotional response

Evaluating PB-meatballs in combination with a tomato sauce significantly increased ratings for all modalities of liking. These findings highlight the importance of considering other meal components when conducting consumer testing with PBMAs to better understand how these products will perform when consumed in real life. This study only considered one sauce which in this case increased liking suggesting the sauce was congruent with the products, but previous research has shown liking of PBMAs to differ depending on the chosen meal context. For example, Elzerman et al. (2011) showed liking of two PBMAs (‘mince’ and ‘pieces’) differed depending on the meal (rice, spaghetti, soup, and salad) in which they were consumed. Liking of the less-liked ‘mince’ increased when consumed in spaghetti and soup whereas liking of the well-liked ‘pieces’ decreased when consumed in all four meals. Similarly, van Bergen et al. (2024) found when two PBMAs (‘chicken’ and ‘mince’) were consumed in meal box meals the PBMAs were liked the most when consumed in Mexican meals and liked the least when consumed in Dutch meals. Therefore, when pairing PBMAs with other meal components in future research, it is important to carefully consider the selected components.

For the less preferred Veggie Balls, the impact of sauce addition on appearance, expected and flavour liking was greater than for the Beyond-Meat Balls. Sensory characterisation was not performed in this study, but it is suspected the sauce masked or decreased the intensity of unfavourable appearance and flavour attributes in the Veggie Balls. Previous studies have shown that the sensory perception of individual food items is affected by combining them with other food components (Gonzalez-Estanol et al., 2022; Gonzalez-Estanol et al., 2023; Meinert et al., 2011; van Eck et al., 2019; van Eck et al., 2021). For example, Gonzalez-Estanol et al. (2023) found combining soy and hemp burger patties with a bun and tomato ketchup reduced the intensity of negative drivers of liking including bitter taste, beany and nutty flavour and chunky texture but also decreased the intensity of positive drivers of liking including meaty flavour and fat flavour. Also, van Eck et al. (2019) found when carrots and bread were combined with mayonnaise the characteristic taste and flavour intensities of the bread (i.e. *sweet, yeast*) and carrots (i.e. *bitter, sweet, green*) were reduced. van Eck et al. (2019) suggested this is likely due to a dilution effect (Kroll & Pilgrim, 1961) where the concentration of taste and flavour compounds of a single food is reduced by the addition of another food thereby decreasing the intensity of its characteristic tastes and flavours. Additionally, masking the appearance of the Veggie Balls with sauce is likely to have increased product familiarity by more closely resembling the appearance of a traditional meatball. More familiar foods can contribute to reducing initially negative responses towards novel foods (Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994) and familiar products are usually better liked than unfamiliar products (Tuorila & Hartmann, 2020).

Despite the sauce addition significantly increasing liking of the Veggie Balls, overall, flavour and texture liking for this product was still relatively low. When averaged over the environments, overall, flavour and texture ratings only slightly exceeded 50 (where 50 corresponded to neither dislike nor like on the 100-point scale). Appearance and expected liking for the Veggie Balls with sauce (when averaged over the environments) exceeded 70 (on the 100-point scale) suggesting the sauce was successful in making the Veggie Balls look appealing but the flavour and textural attributes did not meet the expectations set by the appearance.

In addition to liking, ratings of several emotions increased when the PB-meatballs were served with sauce. The *product*sauce* interaction was not significant for any emotions suggesting the increase in ratings was not product-specific and based on the presence of the well-liked sauce. These emotions were primarily positive and included both positive low arousal emotions e.g. 'nostalgic', 'pleasant/grateful' and 'loving' potentially elicited by positive memories of eating spaghetti and meatballs/Bolognese, and positive high arousal emotions 'energetic', 'adventurous', 'amazed' and 'happy' perhaps triggered by the meeting or exceeding of expectations. Positive emotions 'hopeful' and 'hungry' also increased suggesting the sauce increased expectations ('hopeful') and increased the desire to eat/keep eating ('hungry'). Feelings of 'anxiousness' also increased, likely stemming from uncertainty regarding what was concealed under the sauce. However, the intensity rating for this emotion remained relatively low. Finally, ratings for the "neutral" emotion decreased suggesting consumers felt less neutral towards the products when the sauce was present. As has been mentioned previously, emotions play a key role in food choice decision-making (Loewenstein & Lerner, 2003) and experiencing positive emotions is highly relevant to the acceptance of novel foods (Jiang et al., 2014) and plant-based foods specifically (Bryant et al., 2019; Chen, 2022; Onwezen et al., 2021). As this is the first study to investigate the effect of combining PBMAs with other food components on emotional response, future research needs to investigate these findings further with other PMBAs and meal components to confirm if it is a promising strategy for enhancing positive emotional response towards PBMAs.

It is important to note that while sauce addition enhanced positive emotions, it was insufficient to mask negative emotions which could be a barrier to repeat consumption. The lesser-liked Veggie Balls received significantly higher intensity ratings for all negative emotions compared to the Beyond-Meat Balls. Among these emotions, 'disappointed' and 'dissatisfied' received the highest intensity ratings, followed by 'uncertainty,' 'suspicion,' 'deceived,' and 'bored.' It seems that presenting the product as a PB-meatball, despite not replicating the sensory properties of a traditional meatball, led to the product not meeting consumer expectations, hence resulting in dissatisfaction. The remaining emotions mentioned share a common theme of doubt or mistrust,

likely stemming from the discrepancy between the product being described as a meat-ball alternative and the actual experience. While this is speculation it has implications for the marketing of PBMAs that do not replicate the sensory properties of meat.

4.5.2 Impact of eating environment on liking and emotional response

Testing in a congruent environment notably impacted liking ratings toward the less-liked Veggie Balls but did not have a significant impact on the well-liked Beyond-Meat Balls. Appearance, expected and texture liking ratings for the Veggie Balls were higher in the appropriate DI-Home compared to the inappropriate DI-Concert and T-CLT. Notably, the increase in liking in the home was restricted (apart from texture liking) to liking based on visual assessment (expected liking and appearance liking). Previous research has also shown expected liking ratings to be higher when a product is assessed in an appropriate/congruent digital-IE compared to an inappropriate/incongruent one (Liu et al., 2019; van Bergen et al., 2021) or when presented with an image of a food in a congruent compared to an incongruent situation (Papies et al., 2022). However, the effects of food-context congruency on actual liking upon tasting have been inconsistent with some studies finding no effect on actual liking (Chen et al., 2020; Liu et al., 2019; Papies et al., 2022; van Bergen et al., 2021) whereas others have found actual liking to be higher in a food-context congruent environment (Picket & Dando, 2019; Schouteten et al., 2024; Song et al., 2022). Differences in findings regarding the influence of food-context congruency on liking (and emotional responses) are likely attributed to several factors including product category effects, the initial level of product liking, differences in test design (such as scales used and analysis methods employed), the environments used and their relevance to the participants, and variations in the environment set-up e.g. VR versus immersive rooms, quality of video/images used, and used of audio or olfactory cues, to name a few.

The digital-IEs also specifically influenced emotional response towards the Veggie Balls. Consumers felt more ‘hungry’ in the DI-Home and DI-Concert environments compared to the T-CLT, suggesting a greater desire to eat in the digital-IEs. Papies et al. (2022) observed an increased desire to eat when participants were presented with an image of food in a congruent

situation compared to an incongruent situation. Additionally, consumers felt less 'disappointed' towards the Veggie Balls in the DI-Home compared to the DI-Concert. While familiarity was not assessed in the present study it is assumed the Veggie Balls were less familiar than the Beyond-Meat Balls as they did not mimic the sensory properties of a traditional meatball. For unfamiliar products, contextual factors can provide a frame of reference with regard to possible usages, whereas familiar or well-liked foods might be relatively less influenced by specific consumption contexts (Giacalone et al., 2015). Similarly, Jaeger et al. (2019) observed an appropriateness-liking relationship, where products that are better liked are perceived as more appropriate. Furthermore, Kong et al. (2020) found no effect of context (VR 5-star resort and VR music concert) on the liking of three chocolate samples and proposed familiarity with the product and a strong preference effect as opposed to context effect as possible explanations. The DI-home environment potentially served as a frame of reference for participants when evaluating the lesser-liked Veggie Balls, aiding them in envisioning how the product could fit into real-life scenarios. This finding warrants further research, as it carries implications for consumer testing practices in general. It suggests that less-liked or less-familiar products may benefit from being tested in relevant eating environments as contextual information can help consumers better understand and appreciate the product. Conversely, for familiar or well-liked products, this may be less necessary, as consumers can already have established preferences and associations.

Differences in emotional response between environments were also observed regardless of product, with intensity ratings for several positive emotions being higher in the DI-Home compared to the other environments. This suggests emotional response is more positive towards PB-meatballs when consumed in a situationally appropriate environment such as the home. 'Anxious' was the only negative emotion to significantly differ between the environments, being rated higher in the DI-Concert compared to the T-CLT. This increase could be attributed to eating in an incongruent environment and other factors, such as participants eating with a bowl on their knees in a dimly lit room. Similarly, Pennanen et al. (2020), found that emotional responses to rye nacho chips and chocolate varied with different digital-IEs. Regardless of product, positive

emotions were rated higher in a sunny day environment, but also found negative emotions to be rated higher in a rain shower environment. De Wijk et al. (2022) compared emotional responses to sushi, iced tea, and a popsicle in beach and restaurant contexts recreated using an immersive room. Although the popsicle was congruent with the beach, sushi with the restaurant, and iced tea with both, no product-context interactions were found. Participants were happier, more interested, and less calm in the beach context compared to the restaurant, regardless of the product. Compared to this thesis, the degree of food-context (in)congruency in De Wijk et al. (2022) may not have been sufficient to evoke different emotional responses (i.e., it is not unheard of to eat sushi at the beach). In another study, Schouteten et al. (2024) found no difference in emotional response towards watermelon and chocolate truffles within a context or between contexts, where the contexts were a VR summer environment (congruent with watermelon) and a VR winter environment (congruent with chocolate truffles). In their study, participants selected a single emotion word pair (Jaeger et al., 2021) to describe their emotional response, which likely reduced discriminability. Additionally, both samples were widely accepted, and the environments were both quiet, calm, and relaxing.

Between the different environments, the presence or absence of sauce also had an impact on emotional response. When sauce was absent ratings for ‘adventurous’ were higher in the DI-Concert compared to the T-CLT, which seems reasonable as consumers are unlikely to have consumed plain meatballs at a concert before, thus making it an ‘adventurous’ experience. Low, Diako, et al. (2021) also observed higher ratings for ‘adventurous’ towards tea-break snacks in an augmented-reality café compared to sensory booths, supporting the notion that consumers can feel an increased sense of adventurousness in digital-IEs. Further, in the absence of sauce ratings for ‘curious’ were higher in the T-CLT compared to the digital-IEs, and when sauce was present ratings for ‘bored’ were lower in the traditional CLT compared to the DI-Home. Contradictory, Low, Diako, et al. (2021) found consumers to feel more ‘bored’ towards a caramel slice in sensory booths compared to an augmented-reality café. In the present research, consumers were all exposed to the samples for the first time in the T-CLT without the sauce, so it's unsurprising that

ratings for 'curious' were higher compared to the digital-IEs. Additionally, it's plausible that consumers felt less 'bored' towards the samples in the T-CLT when sauce was present, compared to the DI-Home, as it was also their first exposure to the samples. Such differences may not have been evident if exposure to the three environmental conditions had been balanced.

4.5.3 Impact of eating environment versus meal context on consumer response

This research emphasised that pairing PB-meatballs with an appropriate and well-liked meal component increased liking (expected, appearance and flavour) more for a disliked, compared to a liked product. Moreover, testing in an appropriate eating environment further enhanced liking (expected, appearance and texture) toward the disliked product but not the liked product, indicating heightened sensitivity of the disliked product to contextual influences. However, this study only considers one sauce and two eating environments, thus future research should investigate if similar trends are observed with other PBMAs in other meal contexts and eating environments. Future research should also investigate if disliked products are more susceptible to contextual influences across different product categories.

When considering both products, this study found that pairing with the sauce exerted a stronger influence on consumer response compared to the eating environment. However, testing in an appropriate eating environment still enhanced liking responses for the Veggie Balls and increased ratings of positive emotions for both products. This suggests that while the meal context might hold greater importance, both factors were influential on consumer response. Subsequent research is necessary to validate these findings and explore further the interplay between meal context, eating environment, and consumer responses towards PBMAs.

4.5.4 Differences in engagement and presence between environments and consumer segments

Total engagement and presence scores were higher in the DI-Home and DI-Concert compared to the T-CLT. This is consistent with previous research that also found higher engagement in digital-IEs (Bangcuyo et al., 2015; Hathaway & Simons, 2017; Sinesio et al., 2019; Zandstra et al., 2020).

While the total engagement and presence scores did not differ between the digital-IEs, scores differed for the dimensions 'Usability', 'Immersion' and 'Distraction'.

For 'Usability' the DI-Home scored significantly higher than the other environments, indicating that the appropriate DI-Home proved better in assisting the consumers in the evaluation of the samples. For 'Immersion', the DI-Concert scored higher than the DI-Home. As this dimension related to the feeling of being in the real environment (e.g. I felt like I was at a classical music concert) the set-up for the classical music concert was more effective in simulating the real environment. It is noteworthy that in the DI-Concert, a static image was used to portray the interior of the theatre hosting the concert, while video footage of an orchestra performing was projected onto one of the walls. In contrast, in the DI-Home, a static image was used to portray the inside of a home and a television screen was used to play videos of current events stories. Differences in the nature of the set-up of the digital-IEs could have contributed to the differences in immersion. Moreover, a home is inherently personal, and the home environment created for the study may not have accurately reflected each participant's own home. Additionally, the presence of other research participants, who are likely to be strangers, in a home setting is uncommon, which could make it more challenging for participants to connect with the environment. In contrast, a concert setting is less personal, and the presence of strangers is expected and normal. Future work should investigate the most appropriate way to create a home environment in the lab or if home-use tests are a better solution.

Interestingly, the 'Distraction' dimension scores for DI-Concert did not differ from the T-CLT whereas the DI-Home scored significantly lower than the other two environments suggesting this environment was more distracting (reverse scored). The DI-Home included a television playing news stories on current events. The intention of including the television was to enhance the feeling of being in a home and to provide audio. Several participants commented, "the TV was distracting but made it [the test room] feel more like a home". It seems that the television served as a distraction and potentially caused a "Break-In-Presence (BIP)", where BIP theory states that in a situation where a user is exposed to stimuli from both the virtual and the real world, the user may

stop responding to the virtual stream and respond instead to the real sensory stream (Slater & Steed, 2000; Wang et al., 2006). However, this poses the question, is the distraction of the TV an issue if it is helping the environment feel more realistic?

Of the two clusters identified from responses to the engagement and presence questionnaire, cluster 1 exhibited significantly higher total engagement and presence scores compared to cluster 2 across all three environments. In the digital-IEs cluster 1 consistently scored significantly higher than cluster 2 across all dimensions, however, in the T-CLT differences between the clusters were observed for 'Environmental Aesthetics', 'Sensory Awareness', 'Involvement', and 'Realism' but not for 'Usability', 'Novelty', 'Immersion', and 'Distraction'. The less pronounced differences between the clusters in the T-CLT suggest that cluster 1 was more impacted by the digital-IEs than cluster 2.

In comparing consumer responses between the two engagement clusters, cluster 1 rated the samples higher for liking across all modalities and exhibited more positive and less negative emotional responses. These differences between the clusters remained consistent across both immersive and traditional test environments, except for emotions 'adventurous', 'calm' and 'curious'. Cluster 1 rated the samples significantly higher for emotions 'adventurous', 'calm' and 'curious' in the DI-Home and DI-Concert compared to cluster 2. The potential novelty and excitement of conducting the sample assessment in the digital-IEs likely made cluster 1 feel more 'adventurous' and 'curious', and the digital-IEs could have made the sample assessment feel less like a "test" resulting in cluster 1 feeling more 'calm'. As the differences in liking and emotional response between the clusters were consistent (except for 'adventurous', 'calm' and 'curious') across both immersive and traditional test environments this suggests that cluster 1 did not respond differently in the digital-IEs compared to cluster 2 despite being more "engaged" in these environments.

It is possible the engagement clusters identified were a consequence of different response styles in scale usage (Tutz & Berger, 2016). However, this would not explain why differences were observed between the clusters for all dimensions of the engagement and presence questionnaire

in the digital-IEs but not for 'Usability', 'Novelty', 'Immersion', and 'Distraction' in the traditional environment, as well as why cluster 1 felt more 'adventurous', 'curious' and 'calm' in the digital-IEs. These findings warrant further investigation to determine if some consumers experience higher levels of engagement and presence in digital-IEs. Additionally, various factors contribute to an individual's sense of presence in digital-IEs including psychological factors such as personality, cognitive abilities, and cognitive style, along with demographic factors (Martingano et al., 2023; Sacau et al., 2008; Wong et al., 2023). Additionally, prior knowledge and experience with technology, as well as attitudes and openness toward new technologies may impact (Martingano et al., 2023; Sacau et al., 2008; Wong et al., 2023). Thus, future research should explore whether similar consumer segments can be identified in digital-IEs and seek to characterise these segments based on the aforementioned factors.

4.5.5 Limitations and Future Research

While this study was successful in providing new insights into the impact of meal context and eating environment on consumer response to PB-meatballs, some limitations warrant acknowledgment. Firstly, only two meatball alternative products were included which could restrict the generalisability of the findings to a broader range of PB-meatballs or PBMAs in general. Furthermore, not all contextual factors were considered e.g. who the participant was eating with, and the meatball alternatives were served only with sauce and lacked other common accompaniments such as pasta. Additionally, the serving size was relatively small. The meal context therefore may not accurately reflect typical consumer consumption habits potentially influencing their experiences and evaluations of the products. Another limitation is that sensory attributes were not measured in this study thus the impact of the sauce addition on sensory attributes could not be assessed. The distinctiveness of the samples and the limited number of samples presented in each session may have predisposed participants to remember the samples in the following sessions and form preconceived opinions, potentially biasing their responses. This bias could be particularly pronounced since all participants assessed the samples in the T-CLT (control environment) first. When choosing to use a classical music concert as the incongruent environment, consideration was not given to the potential effect "positive" music can have on

consumer responses. For example, emotions evoked by the music could be transferred to the tasting experience (Galmarini et al., 2021), or music associated with positive emotions could have increased liking (Reinoso-Carvalho et al., 2019). Consequently, the choice to use classical music could have impacted the results. Lastly, while the study aimed to simulate a home environment, it may not have fully represented individuals' actual home settings, potentially influencing their evaluations of the meatball alternatives.

These limitations present several opportunities for future research. Firstly, investigating the impact of meal context on liking and emotional responses using a broader range of PBMA products and accompanying food components, as well as more realistic portion sizes. Additionally, measuring the impact on sensory attributes would be valuable in understanding how accompanying foods may mask or enhance certain sensory characteristics of PBMAs. Furthermore, more research is needed to understand the impact of contextual variables on liked and disliked products to see if similar findings to the present study i.e. less liked products more sensitive to contextual influences, are observed in other product categories. Moreover, further investigation is needed into the different experiences of engagement and presence among consumers in digital-IEs, and the factors contributing to an individual's sense of presence. Finally, given that the home is a common eating environment but is highly personal to each individual, research into how digital-IEs can be better utilised to understand consumer responses “at home” is warranted.

4.6 Conclusions

In conclusion, this study demonstrated the significant impact meal context and digital-IEs can have on liking and emotional response towards PB-meatballs. It was shown that sauce addition significantly increased intensity ratings for all liking modalities and several positive emotions for both PB-meatballs, underscoring the important role meal context/ food accompaniments play in consumer response to PBMAs. Regardless of the sample, ratings for several positive emotions were higher in the DI-Home compared to the other two environments highlighting the positive impact testing in relevant eating environments can have on emotional response and suggesting

that emotional responses to traditional test environments are not reflective of real-life experiences. Furthermore, the study identified that consumer responses towards the less-liked Veggie Balls were more sensitive to contextual influences compared to the Beyond-Meat Balls. This suggests that lesser-liked (and possibly less familiar) products may benefit from contextual framing more than well-liked products. Engagement and presence were found to be higher in the digital-IEs compared to the traditional environment, indicating the potential of digital-IEs to enhance consumer engagement and presence during product testing. Lastly, consumers could be clustered into high and low-engagement and presence clusters. The high engagement cluster was observed to provide higher liking and positive emotional response intensity ratings; however, this pattern was consistent across both the digital-IEs and the T-CLT suggesting that the more engaged cluster did not respond differently in the digital-IEs compared to the less engaged cluster. Finally, this study has highlighted several opportunities for future research to better understand the impact of both meal context and digital-IEs on consumer responses to PBMAs and other product categories.

Chapter 5: General Discussion

5.1 Overall summary

The research presented in this thesis investigated the use of two innovative techniques in sensory consumer research, emotional response measures and digital-IEs to better understand consumer responses to PBMAs. For the first time an emotion lexicon was developed to identify emotions specifically relevant to both meat and PB-patty consumption and digital-IEs were used during lexicon development to evoke emotions relevant to different eating scenarios (**Study 1**). The lexicon was used to emotionally profile a range of meat and PB-patties alongside liking, sensory attributes, and perceived similarity to a meat patty to identify sensory attributes driving liking and emotional response. Segmentation identified consumers with differing overall liking and emotional responses towards the patties (**Study 2**). Lastly, contextual variables, including eating scenarios created using digital-IEs and meal context, were found to impact liking and emotional response towards PB-meatballs. Engagement and presence differed between the digital-IEs and a T-CLT, and segmentation identified consumers who experienced different levels of engagement and presence in the digital-IEs (**Study 3**). This chapter summarises each study's main findings, discusses their practical applications, outlines research strengths and limitations, and suggests directions for future work.

5.2 Summary of major findings

5.2.1 Study 1: Development of a consumer-led emotion lexicon for meat and plant-based burger patties using digitally recreated eating contexts

Study 1 led to the publication of the first emotion lexicon for comparison of PBMA patties (and PBMAs in general) (Orr et al., 2023), and used digital-IEs to increase its ecological validity (Bangcuyo et al., 2015; Galiñanes Plaza et al., 2019; Giezenaar & Hort, 2021). The developed lexicon contained several emotions, many of which were negative, not present on generic lexicon (e.g. EsSense Profile® (King & Meiselman, 2010) or the valence × arousal circumplex-inspired emotion questionnaire CEQ (Jaeger et al., 2020)). This emphasises the advantage of a product-specific lexicon for capturing important emotions that may be missing on generic lexicon, while

also only including relevant emotions (Jaeger et al., 2013; Ng et al., 2013). In food-related emotions research, positive emotions often outnumber negative ones (Bhumiratana et al., 2014; King & Meiselman, 2010; Nestrud et al., 2016; Ng et al., 2013; Spinelli et al., 2014), since food consumption is generally considered a pleasurable experience for healthy humans (Panagiotou & Gkatzionis, 2022). However, the prominence of negative emotions aligned with existing knowledge that acceptance of PBMAs is low due to failure to meet consumer expectations and unappealing sensory characteristics (Chigwedere et al., 2022; Elzerman et al., 2015; Elzerman et al., 2013; Giacalone, Clausen, et al., 2022; Hartmann & Siegrist, 2017). Additionally, the presence of terms such as 'deceived', 'afraid' and 'suspicious' indicated apprehension among some consumers towards PB-patties. The inclusion of negative terms in the final lexicon was therefore important for capturing emotions working against acceptance, particularly for non-product users (Dalenberg et al., 2014; Meiselman, 2015).

For the first time, digital-IEs were used in a published study in consumer sensory research for the purpose of emotion term generation. Although comparing emotion terms generated in the two eating situations—a home and a gastropub—was not an objective of the study, unique emotions were perceived in these different situations suggesting that immersive rooms have the potential to be utilised in future emotion-generation activities.

5.2.2 Study 2: Consumer sensory, emotional and liking responses to meat and plant-based burger patties

Study 2 profiled a range of burger patties (meat and plant-based), to assess liking, emotional response, sensory attributes, and perceived similarity to a beef patty. It was the first study to explore emotional responses to PB-patties with varying levels of resemblance to beef and to include patties made from wholefoods with no meat-like characteristics.

A strong preference for PB-patties that closely resembled beef was identified, with sensory attributes like 'strong beef' flavour and 'juicy' texture driving higher liking and positive emotional responses. Notably, the Impossible Foods and Beyond Meat patties received liking scores similar to the beef patty, challenging previous claims that sensory quality is a barrier to

PBMA acceptance (Fiorentini et al., 2020; Giacalone, Clausen, et al., 2022; Onwezen et al., 2021), at least for these two products, and demonstrated it is achievable for PBMAs to be liked similarly to their meat counterparts with focused product development. Conversely, wholefood patties, which were the least similar to beef, were less liked and associated with more negative emotions. Several sensory attributes spanning appearance, flavour and texture that were characteristic of the wholefood patties were identified as drivers of disliking. Giezenaar, Orr, et al. (2024) observed similar trends with a range of PBMAs beyond just burger patties. A Hybrid beef-vegetable patty was also investigated and ranked in the middle between the meat analogue patties and the Wholefood patties in terms of liking and consumers were divided in their emotional response with both positive and negative emotions prominent.

Study 2 identified consumer segments based on overall liking and emotional responses, showing that consumer preferences for meat and plant-based patties are not homogeneous. Three similarly sized segments emerged based on overall liking: 'plant-based patty enthusiasts,' 'beef and meat analogue patty enthusiasts,' and 'plant-based patty sceptics.' Despite liking scores towards different patty types differing between these segments, all segments still showed a preference for meat or meat-like plant-based patties. Clustering based on emotional responses revealed a smaller segment that was more positive, particularly towards beef, hybrid, and meat analogue patties and a larger segment that was less positive and more negative, especially towards meat analogue patties. The 'plant-based patty enthusiasts' liking segment had a higher proportion of Generation X consumers compared to Millennials, but other factors like gender, diet, and PBMA consumption frequency were not effective or relevant in characterising the overall liking or emotional response segments. Additionally, due to the relatively small cluster sizes (30 to 38 consumers), strong conclusions or commercial decisions regarding these identified segments should be avoided (Castura et al., 2022; Llobell et al., 2019).

Finally, **Study 2** enabled validation of the new emotion lexicon for its ability to discriminate PB-patties varying in sensory properties. Significant differences were observed in the use of 22 out of 24 emotion categories across the patties, confirming the relevance of these emotions in

distinguishing between meat and plant-based patties. Emotions ‘neutral’ and ‘anxious’ did not discriminate across the patties indicating these emotions were used similarly across all products investigated. Greater variation in the use of these emotions was observed in Giezenaar, Orr, et al. (2024) when a wider range of PBMA products were used.

5.2.3 Study 3: Investigating the effect of contextual variables on consumer response to plant-based meatball alternatives

Study 3 first identified through an online survey that a home environment was considered the most appropriate for consuming PB-meatballs, followed by a restaurant, with other options including a café/canteen and a pub. In contrast, a music concert was identified as the most inappropriate setting, with other options including the beach, a car, and a park.

Study 3 revealed that the liking of the less preferred Veggie Balls was significantly influenced by the consumption environment, whereas the well-liked Beyond-Meat Balls were not. Specifically, for the Veggie Balls expected, appearance and texture liking was higher when consumed in the DI-Home environment compared to the DI-Concert and T-CLT. Additionally, consumers felt more ‘hungry’ and less ‘disappointed’ towards the Veggie Balls in the DI-Home compared to the T-CLT. These findings suggest the DI-Home environment provided a frame of reference for a possible usage situation, which potentially altered participants' expectations for this product (Giacalone et al., 2015). Additionally, regardless of product, intensity ratings for several positive emotions were higher in the DI-Home compared to the other two environments suggesting emotional response is more positive towards PB-meatballs when consumed in a situationally appropriate environment such as the home.

Study 3 also found that combining PB-meatballs with tomato sauce significantly increased all liking modalities for both products. This indicates that assessing PBMAs as part of a meal, rather than in isolation, can increase acceptance. The sauce addition had a greater impact on appearance, flavour and expected liking for the less preferred Veggie Balls compared to the Beyond-Meat Balls. It is suspected the sauce masked or decreased the intensity of unfavourable appearance and flavour attributes in the Veggie Balls. In addition to increasing liking, ratings for several positive

emotions also increased when sauce was present, regardless of the product. Therefore, combining PBMAs with a well-liked sauce appears to be a promising strategy for enhancing positive emotional responses towards these products, which is highly relevant to their acceptance (Bryant et al., 2019; Chen, 2022; Onwezen et al., 2021).

Finally, **Study 3** found that self-reported engagement and presence, determined using the questionnaire by Bangcuyo et al. (2015), was higher in the digital-IEs compared to the T-CLT. While similar findings have been reported in previous research (Bangcuyo et al., 2015; Hathaway & Simons, 2017; Sinesio et al., 2019; Zandstra et al., 2020), this study uniquely identified two consumer segments based on their engagement and presence scores in the digital-IEs. One segment exhibited significantly higher scores compared to the other across all three environments, but this difference was notably less pronounced in the T-CLT compared to the digital-IEs. It was hypothesised that the more engaged segment would assess the samples differently regarding liking and/or emotional response in digital-IEs, but the results showed that this segment consistently rated the samples higher in liking and positive emotional response across all environments, not just in digital-IEs. As a result, it's unclear whether the differences were due to the impact of the digital-IEs or potentially due to differences in scale usage.

5.3 General discussion and practical applications

5.3.1 Sensory acceptability of PBMAs among meat-eating consumers

This thesis utilised liking and emotional response measures to gauge the current acceptance of PBMAs among New Zealand meat-eating (flexitarian and omnivore) consumers. The findings of **Study 2** and **Study 3** highlight the potential for PBMAs that closely replicate meat to be accepted by meat-eating (omnivore and flexitarian) consumers based on liking scores and higher citations/ratings for positive emotions compared to negative ones. It was surprising to observe that liking ratings for some meat analogue patties (**Study 2**) were similar to those of a meat patty as well as high liking ratings for the Beyond-Meat Balls (**Study 3**) as previous research has reported unappealing sensory characteristics (Chigwedere et al., 2022; Giacalone, Clausen, et al., 2022) and failure to meet consumer expectations regarding replicating the sensory properties of

meat (Elzerman et al., 2015; Elzerman et al., 2013; Hartmann & Siegrist, 2017) as major barriers to acceptance of PBMAs. Additionally, Schouteten et al. (2016) found an overwhelmingly negative emotional response (e.g. ‘disappointed’, ‘discontent’, ‘disgust’, dissatisfied’, and ‘distrust’) towards a PB-patty (meat analogue). However, some of these studies are now several years old and given significant advancements in technology in recent years, their findings may not accurately reflect the characteristics of products currently available on the market and people may be more familiar with these products now.

Acceptance of a Hybrid (beef-vegetable) patty was also investigated. Hybrid products would offer an alternative to PBMAs catering to consumers who are not interested in switching to entirely plant-based options but are looking for ways to lower their meat consumption while still enjoying the familiar taste and texture of meat (Grasso, 2020). Previous research has shown liking of hybrid patties as not significantly different to a beef patty (Neville et al., 2017) or even to exceed liking for a beef patty (Grasso et al., 2022). However, in the present research, the Hybrid patty was liked significantly less than the beef patty and sat between the meat analogues and the wholefood patties in terms of liking and emotional response. That being said, when consumers were clustered based on overall liking, ratings for the Hybrid improved for the 'meat and meat analogue enthusiasts' and 'plant-based patties enthusiasts.' Therefore, with reformulation (e.g., reducing the percentage of vegetable ingredients or altering the vegetable ingredients) so that the vegetable ingredients do not dominate the sensory profile, there is potential for Hybrid patties to be accepted by some meat-eating consumers.

On the other hand, wholefood products which do not replicate meat were not well received by meat-eating consumers and would require significant product development to increase acceptance. In **Study 2**, a segment of consumers was identified with higher overall liking ratings towards these products compared to the other segments suggesting there could be a small market for such products. However, it is questionable whether the demand for such products is currently high enough to keep their production viable, given the recent closure of Food Nation who found the financial investment was greater than the return (Morrison, 2023). If this segment were to be

targeted further investigation is required to characterise these consumers and identify situations (if any) in which they would choose a wholefood product over a meat analogue product. Additionally, a recent online survey by Weerawarna N.R.P et al. (2024), exploring motivations and barriers to plant-based product consumption among New Zealand flexitarians, identified 'tastes good' as the most important criteria for selecting PBMAs outweighing the importance of the product tasting like meat. This suggests that focusing on enhancing the overall sensory experience of plant-based products could be more effective in appealing to New Zealand flexitarians than solely focusing on meat-like attributes. This also suggests a gap in the market for products that taste good and that do not try to replicate meat.

Cultured meat is another alternative to conventional meat, produced by culturing stem cells collected from animals in a nutrient-rich growth medium to replicate the appearance, taste and cooking properties of conventional meat (Giezenaar et al., 2023; Post et al., 2020). Although the technology for large-scale production is still in development and only currently approved for commercial sale in Singapore (Aravindan & Geddie, 2020), there is potential for it to become a significant alternative to meat. An online survey conducted by Giezenaar et al. (2023) with New Zealand consumers found 30% were willing to regularly purchase cultured meat instead of conventional meat indicating a promising future once it is available and affordable. The introduction of cultured meat may eventually impact the demand for meat-like PBMAs. However, it is likely to be some time before cultured meat is widely commercially available. In the meantime, PBMA developers should prioritize improving sensory quality to stay competitive, as sensory experience remains the primary factor for consumer acceptance (Martins & Pliner, 2005; Weerawarna N.R.P et al., 2024).

5.3.2 Emotional response as an additional source of information of the consumer experience

When this research commenced the key emotions consumer experience towards PBMAs were unknown. Schouteten et al. (2016) was the only study to have previously investigated emotional response to consumption of PBMAs and only included one plant-based sample. This thesis has filled this gap in the literature first by identifying the key emotions consumers experience towards

meat and PB-patties in two relevant use case scenarios to form an emotion lexicon (**Study 1**). The developed lexicon provided a tool for **Study 2** and **Study 3** to assess consumer emotional response to PBMAs using only relevant emotion terms.

Study 2 demonstrated the lexicon's ability to discriminate across a range of meat and plant-based patties across almost all of the 24 emotion categories. However, the largest distinction in positive and negative emotions between the patties was between those that resembled meat (meat and meat analogues) and those that did not (wholefood). Similarly, in **Study 3** the lexicon discriminated the PB-meatballs for all 24 emotion categories. Not surprisingly, products with higher overall liking scores were associated with positive emotions as also found in previous research (Falkeisen et al., 2022; Giezenaar, Orr, et al., 2024; Jaeger et al., 2023). In **Study 2**, valence, which is strongly correlated with liking, explained the majority of variation among the samples (**Figure 3.3**), while arousal contributed only a small percentage. The most cited positive emotions were 'satisfied,' 'pleasant/grateful,' and 'happy,' while 'dissatisfied,' 'disappointed,' and 'uncertain' were the most cited negative emotions. Similarly, in **Study 3**, these emotions received the highest intensity ratings. According to the circumplex model of emotions (**Figure 1.1**) (Russell, 1980), these terms (excluding 'uncertain') fall at the extreme ends of the valence dimension. This prominence of valence in the findings reflects how respondents are more inclined to articulate straightforward emotional responses that align with their liking or disliking of the products. As Thomson et al. (2010) explain, liking and emotional response are often correlated as it is easier for participants to associate positive conceptualisations with things they like and negative conceptualisations with things they do not like. Consequently, it is unclear whether other emotions, such as those related to arousal, were not experienced or if the positive and negative emotions previously mentioned were experienced more strongly, potentially overshadowing the articulation of more complex emotions. Respondents experiencing difficulty in articulating emotions and the capture of only conscious, declared opinions have previously been reported as limitations of explicit measures of emotion (Kaneko et al., 2018). Implicit measures of emotions could assist in uncovering unconscious or less immediately accessible emotions, however, there are several limitations to

implicit measures that need to be overcome before they can be fully utilised (*see* **1.1.3**). In some cases, however, emotions differentiated between products that were similarly liked, as found in previous research and promoted as an advantage of including emotional response measures (Falkeisen et al., 2022; Ng et al., 2013).

Using a product-specific emotion lexicon allowed for the inclusion of emotion terms not present on generic emotion lexicon (e.g. Jaeger et al. (2020) and King and Meiselman (2010)). Several of these terms were negatively classified (e.g., 'angry', 'anxious', 'afraid', 'suspicious', 'disappointed', 'deceived') and their inclusion was advantageous for differentiating the less preferred wholefood products from the meat analogue products in **Study 2** and **Study 3.** These emotions were also useful for providing insights into the consumer experience of PBMAs that would have been missed if a generic lexicon had been used or if only liking measures had been used. For example, if a patty doesn't closely resemble consumer expectations for a beef patty feelings of 'uncertainty' are evoked, as was found in **Study 2**. Other examples are 'suspicious' and 'deceived' which were evoked by meat analogue patties that were not perceived to be *very-meat-like* which suggests when consumers expect a product to be meat-like based on the appearance, but this expectation is not met upon tasting, negative feelings like 'suspicious' and 'deceived' can be evoked. Collier et al. (2021) also identified 'uncertainty' and 'scepticism' about the composition of PBMAs as the main barriers to purchase and consumption in an online survey. Positive terms unique to the developed lexicon (e.g. 'hopeful', 'amazed', 'hungry') were also useful in providing additional insights into the consumer experience. For example, Consumers felt most 'amazed' by the two most liked PB-patties in **Study 2** and the Beyond-Meat Balls in **Study 3** indicating a potential exceeding of expectations by these products. Additionally, 'curious' was frequently cited among the PB-patties and PB-meatballs, which can be advantageous for PBMAs as curiosity can motivate consumers to try new foods (Stone et al., 2022).

Lastly, **Study 3,** further demonstrated valuable insights which can be gained by assessing emotional responses that would be missed if only liking is assessed. For example, despite liking of the highly liked Beyond-Meat Balls not differing between the eating environments, ratings for

several positive emotions were higher in the DI-Home regardless of the product. Additionally, consumers felt less 'disappointed' and 'hungrier' towards the lesser-liked Veggie Balls, emphasising the important role the eating environment can play in altering consumer acceptability for some PBMAs. For further discussion on the impact of contextual variables on the acceptance of PBMAs, *see* **section 5.4.2.**

5.3.3 Future use of the meat and plant-based patties emotion lexicon

While most of the 24 emotion categories included in the developed emotion lexicon were useful in discriminating the samples in **Study 2** and **Study 3**, the negative emotions 'anxious', 'afraid', and 'angry' received noticeably low average citation proportions in **Study 2** (<5%). It was initially thought the experience of these emotions was not intense enough to exceed participants' thresholds to check an emotion when using CATA (Meiselman, 2016), however, in **Study 3** when participants rated these terms, low average intensity ratings were also observed (<15/on 100-point scale). This suggests that these emotions could be less relevant to the consumer experience with PBMAs than initially thought and can be excluded from the lexicon in future work. However, it is worth noting that these terms might be more relevant to meat excluders, who were involved in the lexicon development but were not included in **Study 2** and constituted a small number of consumers in **Study 3**. Alternatively, these emotions may be more relevant to the gastropub eating environments used during the lexicon development. Thus, in situations where meat excluders or a dining out setting are being investigated, the relevance of these terms could be explored further.

Shortly after the publication of the emotion lexicon (Orr et al., 2023), Zandstra et al. (2023) published an online study on emotions evoked by images of PB-patties. Using literature (King & Meiselman, 2010; Schouteten et al., 2016) and a small focus group, they identified 13 relevant emotion terms, most of which overlapped with the lexicon from this thesis, except for 'proud,' 'cool,' and 'guilty.' This corroborates the relevance of the emotion categories identified to the consumption of PB-patties, although both studies identified additional terms. Zandstra et al. (2023) emphasised emotions 'proud' and 'guilty', for which they found the most consistent and

pronounced differences between plant-based and meat burgers, should not be ignored. Thus, these emotions could be added to the developed lexicon for future research.

While the emotion lexicon developed in **Study 1** was specific to burger patties, when applied in **Study 3** with PB-meatballs and in an additional study by Giezenaar, Orr, et al. (2024), where 21 different PBMAs were profiled for emotional response, citation proportions/ratings significantly differed between samples for all 24 emotions. Additionally, a bench-testing session was conducted by Giezenaar, Orr, et al. (2024) to verify the applicability of the emotional terms, and participants were invited to suggest any additional emotional terms they deemed relevant. However, no additional terms were proposed, indicating that the emotion lexicon is suitable for application to other PBMA products beyond burger patties and can be used and adapted by other researchers and food manufacturers for their research with PBMAs. Additionally, Zandstra et al. (2023) have shown the relevance of the emotion lexicon to Dutch consumers, suggesting its potential generalisability to other countries or cultures. However, further investigation is advised to ensure the inclusion of additional emotions that may be relevant to the country/culture of interest.

5.3.4 Contextual influences on consumer response to PBMAs

A secondary theme of this thesis was the application of digital-IEs to recreate likely eating scenarios for PBMAs, aiming to capture consumer responses that better reflect real-life eating experiences. The findings of **Study 1** and **Study 3** have shown that liking and emotional response towards PBMAs can be influenced by the eating environment and demonstrated the ability of digital-IEs created using an immersive room to modify liking and emotional response toward PBMA products. This was demonstrated first by the perception of unique emotion terms in the two eating scenarios employed in **Study 1**. Secondly, in **Study 3**, intensity ratings for some positive emotions increased when the PB-meatballs were assessed in the contextually appropriate DI-Home compared to the T-CLT and the contextually inappropriate DI-Concert. Additionally, some modalities of liking increased for the lesser-liked Veggie Balls when assessed in the DI-Home environment compared to the T-CLT and DI-Concert. Overall, these findings highlight that

acceptance of PBMAs can be sensitive to the consumption context (Michel et al., 2021; Motoki et al., 2021) therefore, interpreting findings from traditional testing environments may not reflect real-life experiences for some PBMA products (Stelick & Dando, 2018). Consequently, it is recommended that future research regarding consumer acceptance of PBMAs be conducted in more realistic eating environments e.g. digital-IEs.

In addition to digital-IEs better reflecting true eating environments compared to traditional testing environments such as sensory booths, digital-IEs can also enhance participant engagement during product testing (Bangcuyo et al., 2015; Hathaway & Simons, 2017; Sinesio et al., 2019; Zandstra et al., 2020). Furthermore, the findings of Bangcuyo et al. (2015) and Hathaway and Simons (2017) suggest that product preference data collected in digital-IEs is more discriminating and more reliable due to increased engagement, with reliability assessed through duplicate testing across sessions. These advantages further highlight the benefits of using digital-IEs. However, greater consideration should be given to individual differences regarding experiences of engagement and presence in digital-IEs, as people can experience different levels of presence, which in turn could impact engagement, even when they are immersed in the same virtual environment setting, as observed in **Study 3** and highlighted by Martingano et al. (2023). Therefore, a better understanding of the individual factors influencing engagement and presence and the impact on results is required (*see* **5.4.4** for further discussion) to utilise digital-IEs to their full potential in consumer testing. One final point here is that reporting engagement and presence scores as one total score can be misleading, as engagement and presence are ultimately two different constructs. For example, a sensory laboratory could be more engaging, but participants may experience a lesser sense of presence because there are no digital-IEs to experience. Conversely, a digital-IE could result in a higher presence but lesser engagement. As a result, the total engagement and presence scores can come out similar, masking the true differences between the environments. Measuring engagement and presence separately using questionnaires such as the Engagement Question developed by Hannum and Simons (2020) and the Igroup Presence Questionnaire (Schubert, 2003), could be considered going forward.

Study 3 also demonstrated the important role meal context can play in increasing acceptance of PBMAs as pairing the PB-meatballs with a well-liked sauce increased ratings for all liking modalities and intensity ratings for several positive emotions. Previous research has shown liking of some PBMAs increases depending on the dish in which they are prepared (Cordelle et al., 2022; Elzerman et al., 2011), whereas the impact on emotional response had not been previously explored. Pairing the PB-meatballs with the sauce exerted a stronger influence on consumer response compared to the eating environment and therefore should be prioritised in future research regarding the acceptance of PBMAs. Failure to consider the meal context could produce misleading results for product development or marketing decisions.

Study 3 also indicated that contextual influence (meat context and eating environment) could have a greater impact on liking and emotional response for a lesser-liked PBMA product (i.e. Veggie Balls) compared to a well-liked PBMA product (i.e. Beyond-Meat Balls). This has implications for future research, suggesting that the acceptance of less liked or less familiar PBMA products, or potentially even novel foods in general, can be increased by combining with well-liked meal components and by suggesting appropriate eating environments. However, this study only considered two products, one sauce, and three eating environments. Therefore, future research should investigate whether similar trends are observed with other PBMAs in different meal contexts and eating environments.

5.4 Strengths and limitations

There were many strengths to this thesis that advanced knowledge concerning the value of consumer-led lexicons and use of digital-IEs as well as consumer evaluation of PBMAs that should be highlighted, although some limitations also need acknowledging.

Study 1 was the first published study to develop an emotion lexicon specifically for use with PBMAs. The development of this lexicon has presented a validated tool for the study of relevant emotions in subsequent research into emotional responses to PBMAs. Other strengths of this study included the large number of consumers involved in the lexicon development process and the inclusion of different dietary and age groups, to capture emotions felt by potential end users

of the lexicon. Furthermore, the use of digital-IEs to simulate two typical burger-eating situations likely assisted in capturing relevant emotions. For **Study 2,** the range of samples included made this study, to the researcher's knowledge, the first to measure emotional responses to PB-patties that varied in their similarity to a beef patty and included PB-patties made from wholefoods with no meat-like characteristics. Thus, a strength of this study was the diversity of the samples included. Another strength was the use of an emotion lexicon developed specifically for the products being investigated which allowed for the capture of only relevant emotions. Additionally, this study considered consumer segmentation when analysing the overall liking and emotional response data investigating any interesting and important findings that could have been masked by only considering the averaged data (Köster, 2009). Strengths of **Study 3** included considering both the impact of eating scenario and meal context on consumer response to PB-meatballs; ensuring participants agreed that the selected eating scenarios were (in)appropriate for the consumption of PB-meatballs; and balancing the presentation order of the digital-IEs. Additionally, **Study 3** was the first published study within the field of sensory consumer research to consider segments of consumers with varying levels of engagement in digital-IEs and to consider the impact this could have on consumer response.

Limitations of the individual studies have been discussed in their respective chapters. Limitations across the entire thesis will be discussed here. First, despite the emotion lexicon being developed with the input of meat excluders (e.g. vegetarians and vegans), subsequent investigation into how the liking and emotional responses of these consumers differed from meat-eating consumers was not considered. As a result, the understanding of preferences for PBMAs among meat excluders was not fully explored. Additionally, the influence on preference for PBMAs of factors such as food choice motives, food neophobia and meat attachment were not considered. Second, using commercially available products with a high turnover means that several of the products investigated are no longer available for purchase. However, this approach still provided valuable insights into current consumer preferences, which can inform future product development, even if the specific products studied are no longer on the market. Third, across the studies, participants

were informed that they would be tasting PBMAs which might have introduced an expectation bias, possibly skewing evaluations toward comparisons with meat. The studies also used unbranded products, therefore the influence of extrinsic characteristics e.g. brand, packaging, price, labels, and claims, on consumer preferences was not investigated. Fourth, the reliance on self-reported information introduces potential biases, as participants may provide socially desirable responses, struggle to articulate their liking or emotional response, or may not give fully considered answers to complete the test more quickly. Fifth, the studies were conducted at a single time point, limiting insights into how preferences might change over time. Finally, while the research considered context through the use of digital-IEs, it did not explore how responses collected in these environments compare to real-life settings, such as participants' own homes. Additionally, not all contextual variables e.g. social context were considered. While the research findings offer valuable insights, these limitations should be considered when interpreting the findings. Future research could address these limitations to provide a more comprehensive understanding of PBMA acceptance. Ways in which this could be achieved will be discussed in the following section.

5.5 Future directions

5.5.1 Additional measures of the consumer experience of PBMAs

This thesis utilised explicit self-report questionnaires to assess emotional responses to PBMAs. Additional measures, such as conceptual profiling/associations, a process for accessing associated meaning with a product (Thomson et al., 2010), could be used to further deepen understanding of how consumers perceive PBMAs. Thomson (2016) explains that conceptualisations can impact emotions, which may be positively or negatively rewarding, thereby influencing our motivation to start, continue, or cease interaction with an object (e.g., "this chocolate is fattening, so I feel guilty eating it, so I will not"). Thus, measuring conceptualisations can provide further insights into how consumers experience PBMAs and potentially help explain the emotions experienced when consuming the product. Conceptual associations can be assessed similarly to emotions, where consumers are provided with a list and check or rate the applicable associations. For example, in an online survey, Michel et al. (2021) sought to understand associations with meat

alternatives by asking participants to rate different products (e.g. tofu, vegetarian nuggets) on eleven bipolar adjective scales, such as 'traditional/modern,' 'cheap/expensive,' and 'disgusting/tasty.' Alternatively, implicit methods can be used such as an implicit response time Go/No-go task (Weerawarna N.R.P et al., 2023) or best-worst scaling (Thomson, 2016). Attitudinal and behavioural associations, as utilised by Jaeger et al. (2023) to understand perceptions of plant-based yogurt, could be additional measures to consider e.g. “the fact that this product is plant-based makes me feel more positive about it".

This thesis has solely focused on a cognitive explicit measure of emotional response, which measures conscious emotions but can be subject to bias. Implicit measures on the other hand are believed to measure unconscious emotions which are not experienced as feelings but have potentially strong effects on behaviour (Meiselman, 2021). Consequently, some emotion measurement researchers have suggested using a combination of measures such as cognitive explicit and physiological implicit measures (*see* **1.1.3**) to provide more comprehensive insights (Low et al., 2022). For example, Samant et al. (2017) found that with basic taste solutions, emotional responses measured using self-reported emotion questionnaires and facial expression analysis performed best in predicting overall liking and preference. Samant et al. also investigated physiological autonomic nervous system measures (e.g., electrodermal activity, heart rate, and skin temperature); however, these showed limited contribution to predicting liking or preference. This suggests that the added value in predicting liking and preference might differ depending on which implicit method is used (Schouteten, 2021).

Additionally, it would be valuable to explore how emotional responses evolve over time, whether in a single sitting such as the emotions experienced before, during, and after consumption using temporal methods e.g. Temporal dominance of emotion (Jager et al., 2014), or through repeated exposure over several meals (Bryant et al., 2019; Hoek et al., 2011). This could reveal insights into whether the initial confrontation with the product serves as a barrier to acceptance.

5.5.2 Barriers beyond sensory quality

The research in this thesis has specifically concentrated on investigating the emotional response to the unbranded product experience where consumers assessed products based on their intrinsic characteristics e.g. sensory characteristics. The findings of this thesis indicated a primarily positive emotional response to the unbranded assessment of PBMAs that closely resemble meat. However, while the sensory experience is crucial for acceptance (Martins & Pliner, 2005), the extrinsic characteristics e.g. brand, packaging, price, labels, claims, of a product can also affect the purchasing decision (Symmank, 2023). For example, in a discrete choice experiment Giezenaar, Godfrey, et al. (2024) found claims related to protein source and health to be more important to product choice than claims related to the origin of ingredients or environmental sustainability. Furthermore, vegan labelling has been found to negatively influence the perception of tastiness, healthiness and the willingness to buy plant-based foods among consumers who prefer meat-eating over veganism (Demartini et al., 2022). Emotional response and conceptual associations should be considered in future research regarding extrinsic product characteristics of PBMAs to identify characteristics that evoke a positive response while also identifying those that evoke a negative response which may act as barriers to acceptance.

The averaged scores (**Study 2**) indicated a generally positive response regarding liking and emotional response towards the meat analogue patties. However, segmenting consumers based on liking revealed a cluster of 'PB-patty sceptics'. Additionally, segmenting based on emotional response identified a segment that was less positive and more negative towards the meat analogue samples. Future research should investigate if similar segments are identified from a larger sample size and investigate the relationship between these segments and other personal-related factors that have been identified as barriers to PBMA consumption such as meat attachment (Broeckhoven et al., 2021; Graça et al., 2015), food neophobia (Bryant et al., 2019; De Koning et al., 2020; Hoek et al., 2011; Onwezen et al., 2021), and food choice motives (Giezenaar, Godfrey, et al., 2024; Hoek et al., 2011; Onwezen et al., 2021; Rosenfeld & Tomiyama, 2020; Weerawarna N.R.P et al., 2024). Understanding how these factors influence preference and emotional response towards PBMAs could help identify consumer characteristics that hinder acceptance of PBMAs.

While several studies have used questionnaires to identify these factors as barriers to acceptance of PBMAs, the impact of these factors on liking and emotional response during actual product consumption is under-explored.

5.5.3 The role of contextual variables in the acceptance of PBMAs

Future research is required to understand why an increase in liking and positive emotional response was observed when the PB-meatballs were combined with the sauce. For example, does the sauce mask undesirable sensory attributes in the PBMAs (Gonzalez-Estanol et al., 2022; Gonzalez-Estanol et al., 2023; Meinert et al., 2011; van Eck et al., 2019; van Eck et al., 2021), or does introducing a potentially unfamiliar food with a familiar sauce increase acceptability? (Stallberg-White & Pliner, 1999). Investigating these factors can provide valuable insights into how to enhance the acceptance of PBMAs. Such research should also consider more realistic portion sizes, different types of PBMAs, and various types of dishes to provide a comprehensive understanding.

Further investigation into the role of the eating environment in the acceptance of PBMAs is also warranted. In addition to 'a home', **Study 3** and Motoki et al. (2021) identified 'a restaurant' to be an appropriate environment for the consumption of PBMAs. Future research could explore how a restaurant setting impacts liking and emotional response towards PBMAs. Furthermore, determining how expectations for a product intended for home consumption compare to those for a product intended for restaurant consumption (specifying the type of restaurant) would help identify what types of PBMAs best suit each situation. Such comparisons could potentially lead to more targeted and effective product development and marketing strategies. Additionally, the consumption environment can act as a barrier to acceptance. While **Study 3** showed a classical music concert to be an inappropriate environment for the consumption of PBMAs, this was an extreme example of incongruency and not a situation where one would typically eat. However, previous research has shown specific eating situations to be considered less appropriate for consuming PBMAs. For example, PBMAs are perceived as less appropriate in formal eating situations, such as family Sunday meals, business lunches, or barbecue parties (Michel et al.,

2021) as well as when dining with acquaintances or at pubs or bars (Motoki et al., 2021). Understanding consumers' emotions or conceptual associations towards consuming PBMAs in situations considered less appropriate can provide insights into why this is the case. For instance, is it less appropriate to consume PBMAs at the pub or bar due to embarrassment or fear of judgment, as vegetarianism (non-meat eating) is considered less masculine? (Kemper et al., 2023), or do PBMA offerings currently not cover food typically consumed in a pub? Assessing these factors can help identify and address barriers to broader acceptance and consumption of PBMAs.

The social context (e.g. with friends, family, work colleagues, alone) in which people eat or make food choices influences what and how much is consumed (Higgs & Ruddock, 2020). Different social contexts have been previously identified as more or less appropriate for the consumption of PBMAs through online surveys. For example, Elzerman et al. (2021) found that omnivores consider consuming PBMAs less appropriate compared to their meat counterparts when dining with family or socialising with friends. However, PBMAs were rated as more appropriate than meat when dining with vegetarians. Additionally, the consumption of PBMAs is considered less appropriate at business lunches, with family for Sunday dinner (Michel et al., 2021) or when dining with acquaintances (Motoki et al., 2021). Nath et al. (2020) investigated the impact of social context on liking and implicit emotional response to food images. When participants viewed food images with a stranger muscle activity indicative of a disgust response and lower liking ratings were observed. No differences in muscle activity or liking were found between subjects who participated alone and with a friend. Therefore, the social context is likely to influence liking and emotional response to the consumption of PBMAs and should be considered in future research.

5.5.4 Improving the ecological validity of consumer testing

This thesis has demonstrated that a congruent home environment created using digital immersion can evoke different emotional responses and liking ratings towards PB-meatball products compared to an incongruent and traditional testing environment. However, since a home is

inherently personal, a DI-Home is unlikely to accurately reflect each participant's own home. How responses collected in a DI-Home compared to those in participants' real-life homes was not investigated in this thesis and has yet to be explored in the literature. Therefore, such validation should be investigated in future research and is required before consumer testing in DI-Home environments can be recommended as an alternative to testing in participants' homes (e.g. home-use tests). Such comparisons have been made previously for less personal settings. For example, Low, Lin, et al. (2021) found an augmented reality headset playing video footage of a café to evoke similar emotional responses and discrimination between tea break snacks as the real café.

Furthermore, as mentioned in **section 5.4.3** above, the social context in which we eat or make food choices influences what and how much we choose to consume (Higgs & Ruddock, 2020) and can influence liking and emotional response (Nath et al., 2020). In consumer testing, participants typically attend on their own with other research participants (strangers). Therefore, to enhance the realism of consumer testing, strategies to better incorporate social context should be investigated. One approach could involve inviting participants to attend studies with their partners, family members or friends, or using visual prompts like photos of family or friends (depending on the intended consumption scenario for the product). Alternatively, participants, even if they do not know each other, could be allowed to socialise (but not discuss the samples) when they are not occupied with the test (De Wijk et al., 2022; Sinesio et al., 2019). However, these strategies would only be possible if using an immersive room. In situations where a mounted headset, such as a VR headset, is used, strategies could include incorporating other people into the digital recording that plays through the headset or utilising artificial intelligence, such as virtual avatars, to provide instructions or be included in the simulation (Delarue et al., 2019; Sinesio et al., 2019). However, this may not necessarily reflect the specific people participants would usually eat with.

A better understanding of which types of products benefit most from testing in digital-IEs is needed, as the use of these environments in consumer testing may be unnecessary or unsuitable for all products. For example, in **Study 3** some modalities of liking for the lesser-liked Veggie

Balls differed between the eating environments whereas liking for the well-liked Beyond-Meat Balls was consistent. Therefore, in the case of the Beyond-Meat Balls assessing liking in the DI-Home was unnecessary. Similarly, Kong et al. (2020) found no effect of context (VR 5-star resort and VR music concert) on liking of three chocolates and proposed familiarity with the product and a strong preference effect as opposed to context effect as possible explanations. Furthermore, Giacalone et al. (2015) found consumers perceived familiar beers to be appropriate for more usages while unfamiliar beers were more specifically tied to a few specific usages, suggesting familiarity influences the perceived versatility of a product. Potentially, less-liked or less-familiar products e.g. novel foods may benefit more from being tested in relevant eating environments, as contextual information can provide a frame of reference with regard to possible usages (Giacalone et al., 2015). Conversely, for familiar or well-liked products, this may be less necessary, as consumers already have established preferences and associations. A different scenario is that of Colla et al. (2023) who evaluated apple juice samples in sensory booths, an evoked café (using pictures), a VR café, and an actual café. They found no significant differences in emotional response, beverage choice, or consumption across conditions, suggesting immersive or real-life settings are unnecessary for these measurements. However, liking differed between the VR café and the real-life café, indicating that testing in a real-life café was necessary to accurately capture liking for apple juice. A better understanding of which products can benefit the most from testing in digital-IEs will help prevent unnecessary testing and resource use.

Finally, further investigation is warranted into the effect of individual factors on consumer experiences of engagement and presence in digital-IEs. Various factors contribute to an individual's sense of presence in digital-IEs. These include psychological factors such as personality, cognitive abilities, and cognitive style, along with demographic factors like ethnicity, gender, and age. Additionally, prior knowledge and experience with technology, as well as attitudes and openness toward new technologies (Martingano et al., 2023; Sacau et al., 2008; Wong et al., 2023). Thus, future research should identify segments of consumers who experience higher engagement and presence in digital-IEs similar to **Study 3**, or whose preferences are

context-sensitive, as identified by Nijman et al. (2019), and seek to characterise these segments based on the aforementioned factors. Such information would be useful when recruiting participants for studies utilising digital-IEs to increase the likelihood that these environments are assisting participants imagine they are in a real-life environment.

5.6 Conclusions

This thesis sought to develop a new understanding of consumer emotional engagement with PBMAs. Given the limited research previously conducted in this area, the research presented serves as an initial exploration and foundation for future research to build upon. The major findings from this thesis were as follows:

1. Emotion lexicon development: This thesis provided an emotion lexicon that can be used by researchers and food manufactures interested in understanding consumer emotional responses to PBMAs. This lexicon enables focused exploration of the key emotions consumers associate with PBMAs, providing more nuanced insights than a generic emotion lexicon.

2. Consumer preference for meat-like PBMAs: PBMAs that closely resemble their meat counterparts were found to be the most appealing to meat-eating consumers (flexitarians and omnivores). Therefore, to encourage the uptake of PBMAs among these diet groups, product development efforts should continue to focus on closely matching the sensory profiles of conventional meat products, while also improving the sensory experience of PBMAs that do not mimic meat.

3. Meal context and eating environment: this thesis demonstrated liking and emotional response towards PBMAs can be impacted by meal context and eating environment. Contextual factors should therefore be considered in future research as failure to do so could produce misleading results for product development or marketing decisions.

4. Potential of digital-IEs for contextual consumer insights: this thesis demonstrated that digital-IEs can evoke different liking and emotional responses to the same product. This

underscores the potential of digital-IEs as a tool for gaining insights into consumer responses in contextually relevant settings, when testing in a real-life environment is not practical.

Overall, this research contributed to a deeper understanding of consumer preferences and emotional responses towards PBMAs, which is crucial for their successful integration into mainstream diets. In the coming years, as the global population grows and the demand for protein rises, it will be exciting to see how consumer acceptance of PBMAs evolves and how product offerings adapt to these changing preferences. As PBMAs continue to develop, it would be good to see such products move beyond the label of 'alternatives' and establish an identity of their own, distinct from conventional meat.

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Appendices

Appendix A. Discussion guide and activity sheet for emotion lexicon development discussion groups.

Discussion Guide – Emotional Lexicon Development

Welcome - 1 minute

Welcome everyone! I am Rebekah, a PhD student here at Massey. Thank you for coming today and contributing to my research on emotional response to burger patties. We also have my supervisor Caroline here who will be watching this session.

The aim of this session is to come up with a list of emotion terms in response to how we feel when eating different burger patties. These patties do not contain meat or any animal products except for one which is beef (Meat excluders/reducers: I will indicate the beef sample and you are not required to eat it.) This session is expected to take just over an hour.

Consent forms and information sheet – 2 minutes

Check everyone has read and understood the information sheet and signed a consent form. Collect consent forms. Check no one has any questions regarding the information sheet/consent form.

Housekeeping - 3 minutes

- Check no one has any allergies or intolerances to the products they will be tasting (all ingredients are listed on the information sheet).
- Now that you're seated, you're welcome to remove your mask but also feel free to keep it on. The choice is yours.
- Keep phones on silent mode, if you must take a call, you are welcome to do so but please leave the room. You may occasionally see me using my phone. This is for me to communicate with the team working behind the scenes or to check the time.
- If you need to use the bathroom, turn left and exit through the glass door at the end of the hall. You will need an access card to get back through the door. I will leave the access card here.
- Everyone's answers are important and valuable - there are no right or wrong answers. Please respect others' ideas/ emotions and only one person is to speak at a time.
- You should have a worksheet in front of you. This is where I'd like you to clearly write down your emotions when doing the activities. I will collect these at the end of the session to help with data analysis. They are anonymous, and I am not collecting them to assess you.
- Images of eating environments are going to be projected on the walls. If at any time this makes you feel unwell, please let me know and you can leave the session.
- The session is going to be video and audio recorded. This recording will only be viewed by me and my supervisors and is to assist with data analysis. If you have an issue with recording, please let me know now.
- Does anyone have any questions?

Ice breaker – 3 minutes

To start, we will go around the group to introduce ourselves.

- Name
- what you normally do during the day e.g. student, teacher, stay-at-home parent
- Your favourite place to get a burger

I'll start, I'm Rebekah, I'm a full-time student and my favourite burger is a halloumi burger from Lucky Burger in Wellington.

Part 1- Introduction to emotions 10 minutes

Today we are going to taste burger patties and discuss how they make you feel, emotions.

Specifically, we are interested in discussing how these patties make you feel in the moment you are eating them (emotional response). For example, this burger patty makes me feel excited. We are not interested in how you are feeling today i.e. For example, I am nervous and stressed today...; these longer-term feelings are your mood.

Don't need to say this – only for further explanations if needed

- **Emotions** are brief, intense, and focused on a referent, e.g. "That comment makes me feel angry".
- **Moods** are more enduring, build up gradually, are more diffuse, and not focused on a referent, e.g. "I'm angry."

Warm up activity with pictures

<participants provided with about 20 printed pictures related to emotions>

Our first activity is to help get us thinking about different emotion terms. If everyone could ...

- Choose 1 of the pictures that mean something to you/ trigger a memory/ gets your attention (that we can talk about)
- Describe to the group why you chose that picture

How does it make you feel? Or what emotions could the people in the image be feeling?

For example, I chose this photo <choose photo of hands holding a hot drink> because it reminds me of being at home which makes me feel warm and relaxed.

----------START AUDIO RECORDING ----------

Part 3 – Emotion Term Generation – 45 minutes

Now we are going to focus our attention on burger patties. I would like you to think of that favourite burger you mentioned during the introductions, how does eating that burger make you feel? How would a bad burger make you feel?

Please write down your answers on your activity sheet. Go around group and discuss answers.

We are now going to taste 5 samples whilst immersed in two different eating contexts. So you will taste 5 samples in context 1 and another 5 samples in context 2. While tasting each sample I want you to imagine you are in the context shown in the image then write down on your activity sheet how the sample makes you feel. We will taste and discuss the samples in pairs apart from the 5th sample which we will taste on its own. You do not need to consume the whole sample, just enough to assess how it makes you feel. Please cleanse your palate with water and crackers between each sample.

Context One: Meal at home

< Serve sample 1 & 2 and start image projection of meal at home >

I want you to imagine you are at home with your family and/or flat mates and you're having burgers for dinner. You have purchased burger patties from the supermarket and cooked them for dinner. This is the patty that has been prepared.

- Looking at the patty, how does it make you feel?
- Eating the patty, how do you feel?
- Discuss samples 1 & 2, type emotion terms into Word Doc e.g. *How did sample 1 make you feel? (get responses for first sample), ok what about sample 2 do we have any different emotion terms? Did anyone else have xx? If unclear: would that be positive/negative or neither?*

<Serve samples 3 & 4 and continue image projection of meal at home>

I want you to keep imagining you are at home with your family and/or flat mates having burgers for dinner. But now these are the patties that has been prepared for the burgers.

Looking at these patties, how do they make you feel?

- Eating the patties, how do you feel?
- After tasting these two samples do we have any new emotion terms to add to our list?

<Serve sample 5 and continue image projection of meal at home>

Still imagining you are at home with your family and/or flat mates having burgers for dinner. However, now this is the patty that has been prepared.

- Looking at the patty, how does it make you feel?
- Eating the patty, how do you feel?
- Discuss sample 5 type emotion terms not mentioned previously into Word Doc

Context Two: Dinner Out at Gastropub

<Serve samples 1 & 2 and start image projection of restaurant/ pub >

Now I want you to imagine you are at the pub with friends having dinner and a few drinks. You have ordered a burger and you're looking forward to it. This is the patty that arrives in your burger.

- Looking at this patty how do you feel?
- Eating this patty, how do you feel?

Discuss sample 1 & 2: e.g. Jane, how did sample 1 make you feel? Have your emotions changed from the home context? type emotion terms not mentioned previously into Word Doc

<Serve samples 3 & 4 continuing image projection of restaurant/ pub>

I want you to keep imagining you are at the pub with friends having dinner and a few drinks. But now this is the patty that arrives in your burger.

- Looking at these patties how do you feel?
- Eating these patties, how do you feel?

Discuss sample 3 & 4, type emotion terms not mentioned previously into Word Doc

<Serve sample 5 continuing video projection of restaurant/ pub>

Still imagining you are at the pub with friends having dinner and a few drinks. But now this is the patty that arrives in your burger.

- Looking at the patty, how does it make you feel?
- Eating this patty, how do you feel?

Discuss sample 5, type emotion terms not mentioned previously into Word Doc

----------Toilet Break ----------

< Project list of generated terms on wall >

Part 4 – Additional terms EsSense Profile – 5 minutes

< hand out a printed list of the EsSense Profile® >

Looking at the list of emotions shown on the hand-out, please write down

- Any other terms you could have used to describe how the patties made you feel
- Please specify in which context you would use the term

Discuss and add words to list in Word Doc

Part 5 - Removal of irrelevant terms - 5 minutes

If we had to reduce our lists of emotions, which terms would you keep? Consider which terms people are more likely to use/relate to in everyday life when discussing burgers.

- As a group we will go through each term, please say if you would keep it or remove it.
- Also ensure the terms describe emotional response and not the samples themselves (e.g. bland, pleasant)

If a term is suggested for removal, majority should agree (Annotate on list how many agree)

Conclusion - 3 minutes

Thank you very much for your participation today. I will be in touch regarding the follow up activity. As a token of appreciation… <Hand out goody bags>

----------END/STOP AUDIO RECORDING ----------

Activity Sheet: Burger Patty Emotion Generation

Unique Panellist Code:

Date:

Part A

	Emotions
My favourite burger is **.....** **it makes me feel:**	
A bad burger would make me feel:	

Part B

Meal at Home: *Imagine you are at home with your family and/or flatmates and you're having burgers for dinner.*

Sample 143	**Emotions**
Looking at sample 143 I feel… While eating sample 143 I feel…	
Sample 708	**Emotions**
Looking at sample 708 I feel… While eating sample 708 I feel…	
Sample 472	**Emotions**
Looking at sample 472 I feel… While eating sample 472 I feel…	
Sample 596	**Emotions**
Looking at sample 596 I feel… While eating sample 696 I feel…	
Sample 973	**Emotions**
Looking at sample 973 I feel… While eating sample 973 I feel…	

Meal at Gastropub: *Imagine you are at the pub with friends having dinner and a few drinks. You have ordered a burger and you're looking forward to it.*

Sample 014	**Emotions**
Looking at sample 014 I feel… While eating sample 014 I feel…	
Sample 628	**Emotions**
Looking at sample 628 I feel… While eating sample 628 I feel…	
Sample 821	**Emotions**
Looking at sample 821 I feel… While eating sample 821 I feel…	
Sample 279	**Emotions**
Looking at sample 279 I feel… While eating sample 279 I feel…	
Sample 315	**Emotions**
Looking at sample 315 I feel… While eating sample 315 I feel…	

Part C

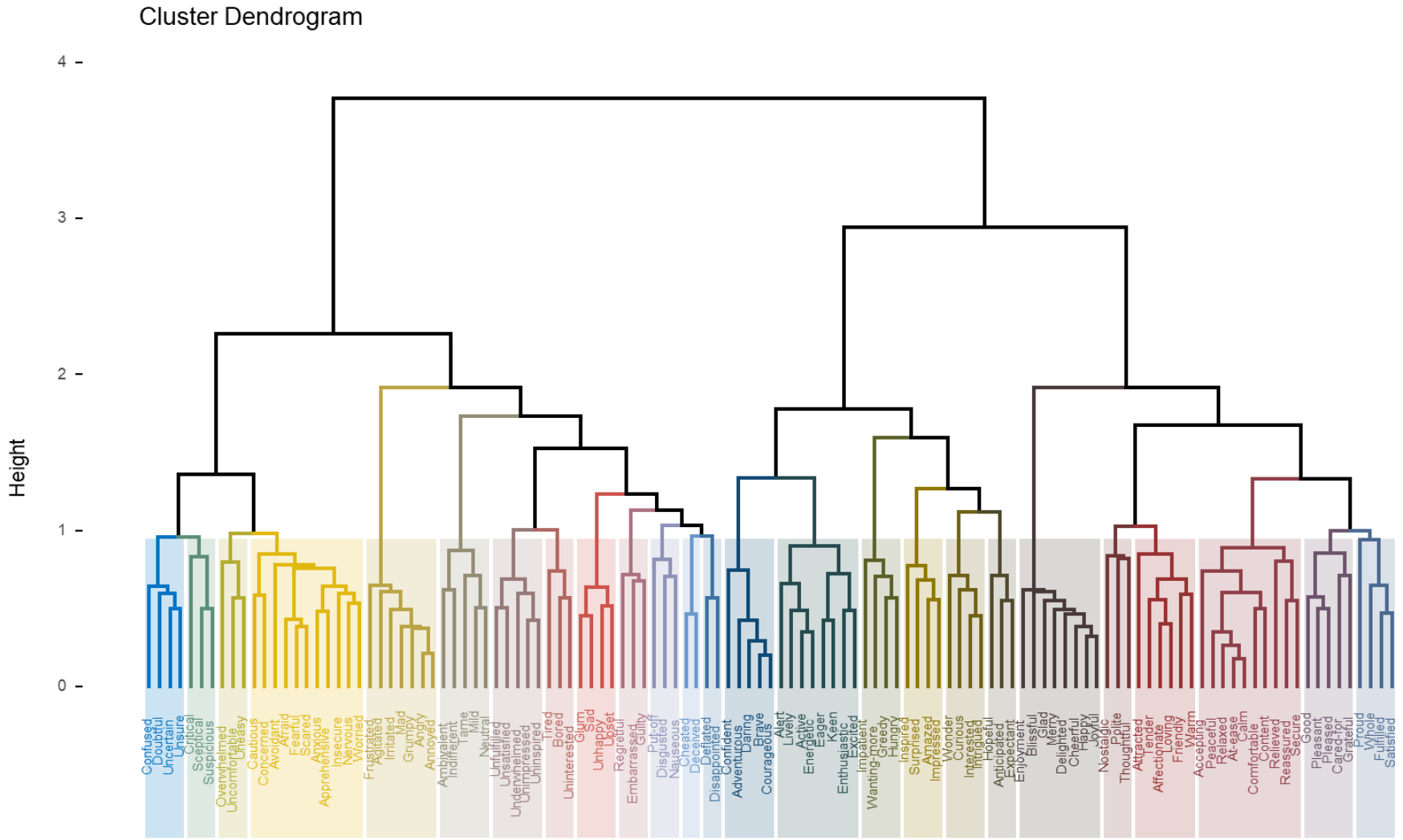
Looking at the list of emotion terms presented, please write down any terms that are similar/ close to those you have used or other terms you could have used. If you are not sure of the meaning of an emotion, please refer to the emotion's definitions list.

Additional or Similar Emotion Terms

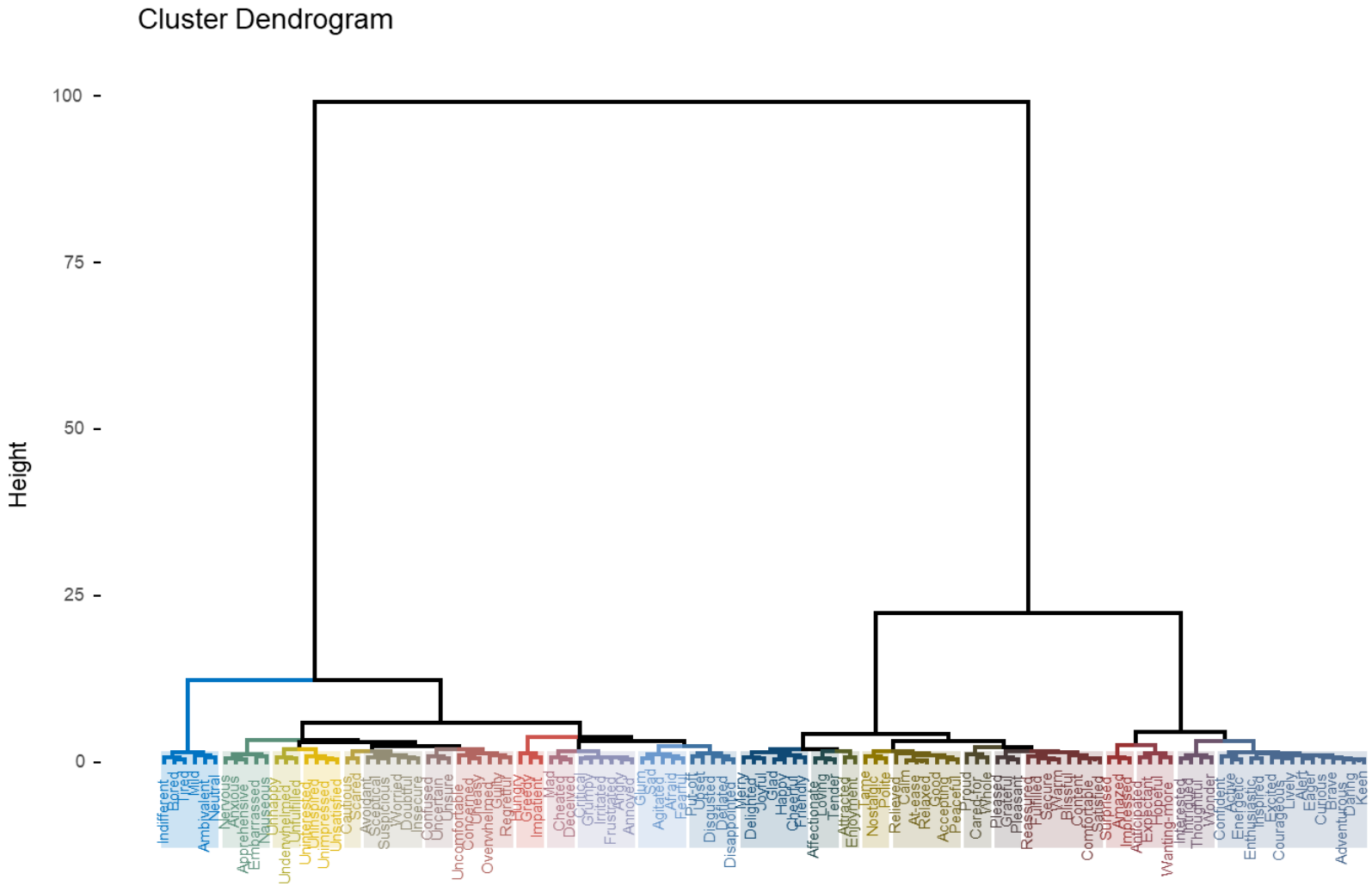
Looking at the list of emotion terms presented, do you think all these terms are relevant to burger patties? Please write down the emotion terms you would remove from the list (if any).

Emotion Terms I Would Remove

Appendix B. Cluster dendrogram original dissimilarity matrix HCA solution for 25 clusters.



Appendix C. Cluster dendrogram standardised dissimilarity matrix HCA solution for 25 clusters.



Appendix D. Hybrid patty preparation instructions**.**

Formulation for 10 x 90g patties + extra

- 200g Classic Kiwi Vince Mince (Olive and Ash Ltd, New Zealand)
- 250ml Boiling Water
- 450g Beef Mince Premium Grass Fed NZ Beef (Countdown, New Zealand)
- 2 x Free-Range Eggs (Countdown, New Zealand)
- 100g Potato Flakes (Value, New Zealand)

In a glass mixing bowl Classic Kiwi Vince Mince was rehydrated with boiling water then left to sit for 5 minutes, before stirring. In a separate bowl free-range eggs were lightly whisked and set aside. The mince mixture was cooled for a further 10-minutes to be allowed to be handled. Using gloved hands, the vegetable mince mixture was then thoroughly combined with uncooked beef mince, potato flakes and whisked eggs. The mixture was then weighed out into 90g portions and moulded into a patty shape using a circular cookie cutter. Patties were placed on an aluminium baking tray lined with baking paper and coved with cling wrap, then stored in the refrigerator (less than 5°C) until time of cooking.

Appendix E. Quorn patty preparation instructions.

Formulation for 10 patties (90g each)

- 750g x Quorn™ Mince (Quorn Foods, United Kingdom)
- 14g Olive Oil (Countdown, New Zealand)
- 6g x Onion Powder (MasterFoods, New Zealand)
- 6g x Garlic Powder (MasterFoods, New Zealand)
- 3g x Dried Rosemary (MasterFoods, New Zealand)
- 30g x Marmite (Sanitarium, New Zealand)
- 30g x Boiling Water
- 190g x Wholemeal Breadcrumbs (Sun Valley Foods, New Zealand)
- 2 x Free-Range Eggs (Countdown, New Zealand)
- 3g x Salt (Cerebos, New Zealand)

Olive oil was heated over a medium heat in a large frying pan on an induction cooktop (Fisher and Paykel, New Zealand). Frozen Quorn Mince™ was added to the pan and cooked for 2.5 minutes. Onion powder, garlic powder, and dried rosemary were then added to the pan and cooked for a further 2.5 minutes until the mince mixture was wet. The pan was then removed from the heat to allow the mixture to cool for 10-minutes before being handled. In a glass bowl Marmite was dissolved in equal parts boiling water. In a separate bowl free-range eggs were lightly whisked and set aside. Using gloved hands, the mince mixture was thoroughly combined with the Marmite dissolved in boiling water, whisked eggs, breadcrumbs and iodised table salt. The mixture was then weighed out into 90g portions and moulded into a patty shape using a circular cookie cutter. Patties were placed on an aluminium baking tray lined with baking paper and covered with cling wrap then stored in the refrigerator (less than 5°C) until time of cooking.

Appendix F. Emotion lexicon provided to participants during sample assessment.

Meat and Plant-Based Patties Consumer Study
Emotion Words List

Emotion	Similar Emotions
Adventurous	Brave/ Confident/ Courageous
Afraid	Cautious/ Concerned/ Uneasy
Amazed	Impressed/ Surprised
Angry	Irritated/ Annoyed/ Frustrated
Anxious	Apprehensive/ Nervous
Bored	Tired/ Lacking Interest
Calm	Content/ Relaxed/ Comfortable
Curious	Interested/ Intrigued/ Wonder
Deceived	Cheated
Disappointed	Deflated
Disgusted	Repulsed/ Put-off
Dissatisfied	Unimpressed/ Uninspired
Energetic	Excited/ Active/ Eager
Happy	Delighted/ Enjoyment/ Cheerful
Hopeful	Expectant/ Anticipation
Hungry	Greedy/ Impatient/ Wanting-more
Loving	Friendly/ Affectionate/ Attracted
Neutral	Ambivalent/ Mild/ Indifferent
Nostalgic	Polite/ Positive reminder of past times
Pleasant/ Grateful	Pleased
Satisfied	Content/ Fulfilled/ Expectations meet
Suspicious	Sceptical/ Avoidant
Uncertain	Confused/ Unsure
Unhappy/ Sad	Glum/ Upset

Appendix G. Summary of Chi-squared and p-values from Analysis of Deviance of GLM on emotion category citation proportions.

Emotion Category	Product (DF=11)		Visit (DF=1)		Emotion Cluster (DF=1)		Product*Emotion Cluster (DF=11)	
	Chi-square	p	Chi-square	p	Chi-square	p	Chi-square	p
Adventurous	20.88	0.035*	0.34	0.56	43.24	<0.001***	15.43	0.16
Afraid	57.56	<0.001***	0.21	0.64	2.55	0.11	7.45	0.76
Amazed	66.04	<0.001***	0.036	0.85	82.79	<0.001***	16.98	0.11
Angry	45.42	<0.001***	1.62	0.20	3.69	0.055	10.21	0.51
Anxious	22.58	0.020*	0.18	0.67	3.16	0.075	7.75	0.73
Bored	60.30	<0.001***	0.56	0.45	10.28	0.001**	15.47	0.16
Calm	41.78	<0.001***	0.59	0.44	50.40	<0.001***	14.56	0.20
Curious	56.32	<0.001***	0.092	0.76	23.97	<0.001***	9.76	0.55
Deceived	58.76	<0.001***	1.98	0.16	3.79	0.051	9.94	0.55
Disappointed	149.74	<0.001***	3.26	0.07	5.72	0.017*	25.07	0.008**
Disgusted	146.45	<0.001***	2.30	0.13	12.18	<0.001***	20.08	0.044*
Dissatisfied	122.56	<0.001***	0.71	0.40	9.65	0.002**	20.30	0.041*
Energetic	102.82	<0.001***	0.13	0.72	82.12	<0.001***	17.85	0.085
Happy	190.76	<0.001***	0.062	0.80	1111.40	<0.001***	36.22	<0.001***
Hopeful	42.93	<0.001***	0.76	0.38	59.39	<0.001***	9.48	0.58
Hungry	145.38	<0.001***	1.01	0.31	30.22	<0.001***	15.46	0.16
Loving	65.49	<0.001***	0.35	0.55	94.09	<0.001***	23.22	0.016*
Neutral	14.65	0.20	0.18	0.67	6.35	0.012*	15.40	0.16
Nostalgic	31.12	0.0011**	0.95	0.33	8.45	0.004**	10.41	0.49
Pleasant/ Grateful	175.91	<0.001***	3.15	0.07	111.79	<0.001***	27.41	0.004**
Satisfied	205.50	<0.001***	1.46	0.22	45.14	<0.001***	23.36	0.016*
Suspicious	73.76	<0.001***	0.48	0.49	4.26	0.039*	22.66	0.019*
Uncertain	54.43	<0.001***	2.19	0.14	3.45	0.063	24.61	0.01*
Unhappy/Sad	117.51	<0.001***	2.19	0.14	1.10	0.29	14.67	0.20

Significant effects indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)

Appendix H. Correlation (r) of emotion attributes and supplementary variables to PC1 to PC4 of PCA biplots Figure 3.3.

	Principal component													
	PC1				**PC2**				**PC3**				**PC4**	
	Negative pole		Positive pole		Negative pole		Positive pole		Negative pole		Positive pole		Negative pole	Positive pole
	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute r	Attribute r
Emotions	Amazed	-0.88	Afraid	0.77	Calm	-0.63	Adventurous	0.76			Curious	0.78		
	Calm	-0.67	Angry	0.83	Neutral	-0.88								
	Energetic	-0.84	Anxious	0.82										
	Happy	-0.94	Bored	0.82										
	Hopeful	-0.85	Deceived	0.76										
	Hungry	-0.87	Disappointed	0.94										
	Loving	-0.95	Disgusted	0.93										
	Nostalgic	-0.82	Dissatisfied	0.99										
	Pleasant	-0.94	Suspicious	0.85										
	Satisfied	-0.97	Uncertain	0.85										
			Unhappy	0.95										
Supplementary Variables	Overall liking	-0.99												
	Appearance liking	-0.98												
	Texture liking	-0.96												
	Flavour liking	-0.97												
	Perceived similarity to meat	-0.86												

Attributes were considered important when r>0.6 or <-0.6

Appendix I. Summary of Chi-squared and p-values from Analysis of Deviance of GLM on sensory attribute citation proportions.

Modality	Attribute	Product (DF=11)		Visit (DF=1)	
		Chi-square	p	Chi-square	p
Appearance	Browning on outside	245.78	<0.001***	0.220	0.638
	Fried crumb coating	544.08	<0.001***	0.260	0.611
	Dark brown colour	163.60	<0.001***	0.129	0.719
	Light brown colour	493.39	<0.001***	0.430	0.512
	Green colour	900.86	<0.001***	0.650	0.420
	Orange colour	624.61	<0.001***	0.870	0.350
	Greasy/oily	200.63	<0.001***	0.040	0.844
	Dry	393.98	<0.001***	0.120	0.732
	Pink/red centre	342.58	<0.001***	0.000	1
	Moist	362.95	<0.001***	2.140	0.143
	Fibrous	156.75	<0.001***	0.230	0.632
	Hard/dense	297.28	<0.001***	1.860	0.172
	Crumbly	345.93	<0.001***	0.062	0.803
	Chunky	157.15	<0.001***	0.460	0.496
	Visible ingredients	979.4	<0.001***	3.78	0.052
Texture/ mouthfeel	Dry	453.04	<0.001***	1.20	0.273
	Moist	351.85	<0.001***	0.103	0.748
	Juicy	228.79	<0.001***	0.802	0.370
	Chewy/rubbery	304.06	<0.001***	0.21	0.650
	Cohesive	73.33	<0.001***	0.06	0.814
	Greasy/oily	196.08	<0.001***	0.04	0.840
	Grainy	280.28	<0.001***	1.65	0.199
	Hard/dense	285.26	<0.001***	5.846	0.016*
	Soft	437.26	<0.001***	1.20	0.274
	Pasty/ doughy	319.61	<0.001***	0.08	0.782
	Springy	179.94	<0.001***	0.29	0.589
	Tender	147.65	<0.001***	0.10	0.757
	Chunky	161.89	<0.001***	1.40	0.236
	Fibrous	100.77	<0.001***	0.14	0.710
	Inconsistent	141.68	<0.001***	0.83	0.362
	Crunchy	82.92	<0.001***	0.569	0.451
	Crumbly	387.52	<0.001***	0.06	0.804
Flavour/taste	Smoky/ Grilled	347.37	<0.001***	0.93	0.334
	Strong beef	707.92	<0.001***	0.14	0.707
	Weak beef	254.71	<0.001***	0.03	0.863
	Metallic/ blood	75.434	<0.001***	1.629	0.202
	Breadcrumbs/wheat	199.69	<0.001***	0.00	1

Appendix I. Summary of Chi-squared and p-values from Analysis of Deviance of GLM on sensory attribute citation proportions (continued).

Modality	Attribute	Product (DF=11)		Visit (DF=1)	
		Chi-square	p	Chi-square	p
Flavour/taste	Fat	244.08	<0.001***	0.92	0.337
	Black pepper	337.46	<0.001***	0.10	0.754
	Salty	29.10	0.002**	0.49	0.484
	Savoury/ umami	22.55	0.020*	0.10	0.758
	Sweet	103.38	<0.001***	0.06	0.802
	Mixed herbs	211.62	<0.001***	0.46	0.500
	Beany	264.25	<0.001***	1.07	0.301
	Nutty	262.90	<0.001***	0.07	0.792
	Garlic/ onion	119.78	<0.001***	2.65	0.103
	Root vegetables	396.06	<0.001***	0.02	0.887
	Brassicas	181.88	<0.001***	0.35	0.552
	Tomato	329.81	<0.001***	0.414	0.520
	Mushroom/ earthy	241.88	<0.001***	2.405	0.121
	Hot spices	354.93	<0.001***	0.014	0.906
	Aromatic spices	241.91	<0.001***	0.49	0.484

Significant effects indicated by *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)

Appendix J. Correlation (r) of sensory attributes and supplementary variables to PC1 to PC4 of PCA biplots (Figure 3.4A and Figure 3.4B).

	Principal component															
	PC1				**PC2**				**PC3**				**PC4**			
	Negative pole		Positive pole		Negative pole		Positive pole		Negative pole		Positive pole		Negative pole		Positive pole	
	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute	r
Sensory attributes	Beany flavour	-0.78	Chewy/rubbery	0.64	Chunky appearance	-0.66	Aromatic spices/ flavour	0.61	Crumbly appearance	-0.65	Black pepper flavour	0.79	Breadcrumb/ wheat flavour	-0.60	Mushroom/ earthy flavour	0.70
	Brassicas flavour	-0.68	Fat flavour	0.92	Chunky texture	-0.75	Garlic/ onion flavour	0.70	Weak beef flavour	-0.75	Hot spices flavour	0.60	Fried crumb coating appearance	-0.72		
	Chunky appearance	-0.60	Fibrous appearance	0.77	Dark brown colour appearance	-0.61	Mixed herb flavour	0.60								
	Crumbly texture	-0.60	Fibrous texture	0.76	Dry appearance	-0.68	Moist appearance	0.73								
	Dry appearance	-0.63	Greasy/oily appearance	0.83	Dry texture	-0.68	Moist texture	0.76								
	Dry texture	-0.62	Greasy/oily texture	0.86	Hard/dense appearance	-0.81	Pasty/ doughy texture	0.85								
	Grainy/granular texture	-0.81	Juicy texture	0.79	Hard/dense texture	-0.83	Soft texture	0.91								
	Inconsistent texture	-0.82	Light brown colour appearance	0.68												
	Mixed herb flavour	-0.61	Metallic/blood flavour	0.73												
	Nutty flavour	-0.74	Savoury/umami flavour	0.66												

Appendix J. Correlation (r) of sensory attributes and supplementary variables to PC1 to PC4 of PCA biplots (Figure 3.4A and Figure 3.4B) (continued).

	Principal component											
	PC1				**PC2**				**PC3**		**PC4**	
	Negative pole		Positive pole		Negative pole		Positive pole		Negative pole	Positive pole	Negative pole	Positive pole
	Attribute	r	Attribute	r	Attribute	r	Attribute	r	Attribute r	Attribute r	Attribute r	Attribute r
Sensory attributes	Root vegetable flavour	-0.65	Smoky/grilled flavour	0.92								
	Visible ingredients appearance	-0.87	Springy texture	0.83								
			Strong beef flavour	0.70								
			Tender texture	0.75								
			Weak beef flavour	0.60								
Supplementary variables			Overall liking	0.83								
			Appearance liking	0.75								
			Texture liking	0.88								
			Flavour liking	0.85								
			Perceived similarity to meat	0.88								

Attributes were considered important when r>0.6 or <-0.6

Appendix K. Emotion cluster emotion citation proportions by product**.**

Emotion Category	Cluster	Beef	Quorn	Beyond Meat	Vegie Delights	Hybrid	Impossible Meats	Birds Eye	Food Nation_1	Food Nation_2	Pams	Bean Supreme_1	Bean Supreme_2
Adventurous[1]	1	0.102	0.109	0.063	0.094	0.063	0.047	0.016	0.102	0.125	0.141	0.078	0.078
	2	0.179	0.231	0.410	0.308	0.154	0.308	0.128	0.167	0.154	0.256	0.154	0.154
Afraid	1	0.016	0.031	0.016	0.016	0.047	0.000	0.031	0.102	0.125	0.016	0.031	0.031
	2	0.013	0.000	0.000	0.026	0.000	0.000	0.000	0.077	0.077	0.000	0.051	0.026
Amazed[1]	1	0.109	0.016	0.047	0.016	0.031	0.047	0.016	0.008	0.016	0.047	0.031	0.031
	2	0.218	0.077	0.410	0.256	0.103	0.436	0.282	0.051	0.128	0.154	0.051	0.128
Angry	1	0.000	0.016	0.000	0.000	0.078	0.000	0.031	0.055	0.031	0.000	0.094	0.063
	2	0.013	0.026	0.000	0.000	0.000	0.000	0.000	0.026	0.026	0.000	0.077	0.000
Anxious	1	0.031	0.016	0.063	0.016	0.078	0.016	0.016	0.094	0.047	0.031	0.078	0.063
	2	0.013	0.026	0.000	0.026	0.026	0.026	0.000	0.038	0.077	0.026	0.077	0.026
Bored[1]	1	0.023	0.109	0.063	0.047	0.047	0.063	0.078	0.039	0.141	0.031	0.203	0.141
	2	0.026	0.128	0.026	0.205	0.077	0.051	0.051	0.167	0.231	0.179	0.282	0.154
Calm[1]	1	0.109	0.063	0.109	0.078	0.078	0.188	0.266	0.047	0.031	0.109	0.063	0.109
	2	0.321	0.308	0.179	0.154	0.333	0.231	0.282	0.205	0.128	0.282	0.128	0.308
Curious[1]	1	0.141	0.219	0.406	0.328	0.250	0.219	0.281	0.156	0.188	0.375	0.219	0.234
	2	0.231	0.487	0.462	0.308	0.462	0.282	0.538	0.321	0.282	0.462	0.256	0.359
Deceived	1	0.000	0.125	0.109	0.109	0.141	0.094	0.078	0.094	0.125	0.078	0.156	0.094
	2	0.000	0.128	0.000	0.026	0.154	0.026	0.026	0.077	0.103	0.051	0.154	0.077
Disappointed[1,2]	1	0.109[a]	0.453[a]	0.078[a]	0.250[a]	0.281[a]	0.141[a]	0.141[a]	0.367[a]	0.281[a]	0.125[a]	0.406[a]	0.281[a]
	2	0.064[a]	0.128[b]	0.026[a]	0.077[b]	0.179[a]	0.051[a]	0.026[a]	0.410[a]	0.256[a]	0.231[a]	0.462[a]	0.256[a]
Disgusted	1	0.047	0.094	0.031	0.078	0.172	0.047	0.047	0.281	0.250	0.031	0.250	0.109
	2	0.000	0.000	0.000	0.000	0.051	0.000	0.000	0.167	0.205	0.051	0.282	0.051
Dissatisfied[2]	1	0.094[a]	0.313[a]	0.141[a]	0.188[a]	0.297[a]	0.172[a]	0.203[a]	0.367[a]	0.359[a]	0.172[a]	0.391[a]	0.328[a]
	2	0.103[a]	0.205[a]	0.026[a]	0.128[a]	0.179[a]	0.000[b]	0.026[b]	0.346[a]	0.359[a]	0.154[a]	0.359[a]	0.179[a]
Energetic[1]	1	0.164	0.031	0.063	0.031	0.016	0.109	0.016	0.016	0.047	0.063	0.016	0.047
	2	0.308	0.128	0.564	0.256	0.256	0.385	0.179	0.077	0.077	0.205	0.077	0.154

Appendix K. Emotion cluster emotion citation proportions by product (continued).

Emotion Category	Cluster	Beef	Quorn	Beyond Meat	Vegie Delights	Hybrid	Impossible Meats	Birds Eye	Food Nation_1	Food Nation_2	Pams	Bean Supreme_1	Bean Supreme_2
Happy[1,2]	1	0.375[a]	0.047[a]	0.234[a]	0.203[a]	0.141[a]	0.188[a]	0.094[a]	0.063[a]	0.078[a]	0.234[a]	0.047[a]	0.094[a]
	2	0.564[b]	0.359[b]	0.769[b]	0.436[b]	0.333[b]	0.846[b]	0.564[b]	0.077[a]	0.282[b]	0.410[a]	0.154[a]	0.333[b]
Hopeful[1]	1	0.102	0.094	0.125	0.125	0.078	0.172	0.109	0.039	0.031	0.156	0.016	0.016
	2	0.244	0.308	0.256	0.256	0.282	0.256	0.359	0.179	0.103	0.282	0.128	0.205
Hungry[1]	1	0.234	0.094	0.078	0.031	0.125	0.141	0.031	0.047	0.031	0.094	0.000	0.063
	2	0.372	0.179	0.359	0.256	0.205	0.333	0.231	0.051	0.051	0.154	0.000	0.051
Loving[2]	1	0.102[a]	0.016[a]	0.047[a]	0.047[a]	0.016[a]	0.031[a]	0.031[a]	0.000[a]	0.000[a]	0.063[a]	0.016[a]	0.000[a]
	2	0.231[b]	0.179[b]	0.359[b]	0.154[a]	0.231[b]	0.333[b]	0.333[b]	0.064[a]	0.128[a]	0.154[a]	0.000[a]	0.154[a]
Neutral[1]	1	0.117	0.156	0.156	0.219	0.141	0.188	0.266	0.094	0.172	0.172	0.109	0.188
	2	0.205	0.179	0.077	0.179	0.308	0.128	0.256	0.205	0.256	0.179	0.308	0.231
Nostalgic	1	0.125	0.016	0.078	0.063	0.047	0.031	0.078	0.023	0.031	0.047	0.031	0.063
	2	0.141	0.103	0.103	0.128	0.103	0.154	0.179	0.064	0.077	0.051	0.000	0.051
Pleasant/Greatful[1,2]	1	0.281[a]	0.078[a]	0.219[a]	0.078[a]	0.109[a]	0.313[a]	0.250[a]	0.109[a]	0.031[a]	0.328[a]	0.063[a]	0.094[a]
	2	0.551[b]	0.308[b]	0.821[b]	0.487[b]	0.410[b]	0.718[b]	0.667[b]	0.128[a]	0.205[b]	0.462[a]	0.154[a]	0.333[b]
Satisfied[1,2]	1	0.461[a]	0.094[a]	0.219[a]	0.219[a]	0.234[a]	0.281[a]	0.203[a]	0.094[a]	0.047[a]	0.297[a]	0.063[a]	0.172[a]
	2	0.603[b]	0.333[b]	0.667[b]	0.436[b]	0.282[a]	0.667[b]	0.513[b]	0.077[a]	0.205[b]	0.385[a]	0.077[a]	0.308[a]
Suspicious[2]	1	0.078[a]	0.109[a]	0.219[a]	0.156[a]	0.172[a]	0.063[a]	0.141[a]	0.281[a]	0.266[a]	0.125[a]	0.156[a]	0.172[a]
	2	0.051[a]	0.154[a]	0.026[b]	0.026[a]	0.128[a]	0.077[a]	0.000[a]	0.231[a]	0.308[a]	0.077[a]	0.231[a]	0.154[a]
Uncertain[2]	1	0.117[a]	0.266[a]	0.313[a]	0.266[a]	0.188[a]	0.125[a]	0.219[a]	0.211[a]	0.313[a]	0.172[a]	0.203[a]	0.250[a]
	2	0.115[a]	0.282[a]	0.103[b]	0.205[a]	0.282[a]	0.077[a]	0.128[a]	0.397[b]	0.436[a]	0.256[a]	0.436[b]	0.333[a]
Unhappy/Sad	1	0.039	0.141	0.031	0.078	0.156	0.078	0.078	0.219	0.203	0.109	0.359	0.156
	2	0.051	0.051	0.000	0.077	0.205	0.026	0.000	0.282	0.231	0.077	0.231	0.077

[1] Significant main effect of cluster membership for this emotion category

[2] Significant interaction effect of cluster membership and product for this emotion category

[a, b] different letters indicate differences between clusters in mean citation proportion within a product, as determined by post hoc testing adjusted with Tukey-corrections to allow for multiple comparisons. Only applied to emotion categories where a significant interaction effect of cluster membership and product was identified.

Appendix L. Mean liking ratings and standard errors (SE) for each sample when evaluated in each environment.

Liking Modality	Environment	Veggie Balls	Veggie Balls + Tomato sauce	Beyond-Meat Balls	Beyond-Meat Balls + Tomato sauce	Tomato sauce
Expected liking	T-CLT	52.10 ± 1.95	72.99 ± 1.80	70.46 ± 1.66	78.17 ± 1.63	62.67 ± 2.24
	DI-Home	60.62 ± 2.03	74.81 ± 1.69	72.37 ± 1.78	75.84 ± 1.67	65.50 ± 2.09
	DI-Concert	56.48 ± 1.94	56.48 ± 1.94	69.58 ± 1.73	73.97 ± 1.83	63.38 ± 2.09
	Pooled	56.20 ± 2.01	72.74 ± 18.5	70.68 ± 1.75	75.86 ±1.72	63.84 ± 2.13
Overall liking	T-CLT	43.77 ± 2.11	50.65 ± 2.06	74.42 ± 2.05	78.81 ± 1.69	76.12 ± 1.83
	DI-Home	49.05 ± 2.20	53.36 ± 2.31	75.21 ± 1.94	79.77 ± 1.91	72.64 ± 1.65
	DI-Concert	45.50 ± 2.26	45.50 ± 2.26	76.22 ± 1.86	79.23 ± 1.86	72.91 ± 1.97
	Pooled	45.94 ± 2.26	50.85 ± 2.31	75.07 ± 1.98	78.90 ± 1.82	73.81 ± 1.90
Appearance liking	T-CLT	50.14 ± 2.17	70.56 ± 1.83	69.43 ± 1.91	77.68 ± 1.50	68.70 ± 1.94
	DI-Home	60.47 ± 2.11	73.61 ± 1.72	72.57± 1.74	75.07 ± 1.72	67.28 ± 1.90
	DI-Concert	55.10 ± 1.91	55.10 ± 1.91	67.90 ± 1.87	72.69 ± 1.73	62.23 ± 2.01
	Pooled	54.99 ± 2.14	70.89 ± 1.80	69.77 ± 1.85	75.06 ± 1.67	66.04 ± 1.96
Flavour liking	T-CLT	47.26 ± 2.05	55.41 ± 2.04	75.05 ± 1.86	78.60 ± 1.71	73.58 ± 2.03
	DI-Home	50.58 ± 2.18	55.98 ± 2.24	75.85 ± 1.78	78.41 ± 1.70	71.32 ± 1.90
	DI-Concert	46.16 ± 2.26	46.16 ± 2.26	76.63 ± 1.85	79.75 ± 1.78	70.51 ± 2.04
	Pooled	47.88 ± 2.21	54.63 ± 2.29	75.66 ± 1.86	78.91 ± 1.74	71.79 ± 2.06
Texture liking	T-CLT	39.40 ± 2.12	41.50 ± 2.27	69.52 ± 2.11	74.64 ± 1.96	76.74 ± 1.80
	DI-Home	44.01 ± 2.28	48.00± 2.49	70.65 ± 2.09	75.55 ± 2.18	72.86 ± 1.63
	DI-Concert	39.50 ± 2.33	39.50 ± 2.33	72.82 ± 1.98	77.23 ± 1.94	73.88 ± 1.90
	Pooled	40.74 ±2.34	44.03 ±2.45	70.79 ± 2.10	75.67 ±2.01	74.45 ±1.92

Appendix M. Mean emotion category ratings and standard errors (SE) for each sample and when evaluated in each environment.

Emotion Category	Environment	Veggie Balls	Beyond-Meat Balls	Tomato sauce	Veggie Balls + Tomato sauce	Beyond-Meat Balls + Tomato sauce
Adventurous	T-CLT	27.94 ± 2.57	40.20 ± 2.87	38.06 ± 2.80	30.64 ± 2.59	46.05 ± 3.08
	DI-Home	31.06 ± 2.64	46.46 ± 2.84	40.69 ± 2.73	33.77 ± 2.70	51.03 ± 2.83
	DI-Concert	30.43 ± 2.65	49.19 ± 2.76	43.85 ± 2.79	29.18 ± 2.70	47.39 ± 3.07
Afraid	T-CLT	15.77 ± 2.22	8.62 ± 1.52	7.40 ± 1.47	11.95 ± 2.07	6.72 ± 1.43
	DI-Home	13.34± 2.06	7.74 ± 1.71	7.74 ± 1.56	12.78 ± 2.24	7.39 ± 1.54
	DI-Concert	13.15± 2.14	7.60 ± 1.32	9.44 ±1.86	15.81 ± 2.46	8.59 ±1.73
Amazed	T-CLT	22.88 ± 2.31	51.97 ± 2.91	38.69 ± 2.95	27.17 ± 2.56	52.73 ± 2.91
	DI-Home	24.62 ± 2.47	50.55 ± 2.90	40.56 ± 2.81	28.74 ± 2.60	56.89 ± 2.89
	DI-Concert	25.37 ± 2.64	49.22 ± 2.89	37.75 ± 2.89	30.05 ± 2.78	52.75 ± 3.16
Angry	T-CLT	11.71 ± 1.89	6.40 ± 1.41	5.57 ± 1.42	12.30 ± 2.06	5.15 ± 1.23
	DI-Home	13.93± 2.26	5.67 ± 1.46	7.02 ± 1.46	12.74 ± 2.26	6.09 ± 1.33
	DI-Concert	13.20 ± 2.13	5.09 ± 1.11	7.14 ±1.41	14.67 ± 2.31	5.36 ±1.25
Anxious	T-CLT	16.10 ± 2.20	7.49 ± 1.43	9.40 ± 1.88	14.99 ± 2.19	7.63 ± 1.49
	DI-Home	17.06 ± 2.18	8.89 ± 1.83	9.53 ± 1.87	18.07 ± 2.59	9.82 ± 1.91
	DI-Concert	17.76 ± 2.41	9.76 ±1.63	11.92 ± 2.03	20.13 ± 2.60	10.82 ± 1.89
Bored	T-CLT	29.40 ± 2.74	8.86 ± 1.62	11.13 ± 1.83	22.29 ± 2.61	7.38 ± 1.42
	DI-Home	25.70 ± 2.64	8.65 ± 1.53	12.94 ± 2.06	30.15 ± 3.08	8.41 ± 1.52
	DI-Concert	23.07 ± 2.52	11.58 ± 1.84	13.28 ± 1.96	25.67 ± 2.86	9.38 ±1.81
Calm	T-CLT	34.87 ± 2.43	49.97 ± 2.39	48.09 ± 2.31	33.88 ± 2.51	48.16 ± 2.57
	DI-Home	41.80 ± 2.67	61.38 ± 2.31	55.74 ± 2.12	44.11 ± 2.32	60.48 ± 2.23
	DI-Concert	39.38 ± 2.43	54.46 ± 2.42	51.56 ± 2.73	40.57 ± 2.54	54.49 ± 2.79
Curious	T-CLT	39.01 ± 2.63	54.98 ± 2.59	47.68 ± 2.49	35.98 ± 2.61	51.35 ± 2.69
	DI-Home	33.30 ± 2.78	49.69 ± 2.82	42.46 ± 2.77	35.95 ± 2.52	49.83 ± 3.12
	DI-Concert	36.71 ± 2.65	47.21 ± 2.76	44.27 ± 2.81	32.49 ± 2.83	47.12 ± 3.18
Deceived	T-CLT	25.05 ± 2.58	10.15 ± 1.71	10.45 ± 2.01	25.71 ± 2.76	8.80 ± 1.64
	DI-Home	25.53 ± 2.69	8.77 ± 1.73	11.28 ± 2.00	25.31 ± 2.83	7.49 ± 1.56
	DI-Concert	24.63 ± 2.77	7.80 ± 1.39	11.56 ± 1.95	27.55 ± 2.84	9.11 ± 1.71
Disappointed	T-CLT	35.87 ± 3.09	11.23 ± 2.05	12.66 ± 2.29	34.77 ± 2.88	8.73 ± 1.50
	DI-Home	34.47 ± 2.90	9.43 ± 1.83	14.39 ± 2.19	34.41 ± 2.23	9.99 ± 1.76
	DI-Concert	36.63 ± 3.15	8.39 ± 1.55	14.37 ± 2.32	34.19 ± 3.21	9.11 ± 1.78

Appendix M. Mean emotion category ratings and standard errors (SE) for each sample and when evaluated in each environment (continued)

Emotion Category	Environment	Veggie Balls	Beyond-Meat Balls	Tomato sauce	Veggie Balls + Tomato sauce	Beyond-Meat Balls + Tomato sauce
Disgusted	T-CLT	22.80± 2.45	9.95 ± 1.82	6.92 ± 1.72	20.03± 2.49	6.24 ± 1.34
	DI-Home	24.58 ± 2.95	7.96 ± 1.97	8.22 ± 1.82	23.31 ± 2.90	7.11 ± 1.65
	DI-Concert	20.35 ± 2.67	6.78 ± 1.62	6.72 ± 1.46	23.08 ± 2.87	7.92 ± 1.90
Dissatisfied	T-CLT	41.49 ± 3.00	13.35 ± 2.23	14.97 ± 2.50	35.58± 2.88	9.07 ± 1.53
	DI-Home	39.12 ± 3.16	11.69 ± 2.10	15.70 ± 2.29	36.45 ± 3.21	11.58 ± 2.02
	DI-Concert	36.77± 3.09	9.95 ± 1.67	16.43 ± 2.35	35.19± 3.30	9.60 ± 1.81
Energetic	T-CLT	20.76 ± 2.13	45.02 ± 2.95	43.97±2.70	25.63 ± 2.44	50.67 ± 2.82
	DI-Home	26.90 ± 2.48	50.60 ± 2.78	44.77 ± 2.56	28.94 ± 2.60	56.12 ± 2.80
	DI-Concert	29.39 ± 2.70	50.12 ± 2.73	42.90 ± 2.98	32.14 ± 2.76	50.93 ± 3.11
Happy	T-CLT	28.49 ± 2.41	58.04 ± 2.80	53.99 ± 2.69	31.22 ± 2.66	62.04 ± 2.69
	DI-Home	33.65 ± 2.60	60.86 ± 2.52	56.50 ± 2.55	36.81 ± 2.69	67.75 ± 2.48
	DI-Concert	35.06 ± 2.69	60.07 ± 2.63	50.79 ± 2.98	35.69 ± 2.72	62.04 ± 2.85
Hopeful	T-CLT	27.33 ± 2.43	47.57 ± 2.74	42.64 ± 2.89	29.71 ± 2.44	51.32 ± 2.83
	DI-Home	29.26 ± 2.64	52.45 ± 2.82	49.74 ± 2.45	31.53 ± 2.66	56.90 ± 2.84
	DI-Concert	30.87 ± 2.62	51.78 ± 2.72	44.87 ± 2.78	31.03 ± 2.69	51.91 ± 3.06
Hungry	T-CLT	22.54 ± 2.26	51.33 ± 2.91	49.13 ± 2.90	29.76 ± 2.72	57.11 ± 2.88
	DI-Home	30.46 ± 2.55	59.66 ± 2.67	54.63 ± 2.71	35.53 ± 2.68	57.91 ± 3.14
	DI-Concert	30.99 ± 2.59	52.81 ± 2.86	46.71 ± 2.92	32.29 ± 2.71	54.52 ± 3.14
Loving	T-CLT	19.84 ± 2.31	40.84 ± 3.14	39.44 ± 2.96	25.20 ± 2.52	44.85 ± 3.28
	DI-Home	29.90 ± 2.69	52.82 ± 2.86	49.35 ± 2.78	33.38 ± 2.78	59.41 ± 2.79
	DI-Concert	27.20 ± 2.65	45.90 ± 3.15	42.42 ± 3.04	30.33 ± 2.79	49.64 ± 3.24
Nostalgic	T-CLT	15.70 ± 2.11	32.57 ± 2.92	44.85 ± 3.09	20.79 ± 2.40	42.76 ± 3.27
	DI-Home	23.19 ± 2.61	45.13 ± 3.02	50.87 ± 2.92	25.30 ± 2.67	48.37 ± 3.17
	DI-Concert	22.37 ± 2.51	37.33 ± 2.92	42.24 ± 3.12	28.06 ± 2.60	45.72 ± 3.29
Neutral	T-CLT	35.69 ± 2.40	25.72 ± 2.49	29.86 ± 2.70	29.82 ± 2.43	19.42 ± 2.24
	DI-Home	33.05 ± 2.38	22.03 ± 2.32	28.27 ± 2.42	25.99 ± 2.18	22.57± 2.30
	DI-Concert	30.65 ± 2.27	24.75 ± 2.41	27.28 ± 2.38	27.66± 2.37	24.69 ± 2.41
Pleasant/Grateful	T-CLT	29.75 ± 2.46	57.86 ± 2.71	55.99 ± 2.49	34.35 ± 2.69	61.79 ± 2.54
	DI-Home	35.66 ± 2.52	63.44 ± 2.43	57.73 ± 2.44	36.06 ± 2.75	69.83 ± 2.32
	DI-Concert	34.64 ± 2.67	60.52 ± 2.56	51.83 ± 2.68	35.89 ± 2.75	62.78 ± 2.66

Appendix M. Mean emotion category ratings and standard errors (SE) for each sample and when evaluated in each environment (continued).

Emotion Category	Environment	Veggie Balls	Beyond-Meat Balls	Tomato sauce	Veggie Balls + Tomato sauce	Beyond-Meat Balls + Tomato sauce
Satisfied	T-CLT	28.90 ± 2.48	63.57 ± 2.63	58.21 ± 2.65	32.80 ± 2.65	65.30 ± 2.58
	DI-Home	31.86 ± 2.63	63.31 ± 2.68	54.53 ± 2.70	34.91 ± 2.69	68.61 ± 2.65
	DI-Concert	31.74 ± 2.74	60.89 ± 2.50	51.32 ± 2.74	33.06 ± 2.66	61.99 ± 2.91
Suspicious	T-CLT	27.39 ± 2.67	13.25 ± 2.07	12.09 ± 2.01	22.42 ± 2.64	12.37 ± 2.01
	DI-Home	26.45 ± 2.71	10.89 ± 2.21	10.27 ± 2.02	24.39 ± 2.86	9.47 ± 1.75
	DI-Concert	23.79 ± 2.72	11.98 ± 1.82	12.82 ± 2.10	24.81 ± 2.76	11.96 ± 1.93
Uncertain	T-CLT	32.01± 2.57	13.55 ± 1.93	15.38 ± 2.24	26.76± 2.68	12.39 ± 1.90
	DI-Home	28.14 ± 2.81	12.52 ± 2.06	13.23 ± 2.17	28.16 ± 2.89	9.05 ± 1.70
	DI-Concert	27.17 ± 2.79	13.98± 2.02	19.36 ± 2.52	26.10 ± 2.78	16.03 ± 2.29
Unhappy/Sad	T-CLT	25.60 ± 2.76	7.55 ± 1.51	9.54 ± 1.94	20.19 ± 2.53	7.11 ± 1.43
	DI-Home	21.44 ± 2.70	7.62 ± 1.65	8.97 ± 1.71	22.26 ± 2.73	7.80 ± 1.54
	DI-Concert	22.28 ± 2.57	6.77 ±1.40	10.53 ± 1.91	21.97 ± 2.80	7.29 ±1.60

Appendix N. Mean scores (± SE) for each questionnaire item on the engagement and presence questionnaire by environment.

Dimension	Statement/question	T-CLT	DI-Home	DI-Concert
		Mean ± SE	Mean ± SE	Mean ± SE
Usability	The test environment assisted in my evaluations of the samples	$7.4^{a} \pm 2.4$	$21.7^{b} \pm 2.2$	$9.1^{a} \pm 2.8$
Novelty	The test environment made me feel curious	$-2.7^{a} \pm 2.5$	$19.0^{b} \pm 2.2$	$21.7^{b} \pm 2.4$
	The test environment distracted me	$-26.0^{a} \pm 2.5$	$-5.4^{b} \pm 3.0$	$-9.0^{b} \pm 2.9$
Environmental aesthetic	The test environment was appealing	$-2.4^{a} \pm 2.4$	$27.9^{b} \pm 1.8$	$24.6^{b} \pm 2.4$
	The test environment engaged my senses	$-3.8^{a} \pm 2.9$	$25.3^{b} \pm 1.9$	$20.6^{b} \pm 2.4$
Involvement	The test experience was boring*	$16.9^{a} \pm 2.7$	$32.4^{b} \pm 2.0$	$36.7^{b} \pm 1.9$
	The test experience was fun	$10.8^{a} \pm 2.5$	$25.2^{b} \pm 2.1$	$28.0^{b} \pm 2.1$
	I was engaged in the sensory task I performed	$31.1^{a} \pm 1.6$	$27.0^{a} \pm 1.9$	$27.9^{a} \pm 1.9$
Sensory Awareness	How completely were all your senses engaged by the test environment?	$13.5^{a} \pm 2.1$	$21.8^{b} \pm 2.0$	$21.6^{b} \pm 2.1$
	How much did the visual aspects of the test environment involve you?	$-13.3^{a} \pm 3.1$	$24.0^{b} \pm 1.9$	$20.7^{b} \pm 2.3$
	How much did the sound aspects of the test environment involve you?	$-22.9^{a} \pm 2.9$	$25.6^{b} \pm 2.0$	$28.7^{b} \pm 2.0$
Immersion	I felt like I was in a home	$-32.7^{a} \pm 2.1$	$16.6^{b} \pm 2.2$	$-33.9^{a} \pm 2.2$
	I felt like I was at a classical music concert	$-41.5^{a} \pm 1.7$	$-42.4^{a} \pm 1.4$	$24.9^{b} \pm 2.4$
	I lost track of time	$-13.1^{a} \pm 2.9$	$1.0^{b} \pm 2.7$	$13.4^{c} \pm 2.9$
	How disconnected did you feel from the test environment? *	$19.1^{a} \pm 2.6$	$30.3^{b} \pm 2.1$	$25.2^{ab} \pm 2.4$
Realism	How much did your experiences in the test environment seem consistent with your real-world experiences?	$-22.0^{a} \pm 2.6$	$12.0^{b} \pm 2.2$	$0.8^{c} \pm 2.7$
	How completely did you feel immersed in the test environment?	$-1.8^{a} \pm 2.8$	$21.2^{b} \pm 2.0$	$20.0^{b} \pm 2.3$
	How involved were you in the test environment experience?	$2.6^{a} \pm 3.1$	$22.6^{b} \pm 2.0$	$22.6^{b} \pm 2.2$
Distraction	How aware were you of events occurring in the real world around you? *	$10.4^{a} \pm 3.0$	$-3.3^{b} \pm 2.7$	$11.7^{a} \pm 2.7$
	How quickly did you adjust to the test environment experience?	$20.8^{a} \pm 2.1$	$26.9^{b} \pm 1.8$	$24.4^{ab} \pm 1.8$
	How much did the test environment interfere or distract you from performing your sensory evaluation? *	$32.3^{a} \pm 2.3$	$14.4^{b} \pm 2.7$	$16.6^{b} \pm 2.5$

* Reverse-coded item. Due to the negatively worded question format, values are reversed scored. ^{abc} different lowercase letters across rows indicate significant differences between means across environments obtained from post hoc Tukey multiple comparison tests ($p<0.05$).

Appendix O. Consumer cluster mean scores (± SE) for each questionnaire item on the engagement and presence questionnaire by environment.

Statement/question	T-CLT		DI-Home		DI-Concert	
	Cluster One	**Cluster Two**	**Cluster One**	**Cluster Two**	**Cluster One**	**Cluster Two**
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
The test environment assisted in my evaluations of the samples	9.2±3.5	5.1±3.2	29.8±2.5	11.7±3.4	19.9±3.3	-4.1±3.9
The test environment made me feel curious	2.0±3.6	-8.6±3.4	26.5±2.7	9.9±3.2	35.1±2.3	5.2±3.5
The test environment distracted me	-26.0±3.6	-26.1±3.3	11.2±4.3	1.7±3.9	14.7±4.1	2.0±3.9
The test environment was appealing	2.5±3.3	-8.3±3.3	33.6±1.9	20.9±2.9	36.6±2.3	10.0±3.7
The test environment engaged my senses	0.4±4.1	-9.0±4.0	32.6±2.2	16.5±2.7	32.7±2.8	5.7±3.1
The test experience was boring*	21.7±3.5	11.0±3.9	39.8±2.1	23.4±3.1	44.6±1.6	27.0±3.2
The test experience was fun	16.1±3.3	4.4±3.7	32.8±2.5	16.0±3.2	40.5±1.6	12.8±3.2
I was engaged in the sensory task I performed	37.3±1.6	23.6±2.7	35.4±2.5	16.8±2.4	37.4±1.9	16.2±2.7
How completely were all your senses engaged by the test environment?	16.6±3.1	9.7±2.9	29.8±2.5	12.0±2.6	33.6±2.0	6.9±3.0
How much did the visual aspects of the test environment involve you?	-10.1±4.3	-17.2±4.3	32.1±2.3	14.2±2.6	36.7±1.8	1.1±2.7
How much did the sound aspects of the test environment involve you?	-19.1±4.4	-27.7±3.5	31.1±2.3	19.0±3.3	39.8±1.9	15.2±3.0
I felt like I was in a home	-30.8±3.0	-34.9±2.8	25.3±2.4	5.9±3.5	-32.2±3.2	-35.9±3.0
I felt like I was at a classical music concert	-39.7±2.5	-43.7±2.0	-43.5±2.0	-41.0±1.9	35.1±2.4	12.3±3.8
I lost track of time	-11.3±4.3	-15.2±3.8	2.5±3.9	-0.8±3.5	19.8±4.0	5.6±3.8
How disconnected did you feel from the test environment? *	24.3±3.5	12.8±3.7	37.7±2.3	21.3±3.3	34.6±3.0	13.7±3.1
How much did your experiences in the test environment seem consistent with your real-world experiences?	-17.2±3.8	-27.9±3.4	21.4±2.6	0.5±2.9	11.1±3.6	-11.8±3.3
How completely did you feel immersed in the test environment?	4.8±4.0	-9.8±3.6	30.4±2.1	10.0±2.9	33.2±2.0	3.9±3.2

Appendix O. Consumer cluster mean scores (± SE) for each questionnaire item on the engagement and presence questionnaire by environment (continued).

Statement/question	T-CLT		DI-Home		DI-Concert	
	Cluster One	**Cluster Two**	**Cluster One**	**Cluster Two**	**Cluster One**	**Cluster Two**
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
How involved were you in the test environment experience?	12.4±4.1	-9.2±4.3	32.7±2.0	10.3±2.9	36.3±1.7	5.7±2.9
How aware were you of events occurring in the real world around you? *	7.3±4.4	14.3±3.8	-1.1±4.2	-5.8±3.2	13.5±4.0	9.4±3.7
How quickly did you adjust to the test environment experience?	24.5±2.8	16.3±2.9	33.6±2.1	18.7±2.5	31.9±2.3	15.2±2.2
How much did the test environment interfere or distract you from performing your sensory evaluation? *	31.8±3.2	33.0±3.2	18.7±3.8	9.3±3.8	23.4±3.3	8.3±3.5

* Reverse-coded item. Due to the negatively worded question format, values are reversed scored.

Appendix P. F-values and p-values for main effects of session, cluster, environment, product and sauce and all 2-way, 3-way and 4-way interactions derived from linear mixed effect models for each liking modality.

		Session order (DF=1)	Cluster (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Cluster* Product (DF=1)	Cluster* Sauce (DF=1)	Product* Sauce (DF=1)	Cluster* Environment (DF=2)	Product* Environment (DF=2)	Sauce* Environment (DF=2)	Cluster* Product* Sauce (DF=1)	Cluster* Product* Environment (DF=2)	Cluster* Sauce* Environment (DF=2)	Product* Sauce* Environment (DF=2)	Cluster* Product* Sauce* Environment (DF=2)
Overall liking	F	0.494	15.57	784.364	18.323	1.97	10.229	0.765	0.285	1.131	2.023	0.614	0.018	0.056	1.103	0.062	0.729
	p	0.484	<0.001***	<0.001***	<0.001***	0.14	0.001**	0.382	0.594	0.323	0.133	0.541	0.835	0.946	0.332	0.94	0.482
Appearance liking	F	0.497	19.899	106.887	133.664	9.251	0.46	14.869	33.567	2.358	4.482	5.25	0.549	0.061	0.357	0.353	0.268
	p	0.482	<0.001***	<0.001***	<0.001***	33.567	0.497	<0.001***	<0.001***	0.095	0.011*	0.005**	0.459	0.941	0.7	0.703	0.765
Flavour liking	F	0.718	13.842	657.061	24.262	0.932	5.642	2.868	2.967	0.846	2.155	0.395	0.349	0.936	0.534	0.04	0.355
	p	0.398	<0.001***	<0.001***	<0.001***	0.394	0.018*	0.091	0.085	0.429	0.116	0.674	0.555	0.393	0.586	0.961	0.701
Texture liking	F	0.328	12.387	795.795	13.971	3.625	12.345	0.61	0.027*	0.225	3.243	0.043	0.401	0.903	0.465	0.143	0.485
	p	0.568	<0.001***	<0.001***	<0.001***	0.027*	<0.001***	0.435	0.469	0.799	0.0394*	0.958	0.526	0.406	0.628	0.867	0.616
Expected liking	F	1.182	29.425	97.506	148.625	5.563	2.621	7.956	40.605	2.748	3.122	3.94	2.182	0.048	0.373	0.357	0.751
	p	0.278	<0.001***	<0.001***	<0.001***	0.004**	0.106	0.005**	<0.001***	0.064	0.044*	0.020*	0.14	0.953	0.689	0.723	0.472

Appendix Q. F-values and p-values for main effects of session, cluster, environment, product and sauce and all 2-way, 3-way and 4-way interactions derived from linear mixed effect models for each emotion category.

Emotion		Session order (DF=1)	Cluster (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Cluster *Product (DF=1)	Cluster *Sauce (DF=1)	Product *Sauce (DF=1)	Cluster *Environment (DF=2)	Product *Environment (DF=2)	Sauce* Environment (DF=2)	Cluster *Product*Sauce (DF=1)	Cluster *Product *Environment (DF=2)	Cluster *Sauce *Environment (DF=2)	Product *Sauce *Environment (DF=2)	Cluster *Product *Sauce *Environment (DF=2)
Adventurous	F	3.871	2.51	170.938	4.891	3.112	19.116	3.534	0.664	6.845	1.851	3.071	2.811	0.475	1.045	0.238	0.207
	p	0.0517.	0.116	<0.001 ***	0.0272 *	0.04499*	<0.001 ***	0.060	0.415	0.001**	0.158	0.047*	0.093	0.622	0.352	0.789	0.813
Afraid	F	1.158	6.086	39.011	0.086	0.605	0.008	1.290	0.049	0.028	1.953	2.971	0.011	0.186	1.107	0.393	1.256
	p	0.284	0.015*	<0.001 ***	0.77	0.546	0.928	0.256	0.825	0.972	0.142	0.052	0.917	0.830	0.331	0.675	0.285
Amazed	F	1.49	0.088	359.335	10.325	0.793	27.765	6.158	0.007	1.222	1.947	0.352	0.156	0.205	0.095	0.739	0.040
	p	0.225	0.005**	<0.001 ***	0.001**	0.453	<0.001 ***	0.013*	0.934	0.295	0.143	0.704	0.693	0.815	0.909	0.478	0.961
Angry	F	0.288	8.037	87.432	0.684	0.493	3.063	1.358	0.532	0.028	1.695	0.496	0.001	0.745	1.070	0.09	0.201
	p	0.592	0.005**	<0.001 ***	0.409	0.612	0.080	0.244	0.466	0.972	0.184	0.609	0.972	0.475	0.343	0.914	0.818
Anxious	F	1.11	3.570	65.176	3.874	4.004	0.098	0.006	0.001	0.265	1.146	1.719	0.494	1.120	0.571	0.152	0.166
	p	0.294	0.061	<0.001 ***	0.049*	0.018*	0.754	0.936	0.98	0.767	0.318	0.18	0.482	0.326	0.565	0.859	0.847
Bored	F	0.28	6.035	241.004	0.018	0.166	1.873	0.008	0.318	0.930	0.985	5.018	0.570	1.132	0.212	2.869	0.620
	p	0.598	0.016*	<0.001 ***	0.895	0.847	0.171	0.930	0.573	0.395	0.374	0.007**	0.450	0.322	0.809	0.057	0.538
Calm	F	0.236	4.85	137.494	0.011	31.132	13.526	0.054	0.872	6.568	0.225	0.23	0.491	0.144	0.142	0.19	0.347
	p	0.628	0.030*	<0.001 ***	0.916	<0.001 ***	<0.001 ***	0.816	0.351	0.001**	0.798	0.795	0.484	0.866	0.868	0.827	0.707
Curious	F	0.568	8.583	132.411	0.38	6.46	10.418	1.733	0.036	6.458	0.881	2.203	1.544	0.098	0.075	0.67	0.333
	p	0.453	0.004**	<0.001 ***	0.538	0.002**	0.001**	0.188	0.849	0.002**	0.415	0.041*	0.214	0.907	0.928	0.512	0.717

Appendix Q. F-values and p-values for main effects of session, cluster, environment, product and sauce and all 2-way, 3-way and 4-way interactions derived from linear mixed effect models for each emotion category (continued).

Emotion		Session order (DF=1)	Cluster (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Cluster *Product (DF=1)	Cluster *Sauce (DF=1)	Product *Sauce (DF=1)	Cluster *Environment (DF=2)	Product *Environment (DF=2)	Sauce* Environment (DF=2)	Cluster *Product*Sauce (DF=1)	Cluster *Product *Environment (DF=2)	Cluster *Sauce *Environment (DF=2)	Product *Sauce *Environment (DF=2)	Cluster *Product *Sauce *Environment (DF=2)
Deceived	F	0.579	4.511	210.773	1.291	0.33	3.894	0.028	0.362	0.295	0.268	0.555	0.010	1.282	0.028	0.11	0.168
	p	0.448	0.036*	<0.001***	0.256	0.719	0.049*	0.867	0.548	0.744	0.765	0.574	0.920	0.278	0.972	0.896	0.845
Disappointed	F	0.451	3.000	410.24	0.132	0.691	2.024	0.116	0.205	0.144	3.183	0.699	0.615	0.996	1.244	0.308	0.465
	p	0.503	0.086	<0.001***	0.717	0.501	0.155	0.734	0.65	0.866	0.042*	0.497	0.433	0.369	0.289	0.735	0.628
Disgusted	F	0.021	8.026	186.524	0.013	0.001	0.238	0.057	0.412	0.489	0.187	2.603	0.383	0.751	0.174	0.014	0.002
	p	0.884	0.005**	<0.001***	0.91	0.999	0.625	0.811	0.521	0.613	0.83	0.074	0.536	0.472	0.841	0.986	0.997
Dissatisfied	F	0.239	4.488	391.806	2.118	0.895	3.141	1.248	0.506	0.074	2.078	1.963	0.309	0.061	0.588	0.02	0.721
	p	0.626	0.036*	<0.001***	0.146	0.409	0.077	0.264	0.477	0.928	0.126	0.141	0.578	0.941	0.555	0.981	0.486
Energetic	F	1.452	3.363	338.022	12.2	8.245	29.028	1.123	0.061	1.288	1.509	1.11	0.852	0.019	0.172	0.37	0.189
	p	0.231	0.069	<0.001***	<0.001***	<0.001***	<0.001***	0.289	0.805	0.276	0.222	0.33	0.356	0.981	0.841	0.691	0.828
Happy	F	0.781	8.909	474.407	4.938	8.754	30.913	1.220	0.235	1.761	2.526	0.377	0.717	0.270	0.851	0.009	0.029
	p	0.379	0.003**	<0.001***	0.0264*	<0.001***	<0.001***	0.270	0.628	0.172	0.08	0.686	0.397	0.763	0.427	0.991	0.971
Hopeful	F	0.335	10.296	281.426	5.066	6.44	37.948	1.415	0.155	0.520	0.15	1.331	0.364	0.106	0.067	0.052	0.053
	p	0.564	0.002**	<0.001***	0.024583*	0.0016*	<0.001***	0.234	0.694	0.595	0.861	0.265	0.546	0.899	0.935	0.95	0.948

Appendix Q. F-values and p-values for main effects of session, cluster, environment, product and sauce and all 2-way, 3-way and 4-way interactions derived from linear mixed effect models for each emotion category (continued).

Emotion		Session order (DF=1)	Cluster (DF=1)	Product (DF=1)	Sauce (DF=1)	Environment (DF=2)	Cluster *Product (DF=1)	Cluster *Sauce (DF=1)	Product *Sauce (DF=1)	Cluster *Environment (DF=2)	Product *Environment (DF=2)	Sauce* Environment (DF=2)	Cluster *Product*Sauce (DF=1)	Cluster *Product *Environment (DF=2)	Cluster *Sauce *Environment (DF=2)	Product *Sauce *Environment (DF=2)	Cluster *Product *Sauce *Environment (DF=2)
Hungry	F	0.172	11.792	344.018	8.263	10.865	31.304	1.862	0.934	0.873	3.41	1.082	0.000	1.154	0.211	0.81	0.159
	p	0.679	<0.001***	<0.001**	0.00411*	<0.001**	<0.001**	0.173	0.334	0.418	0.033*	0.339	0.996	0.316	0.809	0.445	0.853
Loving	F	1.432	3.901	270.481	15.365	35.045	23.670	0.840	0.0001	1.971	0.149	0.467	0.141	0.031	0.075	0.175	0.064
	p	0.234	0.051	<0.001**	<0.001**	<0.001**	<0.001***	0.359	0.992	0.140	0.862	0.627	0.708	0.969	0.928	0.839	0.938
Neutral	F	0.035	5.754	35.154	7.515	0.137	11.509	0.059	2.36	1.379	2.421	1.628	0.370	0.128	2.776	1.123	0.059
	p	0.851	0.018*	<0.001**	0.006**	0.872	<0.001***	0.808	0.125	0.252	0.089	0.197	0.540	0.879	0.063	0.326	0.943
Nostalgic	F	0.016	8.577	178.175	20.627	17.725	34.093	8.863	0.436	1.604	0.637	1.251	0.132	0.609	0.429	0.782	1.039
	p	0.899	0.004**	<0.001**	<0.001**	<0.001**	<0.001**	0.003**	0.509	0.202	0.529	0.287	0.716	0.544	0.651	0.458	0.354
Pleasant/ Grateful	F	2.357	8.535	465.35	7.694	7.526	20.690	0.204	0.255	0.297	0.268	0.482	1.359	0.409	0.547	0.209	0.241
	p	0.128	0.004**	<0.001**	0.006**	<0.001**	<0.001**	0.651	0.613	0.743	0.765	0.618	0.244	0.665	0.579	0.812	0.786
Satisfied	F	0.549	10.661	521.563	2.965	3.951	31.196	0.905	0.141	0.831	2.566	0.2	0.373	0.217	0.784	0.049	0.059
	p	0.46	0.001**	<0.001**	0.085	0.195*	<0.001**	0.342	0.708	0.436	0.077	0.819	0.541	0.805	0.567	0.952	0.943
Suspicious	F	0.005	2.716	121.671	0.089	0.504	7.685	0.119	0.439	0.104	0.142	1.321	0.943	1.059	0.930	0.449	0.578
	p	0.944	0.102	<0.001**	0.766	0.605	0.006*	0.730	0.508	0.901	0.868	0.267	0.331	0.347	0.395	0.639	0.561
Uncertain	F	1.524	2.422	156.568	0.402	1.92	11.025	0.232	0.754	1.722	1.658	1.264	0.308	0.755	1.650	0.524	1.472
	p	0.22	0.123	<0.001**	0.526	0.147	<0.001**	0.630	0.385	0.179	0.191	0.283	0.579	0.470	0.192	0.592	0.230
Unhappy/ Sad	F	0.06	4.946	188.083	0.033	0.1	0.981	0.578	0.576	2.045	1.669	2.268	0.862	1.126	1.798	0.789	0.569
	p	0.806	0.028*	<0.001**	0.857	0.905	0.322	0.447	0.448	0.130	0.189	0.104	0.353	0.325	0.166	0.455	0.566

p-values presented as *** ($p < 0.001$),** ($p < 0.01$), * ($p < 0.05$)