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# Context matters: How congruency of digital immersive environment and meal context affect consumer evaluations of plant-based products at two different levels of liking

Rebekah Orr [a], Caroline Giezenaar [a], A. Jonathan. R. Godfrey [b], Simone Poggesi [a], Joanne Hort [a,c,*]

[a] Food Experience and Sensory Testing (Feast) Lab, Massey University, Palmerston North 4410, New Zealand
[b] Statistics Group, School of Mathematical and Computational Sciences, Massey University, Palmerston North, New Zealand
[c] Riddet Institute, Massey University, Palmerston North 4410, New Zealand

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ABSTRACT

Context can impact liking and emotional response, meaning traditional consumer testing methods lacking contextual cues may fail to reflect real-life assessments. As research on consumer acceptance of plant-based meat alternatives becomes increasingly popular, it is essential not to overlook the influence of context on acceptance.

Using a within-subject design with 109 consumers, this study aimed to investigate whether affective response (liking and emotional response) to one liked and one disliked plant-based meatball alternative differed between i) a central location test (CLT) and two digitally recreated environments: one congruent (a home), one incongruent (classical music concert), and ii) products tasted alone and combined with tomato sauce.

For both products adding sauce significantly increased liking (overall, appearance, flavour, and texture) ($p < 0.001$) and ratings for several positive emotions ($p < 0.05$). Notably, for the less-liked product, sauce addition had more impact on expected liking ($t = 6.28$, $p < 0.001$), appearance ($t = 5.61$, $p < 0.001$) and flavour ($t = 2.28$, $p = 0.023$) liking compared to the more-liked product. Comparing environments, only the disliked product had higher ratings for expected, appearance, and texture liking in the home compared to the concert and CLT (all $p < 0.05$). Regardless of the product, ratings for several positive emotions were higher ($p < 0.05$) in the congruent home than in the other environments. These results emphasise the need for product evaluations in contexts with greater ecological validity and indicate heightened sensitivity of a disliked meat alternative to contextual influences.

## 1. Introduction

As the global population is projected to approach 10 billion by 2050 (United Nations, 2017), demand for protein is expected to rise substantially. Meeting this demand is complicated by environmental challenges such as climate change, biodiversity loss, and resource use (Willett & Rockström, 2019). Food production is the primary driver of these environmental pressures, with animal-based proteins having a far greater impact than plant-based sources (Aiking, 2011). High consumption of red and processed meat is also linked to elevated risks of type 2 diabetes, cancer, and cardiovascular disease (Ekmekcioglu et al., 2018). Consequently, the EAT-Lancet Commission has recommended a shift towards predominantly plant-based diets with minimal animal-sourced foods (Willett & Rockström, 2019).

Plant-based meat alternatives (PBMAs) aim to support consumers in this dietary transition without having to drastically change the way they eat. PBMAs can be classified as 'meat analogues,' highly processed products designed to mimic meat using ingredients such as pea, soy, or wheat; or less processed 'wholefood' products made from vegetables, grains, and legumes that are not designed to mimic meat (Tso et al.,

*Abbreviations:* **CLT**, Central location Test; DI-Home, Digital Immersive Home; DI-Concert, Digital Immersive Concert; Digital-IE, Digital Immersive Environment; PBMAs, Plant-based meat alternatives; MBAs, Plant-based meatball alternatives.

* Corresponding author at: Prof Joanne Hort. Food Experience and Sensory Testing (Feast) Lab, School of Food and Natural Sciences (SF&NS) PN 452, Massey University, Private Bag 11222, Palmerston North, 4410, New Zealand.
*E-mail address:* j.hort@massey.ac.nz (J. Hort).

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2020).

However, PBMAs' ability to reduce traditional animal protein consumption remains uncertain. The US PBMA market saw rapid growth from 2019 to 2021, but sales slowed in 2022 and declined in 2023 (Mridul, 2023; Pierce et al., 2023). Similar challenges have been observed in New Zealand, where start-up businesses have had to close as operations become financially unviable (Gibbens, 2024; Morrison, 2023). Several factors contribute to the acceptance of PBMAs (Giacalone et al., 2022; Onwezen et al., 2021; Szenderák et al., 2022), but sensory appeal is consistently cited as a major barrier to acceptance (Elzerman et al., 2015; Hartmann & Siegrist, 2017; Hoek et al., 2011; Michel et al., 2021). For PBMAs, when tasted in isolation, liking is closely correlated with perceived similarity to meat, with meat flavour identified as the primary driver of liking. In contrast, wholefood products that are not meat-like are generally disliked and require substantial product development to achieve consumer acceptance (Giezenaar et al., 2024; Orr, 2024).

However, sensory evaluation conducted under traditional consumer testing conditions may not accurately reflect real-world consumer experiences. Contextual factors can strongly influence both liking and emotional responses to food (Cardello & Meiselman, 2018) and incorporating realistic contexts into consumer testing can enhance ecological validity (Schöniger, 2022). Understanding how contextual factors influence PBMA acceptance is therefore critical to improving sensory appeal and consumer satisfaction in real-life settings.

Previous research suggests that specific contexts are considered more appropriate for PBMA consumption than others. PBMAs are considered most appropriate in casual settings, such as eating alone, with family or friends (Michel et al., 2021; Motoki et al., 2021), at home, in cafés, or at food festivals (Motoki et al., 2021). In contrast, family Sunday meals, business lunches, barbecues (Michel et al., 2021), and pubs or bars (Motoki et al., 2021) are considered less appropriate. Motoki et al. (2021) reported restaurants as appropriate, whereas Michel et al. (2021) found the opposite. Less appropriate contexts are often formal dining situations where high-quality meat-based meals, such as roasts, are preferred (Michel et al., 2021), or settings where individuals may wish to avoid drawing attention to their food choices due to concerns about judgment, such as at bars (e.g., vegetarianism is sometimes perceived as less masculine; Kemper et al., 2023). Additionally, not all meat substitutes are equally appropriate for different situations (Elzerman et al., 2021; Elzerman et al., 2022). Elzerman et al. (2022) found that vegetarian stir-fry pieces and vegetarian mince were considered appropriate across a range of contexts, including "eating with family/household" and "cooking a healthy meal," whereas vegetarian steak was deemed appropriate by the fewest participants across all situations, except for "when cooking a special meal." These studies have identified hypothetically appropriate situations for PBMA consumption using online surveys. Limited research has examined how consuming PBMAs in appropriate versus inappropriate situations influences consumer acceptance and emotional response. However, Zandstra et al. (2025) investigated the effect of information and multisensory contexts on meat-related food choices and taste perception. They found that sustainability information combined with a multisensory sustainable context increased selection of plant-based hotdogs, while a meat-inspired multisensory context enhanced their perceived taste, highlighting the important role of information and multisensory cues in food choice and taste experience.

Emerging digital technologies such as virtual reality (VR), augmented reality (AR), and immersive rooms offer new opportunities to conduct sensory and consumer research in more realistic environments whilst still maintaining experimental control (Bangcuyo et al., 2015; Galiñanes Plaza et al., 2019; Giezenaar & Hort, 2021). Gonzalez-Estanol et al. (2023) is the only identified study to have previously incorporated a digital environment in consumer testing of PBMAs. Gonzalez-Estanol et al. (2023) used a digitally recreated casual restaurant setting, complete with room décor and burger boxes, to replicate a typical consumption environment for burgers. This study utilised the restaurant setting but did not include a control setting, thus the impact of the digital restaurant on consumer response remained unknown.

Meal context (the dish in which the PBMAs is prepared), also plays an important role in shaping PMBA acceptance. PBMAs are generally rated more favourably when incorporated into meals than when tasted alone (Elzerman et al., 2011), although preferences vary across dishes. For instance, a soy-based PBMA was preferred in lasagna over white sauce or chop suey (Cordelle et al., 2022). Gonzalez-Estanol et al. (2023) found that adding a bun and sauce to soy and hemp-based patties reduced off-flavour and texture defects but did not improve overall liking, possibly because patties constitute a larger proportion of a dish, making them harder to mask than mince. Preparation methods can also narrow the liking gap with meat, for example, Niimi et al. (2022) found overall liking and texture liking did not significantly differ between PBMA and beef mince prepared in a Bolognaise sauce. These studies have demonstrated that meal context can impact liking of PBMAs but the impact on emotional responses remains largely unexplored. The objectives of the current study presented were to:

1. Determine the effect of evaluation setting appropriateness on consumer response to plant-based meatball alternatives (MBAs)
2. Determine the effect of additional meal context (sauce) on liking and emotional response to MBAs
3. Assess whether evaluation setting and meal context effects were dependent on product liking level

## 2. Materials and methods

This research was considered and assessed as low risk according to the Massey University Human Ethics Committee process (human ethics notification number: 4000027702).

### 2.1. Participants

Participants ($n = 109$) were recruited from the Food Experience and Sensory Testing (Feast) Laboratory consumer database, and flyer distribution around the Manawatu Campus of Massey University, New Zealand. The research was advertised as a 'Plant-Based Meatball Consumer Study', and participants were informed, both in the information sheet and during an introductory presentation prior to the first session, that they would be tasting plant-based samples. Participants were aged between 25 and 55 years to align with a wider research project investigating differences between Millennials (aged 25–40 years) and Generation X (aged 41–55 years) consumers. However, evaluating generation group differences were beyond the scope of the study reported here. Other inclusion criteria required participants to be: (1) familiar with the dish spaghetti and meatballs (2) able to communicate effectively in English, (3) not be allergic or intolerant to the sample ingredients, (4) not be pregnant nor lactating, (5) be willing to try plant-based meat alternatives and (6) agree that the selected environments were (in)appropriate for consuming plant-based meat alternatives. Eligibility was assessed through a self-reported recruitment screening questionnaire. Participants gave written informed consent at the commencement of the study and were compensated with a shopping voucher for their time.

### 2.2. Sample preparation and presentation

To imitate meatballs in tomato sauce (i.e. as per spaghetti and meatballs), two plant-based-meatball alternative samples (hereafter referred to as MBAs) and one tomato-based pasta sauce were selected for this study (Table 1). The MBAs were selected to represent the two extremes of liking in the New Zealand PBMA market based on a previous study (Orr, 2024). The Beyond-Meat Balls were chosen as one of the most liked PBMAs when evaluated as a burger patty (Mean ± SE: 6.4 ±

**Table 1**
Names, ingredients, and images of samples evaluated for appropriateness and affective response.

| Sample Name | Ingredients | Sample Image |
|---|---|---|
| Veggie 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. |  |
| Beyond-Meat Balls | 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). |  |
| Sauce | Tomato Puree (88 %) (Water, Tomato Paste), Onions, Sugar, Sunflower Oil, Salt, Herbs & Spices, Food Acid (Citric). |  |
| Veggie Balls + Sauce | |  |
| Beyond-Meat Balls + Sauce | |  |

0.2 on a 9-pt hedonic scale), second only to the Impossible Burger, which could not be used due to supply issues. The Veggie Balls were selected as the least-liked product (Mean ± SE: 4.1 ± 0.2 on 9-pt hedonic scale) when evaluated as a burger patty in the previous study. The two products also differed in their perceived meat-likeness, with the Beyond Meat balls rated as *somewhat meat-like* (Median = 3 on a 5-point Likert scale) and the Veggie Balls rated as *not at all meat-like* (Median = 1 on a 5-point Likert scale). The tomato pasta sauce was selected based on bulk availability and it being a well-known quality brand. MBAs were evaluated alone and in combination with the sauce. It is acknowledged that the combination of MBAs and sauce does not fully reflect an entire meal where other components such as pasta would usually be present, but addition of pasta increased logistical challenges.

Beyond-meatballs were prepared by dividing Beyond Burger® patties into 16.1 ± 0.2 g portions, shaping them into balls, and freezing them until cooking. Veggie balls were used in their commercially available form without any additional manipulation and were kept frozen until cooking.

Before each evaluation session, three disposable foil dishes (Castaway, New Zealand) were each filled with 200 g of tomato sauce, covered with aluminium foil, and heated in an oven (Fisher and Paykel, New Zealand) at 180 °C, fan force for 15-min. The MBAs were separately pan-fried on an induction cooktop (CI604CTB1, Fisher and Paykel, New Zealand) in two tablespoons (approximately 30 g) of canola oil (Harvest NZ, New Zealand) per 24 meatballs. The MBAs were cooked from frozen until an internal temperature of 75 °C was reached (approximately 10-min). After the trays of tomato sauce were heated for 15-min in the oven, half of the cooked MBAs were combined with the sauce and heated in the oven for a further 15-min (one tray for just the sauce, one tray for Veggie Balls, one tray for the Beyond-Meat Balls). The remaining MBAs 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 until served. The same procedure was followed for the MBAs that had been combined with the sauce, and the sauce on its own, once they had been in the oven for 15-min. Samples (Table 1) were kept in the food warmer for no longer than one-hour. All samples were served in 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.

### 2.3. Test environments

Three test environments were used; A traditional central location test (T-CLT), a digitally created home and a digitally created classical music concert. The selection of digital environments was informed by a preliminary online survey ($n$ = 183) whereby participants were presented with four likely (Home, Restaurant, Pub, Café/Canteen) and four unlikely environments (Beach, Car, Music Concert, Park) for consuming spaghetti and MBAs. They were asked to indicate which environments they were likely and unlikely to choose for eating spaghetti and plant-based meatballs. If more than one option was chosen, they were asked to rank the environments to identify the most likely and more unlikely environments. Based on the responses to this survey, a home environment was selected as an appropriate environment, and a classical music concert was selected as an inappropriate environment.

All three environments were set-up in the "Immersive Space" in the Feast laboratory at Massey University (Fig. 1A-C).

For the T-CLT (Fig. 1A), no contextual information was given. Tables were arranged to accommodate 12 participants, all facing the same blank wall. Each participant received a white tray, water glass, napkin, plastic spork (spoon-fork), and a dish of water crackers.

To create the digital immersive home (DI-Home) (Fig. 1B), 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 obtained from the New Zealand Herald YouTube channel https://www.youtube.com/@nzheraldtv. The intention of having the TV playing was to replicate watching/hearing the evening news and to 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 to *"imagine you are eating dinner at home, [rate how much…]"*.

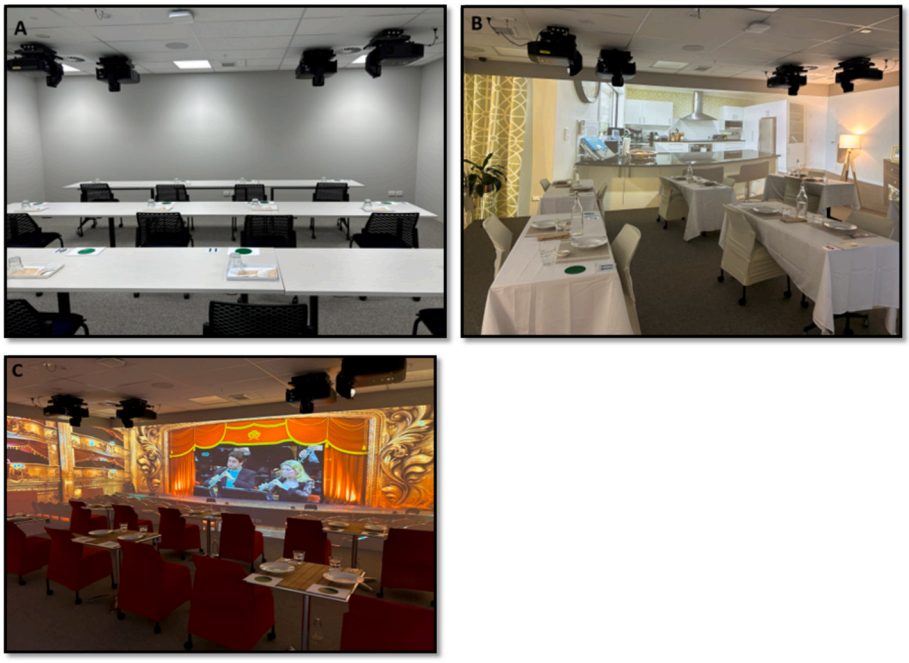


**Fig. 1.** Test Environments: A. Traditional-CLT set-up (no immersion); B. Digital immersive home environment set-up; C. Digital immersive classical music concert set-up.

To create the digital immersive classical music concert (DI-Concert) (Fig. 1C), 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. 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 like consumers were sitting in the audience of the concert. 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 to *"Imagine you are at a classical music concert, [rate how much…]"*. For the immersive environments, the lights were dimmed to optimise the projected images, Dim lighting was also necessary for setting the atmosphere in the DI-Concert setting.

### 2.4. Data collection procedure

Samples were assessed in each eating environment over three separate visits, with one week between visits (Fig. 2). Each visit lasted approximately 30-min. 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

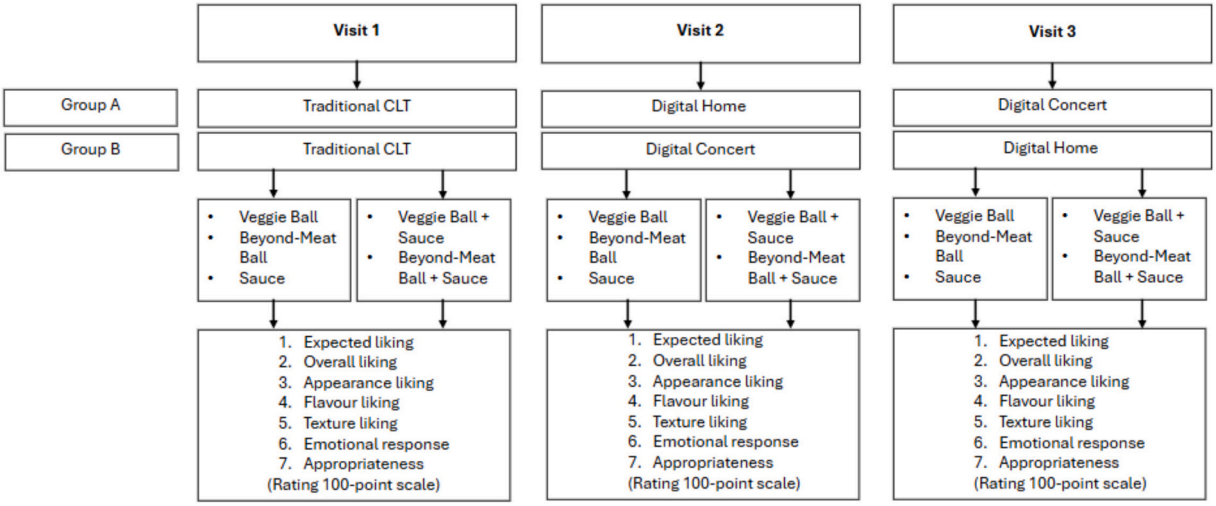


**Fig. 2.** Flow diagram showing the organisation of study sessions, including environments evaluated, products assessed, and responses measured.

exposure to the digital-IEs (DI-Home and DI-Concert) was balanced across participants during their second and third visits.

Within each session, participants evaluated five samples: (1) Veggie Ball without sauce, (2) Veggie Ball with sauce, (3) Beyond-Meat Ball without sauce, (4) Beyond-Meat Ball with sauce, and (5) Sauce on its own. For each sample, participants rated expected overall liking, overall liking, appearance liking, flavour liking, texture liking, emotional response, and the appropriateness of the eating environment. To assess the effect on liking and emotional response of sauce addition, within a session, 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.

Data was collected using Compusense Cloud® Software (Compusense Inc., Ontario, Canada) via iPads. At the start of each session, 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). For example, for appearance liking participants were instructed *"Looking at the sample, rate how much you like the APPEARANCE, by placing the marker anywhere along the scale below:"*. Participants then assessed their emotional response to the sample on continuous line scales (0–100), labelled '*not at all*'*(0)*, '*moderately*' (50) and '*extremely*'(100). An emotion lexicon containing 24 terms specifically for use with PBMAs was employed (Orr et al., 2023). When assessing 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"*. Emotion presentation order was balanced between participants, however, the order was fixed for all samples across the two sessions for each participant as recommended by Meyners and Castura (2016).

To confirm the selected environments were perceived as appropriate or inappropriate, participants rated 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 *"…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?"*

### 2.5. Data analysis

Statistical analyses were performed in R version 4.1.3 (R Core Team, 2022) using 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.

Situational appropriateness, liking and emotional response ratings were all processed and analysed 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 and/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, 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 magnitude of liking change on sauce addition, product liking ratings when tasted alone were subtracted from those when tasted with sauce. A two-sample paired *t*-test was performed on the difference values to determine if modifications to liking with and without sauce differed between the two products.

## 3. Results

### 3.1. Consumer demographics

The study was completed by 109 consumers (82 female, 27 male) aged between 25 and 55 years old (mean = 38.6 ± 7.9 years old). Consumers self-reported a range of dietary behaviours (60 omnivores, 33 flexitarians, 10 vegetarians, 2 pescatarians, 1 vegan, and 3 other diets). The order in which consumers assessed the samples in the digital environments was nearly balanced. A total of 55 consumers evaluated samples in the DI-home environment during their second visit, whilst 54 consumers evaluated samples in the DI-concert environment during their second visit, with the opposite occurring in the third visit.

### 3.2. Situational appropriateness

A significant *environment* effect ($p < 0.001$) was found for situational appropriateness ratings. *"For dinner at home"* was rated most appropriate for sample consumption (mean = 76.5*)* compared to "*at a classical music concert"* (mean = 34.4, $p < 0.001$) and *'In a product test environment"* (mean = 49.7, $p < 0.001$), confirming participants considered the selected environments (in)appropriate as expected.

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 ($p < 0.001$, Table 2). Differences in product appropriateness in the other two environments between products were not observed (Home $p = 0.469$, Concert $p = 0.754$). The *sauce* effect ($p = 0.359$), and *sauce***environment* ($p = 0.307$) and *sauce***product* ($p = 0.916$) interactions on situational appropriateness ratings were not significant.

### 3.3. Product liking

Expected, appearance, flavour, texture and overall liking and their combination with sauce, pooled, and in each environment are summarised in **Supplementary Material** Table 1**.** *P*-values for main and interaction effects derived from linear mixed effect models for each liking modality are presented in Table 3.

**Table 2**
Mean (± SE) perceived situational appropriateness ratings by product (averaged across sauce) by environment.ABC, ab

| | T-CLT | DI-home | DI-concert |
|---|---|---|---|
| | Mean (SE) | Mean (SE) | Mean (SE) |
| Veggie Ball | 44.54(1.98)$^{Aa}$ | 78.35(1.61)$^{Ba}$ | 34.05(2.09)$^{Ca}$ |
| Beyond Meatball | 54.88(2.10)$^{Ab}$ | 75.11(2.01)$^{Ba}$ | 33.80(2.19)$^{Ca}$ |

$^{ABC}$ Different uppercase letters indicate significant differences between mean ratings for a product between environments.

$^{ab}$ Different lowercase letters indicate significant differences between mean ratings of products within an environment.

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

| Liking Modality | | 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) |
|---|---|---|---|---|---|---|---|---|
| Overall liking | F | 784.364 | 18.323 | 1.970 | 0.285 | 2.023 | 0.614 | 0.062 |
| | p | <0.001*** | <0.001*** | 0.140 | 0.594 | 0.133 | 0.541 | 0.940 |
| Appearance liking | F | 106.887 | 133.664 | 9.251 | 33.567 | 4.482 | 5.250 | 0.353 |
| | p | <0.001*** | <0.001*** | <0.001*** | <0.001*** | 0.011* | 0.005** | 0.703 |
| Flavour liking | F | 657.061 | 24.262 | 0.932 | 2.967 | 2.155 | 0.395 | 0.040 |
| | p | <0.001*** | <0.001*** | 0.394 | 0.085 | 0.116 | 0.674 | 0.961 |
| Texture liking | F | 795.795 | 13.971 | 3.625 | 0.524 | 3.243 | 0.043 | 0.143 |
| | p | <0.001*** | <0.001*** | 0.027* | 0.469 | 0.0394* | 0.958 | 0.867 |
| Expected liking | F | 97.506 | 148.625 | 5.563 | 40.605 | 3.122 | 3.940 | 0.357 |
| | p | <0.001*** | <0.001*** | 0.004** | <0.001*** | 0.044* | 0.020* | 0.700 |

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

### 3.3.1. *Influence of product on liking*

A significant product effect was found for all liking modalities (all $p < 0.001$, Table 3), indicating significant differences in liking ratings between the Veggie and Beyond-Meat Balls when averaged across sauce (absent/present) and environment. The Beyond-Meat Balls were rated significantly higher across all liking measures (all $p < 0.001$).

### 3.3.2. *Influence of sauce addition on product liking*

When tasted on its own, tomato sauce was well-liked with a pooled (across eating environments) mean overall liking of 73.81 ± 1.90. A significant *sauce* effect was found for all liking modalities (all $p < 0.001$) indicating liking differences between sauce absent and present when averaged across products and environments. For all liking modalities ratings were significantly higher when sauce was present (all $p < 0.001$).

A significant *product*sauce* interaction was observed for expected liking ($p < 0.001$) **(**Fig. 3A**)** and appearance liking ($p < 0.001$) **(**Fig. 3B**)** indicating a product dependent sauce effect. Sauce addition caused a greater increase in appearance ($t = 5.61$, $p < 0.001$) 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 ($p = 0.085$) **(**Fig. 3C**)**; 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.

### 3.3.3. *Influence of environment on product liking*

A significant *environment* effect existed for appearance ($p < 0.001$), expected ($p = 0.004$) and texture liking ($p = 0.027$), indicating these average liking ratings differed according to the environment. 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 ($p = 0.020$).

However, a significant *product*environment* interaction existed for appearance ($p = 0.011$), expected ($p = 0.044$), and texture ($p = 0.039$) liking indicating the environment effect was product dependent (Fig. 4 **A-C)**. Post hoc tests revealed 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 $p \leq 0.001$; expected liking $p = 0.012$; texture liking $p = 0.023$) and T-CLT (appearance liking $p \leq 0.001$; expected liking $p = 0.002$; texture liking $p = 0.005$). Appearance liking for 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 ($p > 0.05$).

A significant *sauce*environment* interaction was found for appearance ($p = 0.005$) and expected ($p = 0.020$) liking (Fig. 5 **A-B)**. 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 $p \leq 0.001$; 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 not

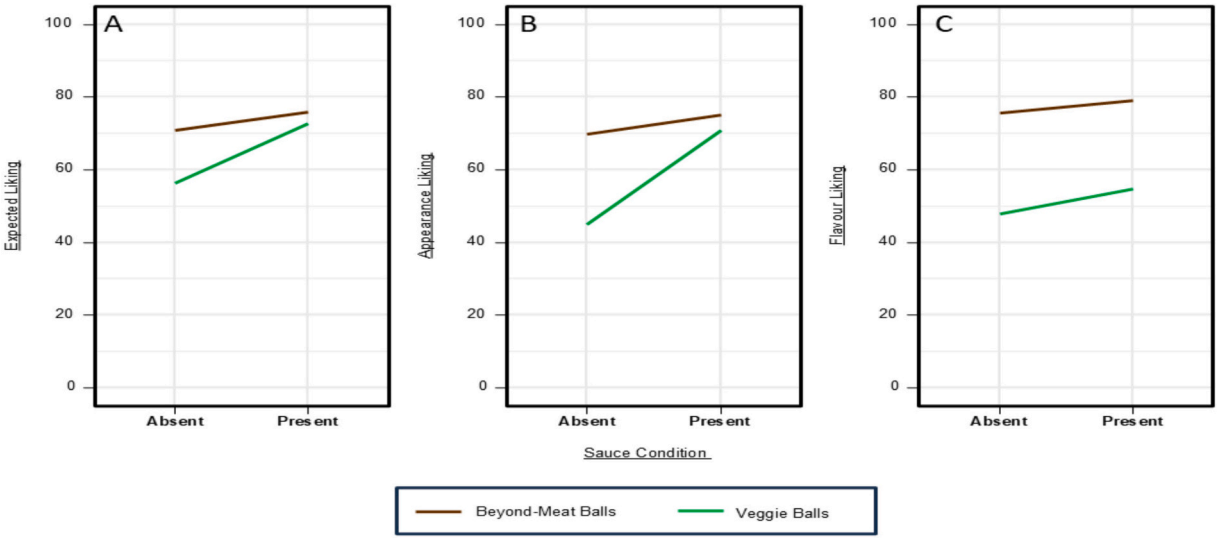


**Fig. 3.** Interaction effects of product and sauce on expected (A), appearance (B) and flavour liking (C).

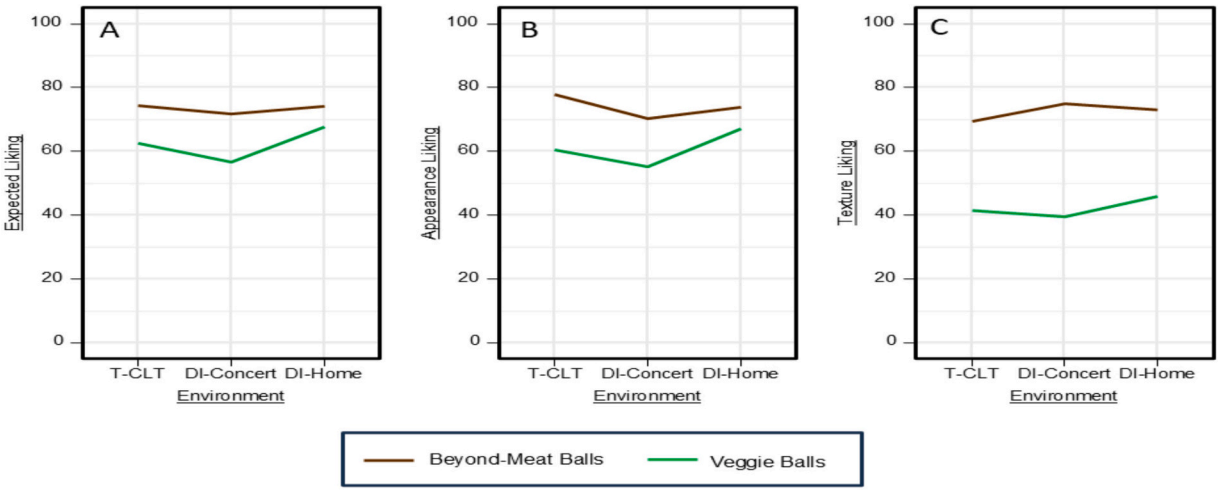


**Fig. 4.** Interaction effects of product and environment on expected (A), appearance (B) and texture liking (C).

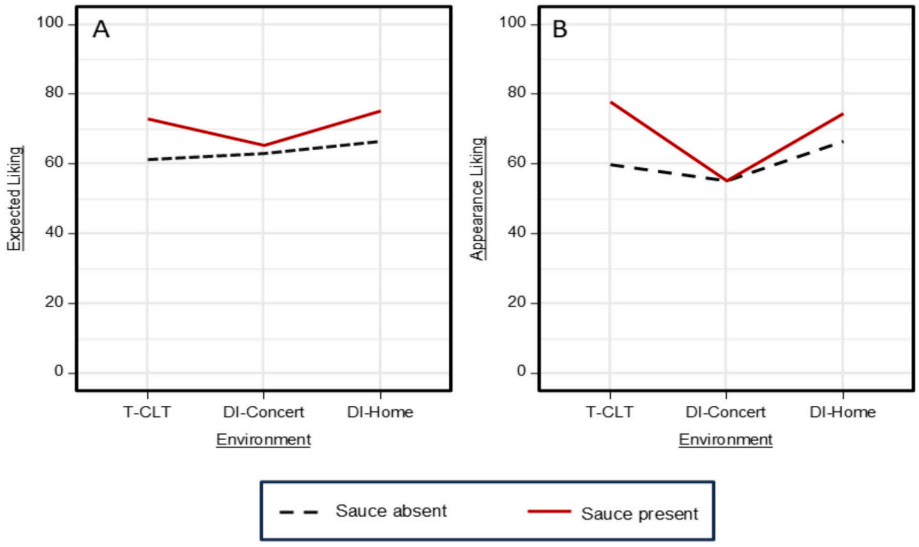


**Fig. 5.** Interaction effects of sauce and environment on expected (A) and appearance (B) liking.

different across environments.

### 3.4. Emotional response

Mean emotion category sample ratings and standard error in each environment are presented in **Supplementary Material** Table 2. F- and *p*-values for main and interaction effects derived from linear mixed effect models for each emotion category are presented in Table 4**.**

#### 3.4.1. Influence of product on emotional response

A significant product effect for all emotion categories ($p < 0.001$, Table 4**)**, indicated differences in emotional response towards the two products when ratings were averaged over sauce (absent/present) and environment. Ratings for all positive emotions categories were significantly higher for Beyond-Meat Balls compared to Veggie Balls and ratings for all negative emotion categories were the reverse (all $p < 0.001$) **(Fig. S1 A-X)**. Ratings for 'curious' were higher for Beyond-Meat Balls compared to Veggie Balls ($p < 0.001$) whereas ratings for 'neutral' were higher for Veggie Balls ($p < 0.001$). In general, intensity ratings for positive emotions were higher (>25 on 100-pt scale) than intensity ratings for negative emotions (<25 on 100-pt scale) except for 'disappointed', 'dissatisfied' and 'uncertain' which were > 25 on 100-pt scale for Veggie Balls.

#### 3.4.2. Influence of sauce on emotional response

A significant sauce effect was found for emotion categories 'adventurous', 'amazed', 'energetic', 'happy', 'hungry', 'hopeful', 'loving', 'nostalgic', 'pleasant', 'anxious', and 'neutral' ($p < 0.05$, Table 4). Ratings for 'neutral' decreased when sauce was present, whereas ratings for other emotion categories increased when sauce was present **(Fig. S2 A-K)**. Sauce addition increased feelings of several positive emotions towards the products. However, it also elicited an increase in feelings of 'anxiousness', although ratings remained relatively low at 14.09 on a 100-pt scale. Sauce addition was not sufficient to decrease feelings of negative emotions. The *product*sauce* interaction was not significant for any emotion categories.

#### 3.4.3. Influence of environment on emotional response

A significant environment effect (all $p < 0.001$) was found for 'calm', 'adventurous', 'energetic', 'pleasant/grateful', 'loving', 'hopeful', 'happy', 'nostalgic', 'hungry', 'satisfied', 'anxious', and 'curious' **(Fig. S3 A-L)**.

In the DI-Home, samples made participants feel significantly more 'calm' ($p < 0.001$), 'loving' ($p < 0.001$), 'nostalgic' ($p < 0.001$),

**Table 4**
F- and p-values for main effects of environment, product and sauce and all 2-way and 3-way interactions derived from linear mixed effect modelsby emotion category.

| Emotion Category | | Product | Sauce | Environment | Product* Sauce | Environment*Product | Environment* Sauce | Environment* Product *Sauce |
|---|---|---|---|---|---|---|---|---|
| | | (DF = 1) | (DF = 1) | (DF = 2) | (DF = 1) | (DF = 2) | (DF = 2) | (DF = 2) |
| Adventurous | F | 170.938 | 4.891 | 3.112 | 0.664 | 1.851 | 3.071 | 0.238 |
| | p | <0.001*** | 0.0272* | 0.045* | 0.415 | 0.158 | 0.047* | 0.789 |
| Afraid | F | 39.011 | 0.086 | 0.605 | 0.049 | 1.953 | 2.971 | 0.393 |
| | p | <0.001*** | 0.770 | 0.546 | 0.825 | 0.142 | 0.052 | 0.675 |
| Amazed | F | 359.335 | 10.325 | 0.793 | 0.007 | 1.947 | 0.352 | 0.739 |
| | p | <0.001*** | 0.001** | 0.453 | 0.934 | 0.143 | 0.704 | 0.478 |
| Angry | F | 87.432 | 0.684 | 0.493 | 0.532 | 1.695 | 0.496 | 0.090 |
| | p | <0.001*** | 0.409 | 0.612 | 0.466 | 0.184 | 0.609 | 0.914 |
| Anxious | F | 65.176 | 3.874 | 4.004 | 0.001 | 1.146 | 1.719 | 0.152 |
| | p | <0.001*** | 0.049* | 0.018* | 0.980 | 0.318 | 0.180 | 0.859 |
| Bored | F | 241.004 | 0.018 | 0.166 | 0.318 | 0.985 | 5.018 | 2.869 |
| | p | <0.001*** | 0.895 | 0.847 | 0.573 | 0.374 | 0.007** | 0.057. |
| Calm | F | 137.494 | 0.011 | 31.132 | 0.872 | 0.225 | 0.230 | 0.190 |
| | p | <0.001*** | 0.916 | <0.001*** | 0.351 | 0.798 | 0.795 | 0.827 |
| Curious | F | 132.411 | 0.380 | 6.460 | 0.036 | 0.881 | 2.203 | 0.670 |
| | p | <0.001*** | 0.538 | 0.002** | 0.849 | 0.415 | 0.041* | 0.512 |
| Deceived | F | 210.773 | 1.291 | 0.330 | 0.362 | 0.268 | 0.555 | 0.110 |
| | p | <0.001*** | 0.256 | 0.719 | 0.548 | 0.765 | 0.574 | 0.896 |
| Disappointed | F | 410.240 | 0.132 | 0.691 | 0.205 | 3.183 | 0.699 | 0.308 |
| | p | <0.001*** | 0.717 | 0.501 | 0.650 | 0.042* | 0.497 | 0.735 |
| Disgusted | F | 186.524 | 0.013 | 0.001 | 0.412 | 0.187 | 2.603 | 0.014 |
| | p | <0.001*** | 0.910 | 0.999 | 0.521 | 0.830 | 0.074 | 0.986 |
| Dissatisfied | F | 391.806 | 2.118 | 0.895 | 0.506 | 2.078 | 1.963 | 0.020 |
| | p | <0.001*** | 0.146 | 0.409 | 0.477 | 0.126 | 0.141 | 0.981 |
| Energetic | F | 338.022 | 12.200 | 8.245 | 0.061 | 1.509 | 1.110 | 0.370 |
| | p | <0.001*** | <0.001*** | <0.001*** | 0.805 | 0.222 | 0.330 | 0.691 |
| Happy | F | 474.407 | 4.938 | 8.754 | 0.235 | 2.526 | 0.377 | 0.009 |
| | p | <0.001*** | 0.026* | <0.001*** | 0.628 | 0.080 | 0.686 | 0.991 |
| Hopeful | F | 281.426 | 5.066 | 6.440 | 0.155 | 0.150 | 1.331 | 0.052 |
| | p | <0.001*** | 0.025* | 0.0016* | 0.694 | 0.861 | 0.265 | 0.950 |
| Hungry | F | 344.018 | 8.263 | 10.865 | 0.934 | 3.410 | 1.082 | 0.810 |
| | p | <0.001*** | 0.004** | <0.001*** | 0.334 | 0.033* | 0.339 | 0.445 |
| Loving | F | 270.481 | 15.365 | 35.045 | 0.000 | 0.149 | 0.467 | 0.175 |
| | p | <0.001*** | <0.001*** | <0.001*** | 0.992 | 0.862 | 0.627 | 0.839 |
| Neutral | F | 35.154 | 7.515 | 0.137 | 2.360 | 2.421 | 1.628 | 1.123 |
| | p | <0.001*** | 0.006** | 0.872 | 0.125 | 0.089 | 0.197 | 0.326 |
| Nostalgic | F | 178.175 | 20.627 | 17.725 | 0.436 | 0.637 | 1.251 | 0.782 |
| | p | <0.001*** | <0.001*** | <0.001*** | 0.509 | 0.529 | 0.287 | 0.458 |
| Pleasant/ grateful | F | 465.350 | 7.694 | 7.526 | 0.255 | 0.268 | 0.482 | 0.209 |
| | p | <0.001*** | 0.006** | <0.001*** | 0.613 | 0.765 | 0.618 | 0.812 |
| Satisfied | F | 521.563 | 2.965 | 3.951 | 0.141 | 2.566 | 0.200 | 0.049 |
| | p | <0.001*** | 0.085 | 0.195* | 0.708 | 0.077 | 0.819 | 0.952 |
| Suspicious | F | 121.671 | 0.089 | 0.504 | 0.439 | 0.142 | 1.321 | 0.449 |
| | p | <0.001*** | 0.766 | 0.605 | 0.508 | 0.868 | 0.267 | 0.639 |
| Uncertain | F | 156.568 | 0.402 | 1.920 | 0.754 | 1.658 | 1.264 | 0.524 |
| | p | <0.001*** | 0.526 | 0.147 | 0.385 | 0.191 | 0.283 | 0.592 |
| Unhappy/ sad | F | 188.083 | 0.033 | 0.100 | 0.576 | 1.669 | 2.268 | 0.789 |
| | p | <0.001*** | 0.857 | 0.905 | 0.448 | 0.189 | 0.104 | 0.455 |

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

'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 consumed in the DI-Concert. In the DI-Concert, 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 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 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 sauce was absent, participants felt more 'adventurous' having consumed samples in the DI-Concert compared to the T-CLT ($p = 0.013$) and participants felt more 'curious' about 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 samples in the DI-Home compared to the T-CLT ($p = 0.027$).

## 4. Discussion

### 4.1. Impact of meal context on liking and emotional response

Evaluating MBAs in combination with 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 be more representative of how products would be 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 as current liking may be under or overestimated depending on their other food context. 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 with other food components (Gonzalez-Estanol et al., 2022; Gonzalez-Estanol et al., 2023; Meinert et al., 2011; van Eck, Fogliano, Galindo-Cuspinera, Scholten and Stieger, 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 are 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 et al., 1994) and familiar products are usually better liked than unfamiliar products (Tuorila & Hartmann, 2020).

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

In addition to liking, ratings of several emotions increased when the MBAs were served with sauce. The *product*sauce* interaction was not significant for any emotions suggesting the increase in ratings were not product-specific and were 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 the product ('hungry'). Feelings of 'anxiousness' also increased, likely stemming from uncertainty regarding what was concealed under the sauce. However, 'anxiousness' intensity ratings remained relatively low. Finally, ratings for "neutral" decreased suggesting consumers felt less neutral towards the products when the sauce was present. These findings infer that preparing PBMAs in a congruent meal context can have a positive impact on emotional response. Such findings are important as 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 especially (Bryant et al., 2019; Chen, 2022; Onwezen et al., 2021). As the first study to examine the effect of combining PBMAs with other meal components on emotional responses, further research is needed to confirm this enhancing effect across different PBMAs and meal types. Moreover, assessing emotional responses in congruent meal contexts is essential for capturing reactions that more accurately reflect real-life consumption experiences.

Notably, whilst sauce addition enhanced positive emotions, it was insufficient to mask negative emotions which could still 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 PBMA but not replicating the sensory properties of a traditional meatball, meant the product did not meet 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's marketing as a meatball alternative and the actual experience. Whilst this is speculation, it has implications for the PBMA marketing when not replicating the sensory properties of meat but inferring they are an alternative.

### 4.2. Impact of eating environment on liking and emotional response

Testing in a congruent environment notably impacted liking ratings towards the less-liked Veggie Balls but did not have a significant impact on the more-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). Differences in expected and appearance liking between the DI-Home and DI-Concert may partly reflect the dimmer lighting in the concert setting; however, higher ratings in DI-Home compared to T-CLT suggest the environment influenced these measures beyond potential effects of lighting alone. Previous research has also shown expected liking ratings to be higher when a product is consumed in an appropriate/congruent DI-environment compared to an inappropriate/incongruent one (Liu et al., 2019; van Bergen et al., 2021). However, the effects of food-context congruency on actual liking upon tasting have been inconsistent with some studies finding no effect (Chen et al., 2020; Liu et al., 2019; 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, 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 ques., to name a few.

The immersive environments 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 immersive environments. Additionally, consumers felt less 'disappointed' towards the Veggie Balls in the DI-Home compared to the DI-Concert. Whilst 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 regards 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 were better liked were perceived as more appropriate. Furthermore, Kong et al. (2020) found no effect of context (VR 5-star resort and VR music concert) on liking of three chocolate samples and proposed familiarity with the product and a strong preference effect as opposed to a 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 envision 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 particularly benefit from being tested in relevant eating situations 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 may already have established preferences and associations. However, in contrast, Papies et al. (2022) found that processing an image of a bowl of soup, a familiar food described by the authors as "moderately tasty," in a congruent (kitchen) versus incongruent (cinema) background situation increased expected liking, desire to eat the soup, and salivation.

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 MBAs when consumed in a situationally appropriate environment such as the home. 'Anxious' was the only negative emotion to significantly differ between the environments, 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 DI-environments. Regardless of product, positive emotions were rated higher in a sunny day environment, whilst negative emotions were rated higher in a rainy 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 the current study, 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, likely reducing discriminability. Additionally, both samples were widely accepted, and both environments were quiet, calm, and relaxing. All the aforementioned studies, including the present one, have utilised explicit measures of emotion. However, De Wijk et al. (2019) found that explicit measures are less sensitive to variations in the experimental context than implicit measures. Consequently, the inclusion of implicit measures, such as facial expressions or heart rate, may reveal stronger effects of environmental context.

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 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 DI-environments. Further, in the absence of sauce ratings for 'curious' were higher in the T-CLT compared to the immersive environments, and when sauce was present ratings for 'bored' were lower in the traditional CLT compared to the DI-Home. Contradictorily, Low 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 immersive environments. Additionally, it is 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.

### 4.3. Impact of eating environment versus meal context on consumer response

This research emphasised that pairing MBAs with an appropriate 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) towards 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 sauce exerted a stronger influence on consumer response compared to eating environment. However, testing in an appropriate eating situation still enhanced liking responses for the Veggie Balls and increased ratings of positive emotions for both products. This suggests that whilst 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 situation, and consumer responses towards PBMAs.

### 4.4. Limitations and future work

This study provides new insights into the impact of meal context and eating environment on consumer response to PBMAs. However, the research had some limitations that warrant acknowledgment. Firstly, this study only included two MBAs which could restrict the generalisability of the findings to a broader range of PBMAs. Furthermore, not all contextual factors were considered e.g. who the participant was eating with, and MBAs were served only with sauce and lacked other common accompaniments such as pasta. Additionally, serving size was relatively small. Meal context, therefore, may not accurately reflect typical consumption habits potentially influencing product experiences and evaluations. Sample distinctiveness and number of samples presented in each session may have predisposed participants to remember samples in 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. Sensory attributes were not measured in this study thus the impact of the sauce addition on sensory attributes could not be assessed. Lastly, whilst the study aimed to simulate a home environment, it may not have fully represented individuals' actual home settings, potentially influencing their evaluations.

It is also acknowledged that the findings observed in this research could partly be due to differences in product familiarity rather than

liking alone as the less liked product did not mimic meat, whereas the more liked product did. However, as familiarity was not measured in this study, no claims regarding its influence can be made. Nonetheless, familiarity and product liking are often strongly correlated, as familiar products tend to be better liked than unfamiliar ones (Tuorila & Hartmann, 2020).

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. Additional emotion terms such as "proud" and "guilty" should be considered for inclusion in future emotion lexicons when working with PBMAs. Zandstra et al. (2024) found that pride and guilt showed the most pronounced differences between meat and plant-based burgers and identified these emotions as potential emotional targets for encouraging a shift towards more plant-based eating. For example, feeling guilty when eating meat and feeling proud when eating plant-based. Additionally, measuring impact on sensory attribute perception would be valuable to understanding how accompanying foods may mask or enhance 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. Finally, given that the home is a common eating environment, but is highly personal to each individual, research into how DI-environments can be better utilised to understand consumer responses "at home" is warranted.

## 5. Conclusions

In conclusion, this study demonstrated the significant impact meal context and DI-environments can have on liking and emotional response towards PBMAs. It was shown that sauce addition significantly increased intensity ratings for all liking modalities and several positive emotions for both MBAs, underscoring the important role meal context/food accompaniments can play in improving consumer response to PBMAs, which should, therefore, ideally be tested in such contexts. Regardless of sample, ratings for several positive emotions were higher in the DI-Home compared to the other environments highlighting the positive impact testing in relevant eating environments can have on emotional response and suggesting that emotional response in 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 and is an important consideration for sensory product testing. Finally, this study has highlighted several opportunities for future research to better understand the impact of both meal context and DI-environments on consumer responses to PBMAs and other product categories.

## CRediT authorship contribution statement

**Rebekah Orr:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Caroline Giezenaar:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization. **A. Jonathan. R. Godfrey:** Writing – review & editing, Visualization, Supervision, Methodology, Formal analysis, Conceptualization. **Simone Poggesi:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization. **Joanne Hort:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

## Ethics statement

As indicated in the manuscript the authors declare that tThis research was considered and assessed as low risk according to the Massey University Human Ethics Committee process (human ethics notification number: 4000027702).

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2025.105776.

## Data availability

Data will be made available on request.

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