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Sensory characterisation and consumer acceptance of plant-based cheese alternatives – A Swiss perspective

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ABSTRACT

Consumer interest in plant-based cheese alternatives (PBCAs) has grown due to concerns about the environment, animal welfare, and health. This study assessed consumer preferences and sensory characteristics of PBCAs in the Swiss market. Four semi-hard and two soft cheese alternatives were evaluated in a consumer test with 219 participants (102 males, 117 females, diverse diet forms). Participants rated overall liking and visual appeal on a 9-point hedonic scale and assessed sensory attributes using check-all-that-apply and just-about-right scales. They also answered questions about attitudes towards plant-based alternatives. Sensory panel data ($n = 10$) completed the study by linking it to the consumer data. The chemical composition of the PBCAs was analysed for dry matter, fat, protein, salt, starch, and sugar content. Statistical analyses, including ANOVA and multiple factor analysis, were used to evaluate preferences and identify sensory attributes influencing liking.

Participants rated PBCAs as trendy but were less convinced of their taste or processing compared to dairy cheeses. Significant differences in overall liking and visual appeal were found, but none of the products were highly liked (scores between 3 and 5.9). No significant differences were observed between dietary groups. Attributes like savoury flavour, smooth texture, and creaminess were positively associated with liking, while bitterness and lack of creaminess were negatively associated. Consequently, to increase acceptance and consumption, PBCAs' sensory profiles and nutritional compositions should be optimised.

1. Introduction

In recent years, there has been an increasing consumer trend towards a more plant-based diet, driven by a growing interest in sustainable food, health concerns and animal welfare (Alehosseini et al., 2025; Janssen et al., 2016; Short et al., 2021). With growing awareness of ethical concerns regarding the treatment of farmed animals or the negative environmental impacts associated with animal agriculture, many consumers are willing to choose plant-based alternatives to reduce their carbon footprints and support more sustainable food systems (Falkeisen et al., 2022a; Pointke et al., 2022; Waehrens et al., 2023a). Furthermore, the growing popularity of plant-based products is being driven by health considerations such as lactose intolerance and milk allergies, as well as the desire to reduce fat intake, especially saturated fat and cholesterol (Boukid et al., 2021; Glover et al., 2024). According to a Swiss survey of more than 2000 participants commissioned by a Swiss retailer to a professional consultancy, cholesterol content and possible negative effects on the cardiovascular system are the two most important health reasons for avoiding animal products (COOP, 2024). Consequently, the market for plant-based foods as alternatives to meat and dairy products has undergone a period of dynamic growth and transformation, driven by these changing consumer preferences for healthier, more animal-friendly and environmentally sustainable food choices (Aschemann-Witzel et al., 2021; Boukid et al., 2021).

The wide range of high-quality dairy cheeses produced in Switzerland is well known and dairy cheese is still an important

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economic factor in the Swiss food agribusiness sector. By contrast, among the range of plant-based foods available on the market, plant-based cheese alternatives (PBCAs) still only account for a small share of the market for plant-based alternative products. In Switzerland, for example, the market share of plant-based cheese alternatives was 0.7 % in 2021, of the total dairy market (Federal Office for Agriculture, NCCS, n.d.). Nevertheless, it is estimated that the global average per capita consumption of PBCAs will be 0.01 kg in 2025, with a turnover of approximately €959.55 million Euros ("Statista - Das Statistik-Portal," n. d.).

PBCAs are defined a plant-based cheese alternative as "an edible material prepared from plant ingredients that is designed to have a similar appearance, texture, and flavor as animal-based cheeses" (Grossmann & McClements, 2021). Other than dairy cheese, PBCAs can be made from a variety of plant materials. Therefore, their production requires the selection of suitable ingredients and technological processes (Grossmann & McClements, 2021). In general, the technologies used today to produce PBCAs are still similar to those traditionally used in the dairy cheese sector. (Craig et al., 2022) and innovations in cheese technology have not specifically focused on the PBCA segment (Harper et al., 2022).

The basic idea behind the production of PBCAs is to replace animal protein and fat components with plant-based alternatives that are ideally equivalent in terms of nutritional value and functional properties (Kamath et al., 2022). In general, PBCAs are non-fermented products primarily made from oils (e.g. coconut) and starches (e.g. potato). This enables production of a product with fat content and structure similar to dairy cheese, addressing the typically low fat and protein levels in plant-based ingredients. This type of PBCA appears to be widespread in the commercial sector. According to Saraco and Blaxland (2020), 80 % of PBCAs in the UK are based on coconut or palm oil, and it is likely that the Swiss PBCA market is similar. By contrast, the small number of commercially available fermented PBCAs are often cashew nut-based (Harper et al., 2022), since cashew nut proteins have pronounced thickening properties (Grossmann & McClements, 2021). Comprehensive reviews of the ingredients and production technologies used for PBCAs were provided by Grossmann and McClements (2021), Kamath et al. (2022), and Lima et al. (2022).

As for many foods, the flavour dimension of PBCAs is considered one of the most important drivers of consumer acceptance, and the lack of aroma and taste of PBCAs seems to be one of the main limiting factors for the regular consumption of these products (Appiani et al., 2023; Laassal & Kallas, 2019). Similarly, the lack of flavour of plant-based alternatives compared to traditional meat products is one of the main factors preventing consumers from incorporating them into their daily diets (Grasso et al., 2021). Qualitative interviews on plant-based alternatives to dairy and meat products have shown that flavour is a decisive factor in consumption, although appearance also plays an important role. If a product resembles meat, its plant-based counterpart must have comparable sensory characteristics, i.e. taste, aroma and texture (Mehner et al., 2024). In addition, the distinct aftertaste of many PBCAs has a negative impact on consumer acceptance of these products (Amyoony et al., 2023). In particular, the presence of undesirable "beany" notes caused by specific aldehydes, alcohols and ketones, can make people reluctant to introduce plant-based dairy alternatives into the diet (Harper et al., 2022). Furthermore, mimicking the texture of traditional dairy products using plant-based foods such as PBCAs is a technological challenge, given that texture is a key factor in consumers' acceptance of these products (Boukid, 2024).

According to Short et al. (2021) there are two possible approaches to addressing the overall sensory profile of PBCAs. The first option and most common approach is to try to imitate the sensory profile of the animal based products, as many consumers seem to prefer PBCAs that resemble traditional animal-based cheeses in terms of their sensory characteristics (Amyoony et al., 2023; Aschemann-Witzel et al., 2021). However, as the physicochemical properties of plant-based raw materials differ from those of milk, it is only possible to partially replicate the sensory characteristics and nutritional composition of animal-based cheeses when formulating PBCAs. Fermentation by lactic acid bacteria might offer an interesting possibility to influence the especially the flavour profile of PBCAs in the desired direction towards dairy cheese. For example, a reduction in off-flavours and an increase in flavour notes positively associated with dairy products by a mixture of *B. subtilis* and selected lactic acid bacteria were found in whole beans and protein concentrates of different pea and bean varieties, chickpeas and faba bean protein (Fernández-Varela et al., 2024; Mwangi, 2024). Furthermore, fermentation of soy milk with lactic acid bacteria resulted in improved spreadability, more stable structure and higher consumer acceptance compared to non-fermented PBCAs (Li et al., 2013). A general review of recent research on the fermentation of plant-based foods is provided by (Mefleh & Darwish, 2024) and (Alehosseini et al., 2025).

The second approach mentioned by Short et al. (2021) focuses on promoting the specific flavour components of the plant raw material, recognising that the sensory profile of PBCAs cannot be compared to the original animal product (Falkeisen et al., 2022a; Kamath et al., 2022).

For example, qualitative focus group discussions revealed that the desire to experience new tastes was one of the main motivations for trying dairy-based alternatives. Those who prioritised diversifying their food choices, including increasing flavour variety, were particularly willing to incorporate plant-based products into their diets (Adamczyk et al., 2022). In this context, the group of flexitarians is supposed to be an important target group, as they are more likely to diversify their diet with more plant-based products ("Smart-Protein-European-Consumer-Survey_2023," n.d.).

2. Main research focus

Studies focusing on the sensory perception of commercial PBCAs by tasting real products are still limited, and most of these studies concluded that the sensory profile of many PBCAs does not meet consumer expectations (Amyoony et al., 2023; Boukid et al., 2021; Falkeisen et al., 2022).

Given the long tradition of cheese making and the importance of cheese in Swiss food culture, it is plausible that most of the Swiss consumers have high expectations of the sensory qualities of cheese, such as flavour and texture (Liggett et al., 2008). Accordingly, it can be assumed that consumers who frequently eat or have eaten cheese also have clear expectations regarding the sensory properties of PBCAs that are on the market or are to be introduced as substitutes for animal-based cheese. According to an online survey of participants across Europe on different categories of plant-based food alternatives, the main differences between the expected and perceived characteristics of semi-hard PBCAs on the market were described as not being cheesy and umami-like enough, and too bland and artificial (Waehrens et al., 2023).

As most studies on PBCAs are based on surveys rather than extensive tasting of real products (Falkeisen et al., 2022; Jaeger et al., 2024), the present study aimed to collect data on the sensory perception of selected real PBCA products available on the Swiss market.

The main objectives of the study were

i) to investigate consumer preferences and sensory perceptions of selected PBCAs commercially available on the Swiss market,
ii) to identify sensory attributes that influence PBCA liking,
iii) to investigate consumer segmentation
iv) to establish a general baseline of perception/acceptance of selected PBCA categories with the aim of monitoring potential changes in the future, i.e. improvements of the sensory profile and consequently of consumer acceptance over time.

The research was carried out as a collaboration between six Swiss institutions and companies: Agroscope Liebefeld, Berne; ETH Zurich, Zurich; University of Applied Sciences (HAFL), Berne; University of

Applied Sciences (ZHAW), Zürich; SAM Sensory and Consumer Research, Zurich, and SensoPLUS, Zug.

3. Materials and methods

3.1. Selection of products

3.1.1. Market analysis and screening

We conducted an informal survey of PBCAs available on the Swiss market. The largest. Swiss retailers and online platforms for vegan products were analysed for PBCAs, with a particular focus on the diversity of products and the potential market shares of individual products advertised as substitutes in different cheese categories. The aim was to identify the most representative sample of products covering a wide range of animal-based cheeses. We then conducted a sensory benchmark test with a total of 19 samples covering 5 "cheese" categories including hard, semihard, soft, fresh and grill cheese alternatives. This selection step revealed that, within a product category, products often differed mainly in terms of their added flavour notes, which limited the sensory diversity of products within a category. In addition, many products, particularly those advertised as alternatives to hard cheese, had an intense and unpleasant off-flavour such as rancid, oxidized notes, most likely due to their high oil content. Therefore, we decided not to include these products in the consumer test, as rancid off-flavours are not acceptable for test samples and additionally, they strongly deviated from the corresponding animal-based cheese product or category. Finally, two samples from each of three different product categories (slices representing semi-hard products, cheese in block form representing semi-hard products, soft cheese) were selected resulting in a total of six products for the consumer test (Table 1). PBCAs were selected to represent the 'cheese' category, which includes widely consumed Swiss products such as semi-hard and soft cheeses. The products also had to be available on the market in similar forms, such as slices and blocks. These two serving forms result in a different texture perception. Finally, care was taken to ensure that the products did not all come from the same producer.

As the selection step showed that the sensory profiles of the various PBCAs clearly differed from those of dairy cheese, we decided not to include dairy cheese in the design, as this would have led to less discrimination in the sensory tests.

As all the products were purchased from the market, no information was available regarding the production date or technology. However, for the sensory tests, care was taken to ensure that all samples within the product group were from the same production batch. Concerning product age, a slight deviation (max. ±14 d) between each product type (block, slice, soft) had to be taken into consideration (some were closer to their indicated best before date than others, e.g. soft cheese).

3.2. Consumer test

3.2.1. Participants

A total of 219 participants (102 male, 117 female) were recruited from the pool of consumer panels of the collaborating institutions. Selection criteria were designed to represent a broad demographic spectrum, including age (≥18 years), gender, diet type and familiarity with plant-based cheese products. Participants were screened to ensure a balanced representation of sensory acuity, with no reported allergies or aversions to the products tested. Table 2 summarises the characteristics of the participants of the consumer study. All participants provided written consent when starting the tasting confirming that they were taking part in the test on a voluntary basis. They were informed of the anonymity of the data collection and of their right to withdraw from the study at any time without giving a reason. They were compensated for their participation. Testing followed the principles outlined by the Declaration of Helsinki.

Table 1
Composition of the tested plant-based cheese alternatives according to the declaration on the packaging.

Block 1	Water, coconut oil, modified starch, starch, salt, aroma, olive extract, β-carotene
Block 2	Water, coconut oil, modified starch, protein starch, lupine flour, salt, citric acid, aroma, sorbic acid
Slice 1	Almonds, coconut oil, modified starch, salt, aroma, potato protein, carrot (colour), apple (colour), citric acid, Na-ascorbate
Slice 2	Water, coconut oil, modified starch, starch, sea salt, apple juice concentrate, Emmental flavour, olive extract, β-carotene, Vitamin B12
Soft 1	Cashew nuts, water, salt, ripening cultures (moulds & bacteria)
Soft 2	Cashew nuts, water, salt, lactic, acid, ripening cultures

3.2.2. Questionnaire

All participants were asked to rate their overall liking of the six samples on a hedonic 9-point category scale, anchored at the left end with 'do not like at all' and at the right end with 'do like extremely'. The same scale was used to rate the visual impressions following the oral evaluation of the samples. In addition, participants described their perception of the sensory characteristics of the samples by ticking all applicable attributes from a given list of 39 attributes (the check-all-that apply (CATA) method). The CATA terms belonging to the same sensory modality were grouped together. First came the visual attributes, followed by the texture and flavour terms. Within each of the three sensory modality blocks, the CATA terms were randomised across samples as well as across participants. This method was chosen because it is a well-accepted and effective tool for the sensory description of foods by consumers (Pineau et al., 2022). Moreover, all participants rated the subjectively perceived intensity of five attributes - firm, creamy, salty, bitter, and overall flavour - on a 5-point just-about-right (JAR) scale with the anchor points "much too little pronounced" (left end of the scale) and "much too pronounced" (right end of the scale).

All participants were also asked to answer demographic questions and to report their frequency of consumption of plant- and animal-based cheeses. The participants rated their agreement with 10 different self-developed statements about plant-based cheese on a scale from 1

Table 2
Demographic characteristics of participants in the consumer study (n = 219).

		Omnivore [%] (n = 124)	Flexitarian [%] (n = 73)	Vegetarian/ vegan [%] (n = 22)
Gender	Female	54.0	54.8	45.5
	Male	46.0	45.2	54.5
Age	18—30 years	29.0	27.4	50.0
	31—40 years	15.3	15.1	22.7
	41—50 years	24.2	20.5	22.7
	51—60 years	17.7	24.7	4.5
	> 60 years	13.7	12.3	0.0
Place of residence	City	43.5	39.7	63.6
	Intermediate	29.0	42.5	22.7
	Rural	27.4	17.8	13.6
Cheese consumption	Daily	15.3	16.4	4.5
	4—6 times /week	28.2	34.2	18.2
	1—3 times/week	43.5	38.4	36.4
	1—3 times/month	9.7	11.0	18.2
	< 1—3 times/ month	3.2	0.0	9.1
	Never	0.0	0.0	13.6
Consumption plant-based dairy products	Daily	7.3	5.5	31.8
	4—6 times /week	8.1	9.6	31.8
	1—3 times/week	21.8	24.7	9.1
	1—3 times/month	28.2	32.9	13.6
	< 1—3 times/ month	24.2	15.1	9.1
	Never	10.5	12.3	4.5

(strongly disagree) to 6 (strongly agree).

3.2.3. Data collection

The tasting order of the three types of PBCAs, as well as the order of the two samples within each of the three categories, followed a William Latin square design. All samples were coded with a random three-digit code and kept at 14 °C until testing. Sensory testing was done at room temperature under daylight conditions. Still water and neutral crackers were provided for neutralisation between samples. All data were collected using the SensoPLUS software (Zug, Switzerland).

3.3. Characterisation of the PBCAs

3.3.1. Objective sensory characteristics

An objective sensory evaluation of the 6 PBCAs evaluated in the consumer test was performed by a trained panel ($n = 10$). All the panellists regularly take part in sensory testing and are highly experienced in using a standardised language to objectively describe the sensory characteristics of cheese.

During the training, the panellists selected attributes that applied to them from a list regularly used for cheese profiling, with the aim of getting an idea about potential differences of the sensory profile of the plant-based cheese alternatives to that of a corresponding animal-based cheese. The list of attributes was complemented with attributes characteristic of plant-based products. For the latter, reference samples were provided to anchor the right, i.e. high-intensity end of the scale.

Each panellist rated the intensity of 20 attributes on an unstructured 100-unit line scale anchored with no intensity on the left and very high intensity of the corresponding attribute at the right end of the scale. The different sample types (block, slices, soft products) were served in separate sessions. All products were evaluated in duplicate. The block-style products were served in 1.5 cm cubes. Of the sliced variants, a whole slice of each product was provided. The loaves (100–120 g) of soft products were cut into 12 pieces, so each panellist received a sample of approximately 8–10 g. Panellists were free in how they tasted the sample. Samples were coded with a 3-digit number and presented according to a William Latin square design. All samples were served at 14 °C under daylight conditions. Still water and neutral crackers were provided for neutralisation between samples. Data were collected using FIZZ software (Version 2.61, Biosystèmes, France).

3.3.2. Chemical characterisation

The content of dry matter, ash, fat, total nitrogen, and NaCl, as well as starch and sugar contents of all the vegetable cheese alternatives, were determined. The loss due to drying and the ash content were determined gravimetrically. After drying for 4 h at 102 °C the samples were heated up to 550 °C to determine the ash content. Fat content was determined by butyrometry according to the Gerber—van Gulik method. Total nitrogen was determined by potentiometry according to the Kjehldahl method. The NaCl content in the PBCAs was calculated from the chloride content, which was determined argentometrically. The amount of starch and the concentration of sugars were determined enzymatically. No micronutrient analysis was performed.

3.4. Statistical analysis

For preference/consumer data, a 2-way ANOVA model (participant and product) followed by a Duncan's multiple range test ($p \leq 5$ %) was chosen. Classic penalty analysis was used to evaluate the JAR data. A correspondence analysis was conducted to analyse the CATA data (Vidal et al., 2015). Hierarchical cluster analysis based on Euclidean distance and the Ward method was used to segment consumers based on their sample liking scores, followed by a penalty-lift-analysis to assess the impact of each characteristic on the overall liking (Meyners et al., 2013). Sensory profiling data was analysed using a mixed model 3-way analysis of variance (ANOVA) with the factors 'panellist', 'product' and 'repetition'. Statistical analyses were performed using XLSTAT version 23.1.6. External Preference Mappings were conducted using R (Version 4.5.0) and the carto function from the *SensoMineR* package (Version 1.27). This approach enabled the visualization and interpretation of consumer preferences in relation to the sensory profile of the products. The contour plots were created with the quadratic regression model in carto.

4. Results

4.1. Consumer testing

4.1.1. Characterisation of participants

Demographic information on the participants grouped according to their indicated diet form revealed that only a few vegetarians/vegans participated in the study (Table 2).

Except for the relatively small group of declared vegetarians and vegans ($n = 22$), the percentage of participating females was slightly higher. Furthermore, the group of vegetarians/vegans consisted mostly of young students who lived in an urban area, whereas the other two diet type groups showed comparable age and living patterns.

Frequency data on cheese consumption showed that all three dietary groups consumed cheese regularly. More than 85 % of omnivores and flexitarians reported consuming cheese at least 1—3 times per week. In the vegetarian/vegan group, more than 50 % reported eating cheese at least 1—3 times per week, while only 13.5 % of participants in this group reported not eating cheese, which refers to those following a vegan diet. As expected, the consumption of plant-based dairy products was highest in the vegetarian/vegan group. More than 60 % of this group reported consuming plant-based dairy alternatives at least 4—6 times per week, whereas more than 60 % of the other two groups consumed these products 1—3 times per month or less (Table 2).

4.1.2. Attitudes towards plant-based cheese alternatives

Participants following a vegetarian or vegan diet had the highest average agreement with all statements except for the statement that PBCAs are more processed than traditional cheese (Fig. 1). With mean scores ranging from 5 to 5.6, the statement that PBCAs are trendy received the highest level of agreement from all three dietary groups, while all participants agreed least with the two statements that PBCAs are less processed and taste better than traditional cheese. Compared to the participants who followed a flexitarian diet or regularly consumed meat, the vegetarian/vegan group of participants was significantly more likely to agree that plant-based products are more climate-friendly, support animal welfare and taste better than their animal-based counterparts. In addition, there was a clear but statistically non-significant trend for vegetarians/vegans to perceive PBCAs as trendier and higher in vitamins and minerals than the other two dietary groups. The mean approval rates of the health statement and other related statements regarding nutritional aspects (fewer calories, easier to digest) were not significantly different based on the participants' diet type.

4.1.3. Overall liking and visual liking

The six PBCAs selected from the range of products commercially available on the Swiss market differed significantly in terms of overall liking and visual liking (Fig. 2). The two slices and the two blocks showed a higher mean visual liking score compared to the overall liking score, while the two soft cheese alternatives showed the opposite behaviour (Fig. 2). Overall, the highest mean value for overall liking was observed for Slice 1, which was significantly more liked than the other five PBCAs tested, whereas Soft 2 showed the lowest mean value for overall liking. However, with average scores ranging from 4 to 5.9 on the 9-point hedonic scale, none of the products tested were highly liked (Fig. 2).

No significant differences in overall liking were observed across the three dietary groups for any of the tested PBCAs. However, the mean

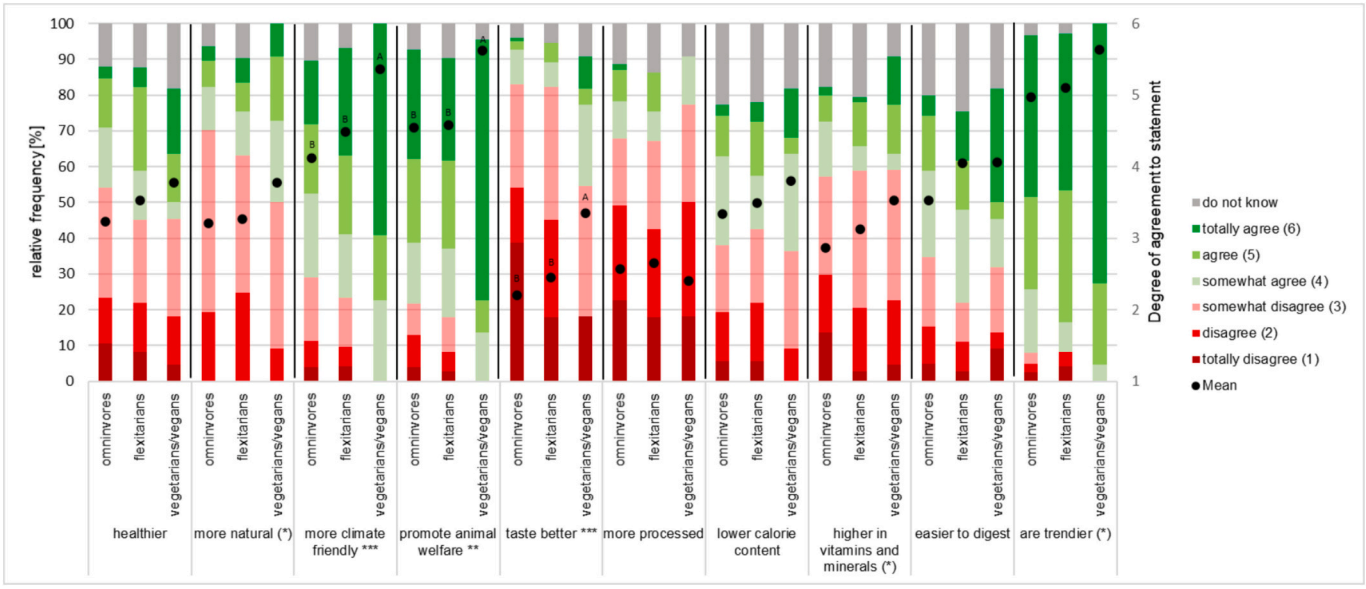


Fig. 1. Frequency distribution and mean value of agreement with selected statements grouped by declared diet type (omnivores: $n = 124$, flexitarians: $n = 73$, vegetarians/vegans: $n = 22$)
Scale from 1 (not agree at all) to 6 (totally agree)
***: significant difference ($p \leq 0.001$), **: significant difference ($p \leq 0.01$),
(*): significant difference ($p \leq 0.1$) Mean values with different letters are significantly different ($p \leq 0.05$).

visual liking scores for Block1 and Soft1 differed significantly between the dietary groups ($p \leq 0.05$). Both products received significantly lower mean scores from the omnivores than from the vegetarians/vegans (ANOVA fixed factorial model, data not shown). However, the vegetarian/vegan group was much smaller than the other two groups, conclusions are limited.

Within each dietary group the liking order of the six products was similar. Slice 1 was liked the most and Soft 2 was the least liked product by all three groups (Table 3). In the omnivore group several products were equally (dis)liked, whereas within the flexitarians more distinct differences in liking between products were observed compared to the other two dietary groups although this group of participants showed the smallest range of liking means, with values ranging from values between 5.9 and 4.3. Higher ratings were given for visual liking than for overall liking, with the exception of the two soft alternatives (Table 3).

Grouping the liking scores by additional demographic factors, such as gender or age did not result in any significant differences between these demographic groups (results not shown).

4.1.4. Sensory product description by consumers

Table 4 summarises the number of frequencies of the attributes provided to describe the qualitative characteristics (CATA list) observed for each of the six PBCAs. The CATA data was analysed by correspondence analysis (CA) to identify the sensory properties associated with each of the six PBCAs evaluated (Fig. 3). As expected, the two PBCAs representing soft cheese were perceived as clearly different from the four other tested products. Visually, the two soft cheese alternatives were mainly characterised by a greyish or beige colour, whereas Slice1, Slice 2 and Block 1 were described as yellowish and Block 2 was described as white.

The two blocks and two slices also had a smooth and uniform texture, whereas the texture of the two soft cheese alternatives was perceived as irregular by many participants.

Participants perceived distinct differences between the two block-style PBCAs in terms of firmness, elasticity, gumminess, and flavour. Block 2 was described as soft, gummy, and sticky, receiving high mentions (51.1 %, 70.3 %, and 32.9 %, respectively), while Block 1 was characterised as compact (55.7 %) and firm (50.2 %). Block 1 was perceived as aromatic, salty, and umami/bouillon-like, contrasting with Block 2's buttery and milky flavour profile, a description that might have been influenced by the white colour of this product.

Slice 2 was described as sweet and nutty by about a quarter of the participants, suggesting that the Emmental flavour added according to the product declaration evoked the perception of flavour notes typically mentioned for animal-based Swiss cheese.

About half of the participants described the two soft cheese alternatives as creamy and soft, with mushroom-like and rather musty aromas. Furthermore, Soft 2 was also relatively often perceived as bitter.

4.1.5. Impact of selected sensory characteristics on overall liking

A penalty analysis was conducted using the overall liking scores and JAR data (Table 5).

A third of participants perceived Block 1 as too firm and more than half as not creamy enough, resulting in a significant decrease in the overall liking score. Furthermore, approximately a quarter of the participants found this product not salty enough. Participants were divided in their opinion on the flavour aspect, with over a third indicating that it was too strong and around 20 % claiming that it was not strong enough. Block 2 had the second lowest liking score of all the tested PBCAs. The results of the penalty analysis suggest that its lack of firmness, saltiness, and low flavour intensity had the most negative impact on its overall liking. Regarding the product's creaminess, participants were divided into two groups. Around a quarter of participants found the sample not creamy enough, while a similar proportion found Block 2 too creamy. These two factors both had a negative impact on the overall liking score.

For both sliced products, the results indicated that the overall liking score was negatively influenced by the intensity of perceived creaminess and the overall aroma, which, for both attributes, was perceived as not strong enough by a relatively high percentage of participants.

With JAR values of 68 % and 82 % for firmness and bitterness, respectively, the perceived intensity of Slice 2 was in the desired range for the majority of participants with these two characteristics. In contrast, Slice 1 was rated as too firm and not salty enough which also seemed to reduce the overall liking score of this product. Both soft products were rated as not firm enough by a high percentage of participants, which had a significant negative impact on the liking score for

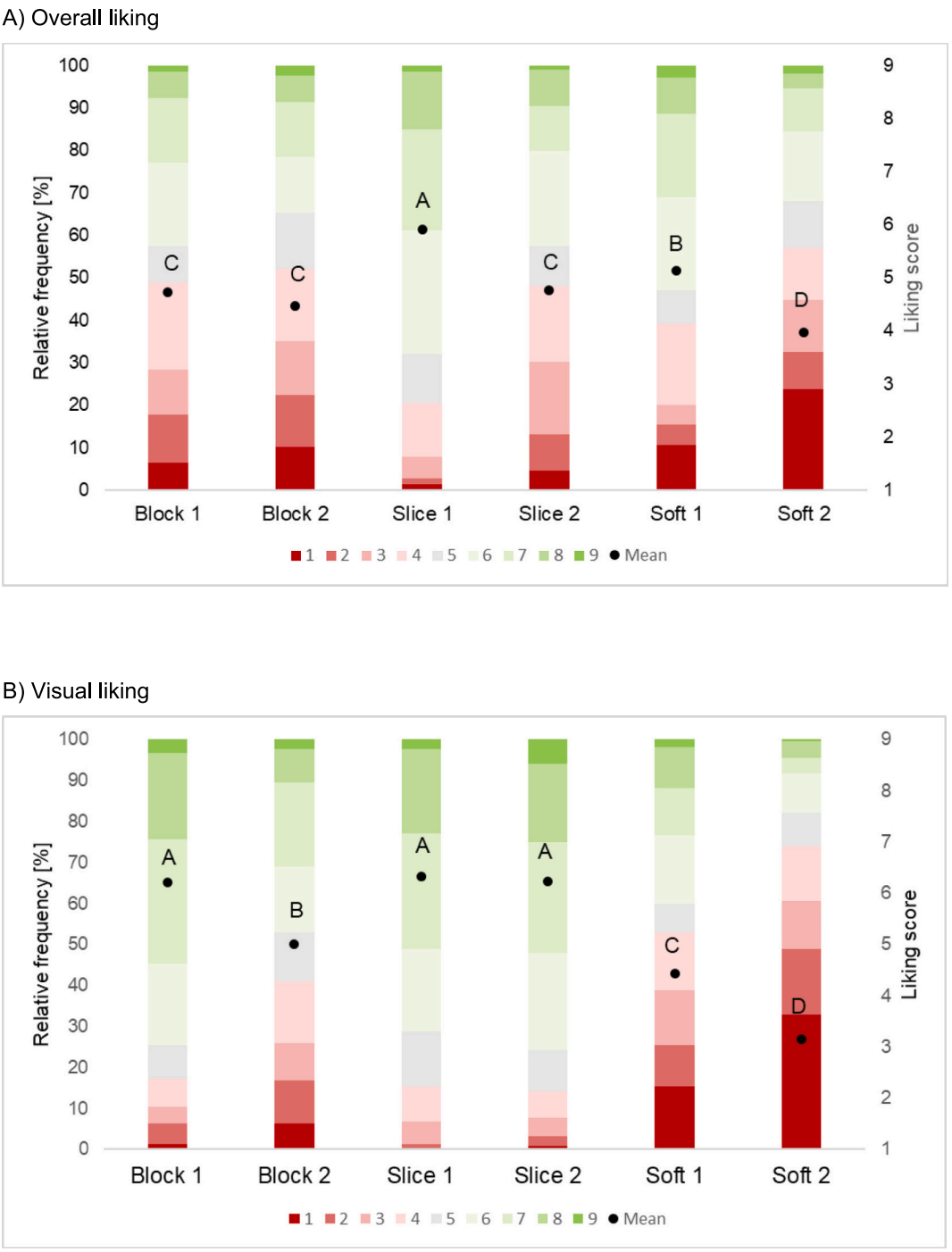


Fig. 2. Frequency distribution and mean value ($n = 219$) of overall liking scores (A) and visual liking scores (B) of the tested cheese alternatives (1 = do not like at all, 9 = do like extremely) and results of mean separation test (Duncan multiple range test). Means with different letters are significantly different ($p \leq 0.05$).

both samples. The results further indicated that the low liking score for Soft 2 was influenced by bitterness and overall flavour, as indicated by the high proportion of participants who rated Soft 2 as too bitter and too strong in flavour.

4.2. Objective characterisation of the PBCAs

4.2.1. Objective sensory characteristics / sensory profiling

A set of 20 flavour and texture descriptors, most of which are also commonly used for the quantitative evaluation of dairy cheese was selected to profile the PBCAs. To compare the sensory profiles of the three tested categories of PBCAs, the full set of attributes was used for all products, knowing that certain attributes would not be relevant for all three categories. The results of the objective sensory evaluation of the six PBCAs evaluated in the consumer test are shown in Fig. 4.

On average, overall aroma intensity was rated relatively low for all three types of PBCAs tested, with mean intensity values over the whole panel ranging from 32 to 49. The other aroma attributes and all taste attributes showed even lower mean intensity values for all PBCAs evaluated. According to the results of the mixed ANOVA model of the 20 attributes evaluated, only seven attributes differed significantly ($p \leq 0.05$) between the two PBCAs served as blocks (Fig. 4A) and six and five of the 20 attributes showed a significant difference in intensity between the two sliced PBCAs and the two soft cheese PBCAs, respectively

Table 3
Overall liking and visual liking grouped by self-declared diet form: Mean, standard deviation and results of mean separation test (Duncan multiple range test) within each diet group. Means with different letters are significantly different ($p \leq 0.05$).

	Overall liking									Visual liking								
	Omnivore			Flexitarian			Vegetarian/ Vegan			Omnivore			Flexitarian			Vegetarian/ Vegan		
	(n = 124)			(n = 73)			(n = 22)			(n = 124)			(n = 73)			(n = 22)		
	Mean	Std		Mean	Std		Mean	Std		Mean	Std		Mean	Std		Mean	Std	
Block 1	**4.5**	2.1	B	**5.1**	2.0	BC	**4.8**	1.8	BC	**5.9**	1.9	A	**6.6**	1.7	A	**6.3**	1.7	AB
Block 2	**4.5**	2.2	B	**4.5**	2.1	D	**4.2**	2.6	C	**5.1**	2.0	B	**4.8**	2.3	B	**5.5**	2.4	B
Slice 1	**5.9**	1.5	A	**5.9**	1.7	A	**6.0**	1.6	A	**6.2**	1.6	A	**6.4**	1.5	A	**5.8**	1.6	AB
Slice 2	**5.0**	2.0	B	**4.6**	1.9	CD	**4.3**	1.8	C	**6.2**	1.7	A	**6.4**	1.6	A	**6.7**	1.5	A
Soft 1	**5.0**	2.3	B	**5.3**	2.1	B	**5.6**	1.7	AB	**4.1**	2.4	C	**4.7**	2.3	B	**5.7**	1.7	AB
Soft 2	**3.8**	2.3	C	**4.3**	2.4	D	**3.9**	1.9	C	**2.9**	2.1	D	**3.3**	2.2	C	**3.7**	2.3	C

Table 4
Number of mentions for the attributes provided for the qualitative description of the PBCAs ($n_{max} = 219$).

frequencies: 0-25 | 26-50 | 51-75 | 76-100 | 101-125 | 126-150 | 151-175 | 176-200

		Block 1	Block 2	Slice 1	Slice 2	Soft 1	Soft 2
Visual	grey/greyish	0	6	0	1	166	183
	orange	15	1	18	0	0	0
	white	1	177	1	30	36	41
	beige	9	22	8	25	62	47
	yellowish	194	17	184	166	7	3
	caramel colo	6	2	11	1	4	5
	artificial	52	82	53	51	46	63
	rough	13	4	2	3	30	33
	smooth	118	119	148	146	19	17
	uniform struc	130	119	136	140	36	20
	irregular struc	7	11	0	3	71	86
	shiny	20	22	19	32	4	4
Texture	firm	110	27	55	78	5	3
	soft	21	112	75	55	135	130
	creamy	22	78	41	24	134	99
	rubbery	60	154	63	82	13	14
	mealy/sandy	37	2	15	15	35	75
	sticky	6	72	4	9	62	44
	smooth	33	50	70	40	62	39
	compact	122	56	93	93	23	18
	dry	58	7	39	50	12	11
	powdery	34	4	11	7	18	24
	burning/stingi	5	4	2	3	40	37
Flavour	sweet	23	37	33	55	4	6
	earthy	22	7	17	14	50	77
	milky	21	107	34	71	18	9
	buttery	39	106	51	96	19	15
	nutty	35	23	32	37	52	54
	fruity	12	10	11	37	3	0
	grassy	15	6	2	6	9	11
	aromatic	112	18	93	31	80	57
	mushroom lik	29	10	20	19	87	102
	musty	23	14	15	24	55	90
	hot	15	1	1	0	66	46
	salty	66	22	73	31	58	49
	sour	28	23	17	32	45	37
	umami/bouillo	51	13	50	17	17	11
	bitter	9	6	2	8	42	88
	astringent	3	3	1	5	17	16

(Fig. 4B&C).

Texture attributes accounted for most of the variation. The block-style samples differed significantly in firmness, elasticity, gumminess, and stickiness. Both the sliced and soft cheese PBCAs differed significantly in firmness, mealiness, and structural homogeneity, with sliced alternatives additionally showing variation in creaminess.

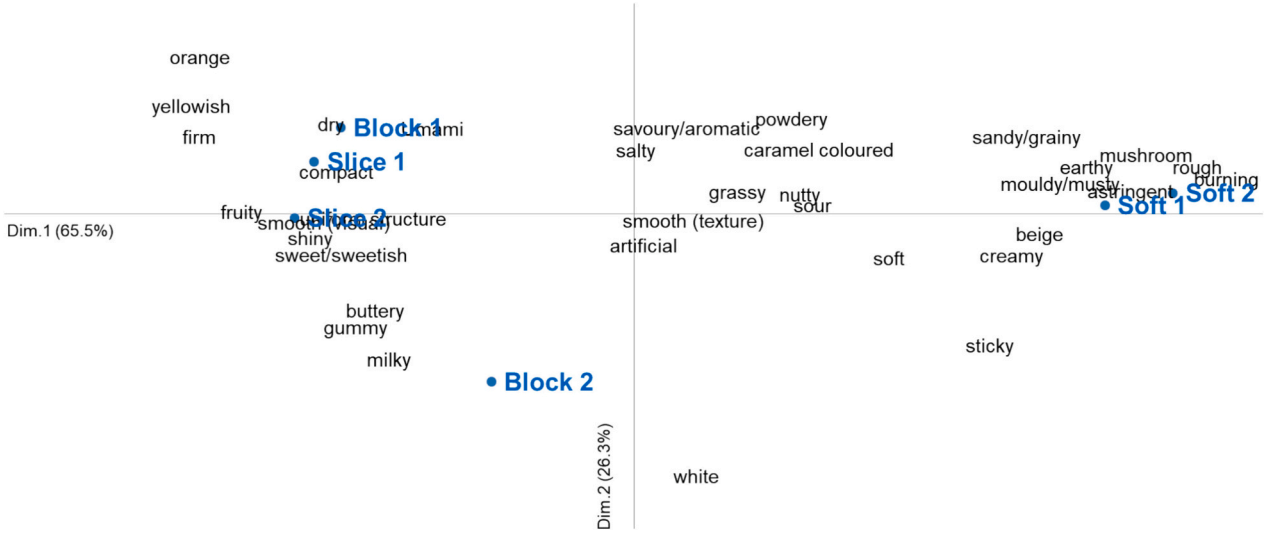


Fig. 3. Result of correspondence analysis (CA) of evaluated PBCAs - map of product and sensory attributes.

Among the sliced samples, Slice 1 exhibited significantly higher umami intensity but lower milky flavour. Near-significant differences were found in bitterness and off-flavour. The two soft cheese alternatives, both based on cashew nuts, presented pronounced mouldy and mushroom-like notes attributed to the white mould surface layer. These products were also rated as more bitter and exhibited significantly different off-flavour profiles. A significant difference was observed in perceived fruitiness, and a tendency towards a difference in the milky note. On average, higher saltiness in PBCAs corresponded with higher overall flavour intensity. None of the evaluated samples exhibited high intensities of the beany or vegetable notes, which are typically considered undesirable in plant-based products (Short et al., 2021).

4.2.2. *Chemical characterisation and nutritional aspects*

Except for Soft, 1 the fat content of the evaluated PCBAs was distinctly lower compared to that found in animal-based full-fat cheese (35 % fat). In addition, the two blocks and the two sliced products contained high amounts of starch but very little protein ranging from 0.1 % to 1.9 % (Table 6).

4.3. *Mapping of sensory and consumer data*

Hierarchical clustering revealed two clusters of participants, which distinctly differed in what type of PBCAs they preferred. The contour plot of the preference mapping for Cluster 1 shows that a high percentage of participants prefer the two soft PBCAs characterised by attributes such as ‘sandy/mealy’, ‘musty/mouldy’, ‘bitter’, ‘beany’ and ‘off-flavour’, while only a low percentage prefer the two block-style products. By contrast, a very different pattern of preferences was observed for Cluster 2. A high percentage of participants preferred the two sliced PBCAs, with a weaker preference for the two block-style samples. Only a small proportion of participants preferred the two soft samples (Fig. 5).

Although the liking scores were generally low, cluster 1 showed a tendency towards higher means of overall liking for the two soft PBCAs ($n = 100$), while cluster 2 ($n = 119$) showed a clear liking order with the two soft PBCAs at the bottom (Table 7). Cluster 1 also showed more significant differences in the overall liking of the six tested PBCAs, while cluster 2 did not show significant differences in liking of the two block-style PBCAs and Slice 2.

Slice 1 was popular with all participants as it was one of the favourite products in both clusters (Table 7).

A penalty-lift analysis was performed for each of the two clusters using the complete CATA dataset of all six PBCAs in combination with overall liking scores. This was done to obtain information on which sensory characteristics drive overall liking of PBCAs of the two clusters (Fig. 6).For both clusters, the attribute ‘savoury/aromatic’ had the greatest positive impact on overall liking. Saltiness also had a positive influence on both clusters, while the attribute ‘artificial’ negatively impacted liking for both groups. For cluster 1, texture aspects such as smoothness, creaminess and softness, as well as a grey colour, had a positive influence, while a white colour and a rubbery texture had a negative influence. For cluster 2, a uniform texture (in terms of both appearance and mouthfeel) and a firm texture had a positive impact on liking. Milky and buttery notes were also important positive characteristics. The attributes ‘mushroom-like’, ‘mouldy/musty’ and a grey colour had a negative effect (Fig. 6).

5. Discussion

5.1. *Consumer preferences and sensory perception of selected PBCAs*

As could be expected from the few studies which included tastings of real products (Falkeisen et al., 2022) the results of the present study show that the tested PBCAs were not highly liked (objective i). With a mean overall liking score of 5.9 only one of the six PBCAs was close to being slightly liked (score 6 on the 9-point hedonic scale), whereas the mean scores of the other five samples ranged from 4.0 to 5.1. Since, with one exception, the mean value of visual liking of the semi-hard PBCAs was higher than the overall liking, it can be assumed that the flavour and texture of the products did not meet consumers’ expectations triggered by the visual aspects of the PBCAs. As the mean intensity ratings for many of the flavour attributes used in the objective sensory evaluation were low, it can be assumed that the low intensity flavour profile of the tested PBCAs did not contribute positively to the overall liking scores. These attributes included aroma, saltiness and umami notes. In contrast to the often relatively pronounced aftertaste and off-flavours associated with PBCAs (Saraco & Blaxland, 2020), all six products tested were rated relatively low in off-flavour, This might be explained by the fact that the selection step excluded products with very pronounced off-flavours to avoid strong aversions from the participants.

Interestingly, the consumer acceptance of plant-based cream cheeses was found to be close to the overall liking of their animal-based counterparts with a difference of less than one- hedonic scale point on a 9-point-scale (Jaeger et al., 2024). This contrasts with the findings of most studies (Falkeisen et al., 2022; Silva et al., 2024; Waehrens et al., 2023), which examined PBCAs that imitated ripened dairy cheese. This difference in cheese category may explain the discrepancy in results.

Table 5
Results of the penalty analysis for the JAR ratings of the product attributes firm, creamy, salty, bitter and overall flavour ($n = 219$). Numbers in italics: Percentage ≤ 20 %, ***: significant $p \leq 0.001$.

		Block 1			Block 2			Slice 1			Slice 2			Soft 1			Soft 2	
	Overall liking (mean)		**4.7**			**4.5**			**5.9**			**4.8**			**5.1**			**4.0**	
		frequency [%]	Overall Liking per category	Penalty score	frequency [%]	Overall Liking per category	Penalty score	frequency [%]	Overall Liking per category	Penalty score	frequency [%]	Overall Liking per category	Penalty score	frequency [%]	Overall Liking per category	Penalty score	frequency [%]	Overall Liking per category	Penalty score
firm	Not enough	*8.2*	*4.8*		53.4	4.1	**1.0*****	*19.6*	*5.2*		*8.7*	*4.1*		44.3	4.2	**1.8*****	62.6	3.5	**1.5*****
	JAR	57.5	5.1		34.7	5.1		68.5	6.2		63.9	5.2		51.1	6.0		33.8	5.0	
	Too firm	34.2	4.2	**0.9****	*11.9*	*4.3*		*11.9*	*5.4*		27.4	3.9	**1.3*****	*4.6*	*4.8*		*3.7*	*3.1*	
creamy	Not creamy enough	55.3	4.3	**1.0*****	26.0	3.9	**1.4*****	33.8	5.3	**1.1*****	50.2	4.2	**1.2*****	*19.2*	*3.7*		27.4	3.4	**1.5*****
	JAR	41.6	5.3		46.6	5.3		60.3	6.4		45.7	5.4		63.9	5.8		39.7	4.9	
	Too creamy	*3.2*	*5.1*		27.4	3.5	**1.8*****	*5.9*	*3.9*		*4.1*	*4.8*		*16.9*	*4.1*		32.9	3.3	**1.6*****
salty	Not salty enough	*16.9*	*4.1*		47.5	3.9		*19.2*	*5.5*		40.6	4.4	**0.9*****	*13.2*	*4.0*		*17.4*	*3.0*	
	JAR	57.1	5.4		48.4	5.2		55.3	6.3		49.3	5.3		63.5	5.6		53.9	4.7	
	Too salty	26.0	3.7	**1.7*****	*4.1*	*3.0*		25.6	5.3	**1.0*****	*10.0*	*3.6*		23.3	4.5	**1.1*****	28.8	3.2	**1.5*****
bitter	Not bitter enough	*8.2*	*3.6*		*19.6*	*3.7*		*11.9*	*5.3*		*12.8*	*3.6*		*7.8*	*3.4*		*6.4*	*3.2*	
	JAR	76.3	5.2		73.5	4.8		82.2	6.1		80.8	5.0		63.0	5.7		33.8	5.0	
	Too bitter	*15.5*	*3.1*		*6.8*	*3.1*		*5.9*	*5.2*		*6.4*	*3.6*		29.2	4.4	**1.3*****	59.8	3.5	**1.5*****
flavour	Not intensive enough	20.1	4.4	**1.4*****	64.8	4.0	**1.8*****	33.3	5.5	**1.0*****	59.4	4.2	**1.7*****	24.7	4.2	**1.6*****	25.6	3.1	**2.2*****
	JAR	41.6	5.8		30.1	5.8		53.9	6.5		32.4	5.9		53.0	5.8		41.6	5.3	
	Too intensive	38.4	3.7	**2.1*****	*5.0*	*2.9*		*12.8*	*4.5*		*8.2*	*4.1*		22.4	4.4	**1.4*****	32.9	2.9	**2.4*****

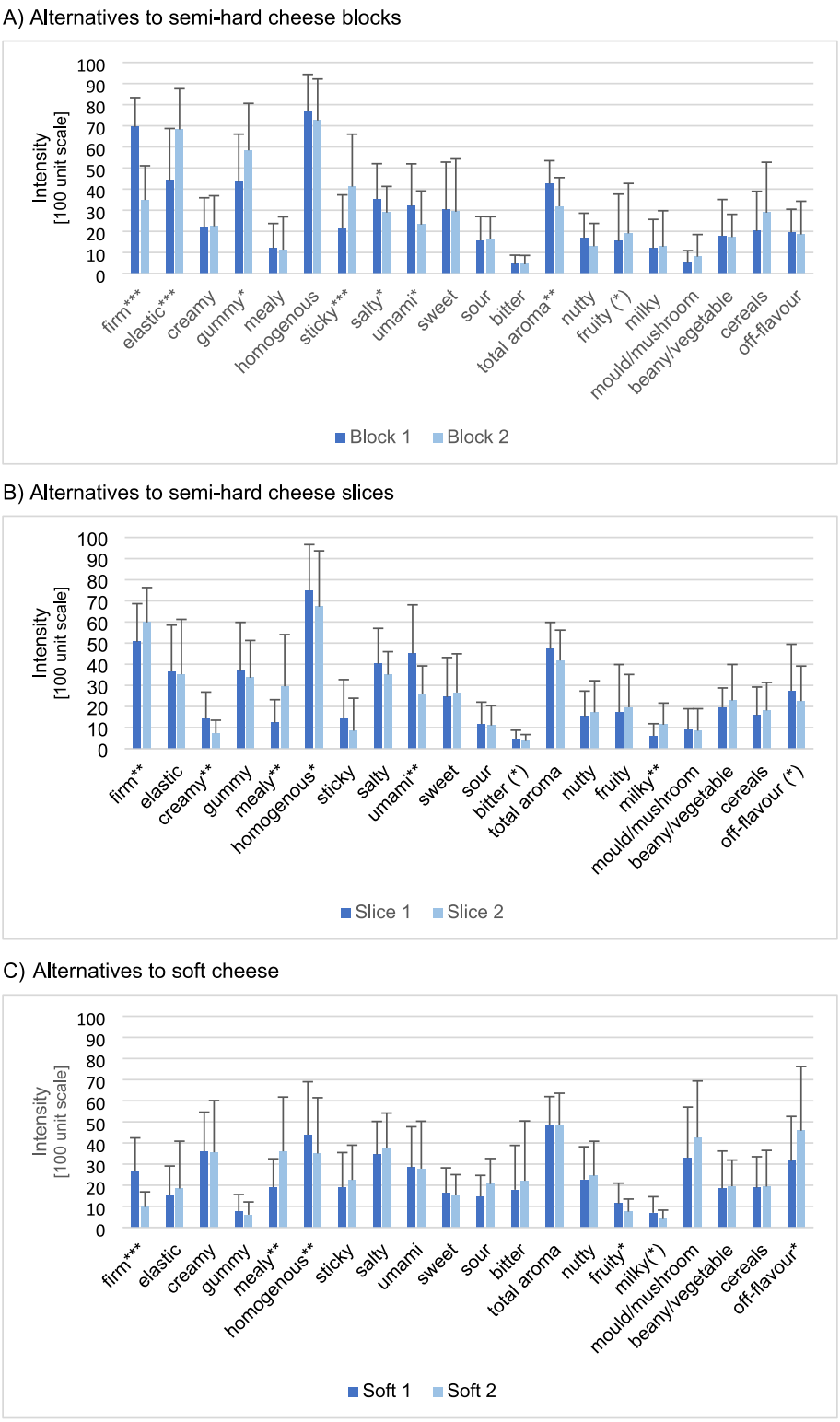


Fig. 4. Sensory profiles of selected plant-based cheese alternatives (n = 10 judges × 2 reps). a) Alternatives served as block b) Alternatives to sliced cheese c) Alternatives to soft cheese
***: significant ($p \leq 0.001$), **: significant ($p \leq 0.01$), *: significant ($p \leq 0.05$), (*): significant ($p \leq 0.1$).

5.2. *Influence of sensory characteristics on PBCA liking*

Flavour is generally considered to be one of the main factors influencing the overall liking of plant-based foods (Waehrens et al., 2023), although many other aspects also influence the consumption of these products (Giacalone et al., 2022).

The JAR data (Table 5) indicated that the flavour of all the tested PBCAs was too bland, which significantly reduced the overall acceptability of the samples. Therefore, it could be expected that the 'savoury flavour' would have the greatest positive impact on the overall acceptability of the PBCAs. This was observed for both clusters of participants (Fig. 6). In line with animal-based cheeses, where high saltiness intensity

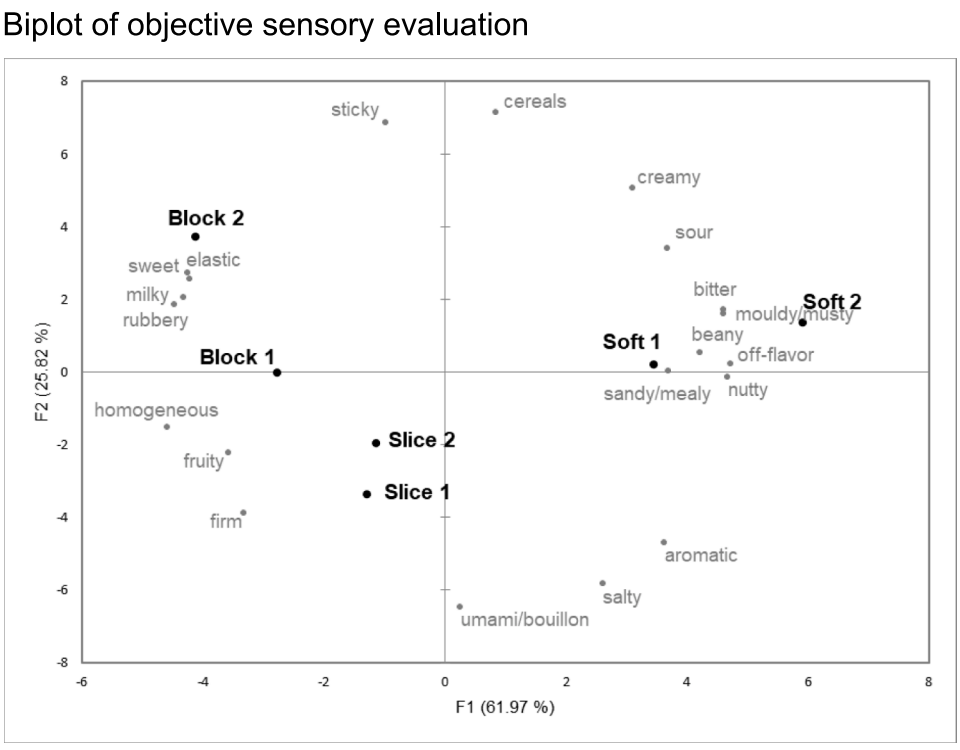
Table 6
Composition of macronutrients, dry matter and sodium of the PBCAs.

	Dry Matter	Fat	Protein*	NaCl**	Starch	Sugars
	[g/100 g]	[g/100 g]	[g/100 g]	[g/100 g]	[g/100 g]	[g/100 g]
Block 1	56.6	22.9	0.1	2.2	18.7	0.0
Block 2	56.8	20.7	1.0	1.8	14.8	0.8
Slice 1	55.7	19.6	1.9	2.4	17.6	1.1
Slice 2	56.3	22.5	0.1	2.0	20.3	5.2
Soft 1	46.2	32.4	14.4	1.5	9.0	0.6
Soft 2	41.8	24.5	13.3	1.5	2.3	1.5

* Calculated from the total N content: amount (g/100 g) * 6.25.
** : Calculated from the content of chloride.

Table 7
Hierarchical clustering of participants (cluster 1, n = 100 and cluster 2, n = 119).
Mean values of overall liking scores and result of mean separation test (Duncan multiple range test) Means with different letters are significantly different ($p \leq 0.05$).

Cluster 1 (n = 100)			Cluster 2 (n = 119)		
Sample	Liking score		Sample	Liking score	
Soft 1	6.4	A	Slice 1	5.8	A
Slice 1	5.7	B	Slice 2	5.0	B
Soft 2	5.1	C	Block 2	4.9	B
Block 1	4.6	D	Block 1	4.6	B
Slice 2	4.3	D	Soft 1	3.9	C
Block 2	3.7	E	Soft 2	2.8	D



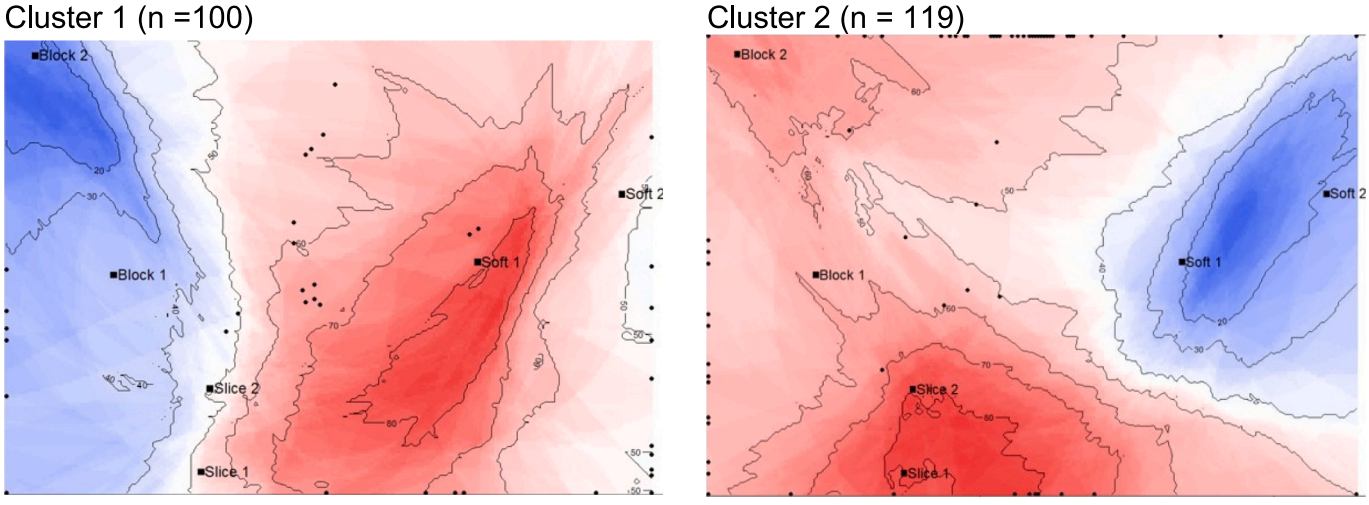


Fig. 5. Sensory preference mapping: Biplot of objective sensory evaluation and contour plots based on liking data for the two clusters - area of consumer acceptance (red colours) and consumer rejection (blue colours). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

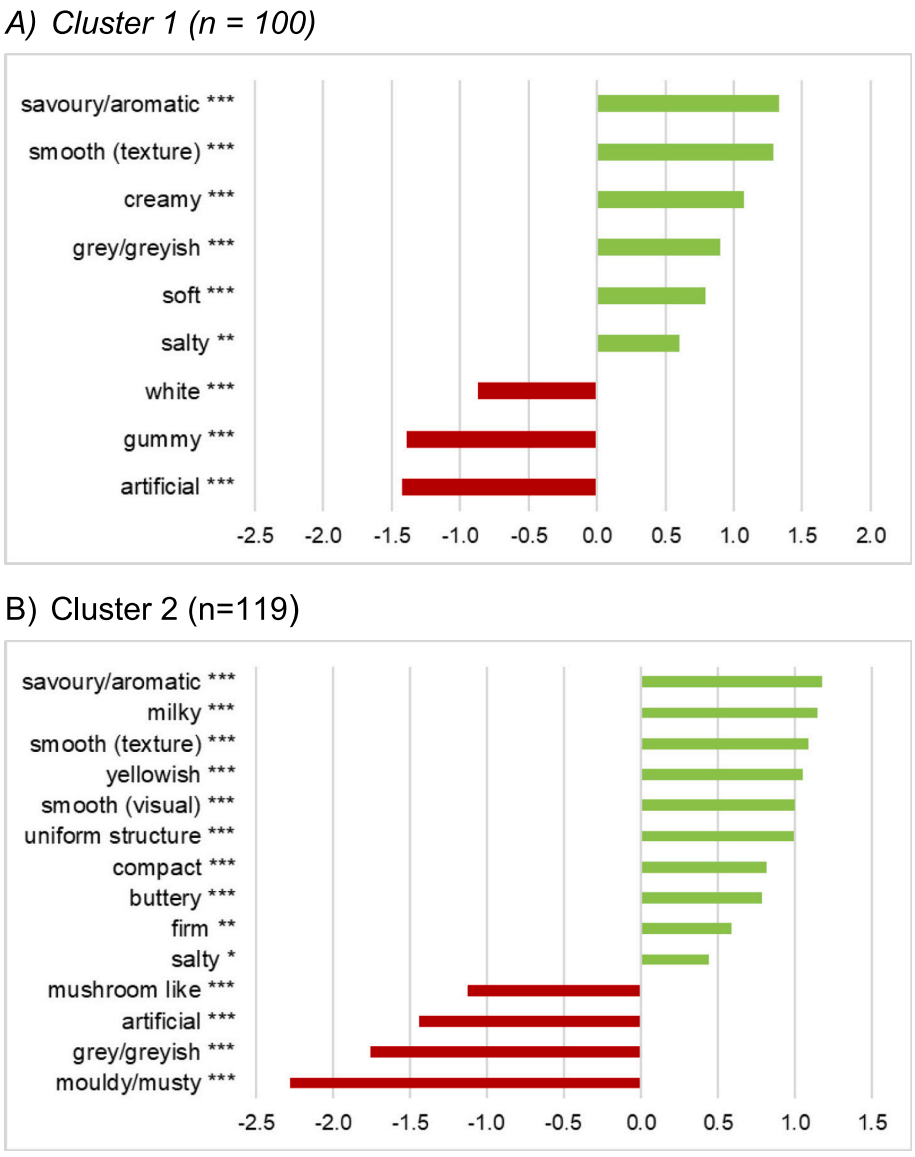


Fig. 6. Penalty (lift) analysis of CATA attributes and liking scores for the two clusters of participants – attributes with significant lift. ***: significant difference ($p \leq 0.001$), **: significant difference ($p \leq 0.01$), *: significant difference ($p \leq 0.05$).

is usually associated with high overall flavour intensity and vice versa (Saint-Eve et al., 2009), saltiness also positively influenced consumer acceptance of the PBCAs. However, for some of the tested PBCAs, the perceived saltiness was imbalanced with the other sensory characteristics, which negatively impacted the overall liking, as indicated by the JAR results (Table 5). The positive impact of the buttery note on the overall liking of PBCAs by Cluster 2 was also observed for plant-based cheddar cheese. (Falkeisen et al., 2022).

Texture modality appeared to be as important as flavour, as the attributes 'smooth texture' and, for Cluster 1 also the attributes 'creamy' and 'soft' showed a significant strong positive influence on overall liking, supporting the findings observed for plant-based cream cheese samples (Jaeger et al., 2024). Interestingly, the grey colour had a positive impact on the overall liking of Cluster 1, whereas it had a significantly negative impact on the overall liking of Cluster 2, probably because participants did not anticipate such shades of colour for products imitating dairy cheese. As expected, the 'artificial' attribute had a highly negative impact on the liking of both clusters, supporting the findings of other studies which showed that the PBCAs on the market were perceived as highly artificial and still lacked overall flavour intensity and other desired characteristics, such as buttery and milky notes (Silva et al., 2024; Waehrens et al., 2023). In addition, (Rune et al., 2025) concluded in their most recent review that, despite ongoing technological progress, PBCAs still struggle to deliver the desired texture characteristics, which are considered a key barrier to consumer acceptance.

Consumer expectations of new products seem to be also strongly related to how they are categorized (Etter et al., 2024). Therefore, if plant-based dairy alternatives are not considered to be in the same food category as their animal-based counterparts, it seems unlikely that they will be substituted (Etter et al., 2024). As cheese production has a long cultural tradition in Switzerland and can be seen as a source of identity, it may be difficult for these products to be seen as valuable substitutes for traditional cheese, even with increased exposure to PBCA (Etter et al., 2024). Similar consumer associations are likely to emerge in other European countries with a long tradition of dairy production. These findings suggest that plant-based products with a distinct sensory profile that is clearly different from traditional cheese are more likely to be accepted, at least by a certain consumer segment, than products marketed as imitations of traditional cheese.

5.3. Consumer segmentation

5.3.1. Hierarchical clustering

Hierarchical clustering was used to identify whether consumers could be grouped according to their preferences of the PBCAs. Based on the different compositions of the tested PBCAs (Table 6), it was expected that participants would cluster into groups showing a tendency to either prefer or not prefer soft PBCAs, as shown in Table 7. However, without information on the participants' preferences for dairy cheese, it is impossible to determine whether these preferences were transferred to the PBCA or whether they were disregarded when the PBCA products were judged.

Schimmel et al. (2025) showed that preferences for flavour and texture were important factors in the motivation and reluctance to consume plant-based cheeses, by clustering consumers according to their preferences for these two sensory modalities rather than overall liking. In particular, product availability was found to be a significant barrier for those who prefer alternatives that taste as similar as possible to traditional dairy cheeses.

5.3.2. Segmentation based on diet form

The study's data was categorized by self-declared diet type to see if the vegetarian/vegan group rated PBCAs more highly than flexitarians and omnivores, as various studies (Pointke et al., 2022; Waehrens et al., 2023) have suggested.

The results (Fig. 1) showed that the vegetarian/vegan group of participants was significantly more likely to agree that plant-based products are more climate-friendly and support animal welfare compared to the two other groups. This supports the hypothesis that topics such as animal welfare and the environment are more important to vegetarians/vegans than the sensory profile of plant-based products, and that therefore less emphasis is placed on this aspect. These results are in line with study results of (Ammann et al., 2023) who also found that vegetarians and vegans tend to rate plant-based products as more climate- and animal-friendly than omnivores. Similarly, Miki et al. (2020) reported that vegetarians and vegans were more likely to cite ethical reasons for following a plant-based diet, whereas flexitarians were more likely to cite health reasons.

Furthermore, based on the results of the agreement on the sensory statement of the PBCAs of the present study (Fig. 1), it could be anticipated that the vegetarian/vegan participants might like these products more than the omnivores and flexitarians. However, this hypothesis was not confirmed in the present study, as no significant differences in liking were found between the three dietary groups for any of the six tested PBCA products (ANOVA fixed factorial model, data not shown). For some of the PBCAs, the vegetarian/vegan participants did not even achieve the highest mean overall liking score, keeping in mind that the group size was small. It should also be noted that the vegetarian/vegan group as a whole disagreed with the statement that PBCAs taste better than traditional cheeses, with a mean score of 3.6 on a 6-point scale. Although the percentage of vegetarian/vegan participants in the consumer test seemed to be representative of the people in Switzerland who follow a vegetarian/vegan diet, which was estimated to be 5 % in 2020 (Swissveg, n.d.), the number of participants who declared to follow a vegetarian/vegan diet ($n = 22$) in our study was small. Further research is needed to validate the observed trends by consumer segmentation according to their diet form.

5.4. Future of sensory perception of selected PBCA on the Swiss market

Switzerland is best known for its hard and semi-hard cheeses, and consumption of these types of cheese is correspondingly high. As cheese plays an important economic role in the Swiss agricultural and food sector, the transition to a more plant-based diet, including PBCAs, is also of great interest to Swiss cheese producers. Given that most hard and semi-hard PBCAs currently on the market consist mainly of oil and starch, it is reasonable to assume that they have significantly different sensory profiles to dairy products. However, to date, there is no data on consumer perception of plant-based cheeses in Switzerland. Thus, one aim of the present study was to collect current data in order to generate a sensory 'baseline' for plant-based cheeses based on consumer data (objective iv).

Although the number of products evaluated was small, this data is essential for showing producers how to sensorially optimise PBCAs to achieve higher consumer acceptance. The use of fermentation, which is crucial for flavour development in dairy cheese production (Yvon & Rijnen, 2001), is still not widely used in PBCA production (Harper et al., 2022) and could be a potential methodology to improve the sensory profile of future PBCAs. To our knowledge, there is no published data available to follow changes in the sensory profile of PBCAs. One major reason for this may be the extremely fast-changing market for these products. The study enabled the collection of data on PBCAs, providing a foundation for monitoring sensory shifts and advancements in these products over time.

Although caution should be taken in extrapolating the results to other consumer groups, above all other nationalities we believe that the results of the consumer test can be at least partially extended to neighbouring European countries, as some of the PBCAs tested are also marketed or produced in other European countries. Taking cultural differences into account, it can therefore be assumed that consumer acceptance of these products might be comparably low, especially in German-speaking countries such as Germany and Austria.

5.5. Nutritional considerations

Given the list of ingredients used in the manufacture of PBCAs, it is not surprising that studies examining the nutritional aspects of PBCAs available on the US (Craig et al., 2022) and European (Clegg et al., 2021) markets have shown that, similar to many other plant-based alternatives, PBCAs have a nutrient profile that is quite different from their dairy counterparts. The majority of PBCAs on the market contain little or no protein, which is inconsistent with the perception of many consumers that PBCAs are a source of protein comparable to cheese (Boukid et al., 2021). The analytical characterisation was therefore included in the study. It could be confirmed that the macronutrient composition of the tested semi-hard PBCAs, particularly their low protein content, is consistent with the literature and appears to be characteristic of products primarily made from starch and oil (Katidi et al., 2023). This makes them poor nutritional substitutes for animal-based cheese (Boukid et al., 2021; Glover et al., 2024; Grossmann & McClements, 2021). Studies showed that over 80 % of PBCAs available in Spain and the UK, as well as more than half in the US, are based on coconut oil and starch (Craig et al., 2022; Fresán & Rippin, 2021; Saraco & Blaxland, 2020). The innovative use of different plant raw materials which are high in proteins, such as chickpeas, lupins or beans, could improve the nutritional profiles of PBCA and enhance their contribution to sustainable diets (Villarino et al., 2024). However, systematic scientific information on the quality and bioavailability of amino acids found in different plant raw materials is lacking (Jaeger et al., 2024). In contrast, cashew-based soft PBCAs, as our two soft cheese alternatives were composed of, have protein levels comparable to dairy soft cheeses found on the Swiss market, although differences in amino acid composition should be taken into account (Swiss Food Composition Database, n.d.). However, depending on the type of modelling used, it has been estimated that the environmental impact of plant-based products, particularly nut-based ones such as almonds and cashews, is similar to that of animal-based products (Green et al., submitted).

Furthermore, the widespread belief that animal-based cheeses are associated with an increased risk of cardiometabolic disease due to their high saturated fat content has been challenged (Øvrum et al., 2012). Recent studies have suggested that dairy cheese may have a neutral or even positive effect on health (Chen et al., 2022; Feeney et al., 2021).

6. Conclusions

In line with the findings of previous studies (Falkeisen et al., 2022; Silva et al., 2024; Waehrens et al., 2023), the results of the study indicate that, regardless of manufacturer and brand, semi-hard and soft PBCAs available on the Swiss market do not seem to be well accepted by consumers. The data suggests that the flavour and texture of the tested PBCAs did not align with the sensory preferences of the study participants, including those participants who were already following a plant-based diet to some extent. As many plant-based products are marketed by producers as imitating the 'original' animal-based products, consumers often expect plant-based products, including PBCAs, to have a similar sensory profile to their animal-based counterparts. It is, therefore, crucial for manufacturers to improve the sensory profile of PBCAs to provide acceptable products that can be incorporated into the daily diet of a wider population.

Particularly in the category of hard and semi-hard PBCAs, innovative production technologies, including ripening processes, may be required to produce PBCAs that more closely resemble their animal-based counterparts. Improving our understanding of the fermentation mechanisms and pathways in plant-based dairy alternatives, and their effect on the taste and texture of these products, could be a promising approach to developing more desirable PBCAs. Most PBCAs that mimic semi-hard and hard dairy cheeses on the market contain no or very little protein but are high in carbohydrates. From a nutritional point of view, these PBCAs are not a valuable alternative to animal-based cheeses. As well as sensory characteristics, manufacturers will face the main challenge of matching the nutritional profile of PBCAs as closely as possible to that of animal-based cheeses, while minimising additives such as flavourings. This will enable them to offer products better matching consumer's preferences.

More in-depth knowledge about the acceptance of PBCAs of different consumer segments (demographic, socio-economic, dietary type, food neophobia, etc.) would be important to encourage consumers to include more plant-based products such as PBCAs in their diets.

Furthermore, marketing strategies that support the launch of new products with an appealing sensory profile, rather than just imitating traditional products, could increase the consumption of plant-based products. Flexitarians, in particular, are an interesting target group because they are often looking to diversify their diets by incorporating more plant-based products.

6.1. Limitations

The evaluation of a total of six products belonging to only three types of PBCAs available on the Swiss market covers only a small part of the number of PBCAs representing products of different animal-based cheese categories commercially available on the market. However, the selection step showed that within a "cheese" category, the sensory profiles of the available PBCAs were very similar and in most cases differed only in the type of flavouring added. In addition, many of the samples evaluated in the selection stage could not be used for the consumer test due to unacceptable flavours, such as rancidity.

Moreover, the size of the different dietary groups differed substantially. Given that only 22 participants declared following a vegetarian/vegan diet, the results of this group might have been influenced by extreme scores of only a few individuals Therefore, if this group is considered the target market for the products, further research should include more vegetarian/vegan participants. The present study focused on the recruitment of participants from the German-speaking part of Switzerland. In the future, all language regions in Switzerland should be considered.

CRediT authorship contribution statement

Barbara Guggenbühl: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Annette Bongartz:** Writing – review & editing, Methodology, Conceptualization. **Saskia Mantovani:** Writing – original draft, Conceptualization. **Katharina Smith:** Software, Data curation. **Thorsten Guksch:** Writing – original draft, Formal analysis, Data curation. **Jeannette Nuessli Guth:** Writing – review & editing, Methodology, Conceptualization.

Ethical statement

Prior to starting the study, participants gave informed consent to take part in the test on a voluntary basis and all testing followed the principles outlined by the Declaration of Helsinki. Formal ethical approval was not obtained.

https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/

Statement: During the preparation of this manuscript, the authors used DeepL Pro for writing assistance to refine the language and improve clarity and grammar of the text. After using this AI tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Author Agreement Statement

We the undersigned declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We understand that the Corresponding Author is the sole contact for the Editorial process. He/she is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

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Declaration of competing interest

All named authors contributed substantially to the underlying research and the preparation of the manuscript. To the best of our knowledge, the named authors have no financial or other conflicts of interest to disclose.

Data availability

Data will be made available on request.

References

Adamczyk, D., Jaworska, D., Affeltowicz, D., & Maison, D. (2022). Plant-based dairy alternatives: Consumers' perceptions, motivations, and barriers—Results from a qualitative study in Poland, Germany, and France. *Nutrients, 14*, 2171. https://doi.org/10.3390/nu14102171

admin, n.d. Ernährungsdatendank CH. Swiss Food Compos. Database. URL https://naehrwertdaten.ch/de/ (accessed 11.10.24).

Alehosseini, E., McSweeney, P. L. H., & Miao, S. (2025). Recent updates on plant protein-based dairy cheese alternatives: Outlook and challenges. *Critical Reviews in Food Science and Nutrition, 1–15*. https://doi.org/10.1080/10408398.2025.2452356

Ammann, J., Grande, A., Inderbitzin, J., & Guggenbühl, B. (2023). Understanding Swiss consumption of plant-based alternatives to dairy products. *Food Quality and Preference, 110*, Article 104947.

Amyoony, J., Moss, R., Dabas, T., Gorman, M., Ritchie, C., LeBlanc, J., & McSweeney, M. B. (2023). An investigation into consumer perception of the

aftertaste of plant-based dairy alternatives using a word association task. *Applied Food Research, 3*, Article 100320. https://doi.org/10.1016/j.afres.2023.100320
Appiani, M., Cattaneo, C., & Laureati, M. (2023). Sensory properties and consumer acceptance of plant-based meat, dairy, fish and eggs analogs: A systematic review. *Frontiers in Sustainable Food Systems, 7*, Article 1268068. https://doi.org/10.3389/fsufs.2023.1268068
Aschemann-Witzel, J., Gantriis, R. F., Fraga, P., & Perez-Cueto, F. J. A. (2021). Plant-based food and protein trend from a business perspective: Markets, consumers, and the challenges and opportunities in the future. *Critical Reviews in Food Science and Nutrition, 61*, 3119–3128. https://doi.org/10.1080/10408398.2020.1793730
Boukid, F. (2024). *Texture enhancement strategies of plant-based meat and drinks alternatives, in: Handbook of plant-based food and drinks design* (pp. 285–296). Elsevier. https://doi.org/10.1016/B978-0-443-16017-2.00023-1
Boukid, F., Lamri, M., Dar, B. N., Garron, M., & Castellari, M. (2021). Vegan alternatives to processed cheese and yogurt launched in the European market during 2020: A nutritional challenge? *Foods, 10*, 2782. https://doi.org/10.3390/foods10112782
Chen, Z., Ahmed, M., Ha, V., Jefferson, K., Malik, V., Ribeiro, P. A. B., … Drouin-Chartier, J.-P. (2022). Dairy product consumption and cardiovascular health: A systematic review and Meta-analysis of prospective cohort studies. *Advances in Nutrition, 13*, 439–454. https://doi.org/10.1093/advances/nmab118
Clegg, M. E., Tarrado Ribes, A., Reynolds, R., Kliem, K., & Stergiadis, S. (2021). A comparative assessment of the nutritional composition of dairy and plant-based dairy alternatives available for sale in the UK and the implications for consumers' dietary intakes. *Food Research International, 148*, Article 110586. https://doi.org/10.1016/j.foodres.2021.110586
COOP. (2024). *Plant Based Food Report 2024 (Studie zum veganen Genuss in der Schweiz)*.
Craig, W. J., Mangels, A. R., & Brothers, C. J. (2022). Nutritional profiles of non-dairy plant-based cheese alternatives. *Nutrients, 14*, 1247. https://doi.org/10.3390/nu14061247
Etter, B., Michel, F., & Siegrist, M. (2024). Consumers' categorizations of dairy products and plant-based milk, yogurt, and cheese alternatives. *Appetite, 203*, Article 107658. https://doi.org/10.1016/j.appet.2024.107658
Falkeisen, A., Gorman, M., Knowles, S., Barker, S., Moss, R., & McSweeney, M. B. (2022). Consumer perception and emotional responses to plant-based cheeses. *Food Research International, 158*, Article 111513. https://doi.org/10.1016/j.foodres.2022.111513
Feeney, E. L., Lamichhane, P., & Sheehan, J. J. (2021). The cheese matrix: Understanding the impact of cheese structure on aspects of cardiovascular health – A food science and a human nutrition perspective. *International Journal of Dairy Technology, 74*, 656–670. https://doi.org/10.1111/1471-0307.12755
Fernández-Varela, R., Hansen, A. H., Svendsen, B. A., Moghadam, E. G., Bas, A., Kračun, S. K., … Poulsen, V. K. (2024). Harnessing fermentation by Bacillus and lactic acid Bacteria for enhanced texture, flavor, and nutritional value in plant-based matrices. *Fermentation, 10*, 411. https://doi.org/10.3390/fermentation10080411
Fresán, U., & Rippin, H. (2021). Nutritional quality of plant-based cheese available in Spanish supermarkets: How do they compare to dairy cheese? *Nutrients, 13*, 3291. https://doi.org/10.3390/nu13093291
Giacalone, D., Clausen, M. P., & Jaeger, S. R. (2022). Understanding barriers to consumption of plant-based foods and beverages: Insights from sensory and consumer science. *Current Opinion in Food Science, 48*, Article 100919. https://doi.org/10.1016/j.cofs.2022.100919
Glover, A., Hayes, H. E., Ni, H., & Raikos, V. (2024). A comparison of the nutritional content and price between dairy and non-dairy milks and cheeses in UK supermarkets: A cross sectional analysis. *Nutrition and Health, 30*, 157–165. https://doi.org/10.1177/02601060221105744
Grasso, N., Roos, Y. H., Crowley, S. V., Arendt, E. K., & O'Mahony, J. A. (2021). Composition and physicochemical properties of commercial plant-based block-style products as alternatives to cheese. *Future Foods, 4*, Article 100048. https://doi.org/10.1016/j.fufo.2021.100048
Green, A., Nemecek, T., Walther, B., & Mathys, A. (2025). *Comparing plant-based drink alternatives and cow's milk based on environmental burdens and a novel nutrient profiling system*.
Grossmann, L., & McClements, D. J. (2021). The science of plant-based foods: Approaches to create nutritious and sustainable plant-based cheese analogs. *Trends in Food Science and Technology, 118*, 207–229. https://doi.org/10.1016/j.tifs.2021.10.004
Harper, A. R., Dobson, R. C. J., Morris, V. K., & Moggré, G. (2022). Fermentation of plant-based dairy alternatives by lactic acid bacteria. *Microbial Biotechnology, 15*, 1404–1421. https://doi.org/10.1111/1751-7915.14008
Jaeger, S. R., Jin, D., & Roigard, C. M. (2024). Plant-based alternatives need not be inferior: Findings from a sensory and consumer research case study with cream cheese. *Foods, 13*, 567. https://doi.org/10.3390/foods13040567
Janssen, M., Busch, C., Rödiger, M., & Hamm, U. (2016). Motives of consumers following a vegan diet and their attitudes towards animal agriculture. *Appetite, 105*, 643–651. https://doi.org/10.1016/j.appet.2016.06.039
Kamath, R., Basak, S., & Gokhale, J. (2022). Recent trends in the development of healthy and functional cheese analogues-a review. *LWT, 155*, Article 112991. https://doi.org/10.1016/j.lwt.2021.112991
Katidi, A., Xypolitaki, K., Vlassopoulos, A., & Kapsokefalou, M. (2023). Nutritional quality of plant-based meat and dairy imitation products and comparison with animal-based counterparts. *Nutrients, 15*, 401. https://doi.org/10.3390/nu15020401
Laassal, M., & Kallas, Z. (2019). Consumers preferences for dairy-alternative beverage using home-scan data in Catalonia. *Beverages, 5*, 55.
Li, Q., Xia, Y., Zhou, L., & Xie, J. (2013). Evaluation of the rheological, textural, microstructural and sensory properties of soy cheese spreads. *Food and Bioproducts Processing, 91*, 429–439. https://doi.org/10.1016/j.fbp.2013.03.001
Liggett, R. E., Drake, M. A., & Delwiche, J. F. (2008). Impact of flavor attributes on consumer liking of Swiss cheese. *Journal of Dairy Science, 91*, 466–476. https://doi.org/10.3168/jds.2007-0527
Lima, M., Costa, R., Rodrigues, I., Lameiras, J., & Botelho, G. (2022). A narrative review of alternative protein sources: Highlights on meat, fish. *Egg and Dairy Analogues. Foods, 11*, 2053. https://doi.org/10.3390/foods11142053
Mefleh, M., & Darwish, A. (2024). *Fermentation: An old and new tool for improved alternative proteins and plant-based foods, in: Handbook of plant-based food and drinks design* (pp. 155–166). Elsevier. https://doi.org/10.1016/B978-0-443-16017-2.00014-0
Mehner, E., Ehlers, M.-H., Herrmann, M., Höchli, B., Holenweger, G., Mann, S., Messner, C., Nemecek, T., Reguant Closa, A., Schäfer, O., Stämpfli, A., Walther, B., & Douziech, M. (2024). *Fleisch- und Milchersatzprodukte – besser für Gesundheit und Umwelt?: Auswirkungen auf Ernährung und Nachhaltigkeit, die Sicht der Konsumentinnen und Konsumenten sowie ethische und rechtliche Überlegungen, 1st ed. vdf Hochschulverlag AG*. https://doi.org/10.3218/4194-1
Meyners, M., Castura, J. C., & Carr, B. T. (2013). Existing and new approaches for the analysis of CATA data. *Food Quality and Preference, 30*, 309–319. https://doi.org/10.1016/j.foodqual.2013.06.010
Miki, A. J., Livingston, K. A., Karlsen, M. C., Folta, S. C., & McKeown, N. M. (2020). Using evidence mapping to examine motivations for following plant-based diets. *Current Developments in Nutrition, 4*, Article nzaa013. https://doi.org/10.1093/cdn/nzaa013
Mwangi, A. S. (2024). *Exploring lactic acid bacteria fermentation parameters to produce legume based cheese alternatives*.
NCCS, N.C. for C.S. (2025). Federal Office for Agriculture FOAG. https://www.nccs.admin.ch/nccs/en/home/das-nccs/das-nccs-im-portrait/organisation/mitglieder-und-partner/bundesamt-fuer-landwirtschaft.html accessed 11.10.24.
Øvrum, A., Alfnes, A., & Almli, V. L. (2012). Rickertsen, K. *Health information and diet choices: Results from a cheese experiment Food Policy, 37*, 520–529.
Pineau, N., Girardi, A., Lacoste Gregorutti, C., Fillion, L., & Labbe, D. (2022). Comparison of RATA, CATA, sorting and napping® as rapid alternatives to sensory profiling in a food industry environment. *Food Research International, 158*, Article 111467. https://doi.org/10.1016/j.foodres.2022.111467
Pointke, M., Ohlau, M., Risius, A., & Pawelzik, E. (2022). Plant-based only: Investigating consumers' sensory perception, motivation, and knowledge of different plant-based alternative products on the market. *Foods, 11*, 2339. https://doi.org/10.3390/foods11152339
Rune, C. J. B., Clausen, M. P., & Giacalone, D. (2025). Sensory evaluation of plant-based cheese: A systematic review with a focus on texture and mouthfeel. *Critical Reviews in Food Science and Nutrition, 1–26*. https://doi.org/10.1080/10408398.2025.2531220
Saint-Eve, A., Lauverjat, C., Magnan, C., Déléris, I., & Souchon, I. (2009). Reducing salt and fat content: Impact of composition, texture and cognitive interactions on the perception of flavoured model cheeses. *Food Chemistry, 116*, 167–175. https://doi.org/10.1016/j.foodchem.2009.02.027
Saraco, M. N., & Blaxland, J. (2020). Dairy-free imitation cheese: Is further development required? *British Food Journal, 122*, 3727–3740.
Schimmel, M. D, Junge, J. Y., Alexi, N., Andersen, G. B. H., Hammershøj, M., Løbner, M. H., & Kidmose, U. (2025). Drivers and Barriers for Plant-Based Cheese Alternatives Adoption: Insights from Diverse Consumer Clusters. *Foods, 14*, 1162–1177. https://doi.org/10.3390/foods14071162
Short, E. C., Kinchla, A. J., & Nolden, A. A. (2021). Plant-based cheeses: A systematic review of sensory evaluation studies and strategies to increase consumer acceptance. *Foods, 10*, 725. https://doi.org/10.3390/foods10040725
Silva, K. K. D. P. E., Domingues Galli, B., Alban, M., Baptista, D. P., Nabeshima, E. H., Marfil, P. H. M., & Gigante, M. L. (2024). Sensory profile of cream cheese and plant-based analogues: An approach through flash-profile, CATA and RATA tests. *International Journal of Food Science and Technology, 59*, 9084–9095. https://doi.org/10.1111/ijfs.17484
Smart-Protein-European-Consumer-Survey_2023 [WWW Document], n.d. URL. https://smartproteinproject.eu/wp-content/uploads/Smart-Protein-European-Consumer-Survey_2023.pdf, (2025) accessed 4.7.25.
Statista - Das Statistik-Portal, n.d. Statista. https://de.statista.com/, (2025) accessed 4.7.25.
Swissveg. (2025). Be Veggie für Tiere, Umwelt und Gesundheit. Swissveg. https://www.swissveg.ch/de/home accessed 4.7.25.
Vidal, L., Tárrega, A., Antúnez, L., Ares, G., & Jaeger, S. R. (2015). Comparison of correspondence analysis based on Hellinger and chi-square distances to obtain sensory spaces from check-all-that-apply (CATA) questions. *Food Quality and Preference, 43*, 106–112. https://doi.org/10.1016/j.foodqual.2015.03.003
Villarino, C. B. J., Alikpala, H. M. A., Begonia, A. F., Cruz, J. D., Dolot, L. A. D., Mayo, D. R., … Tan, E. S. (2024). Quality and health dimensions of pulse-based dairy alternatives with chickpeas, lupins and mung beans. *Critical Reviews in Food Science and Nutrition, 64*, 2375–2421. https://doi.org/10.1080/10408398.2022.2123777
Waehrens, S. S., Faber, I., Gunn, L., Buldo, P., Bom Frøst, M., & Perez-Cueto, F. J. A. (2023). Consumers' sensory-based cognitions of currently available and ideal plant-based food alternatives: A survey in Western, central and northern Europe. *Food Quality and Preference, 108*, Article 104875. https://doi.org/10.1016/j.foodqual.2023.104875
Yvon, M., & Rijnen, L. (2001). Cheese flavour formation by amino acid catabolism. *International Dairy Journal, 11*, 185–201.