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Consumers’ sensory-based cognitions of currently available and ideal plant-based food alternatives: A survey in Western, Central and Northern Europe

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ABSTRACT

Sensory experiences of plant-based (PB) food alternatives play a crucial role in the acceptance and, thus, growth of this market. To facilitate improvements and to better direct the PB food product development, it is important to identify potential gaps in consumers’ sensory-based cognition between currently available and their ideal version of PB food and beverage alternatives. Sensory benchmarking of PB alternatives to chicken, beef, semi-hard cheese, cream cheese, yoghurt and milk was studied via (part 1) a sensory vocabulary development and, subsequently, (part 2) an online survey (n = 416–1829) in Central, Western and Northern European countries using the rapid sensory descriptive method Rate-All-That-Apply. For the PB milk and yoghurt categories, consumers demanded only minor sensory modifications, specifically, towards a less beany and sweet taste. In addition, PB milk and yoghurt alternatives received high liking scores (7.1 and 7.0 out of 9, respectively). Lower liking scores were reported for PB semi-hard cheese alternatives (5.3 out of 9). Sensory improvements of PB semi-hard cheese alternatives should be directed towards more cheese-like, less artificial and less bland attributes. For PB beef alternatives, the products in the category should have a more umami taste and beef-like taste and odour. A more chicken-like taste, texture and odour is desired for PB chicken alternatives. A more balanced, cheesier, less artificial taste and odour is desired for cream cheese alternatives. These findings provide strategic insights to direct the product development of PB food alternatives, which constitutes a pathway for creating new market opportunities considering consumer demand and sensory preferences.

1. Introduction

Plant-based (PB) diets and lifestyles have increased in popularity over the past few years (Dinu, Abbate, Gensini, Casini, & Sofi, 2017). In research, the terms ‘plant-based’ and ‘vegan’ are often used interchangeably, and awareness of the term ‘plant-based’ differs significantly among European countries (Faber, Castellanos-Feijóo, Van de Sompel, Davydoïva, & Perez-Cueto, 2020). In the literature, some define it as a diet with a ‘very limited number of animal-based products’ (Faber et al., 2020; Satija & Hu, 2018), and others define it as a ‘diet free from animal products’ (Freeman et al., 2017; Williams & Patel, 2017). Throughout this paper, ‘plant-based’ indicates food products or diets completely free of animal-based products.

The Smart Protein Project (2021b) reported that approximately 46% of European consumers are reducing their meat consumption, and 39% intend to reduce their meat consumption in the future. Even though only a small proportion (approximately 7%) of Europeans are eating fully or mostly plant-based, the number of Europeans following a flexitarian diet (approximately 20–30%) is rising (Perez-Cueto et al., 2022; Smart Protein Project., 2021b; Veganz, 2020), with the largest share in the Netherlands (42%) and Romania (40%) (Smart Protein Project, 2021b).

The PB food alternative market is not only targeted at plant-based...
Part 2: online consumer survey.

1) Online consumer survey including descriptive sensory attributes from part 1 and using the rapid sensory descriptive method Rate-All-That-Apply (RATA)

2) Data analysis of consumer responses

2.1. Part 1: Development of sensory vocabulary

2.1.1. Selection of PB alternatives

Six food product categories were included, encompassing: chicken, beef, semi-hard cheese (similar to Gouda cheese), cream cheese, yoghurt and milk. The PB food categories were primarily chosen because of their availability and familiarity in the European market, allowing a range of different PB food products in the food category. For each food category, three commercially available PB alternative variants and one animal-based product were selected (see Table 1). For each food category, the products were chosen to represent the variation in the sensory characteristics within the food category. However, for the dairy alternatives, it was ensured that the products had a similar overall profile, i.e. ‘plain’ variants (without added flavouring) and similar fat percentages within the food category. For the meat alternatives, seasoning is usually added; thus, a non-seasoned variant of PB beef and chicken meat product was not possible to obtain. All selected food products were commercially available within the Central, Northern and Western European markets.

2.1.2. Development of descriptive sensory attributes

2.1.2.1. Sensory panel. An external trained sensory panel from Future Consumer Lab, University of Copenhagen, Denmark, was recruited to define the main sensory attributes of the selected food products. The assessors were informed about the study and gave consent to participate. Part 1 of the present study has been viewed and approved by the Research Ethics Committee for the Faculties of Science and Health at University of Copenhagen (504-0248/21–5000). The assessors were previously screened for their tasting abilities according to the International Standards Organization (2011), ISO 3972:2011. They were specifically trained in and familiar with developing sensory vocabularies and performing sensory evaluations of food using standard methods in concordance with (ISO 8586:2012).

Table 1

<table>
<thead>
<tr>
<th>Food category</th>
<th>Origin</th>
<th>Main ingredient</th>
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</thead>
<tbody>
<tr>
<td>Chicken</td>
<td>Animal-based</td>
<td>Chicken</td>
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<tr>
<td></td>
<td>Plant-based</td>
<td>Pea protein</td>
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<td>Soy protein concentratet</td>
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<td>Soy protein concentratet</td>
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<td>Beef</td>
<td>Animal-based</td>
<td>Beef</td>
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<td></td>
<td>Plant-based</td>
<td>Pea protein and rice protein</td>
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<td></td>
<td></td>
<td>Pea protein</td>
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<tr>
<td></td>
<td></td>
<td>Pea protein</td>
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<tr>
<td>Semi-hard cheese</td>
<td>Animal-based</td>
<td>Cow milk</td>
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<td></td>
<td>Plant-based</td>
<td>Almond preparation and coconut oil</td>
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<tr>
<td></td>
<td></td>
<td>Coconut oil</td>
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<td>Soy protein concentratet and coconut oil</td>
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<tr>
<td>Cream cheese</td>
<td>Animal-based</td>
<td>Cow milk</td>
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<tr>
<td></td>
<td>Plant-based</td>
<td>Coconut oil</td>
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<td></td>
<td></td>
<td>Coy protein and soy protein concentratet</td>
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<td></td>
<td></td>
<td>Cashews and coconut oil</td>
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<tr>
<td>Yoghurt</td>
<td>Animal-based</td>
<td>Cow milk</td>
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<tr>
<td></td>
<td>Plant-based</td>
<td>Hulled soybeans</td>
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<tr>
<td></td>
<td></td>
<td>Whole grain oat and potato protein</td>
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<td></td>
<td></td>
<td>Almonds and potato protein</td>
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<tr>
<td>Milk</td>
<td>Animal-based</td>
<td>Cow milk</td>
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<td></td>
<td>Plant-based</td>
<td>Hulled soybeans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pea protein and rice protein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oats</td>
</tr>
</tbody>
</table>
In total, 3 vocabulary development sessions were performed at the sensory laboratory at the University of Copenhagen over 3 consecutive days focusing on beef and chicken in session 1, semi-hard cheese and cream cheese in session 2, and yoghurt and milk in session 3. In total, 7 assessors (3 males and 4 females, 25.4 ± 3.2 years) joined 1 to 3 sessions with sensory vocabulary development, resulting in 4 assessors (1 male and 3 females, 27.0 ± 2.3 years) in session 1, 5 assessors (2 males and 3 females, 24.8 ± 3.3 years) in session 2 and 4 assessors (2 male and 2 females, age = 26.5 ± 3.8 years) for session 3. All assessors were compensated for their participation.

2.1.2.2. Preparation and serving

2.1.2.2.1. Beef. Beef (15–18% fat) and PB beef alternatives were purchased as patties with similar shapes and weights (approximately 150 g). All beef and PB beef samples were approximately 1 cm thick. The samples were cooked in the kitchen of the sensory laboratory at the University of Copenhagen. The samples were cooked in a pan in a preheated oven at 200 °C for, on average, 12 min (turned after approximately 6 min) until a core temperature of at least 72 °C was reached for food safety purposes (United States Department of Health and Human Services, 2017). Afterwards, the samples were allowed to rest for up to 5 min while covered with a cloth. Each assessor received an entire burger for tasting, served on a preheated porcelain plate wrapped with tin foil. A steak knife and fork were provided for tasting the samples.

2.1.2.2.2. Chicken. The PB chicken samples were purchased pre-cut in approximately 1 cm thick pieces. Chicken samples (approximately 2 g fat per 100 g) were prepared as pieces of approximately 15 g, 1 cm thick and with shapes comparable to a rectangular shape, similar to the PB chicken samples. The samples were prepared and cooked in the kitchen of the sensory laboratory at the University of Copenhagen. The chicken and PB chicken samples were cooked in a pan covered with tin foil in a preheated oven at 200 °C. The samples were cooked until a core temperature of 75 °C was reached for food safety purposes (average time 6 min) (United States Department of Health and Human Services, 2017). Each assessor received approximately 5 pieces (on average 80 g) of chicken and PB chicken chunks for tasting served on a preheated porcelain plate wrapped with tin foil. A fork and knife were provided for tasting the samples.

2.1.2.2.3. Semi-hard cheese. Semi-hard dairy cheese (27% fat) and PB semi-hard cheese alternatives were purchased pre-sliced, and all had squared shapes with similar weight and thickness when purchased. One slice of cheese was served on a porcelain plate and covered with plastic foil. One hour before serving, the cheese products were kept until tasting at 14 °C in a Thermex temperature-controlled cabinet, enabling serving temperature at 12–14 °C (ISO 22935–2:2009). The assessors were provided with a fork and knife for tasting the samples.

2.1.2.2.4. Cream cheese, yoghurt and milk. Dairy cream cheese (30% fat), yoghurt (1.5% fat), milk (3.5% fat) and PB cream cheese, yoghurt and milk alternatives were scooped or poured into a transparent 90 ml polystyrene solo cup with a lid. In total, 30 g of cream cheese, 80 ml of stirred yoghurt and 80 ml of milk products were served. The samples were kept at 14 °C in a Thermex temperature-controlled cabin one hour before serving, enabling serving temperature at 12–14 °C (ISO 22935–2:2009, 2009). A spoon was provided to the assessors for tasting the samples.

2.1.2.3. Sensory vocabulary development. The samples were served to the assessors on numbered porcelain plates or in transparent cups for the sensory evaluation. The trained sensory assessors were instructed to smell, look at and taste the food products within each food category and generate sensory attributes describing the sensory variation among these products within all sensory modalities, i.e. odour, appearance, taste, flavour, texture/mouthfeel. Some of the tested PB meat samples were only commercially available in versions with added flavour or seasoning (e.g. barbeque seasoning). Therefore, the assessors were instructed to focus on the sensory properties of the PB meat samples but to avoid developing a vocabulary for the added seasoning. The sensory vocabulary was developed through consensus discussion in the sensory panel.

One sample was served at a time for the beef and chicken samples to secure an appropriate high serving temperature. After one round of sample presentations of beef and chicken products, all samples were presented again to ensure that the developed vocabulary was complete. For semi-hard cheese, cream cheese, yoghurt and milk, 2 samples were served at the time because the serving temperature for the dairy samples was much closer to room temperature than the meat products. Water was provided to the assessors for cleansing between different samples. The assessors could choose sparkling water and tap water as palate cleansers but were instructed to end each cleansing with tap water. The session lasted 3 h for the beef and chicken product category, while the sessions for semi-hard cheese, cream cheese, yoghurt and milk lasted 2 h.

2.2. Part 2: Online consumer survey

2.2.1. Questionnaire development

A web-based survey was conducted in Central (Austria, Germany), Western (Belgium, The Netherlands) and Northern (Denmark, Sweden) Europe. The primary reason for including these countries and European regions was to ensure that similar PB alternatives were available in the markets of these countries as compared to part 1 of the study. The survey was designed in SurveyXact (Ramboll, Denmark) and initially developed in English, but also available in three other native languages, Dutch, Danish and German, which allowed greater reach and accounted for language barriers. Native speakers familiar with sensory attributes translated the survey to Dutch, Danish and German using backward translation. Data were collected anonymously, and no IP addresses of the respondents were collected. The online survey took between 10 and 25 min to complete depending on the individual’s consumption frequency of the studied food product categories.

Overall, the online survey (Supplementary Materials Part 1) addressed consumer background questions, evaluation of the presence of sensory attributes in the studied six PB food product categories, and liking of the PB food products. Furthermore, barriers to consumption of PB food categories and attitudinal questions about interest in novel foods and food beliefs concerning health and environment were included but are not presented in this paper. Consumer background questions covered sociodemographic questions (age, gender, country of residence, education, and living situation), dietary lifestyles and consumption frequency of PB food products.

Respondents were asked to report their consumption frequency of PB chicken, beef, semi-hard cheese, cream cheese, yoghurt or milk alternatives in the past 3 months. Those respondents who reported consuming one or more PB food alternative categories were asked to evaluate the presence of CA’s sensory attributes (as identified in part 1 of the study) and their ideal PB food alternatives (yet to be developed). Before starting the question on rating the sensory attributes of CA and ideal plant-based alternatives, an introduction to the question for each of the plant-based alternative categories was provided to the respondents. It was stated as follows: “We will ask you to evaluate the product characteristics of currently available plant-based [type of food category]. We are aware that products within this product category are different depending on the ingredients and brands. However, we would like you to give your overall opinion”. This was followed by the question: “What [type of sensory modality] factors are present in currently available plant-based [type of food category]?” Please indicate the degree of presence of the following factors.” After rating the CA plant-based [type of food category], the questions were repeated, but the respondents were told to focus on their ideal version of the plant-based [type of food category]. The sensory attributes were presented in a RATA with a 5-point scale with 0 = ‘not present’, 1 = ‘slightly present’,
2 = ‘moderately present’, 3 = ‘very present’ and 4 = ‘extremely present’ (Ares et al., 2014). RATA is an intensity-based variant of Check-All-That-Apply (CATA), and this method allows respondents to rate the intensity of sensory attributes using a category scale. Compared with CATA questions, RATA questions provide more selected items for each sensory attribute, improve food discrimination, and engage respondents in greater cognitive processing (Ares et al., 2014; Reinbach, Giacalone, Ribeiro, Bredie, & Frost, 2014). In the present study, the sensory attributes in the RATA were grouped into sensory modalities: odour, appearance, taste/flavour and texture/mouthfeel. Within each modality, the sensory attributes were randomly presented to the respondents. Additionally, the consumers were asked to indicate their liking of the CA PB alternatives on a 9-point hedonic liking scale ranging from 1 to 9, where 1 = ‘dislike extremely’ and 9 = ‘like extremely’ (Peryam & Pilgrim, 1957).

2.2.2. Recruitment and participation criteria

A survey link was shared within Smart Protein Project’s consortium and network to recruit respondents to the online survey. Furthermore, partial snowball sampling was done by asking connections to share the survey amongst their network groups, for example, by sharing the LinkedIn post or simply posting the link in private chat groups.

Adults aged 18 years and above were included in this study. Upon entering the survey, respondents were given a brief introduction about the survey and how it conforms to the General Data Protection Regulation (GDPR). Additionally, the respondents were informed that data from incomplete responses or small segments of respondent groups might not be included in the analysis. Respondents could only continue with the survey if they provided active consent for their participation and indicated that they were 18 years or older. Participation was thus voluntary, under informed consent, and only for adult respondents. Respondents were notified that the survey was the easiest to complete using a computer or tablet. However, phone use would not pose problems other than a different, sub-optimal layout. The Research Ethics Committee for the Faculties of Science and Health at the University of Copenhagen has evaluated and approved part 2 of the study (504-0247/21–5000).

2.2.3. Data analysis

If any respondents younger than 18 years old had entered the survey, their responses were omitted from further analysis. Furthermore, incomplete responses were excluded as well. Due to low percentages of “others” in the country of residence, these participants were excluded from the final analysis. Another 34 participants were excluded because of careless responding (e.g. straight-lining or survey completion speed). An overview of the data cleaning process is provided in a Data quality statement (Supplementary Materials Part 2). Overall, counts (n) and percentages (%) were used to describe categorical data, herein respondent characteristics and consumption frequency of PB food alternatives. Means were used to describe continuous data, including hedonic rating (liking) of CA PB food alternatives and rating of the presence of sensory attributes in CA PB food products and their ideal counterparts. Linear modelling was used to explore the effect of country of residence and dietary lifestyle on the liking of the CA PB food alternatives and all sensory attributes for each product category. In the linear modelling, “omnivores” in dietary lifestyles were omitted due to a low number of participants. However, other analyses included “omnivores” because their responses were considered valuable for the results. Results of the linear modelling showed that the sensory-based cognition of CA PB food alternatives and their ideal counterparts significantly differed (p < 0.05) across countries and dietary lifestyles. Therefore, a Principal Component Analysis (PCA) was run to investigate whether overall sensory-based cognition of the PB food alternatives differed across countries and dietary lifestyles. As the overall sensory-based cognition was similar across countries and dietary lifestyle groups, further analysis of the sensory-based cognition of the CA and ideal counterparts included averaged scores for all respondents. Student’s t-tests were conducted to investigate whether a significant discrepancy exists in consumers’ sensory-based cognition between the CA PB food alternatives and their ideal counterparts, as this is the simplest and most appropriate statistical method for comparison of RATA obtained intensities (Meyners, Jaeger, & Ares, 2016). When the mean sensory-based cognition of a sensory attribute in the ideal version was higher than the mean for the CA version, it showed that consumers of these PB food alternatives would like a larger presence of this sensory attribute in their ideal product. Likewise, when the mean sensory-based cognition of a sensory attribute in the ideal version was lower than the mean for the CA version, consumers of these PB food alternatives would like a lower presence of this sensory attribute in their ideal version. A p-value of < 0.05 was considered statistically significant. All analyses were conducted in the statistical software R version 4.2.0 (R Core Team, 2022).

3. Results

3.1. Part 1: Sensory vocabularies of six food categories

The final sensory vocabularies for the different food categories consisted of 22 to 35 sensory attributes (Figs. 1-6), with milk having the lowest number of describing sensory attributes and cream cheese having the highest number of describing sensory attributes. These sensory attributes served as input for part 2 in a RATA for consumer evaluation of the food categories: PB beef, chicken, semi-hard cheese, cream cheese, yoghurt and milk alternatives using an online survey. In the online survey, the sensory attributes were adjusted to layman’s terms. Sometimes explanations were added in the brackets after the sensory attributes for better consumer understanding, such as fresh sour (as a positive factor) and sour/vinegary (as a negative factor).

3.2. Part 2: Online survey

3.2.1. Sociodemographic characteristics and consumption of PB alternatives

Descriptive statistics of the survey’s consumers of PB milk, yoghurt, semi-hard cheese, cream cheese, chicken and beef alternatives are provided in Table 2, including sociodemographic characteristics, dietary lifestyle, following a lactose-free diet and consumption frequency of PB alternatives. Between 416 and 1829 consumers were included in the final analysis. The majority of the respondents were females (approx. 80%), had a mean age of 45 years, were residing in Western European countries (>80%), were highly educated (approx. 65%) and lived with partner(s) (approx. 40%), lived alone (approx. 25%) or with partner(s) and child/children (approx. 20%).

The majority of respondents characterised their dietary lifestyle as PB (vegan) (approx. 40–60%), followed by vegetarian (approx. 25%) and part-time vegetarian (flexitarian) (approx. 10–20%). Interestingly, up to 3% of the consumers of PB food alternatives characterised themselves as omnivores indicating that consumers of PB food alternatives are not restricted to one particular dietary lifestyle. Among consumers of PB food alternatives, 40–60% of the respondents consumed a lactose-free diet. PB milk alternatives were consumed most frequently, as 54% of the users of this product indicated that they consumed PB milk alternatives at least once or several times per day. The other studied PB food alternatives were consumed 1–3 times per month or 1–3 times per week by 50–60% of the consumers.

3.2.2. Liking of PB food products

Table 3 shows the mean liking of CA PB milk, yoghurt, semi-hard cheese, cream cheese, chicken and beef alternatives across European regions and dietary patterns. On average, none of the CA PB food alternatives received a score below ‘Neither like nor dislike’ from the consumers (all mean liking > 5 out of 9). Of the studied PB food product categories, PB milk alternatives received a mean liking score of 7.1 out
5

of 9, indicating a relatively high liking for this food category. Central European respondents rated liking of PB milk alternatives higher than those from Northern and Western Europe (p < 0.001). Additionally, vegan respondents stated a higher liking for PB milk alternatives compared to flexitarians and vegetarians (p < 0.001). On average, the PB semi-hard cheese alternatives received a mean liking score of 5.3 out of 9, indicating a ‘Neither Like nor Dislike’. Western European respondents reported the lowest liking of PB semi-hard cheese alternatives compared to Central and Northern Europeans (p < 0.001). Flexitarian and vegetarian respondents rated liking of PB semi-hard cheese alternatives lower than vegan respondents (p < 0.001).

3.2.3. Sensory-based cognition of PB food alternatives

The consumers of PB food alternatives rated the sensory attributes present in CA PB food alternatives and the sensory attributes to be present in their ideal version of them (yet to be developed). No differences within country and dietary lifestyle groups were identified in the overall sensory profile for CA and the ideal version of each studied PB food category. Therefore, the sensory profile of these products will be presented based on averages from all consumers.

3.2.3.1. PB Milk alternatives

Fig. 1 illustrates the consumers’ sensory-based cognition of CA and the ideal version of PB milk alternatives. Respondents described the CA PB milk alternatives as having a moderately uniform, liquid and white colour appearance. The CA PB milk alternatives were evaluated to have only a small presence of all the odour and taste/flavours. Among the taste/flavour attributes, sweet and grain-like were most present. Considering the consumers’ sensory-based cognition of the CA and their ideal versions, there were significant differences for 19 out of 22 sensory attributes, indicating a need to optimise PB milk alternatives to satisfy consumer demands. However, it must be noticed that the gap between CA and the ideal version is a maximum of 0.7 units on the RATA intensity scale, suggesting minor modifications of the sensory profile of PB milk alternatives. Overall, the consumers would like the taste/flavour of ideal PB milk alternatives to be more fresh-sour but less sweet, beany and grain-like.

3.2.3.2. PB Yoghurt alternatives

Fig. 2 shows the consumers’ sensory-based cognition of CA and the ideal PB yoghurt alternatives. The consumers of PB yoghurt products described the CA versions as having a uniform, thick and white colour appearance and a moderately thick texture/mouthfeel. The most intense tastes/flavours were fresh-sour and
sweet; however, these were less than moderately present. Consumers’ sensory-based cognition of the CA and their ideal versions differed significantly for 27 out of 31 sensory attributes. Note that the gap between CA and the ideal version is a maximum of 0.6 units on the intensity scale, suggesting minor modification of the sensory profile of PB yoghurt products. According to the consumers, PB yoghurt products are recommended to have a higher intensity of fresh-sour flavour/taste and be thicker in texture/mouthfeel.

3.2.3.3. PB semi-hard cheese alternatives. The consumers’ sensory-based cognition of the CA and their ideal versions differed significantly for 27 out of 31 sensory attributes. Note that the gap between CA and the ideal version is a maximum of 0.6 units on the intensity scale, suggesting minor modification of the sensory profile of PB yoghurt products. According to the consumers, PB yoghurt products are recommended to have a higher intensity of fresh-sour flavour/taste and be thicker in texture/mouthfeel.

Consumers would like a cheesy odour and flavour/taste to be very much present in PB semi-hard cheese alternatives. In contrast, the bland taste/flavour and artificial odour and taste/flavour should not be present in the ideal versions. Consumers would also like umami taste/flavour and creamy texture/mouthfeel to be present in the ideal versions at moderate intensity. It appeared that consumers find more holes in PB cheese alternatives ideal, as opposed to the current observed level in CA products. Furthermore, consumers indicated that less shiny appearances would be ideal. Lastly, consumers would prefer more creaminess in texture/mouthfeel in ideal products.

3.2.3.4. PB Cream cheese alternatives. Fig. 4 shows the consumers’ sensory-based cognition of CA and the ideal version of PB cream cheese products. The consumers of PB cream cheese products described the CA versions as having a moderate to high presence of light-yellow colour and uniform appearance, firm texture/mouthfeel and mild taste/flavour. Consumers’ sensory-based cognition of the CA and their ideal versions differed significantly for 25 out of 32 sensory attributes. As differences between the CA and ideal version were >1.5 units for several sensory attributes, it suggests that the sensory quality of PB semi-hard cheese alternatives must be improved a lot to match the consumer’s ideal version.

Prefix to the sensory attributes indicates the type of assessment by consumers: O-: Odour, A-: Appearance, T/F-: Taste/flavour, TX/MF-: Texture/Mouthfeel. Intensity ratings: 0 = Not present, 1 = Slightly present, 2 = Moderately present, 3 = Very much present, 4 = Extremely present.
for spreadable appearance, creamy texture/mouthfeel and cream taste/flavour should increase in the ideal version. Furthermore, respondents would like a decrease in the intensity of the white colour appearance, while a firm and uniform appearance must remain unchanged. The largest differences between CA and the ideal version were observed for balanced taste/flavour and cheesy odour and taste/flavour. The consumers would like the intensity of these sensory attributes to increase with 1.2/1.3 units and thus be very much present in their ideal version.

3.2.3.5. PB Chicken alternatives. Fig. 5 illustrates the consumers’ sensory-based cognition of CA and the ideal version of PB chicken alternatives. The consumers of PB chicken alternatives described the CA versions as being moderately tender and having a chicken-like structure in texture/mouthfeel and chicken-like taste/flavour. Consumers’ sensory-based cognition of the CA and their ideal versions differed significantly on 24 out of 30 sensory attributes. In the ideal version of PB chicken alternatives, the intensities of tender and chicken-like structure in texture/mouthfeel and chicken-like taste/flavour should increase by 0.5–0.8 units. Additionally, the juicy texture/mouthfeel and chicken-like odour should increase by 0.9/1 unit and thus be moderate to very much present in the ideal versions. Otherwise, minor intensity modifications are necessary to meet the consumers’ ideal version, for example, ensuring the products are less dry and have less artificial taste/flavours even though it is only slightly present in the CA version.

3.2.3.6. PB Beef alternatives. The consumers’ sensory-based cognition of CA and the ideal version of PB beef alternatives are shown in Fig. 6. The consumers of PB beef alternatives described the CA versions as having a moderately brown colour appearance, uniform, firm and tender in texture/mouthfeel and umami taste/flavour. The consumers’ sensory-based cognition of the CA and ideal versions differed significantly on 23 out of 28 sensory attributes. In the ideal version of PB beef alternatives, the intensities for beef-like odour and taste/flavour, umami taste/
flavour and juicy texture/mouthfeel should increase by 0.7–0.8 units. The difference between CA and the ideal version is a maximum of 0.6 units on the remaining sensory attributes, suggesting minor modifications of the sensory profile of PB beef alternatives.

4. Discussion

The present study’s objective was to investigate consumers’ sensory-based cognition of six categories of CA PB food alternatives compared to the ideal version of these products (yet to be developed). The results revealed that respondents desire improvements in all six product categories, particularly significant improvements in PB semi-hard cheese alternatives.

4.1. Sensory-based cognition of PB food alternatives

4.1.1. PB Milk alternatives

The results showed that respondents would like the taste/flavour of PB milk alternatives to be less sweet and less beany and grainy. Even though humans have an innate preference for sweetness, it may be associated with the consumers’ health awareness, which is one of the motivations to consume PB foods. Also, the sugar level claimed on the packaging of PB milk products is reported to be the most extrinsic important attribute for purchasing these products (McCarthy, Parker, Ameerally, Drake, & Drake, 2017). Furthermore, Collier, Harris, Bendtsen, Norman, & Ntim (2023) revealed that differences in sensory expectations towards dairy milk and PB milk alternatives might exist; however, sweet was a common sensory expectation stated by their respondents. Beany flavour, a common sensory attribute in PB milk alternatives, originates from lipoxygenase activity in legume-based products, such as soy-based milk alternatives (Mäkinen et al., 2016). Some technological interventions have already taken place to improve these characteristics of PB milk (Sebti, Tyagi, & Anurag, 2016). The sensory-based cognition of the grain flavour attribute can be explained by grain (e.g. oats) being a prime ingredient of some PB milk alternatives.

4.1.2. PB Yoghurt products

A texture and taste similar to dairy-based yoghurt is a desire in PB yoghurt alternatives, as reported by the respondents; however, yoghurt-like taste and texture are one of the main technological challenges when developing PB yoghurts. Using PB proteins instead of casein micelles and
whey proteins results in lower amounts of proteins in the final product, off-flavours, and different functionalities compared to dairy proteins (Montemurro, Pontonio, Coda, & Rizzello, 2021). The ideal PB yoghurts’ appearance should have less syneresis (liquid/watery layer or aqueous phase, a common phenomenon in yoghurts during storage (Arab et al., 2022)) and less sweet and beany taste/flavour according to the respondents. A desirable taste and texture in PB yoghurts could be achieved by choosing the optimal starter culture and functional PB protein ingredients for fermentation processes (Jeske, Zannini, & Arendt, 2018; Masià, Geppel, Jensen, & Buldo, 2021). Furthermore, syneresis in PB yoghurts is due to unstable microstructure (or matrix), often a result of the functionalities of the ingredient or the production process, including the fermentation step. Several studies suggest that syneresis in PB yoghurts could be reduced by processing technologies, such as treatment with ultra-high-pressure homogenisation (Montemurro et al., 2021).

4.1.3. PB semi-hard cheese alternatives

The results suggest that consumers demand extensive improvements in the sensory quality of PB semi-hard cheese alternatives to match their ideal version; in particular, a more cheesy and umami taste/flavour, a creamy texture and no artificial odour and taste/flavour. Thus, it suggests that consumers would like their ideal PB semi-hard cheese alternatives to mimic the sensory attributes of dairy cheese. Low acceptance of commercial PB cheese alternatives has also been observed by Saraco and Blaxland (2020), who recommend improvements of PB cheeses to more accurately resemble conventional dairy-based cheeses. Sensory attributes that are generally posed and used in a negative context, such as ‘artificial’ (Fox, Guinee, Cogan, & McSweeney, 2017), should not be present in the ideal version. Limited research has been conducted on creating tasty PB cheese alternatives (Short et al., 2021). However, Bachmann (2001) has stated that the optimal acidity of PB cheese has a pH between 5.1 and 5.7. Respondents in the present study reported a desire for a less shiny appearance. Current PB semi-hard cheese alternatives have been characterised as dyed somewhat too bright (Sugg, 2017). Furthermore, whilst gums and gelling agents have been found to increase the firmness of the final product (Bachmann, 2001), these might not produce the creaminess consumers desire. The texture of PB semi-hard cheese alternatives is influenced by many factors, such as the hydration level of the ingredients, the source and content of fat and their state (liquid or solid, and the crystal polymorphisms), ripening time, protein type and source and overall treatment and production process of the PB cheese (Fox et al., 2017; Jeske et al., 2018). Soybean oil has been found to increase the cohesiveness of PB cheese alternatives and could ensure a higher creaminess. However, soybean oil also increases springiness, leading to a more rubber-like product, which was already deemed too high in commercial PB semi-hard cheese alternatives (Bachmann, 2001).

4.1.4. PB Cream cheese alternatives

Respondents would like PB cream cheese alternatives to be more spreadable in appearance, have a creamy texture/mouthfeel and have a more balanced, cream-like and cheesy taste/flavour. A more creamy...
texture could be modified using different proportions of butyric acid commonly found in plants (Bachmann, 2001). Moreover, most commercial PB cheese alternatives are developed without ripening or using starting cultures and enzymes (Jeske et al., 2018). However, previous studies showed that the taste/flavour and texture of PB cream cheese could be influenced by fermentation using starter cultures, which affects the flavour, creamy texture and spreadability (Jeske et al., 2018; Masiá et al., 2021; Masiá, Jensen, Petersen, & Buldo, 2022). Respondents would like PB cream cheeses to have a less white appearance but remain firm and uniform. The results suggest that consumers wish for PB cream cheese alternatives resembling the sensory attributes of dairy-based cheese products, such as a more spreadable appearance, creamy texture, and cheesy taste and odour.

4.1.5. PB Chicken and beef alternatives

As respondents stated a desire for improvements in PB chicken and beef alternatives regarding meat-like taste, texture and odour, this suggests that consumers desire PB chicken and beef alternatives to resemble the sensory properties of meat. Previous studies have demonstrated that adding seasonings or plant-based spice mixtures can reduce off-flavours and contribute to a poultry-like flavour (Fiorentini et al., 2020). Flavours of cooked meat are complex and, therefore, challenging to mimic in PB meat alternatives. Meat is typically rich in umami taste. The umami taste in PB meat alternatives could be created using umami-rich PB foods or flavourings such as nutritional yeast (Fiorentini et al., 2020). Tenderness and juiciness are important sensory attributes affecting consumers’ acceptance of meat products (Font-i-Furnols & Guerrero, 2014). Creating a meat-like texture/mouthfeel using PB protein and fat sources is one of the biggest challenges for PB meat manufacturers, as PB fat generally has a lower proportion of saturated fat than animal-based fat. There are several technological strategies to improve the texture of PB meat products in tenderness and juiciness and to create a more meat-like structure. A desirable texture largely depends on the type or combination of PB protein and fat selected. PB protein textures could be modified using additives, processing or culinary techniques (Fiorentini et al., 2020). To create fibrous textures from plant protein isolates and concentrates, extrusion techniques, for instance, high moisture extrusion, are widely used processing techniques in the industry as they can be easily applied to produce on larger scales (Dekkers, Boom, & van der Goot, 2018).

4.2. Liking of PB food products

The respondents stated lower liking of the category of PB semi-hard cheese alternatives. PB semi-hard cheese alternatives were also identified as the PB food product category with the demand for the largest improvements in terms of sensory quality. Generally, vegan respondents reported higher liking scores for the studied PB food alternatives than...
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2003; Szejda, Urbanovich, Innovation theory, vegans would be considered respondents with other dietary lifestyles. According to the Diffusion of dietary lifestyles.

Comparison of mean liking of currently available plant-based milk, yoghurt, semi-hard cheeses, cream cheese, chicken and beef products across European regions and

Table 3

Comparison of mean liking of currently available plant-based milk, yoghurt, semi-hard cheeses, cream cheese, chicken and beef products across European regions and dietary lifestyles. a,b

PB = plant-based. a Results are presented as mean (SD) for the continuous variable age and as counts (percentages) for categorical variables.

PB = plant-based. a,b,c Significant differences between country of residence and between dietary patterns in mean liking of the six plant-based alternatives are shown in superscript letters (ANOVA posthoc Tukeys test).

a Results are presented as mean (SD).

b 9-point hedonic scale: 1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike slightly, 4 = Dislike slightly, 5 = Neither Like nor Dislike, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely.

c No results showed for “omnivores”, due to low number of respondents.

d No results showed for “Central Europe”, due to low number of respondents.

consumers group to try and regularly consume PB food alternatives.

Table 2

Descriptive statistics for consumers of plant-based milk, yoghurt, semi-hard cheeses, cream cheese, chicken and beef. a

PB = plant-based.

a Results are presented as mean (SD) for the continuous variable age and as counts (percentages) for categorical variables.
4.3. Strengths and implications

Sensory benchmarking of PB food alternatives is crucial prior to developing alternative protein sources and processes. The developed sensory benchmarking methodology was a strong tool for determining the presence of sensory attributes of both CA and ideal products. Using an online survey was a cost-effective and logistically attainable way to achieve a large number of consumer descriptions of the sensory profile of studied plant-based products. More so, it provided high external validity as the respondents were regular consumers familiar with the product categories and not biased by product brands or trained to respond to questions in a specific manner. The translation of the survey into different languages allowed a greater reach. Additionally, having more languages available increases the respondents’ willingness to answer the survey as they can choose the language they are proficient in. When using sensory attributes in consumer surveys, it is crucial to consider the consumer’s understanding of these. It is recommended that sensory attributes developed by a trained panel are adjusted from professionally described sensory attributes to consumer-friendly terms, eventually supported with explanations in the brackets, as done in this survey. PB food production companies can easily adapt the methodology to give clear pathways for product improvement. However, food producers should ideally follow up with consumer acceptance testing of new prototypes. This exploratory study clearly illustrated a gap in consumer’s sensory-based cognition between CA and their ideal versions of these products (yet to be developed. The findings showed that consumers demand PB products mimicking animal-based products, thus suggesting that food familiarity is important. Overall, this study provided strategic information for future consumer-centric development of PB food categories and for creating new market opportunities considering the demand. Sensory improved products will enhance their adoption by mainstream consumers, support market growth, provide products with a considerably lower environmental footprint, and increase dietary diversity among consumers.

4.4. Limitations

Some limitations of the study have been discovered and should be considered in future work on sensory benchmarking of PB food alternatives. First, the online consumer survey was extensive, and six different PB food categories were included. However, including multiple food categories could allow for comparison across food categories regarding consumers’ sensory-based cognition towards the desired sensory quality and improvements needed for PB food alternatives. Second, the phrase ‘plant-based’ rather than ‘vegan’ was consistently used in the survey. The term ‘vegan’ has been found to have various negative associations; however, it might be a more commonly used term (Buddle, Bray, & Ankeny, 2018; Faber et al., 2020; Maclnms & Hodson, 2015). All concepts and terms used in the survey were clearly stated in the introduction text to avoid or minimise misconceptions. Furthermore, the statements and attributes in the survey have been formulated to obtain a general characterization of the sensory performance of the food category on the market. Third, no quotas or randomisation was used in the sampling method; therefore, the sample is not representative of the countries’ populations; hence, the results should be interpreted with care. Most respondents were female and followed a vegan, vegetarian or flexitarian diet, which resulted from snowball sampling and might detract from the findings’ generalisability. However, the study’s purpose was to conduct a sensory benchmarking study of PB alternatives, and the inclusion of a sufficient number of consumers of PB alternatives was essential. Even though the results are not fully generalizable, they provide strategic insights into a group of consumers leading the direction in dietary shifts towards more plant-based eating and who can provide an informed assessment of their experience with these products.

5. Conclusion

This study identified potential gaps between consumers’ sensory-based cognition of CA and ideal versions (yet to be developed) of PB chicken, beef, semi-hard cheese, cream cheese, yoghurt and milk alternatives. Findings suggest that consumers were satisfied with the CA PB food alternatives because none of the product categories received an average liking score below ‘Neither like nor dislike’ (Liking > 5 out of 9). However, consumers suggested directions for sensory quality optimization. Consumers stated that they desire minor sensory modification for PB milk and yoghurt alternative categories. However, the category of PB semi-hard cheese alternatives needs substantial improvements towards more cheese-like, less artificial and less bland attributes. Additionally, for PB beef alternatives, the ideal products should have a more umami taste and beef-like taste and odour; for PB chicken alternatives a more chicken-like taste, texture and odour is desired; for cream cheese alternatives, a more balanced, cheesier and less artificial taste and odour is desired. These findings strengthen the strategic insights to direct the product development of PB food and beverage alternatives.

CRediT authorship contribution statement

Sandra S. Waehrens: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Visualization, Writing – original draft. Ilona Faber: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Visualization, Writing – original draft. Limei Gunn: Investigation, Methodology, Writing – review & editing. Patrizia Buldo: Methodology, Resources, Writing – review & editing. Michael Bom Frost: Writing – review & editing. Federico J.A. Perez-Cuetos: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

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.

Data availability

The processed data used for creating the Figures are available at https://osf.io/qykt5/.

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Appendix A. Supplementary data

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References

