International Journal of Food Science + Technology

Original article

Sensory profile of cream cheese and plant-based analogues: an approach through flash-profile, CATA and RATA tests

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(Received 13 May 2024; Accepted in revised form 10 August 2024)

Summary The distinct techno-functional and sensory attributes conferred by milk proteins and fat are fundamental in defining the structure, texture and flavour of dairy products. Thus, reproducing cheese-like characteristics in plant-based alternatives while ensuring consumer acceptance is a major challenge. This study aimed to evaluate the sensory profile of commercial cream cheese and plant-based analogues, quantifying consumer perception and discrimination, and correlating with instrumental texture analysis. For that, two milk-based (MB1 and MB2) and three plant-based products (PB1, PB2 and PB3) were evaluated for their proximate composition, texture profile (spreadability and firmness) and sensory properties by combining Flash Profile method (n = 13), Check-All-That-Apply (CATA) test, and Rate-all-that-apply (RATA) test (n = 102) with global acceptance. Milk-based cream cheeses (MB1 and MB2) did not differ significantly from each other and presented greater spreadability when compared to all plant-based cream cheeses (PB1, PB2 and PB3). The texture parameters of the samples were inversely related: the greater the firmness, the lower the spreadability. All forty-two sensory attributes allowed discrimination of the samples into three distinct clusters, with no difference between the milk-based products. The results of the CATA test showed that the attributes most correlated with the sample MB1 were the most desirable for good acceptance of the product. In turn, PB3 showed lower acceptance scores when compared to the plant-based samples PB1 and PB2, and the attributes rancid flavour, vegetable oil aroma and nut aroma mostly contributed to the lower acceptance of PB3. Milk-based products were very close to the ideal product, presenting a creamy and spreadable texture as key attributes for product characterisation and acceptance. The results of RATA test showed a significant difference (P < 0.05) in the intensity of nineteen sensory attributes. Milk-based cream cheeses were more accepted than their plant-based counterparts. The instrumental assessments of firmness and spreadability exhibited a negative correlation, once they were inversely proportional and strongly correlated to sensory data of firm and spreadable texture, respectively. The sensory characteristics of cream cheese analogues may present a barrier to their acceptance by consumers. Attributes such as coconut and flour flavour, artificial cheese aroma and flavour, and spreadable texture played a key role in differentiating dairy products from plant-based ones, contributing to the lower acceptance of the latter.

Keywords Acceptance, dairy analogues, firmness, milk fat, milk proteins, spreadability, texture profile analysis.

Introduction

Milk and dairy products are well-recognised for their nutritional quality and form part of a healthy diet. However, despite the nutritional importance of these products, discussion has been growing on the role of animal proteins, including dairy proteins, in a sustainable diet. Increased environmental awareness, along with other factors such as health concerns, aversion to animal cruelty, and the desire for a healthier lifestyle, are driving consumer interest towards plant-based diets (Aydar *et al.*, 2020).

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doi:10.1111/ijfs.17484

In this context, the plant-based sector is becoming stronger, more sophisticated and technologically advanced, spreading to all sub-sectors of the food industry. Novel plant-based products analogous to animal products, such as burgers, meatballs, cheese and yogurt, are a market reality in different parts of the world. The unique techno-functional and sensory properties of milk proteins and fat provide structure, texture and flavour to dairy products, with an emphasis on cheese. Therefore, replicating the properties of cheese, a protein–fat concentrate, in plant-based products and ensuring consumer acceptance are challenges for the food industry and the development of novel foods.

Caseins account for approximately 80% of milk proteins and are present in milk as stable colloidal structures called casein micelles. These are formed by nanoclusters of colloidal calcium phosphate and four casein fractions (αs1-, αs2-, β-, and κ-casein) that associate to form a highly hydrated structure (37 g H_2O g^{-1} protein) with an average diameter of 120 nm (range 50 – 500 nm), negatively charged, stabilised by electrostatic repulsion and steric repulsion (Walstra *et al.*, 2006; Dalgleish & Corredig, 2012). Cheese manufacturing through acid or enzymatic coagulation requires the destabilisation of casein micelles, resulting in their precipitation. During precipitation, in both coagulation mechanisms, the casein micelle carries the fat globules present in milk in the form of an emulsion stabilised by the milk fat globule membrane, forming new structures. The characteristics of casein micelles and the modifications induced by cheese processing can lead to the formation of the structure and the techno-functional properties of these products (Fox & McSweeney, 2017). Improving the techno-functional characteristics of plant-based cheeses is a significant challenge, and cheese analogues available in the market do not fully meet consumers' expectations (Mattice & Marangoni, 2020). Although animal proteins are recognised for their higher protein quality when compared to plant proteins (Gorissen & Witard, 2018; Berrazaga *et al.*, 2019), the literature suggests that combining various plant sources can result in a complete amino acid profile (Duranti, 2006). On the other hand, unlike milk fat, which is predominantly saturated (Jensen, 2002) and often associated with the risk of chronic diseases, plant oils and fats are mostly composed of polyunsaturated fatty acids (Boyle & Anderson, 2007). In this context, there is a challenge to achieve well-accepted sensory attributes in plant-based cheese, since these organoleptic properties are closely related to the complexity of milk fat and caseins, as well as the modifications of caseins during processing.

The sensory analysis of food has become an indispensable tool for the food industry as it allows for the evaluation of consumer–product interaction, significantly contributing to achieving the level of excellence demanded by the market. Tests such as Flash-Profile (FP), Check-All-That-Apply (CATA) and Rate All That Apply (RATA), a variant of CATA, have gained prominence as valuable tools in consumer studies to describe the sensory perceptions of various products (Ares & Jaeger, 2013; Meyners *et al.*, 2016; Galli *et al.*, 2019). FP is a descriptive technique that allows assessors to express the sensory attributes from their own perspective, choosing and using their words to comparatively evaluate a set of products (Dairou & Sieffermann, 2006). CATA and RATA allow consumers to select all relevant attributes from a provided list to describe a product. CATA is known for its efficiency in describing and differentiating products, and stands out by its simplicity and quick application (Ares *et al.*, 2010; Bruzzone *et al.*, 2012). RATA was developed to overcome a limitation of CATA, which cannot directly measure the intensity of the sensory attributes evaluated (Antúnez *et al.*, 2017).

Traditional cream cheese is produced through the acidic coagulation of milk (with pH 4.6 and mesophilic bacteria), which is standardised to contain 12%–13% fat, followed by pasteurisation and homogenisation. The process involves stirring, heating and centrifuging the acidified curd to obtain a concentrated mass, to which salt and hydrocolloids are added, keeping the curd hot at high temperature during stirring (Kosikowski & Mistry, 1997). According to the Brazilian legislation (Brasil, 2020), cream cheese must have a maximum of 78% moisture and at least 25% fat on a dry matter basis. Its spreadable behaviour is due to its specific composition (fat-to protein ratio and moisture content) as well as the protein aggregates with large spaces filled with whey (Feeney *et al.*, 2021).

In turn, the composition of cream cheese of animal origin significantly differs from that of plant-based analogues (Luz *et al.*, 2023). These authors evaluated 242 plant-based milk substitutes on the Brazilian market for the nutritional content reported on the labelling, including nine brands of cream cheese analogues, and reported the following nutritional values 100 g per of product: proteins between 1.33 and 5.33, total fat from 18.7 to 25, saturated fat from 12.0 to 17.0, carbohydrates from 7.67 to 10.0, dietary fibres from 0.00 to 0.33, sodium from 70.0 to 237 mg, and energy value from 233 to 277 kcal.

The evaluation of the products currently available on the market is essential to identify the technological challenges, aiming to guide the solutions for improvement of these products. In this context, plant-based cream cheese analogues stand out, with an increase in the development of novel formulations by the food industry, driven by the growing consumer interest in healthier alternatives. However, changes in formulation can impact texture and flavour, affecting consumer acceptability (Bemer *et al.*, 2016). Therefore, understanding the sensory attributes that have impact and determine consumer preference is crucial. This study aims to assess the sensory profile of commercial cream cheese and plant-based analogues, by determining both consumer perception and discrimination, the impact of each sensory descriptor on product acceptance, and correlating the findings with the texture profile analyses.

Material and methods

Characterisation of cream cheese and plant-based analogues

Five commercial cream cheese formulations and their plant-based analogues were collected at local markets in the municipalities of São Paulo and Campinas, SP, Brazil. The identification of samples and ingredients are detailed in Table 1. Initially, the products were characterised for the gross composition and texture profile, focusing on the parameters spreadability and firmness. The fat content was determined according to the Bligh & Dyer (1959), total solids were measured by drying in an oven at 105 °C until constant weight, ash content was obtained by incineration at 550 °C and total nitrogen (TN) was analysed by the Kjeldahl method (AOAC, 2006). The crude protein was calculated by multiplying the TN by the respective conversion factor (6.38 for dairy products and 6.25 for plant analogues). The carbohydrate content was estimated by the difference between the total solids and the other components.

The texture analysis of the samples was conducted as described by Da Silva *et al.* (2018) and Foguel *et al.* (2021) with modifications, using a TA.XT PlusC texture analyser 650H and the data were acquired and plotted with the Exponent software (version 6.1.5.0) (Stable Micro Systems Ltd, Godalming, UK). A 90° conical probe (male) was used, which penetrated the sample placed in a conical container (female), the TTC Spreadability Rig. The analyses were performed after storage of the samples at 5 °C for 1 h. The test parameters included a penetration distance of 25 mm, pre-test speed of 10.0 mm s^{-1}, test speed of 3.0 mm s^{-1} and post-test speed of 10.0 mm s^{-1}. The results of spreadability (N*s) and firmness (N) were presented as the average of five repetitions.

Table 1 Identification of commercial samples and ingredients declared on the labels

Sample identification	Ingredients declared on the label
Milk-Based Cream Cheese (MB1)	Milk, cream, whey powder, salt (sodium chloride), lactic acid culture, thickener jatai gum and preservative potassium sorbate
Milk-Based Cream Cheese (MB2)	Milk, cream, salt, lactic acid culture, blend of stabilisers: Carrageenan, carboxymethyl cellulose, locust bean gum, guar gum and preservative potassium sorbate
Plant-Based Cream Cheese (PB1)	Cashew nut milk, coconut oil, potato starch, salt, yeast extract, bamboo fibre, sunflower lecithin, lactic acid, potassium sorbate, nature-identical aroma
Plant-Based Cream Cheese (PB2)	Water, cashew nut, coconut oil, potato starch, salt, nature-identical cream cheese flavour, vinegar, fermentation culture
Plant-Based Cream Cheese (PB3)	Cashew nut milk, sunflower oil, potato starch, sweet tapioca, iodised salt, modified cassava starch, tricalcium phosphate, lactic acid, xanthan gum, yeast extract, potassium sorbate, carrageenan gum

Sensory evaluation of cream cheese and plant-based analogues

The sensory analysis methods FP, CATA (Check-all-that-apply), and RATA (Rate-all-that-apply) were conducted after approval of the Research Ethics Committee of UNICAMP, under registration CAAE66975222.9.0000.5404. The analyses were carried out in individual sensorial booths under white light and controlled temperature (20°C). Each sample (15 g) was served on stainless steel trays, identified by random three-digit codes, and maintained at a temperature of 5 ± 2 °C. Mineral water at room temperature and cracker biscuits were provided to the participants for palate cleansing.

The FP methodology was applied as reported by Dairou & Sieffermann (2006). Thirteen assessors (eight female and five male, aged between 20 and 50 years), who were familiar with cream cheese and declared no dietary restrictions, participated in the study. The assessors were recruited at the State University of Campinas, through pamphlets and communication application. The evaluation sessions were divided into two parts, as reported by Galli *et al.* (2019). First, the assessors received simplified instructions on the FP procedure. Then, a detailed protocol was provided to assist in identifying attributes and subsequent analysis, instructing participants on how to evaluate the samples for the attributes of appearance (colour and consistency), aroma (smelling the sample twice), flavour (tasting the sample), texture (chewing and sensory perception in the mouth) and aftertaste.

During the first FP session, the five samples (MB1, MB2, PB1, PB2 and PB3) were presented to the assessors simultaneously, who were asked to record the similarities and differences among samples. Based on these observations, a personalised evaluation sheet was prepared for each assessor (see Appendix A: Sheet

A1). In the second FP session, the samples were offered to the assessors, who were asked to classify them in an ascending order of intensity for each attribute identified, using an unstructured 10 cm scale (see Appendix A: Sheet A2). The assessors were informed that they were free to modify the evaluation sheet, whether by adding or excluding attributes or even adjusting definitions in the provided glossary. The results were subjected to Generalised Procrustes Analysis (GPA), through the software XLStat Premium 2023.1.1 (Addinsoft, New York, NY, USA), applying consensus and dimensional tests at a significance level of 5%.

To understand consumer perception and acceptance, two types of descriptive tests were applied: an exploratory (CATA) and a quantitative (RATA) test, in addition to an overall acceptance test, involving 102 participants aged between 20 and 50 years, who were recruited at the State University of Campinas, through pamphlets and communication application. The participants had no dietary restrictions or aversions to cream cheese and its plant-based analogues and had at least one prior consumption experience, according to the protocol established by Ares *et al.* (2007).

Evaluation sheets for the CATA and RATA tests were prepared using the description terms identified in the FP test (see Appendix A: Sheet A3). The participants were asked to examine the attributes identified for each sample, indicating whether the attribute was positive or negative (desirable or undesirable in the product), and the intensity of each perceived attribute, on a scale ranging from 1 (very weak, almost imperceptible) to 5 (very strong, predominantly characterising the product). Additionally, on the same sheets, the participants evaluated the samples for global acceptance, appearance, aroma, flavour and texture/consistency, using a structured 9-point hedonic scale (1 = extremely disliked; 5 = indifferent; 9 = extremely liked), as described by Stone *et al.* (2012). Before evaluating the samples, participants were asked to fill out a sheet, selecting terms that, in their view, would describe an ideal and hypothetical cream cheese, as suggested by Bruzzone *et al.* (2015).

The results were analysed using the software XLStat Premium 2023.1.1 (Addinsoft) and the differences were analysed by ANOVA, using Cochran's Q test to verify the homogeneity of variances. Furthermore, pair-wise comparison test using the Marascuilo procedure was carried out, allowing for the identification of specific differences between groups. To determine the relationship between the sensory attributes and the ideal sample, correspondence analyses, based on chi-square distances, and Principal Component Analysis (PCA) were applied to interpret correlations related to product acceptance. The frequency of the sensory attribute was determined by counting the number of evaluators who used the term to describe the samples (Ares *et al.*, 2014; Bruzzone *et al.*, 2015). The results of the RATA test were analysed by ANOVA and Fisher's least significant difference ($P < 0.05$). The results of the acceptance test were analysed by ANOVA, considering sample and assessors as variation factors, at a significance level of 5%. The correlation between data sets was examined through Principal Component Analysis (PCA), constructing a Pearson correlation matrix. This integrated approach to statistical analysis was analysed through the software XLStat Premium 2023.1.1 (Addinsoft).

Results and discussion

Characterisation of cream cheese and plant-based analogues

The gross composition of the samples is shown in Table 2, while the results of the instrumental texture of commercial cream cheeses and their plant-based

Table 2 Nutritional information and proximate composition of commercial cream cheese and plant-based analogues

Parameters (%)	MB1	MB2	PB1	PB2	PB3
Moisture	62.50 ± 0.21	69.11 ± 0.72	57.51 ± 0.10	55.66 ± 0.69	57.04 ± 0.09
Total dry matter	37.50 ± 0.21	30.89 ± 0.7	42.49 ± 0.10	44.34 ± 0.69	42.96 ± 0.09
Fat	22.50 ± 0.14	20.29 ± 0.72	39.26 ± 1.10	33.65 ± 0.86	28.35 ± 0.34
Protein	6.31 ± 0.05	5.57 ± 0.08	2.07 ± 0.16	0.66 ± 0.10	3.57 ± 0.10
Carbohydrates	7.37 ± 1.49	3.80 ± 0.41	0.69 ± 0.68	8.66 ± 1.61	8.59 ± 0.29
Ash	1.39 ± 0.04	1.23 ± 0.11	1.10 ± 0.01	1.37 ± 0.05	2.39 ± 0.10
FDM	60.02 ± 2.69	65.68 ± 1.53	90.82 ± 1.14	75.91 ± 3.00	65.99 ± 0.60
PDM	16.83 ± 0.08	18.05 ± 0.20	4.87 ± 0.36	1.49 ± 0.24	8.30 ± 0.21
ADM	19.45 ± 2.82	12.3 ± 1.37	1.73 ± 1.14	19.5 ± 3.34	20.00 ± 1.02
Fat-to-protein ratio	3.57	3.64	18.65	50.95	7.95

Traditional milk-based formulations (MB1 and MB2) and plant-based analogues (PB1, PB2, and PB3).
ADM, ash on dry matter; FDM, fat on dry matter; PDM, protein on dry matter.

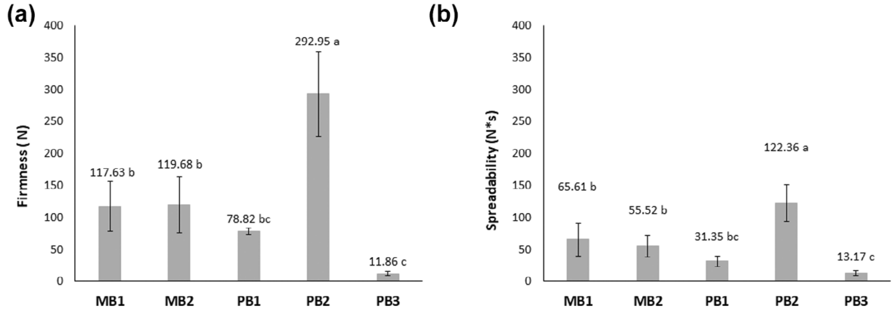

Figure 1 Firmness (a) and spreadability (b) of commercial cream cheese samples and analogues at 5 °C. [a-c]Average values with different letters are significantly different ($P < 0.05$).

analogues can be seen in Fig. 1. The firmness measurement indicates the resistance encountered by the probe when penetrating the sample, and firmer samples require a greater force for penetration. In turn, spreadability is defined by the amount of force required to spread the sample over a specific time interval, indicating that more easily spreadable products require less force. An inverse relationship between these two texture parameters is observed, and samples with greater firmness tend to have lower spreadability, while less firm samples spread more easily.

The milk-based cream cheeses (MB1 and MB2) showed similar spreadability and were significantly more spreadable when compared to their plant-based counterparts (PB1, PB2 and PB3). This variation in texture properties may be due to differences in the formulations and microstructure of the products, as also reported by other authors (Brighenti *et al.*, 2008; Bemer *et al.*, 2016; Feeney *et al.*, 2021; Foguel *et al.*, 2021). The microstructure of traditional cream cheese is composed of compact fat and protein aggregates with large spaces filled with whey, which is affected by the product composition (fat/protein ratio and moisture content) and the homogenisation of milk before cheese making (Feeney *et al.*, 2021). Regarding the moisture content of the samples, the milk-based cream cheeses (MB1 and MB2) had values ranging from 60% to 70%, while the plant-based analogues (PB1, PB2 and PB3) had a moisture content in the range of 50% – 60%. The fat/protein ratios were 3.57, 3.64, 18.65, 50.95 and 7.95 for MB1, MB2, PB1, PB2 and PB3, respectively (Table 2).

In addition to the fat/protein ratio, the composition and structure are important parameters of these products. Milk fat has a complex composition of triacylglycerols, which gives it a natural plastic nature (Herrera *et al.*, 1999). At the storage and evaluation temperature (5 °C), milk fat maintains more than 20% in a liquid state, positively affecting the appearance, spreadability, oil exudation, and sensory properties of the products (Viriato *et al.*, 2018). This characteristic gives dairy products (MB1 and MB2) a smooth texture and desirable spreadability. In contrast, coconut oil, which is rich in saturated fatty acids (Boyle & Anderson, 2007), has almost no liquid fat at this temperature (Goff *et al.*, 2013), which affects the texture properties. The exclusive use of coconut oil in the plant-based cream cheese PB2, combined with a low protein content (1.5% protein in the total dry extract), distinguishes this product from the others for the attributes of firmness (292.95 ± 66.43 N) and spreadability (122.36 ± 28.58 N*s), as shown in Fig. 1. Although PB2 and PB3 had similar fat contents (33.65 ± 0.86 and 28.35 ± 0.34%, respectively), PB3 exhibited lower firmness and higher spreadability. This behaviour may be due to the presence of sunflower oil in its formulation, known for its high content of unsaturated fatty acids (Boyle & Anderson, 2007). The milk-based formulations (MB1 and MB2) had a higher protein content when compared to the analogues (PB1, PB2 and PB3), in addition to the differences in protein structure; the milk-based samples contain mainly caseins, while the plant-based samples, such as cashew nut-based cream cheese (PB), are rich in albumins and globulins, typical of oilseeds (Loveday, 2019). Milk proteins not only offer excellent nutritional properties, but also play a crucial role in the techno-functional, sensory and texture characteristics of dairy products and other food products (Alves & Tavares, 2019). During cream cheese manufacture, the fermentation of milk by lactic acid bacteria causes acidification that modifies the structure of casein micelles, the main protein fractions in milk, thus allowing the formation of a protein network (Dalgleish & Corredig, 2012). The structural changes that occur in proteins during food processing and storage can affect their interactions with other components of the food matrix, influencing the sensory attributes such as texture and flavour. These changes can also affect the technological applications of these proteins, allowing for the adjustment of their functionality to different contexts (Pizones Ruiz-Henestrosa *et al.*, 2014; Quintero *et al.*, 2017).

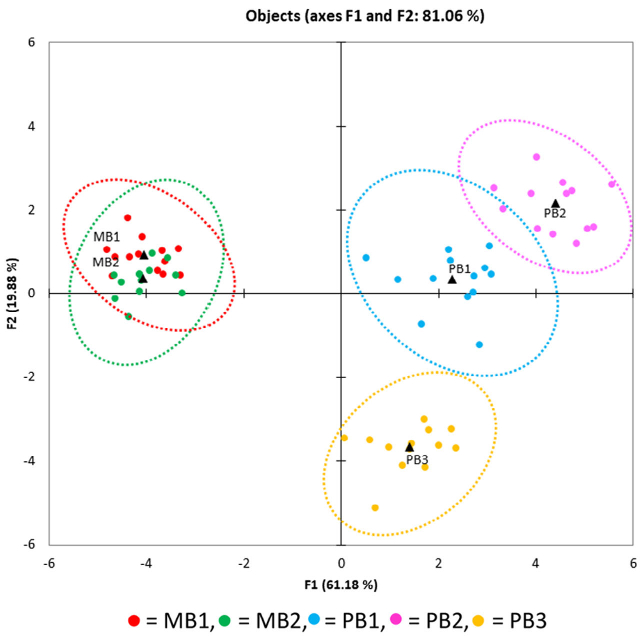

Figure 2 Clustering and dispersion of data using the Flash Profile technique for the five cream cheese samples and the analogues; *ellipses with 95% confidence. MB, Milk based; PB, Plant-based.

Sensory evaluation of cream cheese and plant-based analogues

Flash profile method

In the initial phase of the sensory analysis by the FP method, data from eighteen participants were considered. However, the analysis proceeded with thirteen participants after applying a residue threshold of 10 or lower for participant selection, achieving 81% (F1 + F2) of explained variance. The participants used a variety of terms to describe the cream cheese and their analogues for the attributes appearance, texture, aroma and flavour. The number of attributes ranged from four to sixteen, with an average of ten attributes per participant, resulting in a total of forty-two descriptors. A predominance of descriptors for the attribute flavour was observed, with eighteen different descriptors. The attributes most frequently mentioned by the participants included yellow appearance and artificial cheese aroma (see Appendix A; Figure A1).

The clustering and dispersion analysis of the data collected by the FP method for the five cream cheese samples and their analogues is shown in Fig. 2. The results showed a consensus among the participants, with no data extremely displaced from the identified

Table 3 Best correlated attributes ($r > |0.7|$) with the first two dimensions (F1 = 61.18% e F2 = 19.88%) for each of the thirteen assessors in the Flash-Profile

	F1		F2	
Panellists	Positive	Negative	Positive	Negative
P01	3.Oily; 4.Art.cheese; 1.Opaque; 3.Firm; 4.Nuts	4.Acid; 3.Spreadable	None	3.Creamy
P03	4.Art.cheese; 4.Nuts; 4.Soap; 3.Gel; 1.Grey	2.Cheese; 4.Acid; 4.Milk; 1.Shiny; 3.Smooth; 1.Yellow	None	2.Art.cheese
P04	2.Art.cheese; 4.Art.cheese	1.Shiny; 3.Spreadable; 3.Creamy; 5.Sour; 2.Acid; 3.Smooth	None	2.Coconut; 3.Firm
P05	4.Acid; 2.Art.cheese; 4.Salty	3.Spreadable; 1.Yellow; 3.Creamy; 3.Smooth; 1.Shiny	2.Nuts	4.Nuts
P06	3.Firm; 1.Opaque; 4.Coconut	3.Creamy; 2.Acid	2.Art.cheese; 1.Yellow	None
P08	1.Grey; 1.Opaque; 3.Grainy; 2.Art.cheese; 4.Art.cheese	1.Yellow	None	4.Olive oil
P10	4.Vegetable; 4.Rancid; 1.Grey; 3.Gel; 2.Art.cheese	1.Yellow; 3.Firm; 4.Ricotta; 2.Acid; 4.Milk; 2.Milk	None	2.Oily; 1.White
P11	2.Art.cheese; 4.Art.cheese; 3.Oily	1.Yellow; 1.Shiny; 2.Acid; 4.Cream Cheese; 3.Smooth	1.Brown; 4.Salty; 4.Butter	1.White; 2.Rancid; 4.Rancid; 4.Vegetable
P12	1.Grey; 1.Opaque; 3.Gel; 2.Art.cheese	1.Yellow; 4.Milk; 3.Spreadable; 4.Butter	None	None
P13	1.Grey; 1.Opaque; 2.Art.cheese; 4.Umami; 4.Art.cheese; 4.Butter; 4.Floral; 4.Coconut	1.Shiny; 2.Acid; 3.Smooth; 4.Acid	1.Yellow; 3.Firm	None
P14	4.Art.cheese; 1.Grey	3.Smooth; 1.Shiny; 4.cream cheese	None	2.Vegetable oil
P15	2.Art.cheese	1.Yellow; 3.Creamy; 4.Salty; 1.Shiny; 4.Acid	None	1.White; 2.Fat; 4.Rancid
P17	2.Art.cheese	4.Acid; 1.Yellow	None	4.Salty

1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavour.

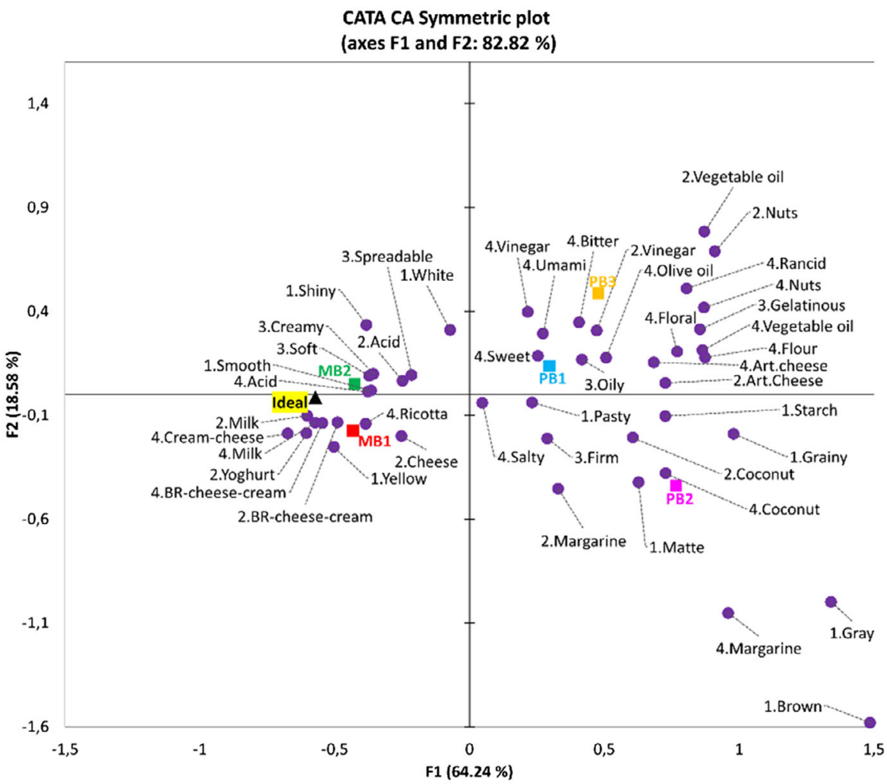

Figure 3 Descriptive map of five commercial cream cheese samples and analogues (vectors) and sensory attributes used to describe them in two dimensional maps of correspondence analysis of CATA frequency and sensory acceptance (n = 102); 1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavour and Sensory descriptors (samples); MB, Milk based; PB, Plant-based.

Table 4 Global acceptance means and their respective standard deviation.

Sample	Global acceptance	SD
MB1	7.63**a**	1.49
MB2	6.71**b**	1.95
PB1	4.42**c**	2.31
PB2	4.10**c**	2.11
PB3	3.26**d**	1.97
P-value	0.001	

Means on the same column followed by the same lowercase letter do not differ significantly in Fisher's test with a confidence level of 95% ($P \leq 0.05$).

groups/quadrants. The samples were grouped into three distinct sets (MB1 + MB2, PB1 + PB2 and PB3 independently), located in separate quadrants. This allows for the identification of the attributes that differentiate them, considering the high correlation attributes for each principal component (F1 and F2).

The group formed by MB1 and MB2 was distinguished from the group PB1 and PB2 primarily in the F1 dimension. Therefore, the sensory attributes associated with this dimension, such as shiny appearance, acidic flavour and creamy texture differentiated these samples, being more prominent in MB1 + MB2. In turn, the group PB3 was distinguished from MB1 + MB2 in both dimensions F1 and F2, but differed from PB1 + PB2 only in F2. This result indicates that the group PB3 was characterised mainly by the coconut aroma, firm texture and nut flavour.

Table 3 shows the attributes identified by the participants, aligned with consumer language, along with their correlations with dimensions 1 and 2. The descriptors commonly mentioned by various participants were used for selecting the most relevant terms for describing the samples, which showed a correlation equal to or greater than 0.7 for each participant (Galli *et al.*, 2019).

CATA test

Fig. 3 shows the graphical representation of the sensory descriptors used in the CATA test. A Correspondence Analysis (CA) was conducted using a contingency table, resulting in a two-dimensional map containing all sensory data. The first two dimensions accounted for

82.82% of the total experimental data, attesting to the robustness and relevance of the data. The analysis of the graph revealed that most of the data explanation was on the dimension F1, indicating that the differences between the attributes were more pronounced on the horizontal axis rather than the vertical axis.

Attributes commonly associated with cream cheese, such as shiny appearance, milk aroma and yogurt aroma (indicative of fermented dairy aroma), were close to the ideal for the product. Conversely, characteristics considered inappropriate or undesirable for this type of product, such as grainy, grey colour and rancid taste, were far from the ideal.

The milk-based samples (MB1 and MB2) differed clearly from the plant-based ones (PB1, PB2 and PB3), positioning closer to the ideal. This proximity was highlighted by key acceptance attributes for cream cheese, such as shiny appearance, milk flavour, Brazilian-cream-cheese (*Requeijão)* flavour and cream-cheese flavour, in addition to creamy and spreadable texture. These findings are in line with the results of instrumental texture and spreadability, which shows the importance of the solid fat to liquid oil ratio at a given temperature for evaluating the technological applications of lipid bases, which exert direct influence on appearance, spreadability, oil exudation and sensory properties of the product (Viriato *et al.*, 2018).

The attributes coconut flavour, vegetable oil aroma, starch texture, nut aroma and nut flavour were identified in the plant-based samples, which can be explained through the formulations of these products (Table 1). These attributes may justify the deviation of these samples from the concept of an ideal product. In particular, the sample PB3 showed significantly ($P < 0.05$) lower acceptance scores when compared to PB1 and PB2 (Table 4), indicating that attributes such as rancid flavour, vegetable oil aroma, and nut aroma contributed negatively to the global acceptance of the product. This observation aligns with the results in Fig. 4, which shows the correlation between the sensory attributes and the global acceptance of the product.

Attributes that align more closely with the ideal product, such as milk aroma, ricotta flavour, Brazilian-cream-cheese flavour, cream cheese flavour and yellow colour, also demonstrated proximity to global acceptance, reinforcing their relevance in the characterisation and acceptance of cream cheeses. On the other hand, attributes considered undesirable and

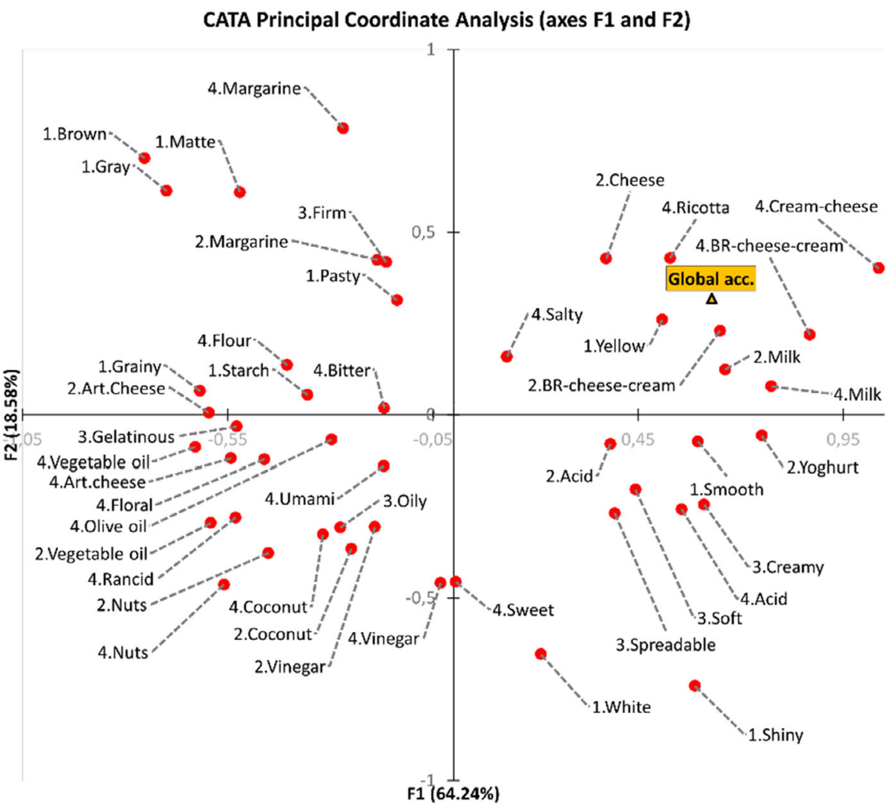

Figure 4 Principal coordinate analysis plot of CATA test; (● Sensory descriptors (samples); △ = Global acceptance). 1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavour.

distant from the ideal (Fig. 3) are consistent with those that decrease consumer acceptance of the product.

The evaluation of global acceptance indicated higher acceptance scores only for the milk-based samples (MB1 and MB2), with scores ranging from 6 to 8 on a 9-point hedonic scale, corresponding to 'liked slightly' to 'liked very much', respectively. In contrast, plant-based samples recorded scores of 3 to 5, corresponding to a perception of 'disliked moderately' to 'indifferent', respectively.

The penalty analysis, detailed in Table A1 of the Appendix, highlighted the attributes necessary to assess the quality of cream cheese, as well as those that do not have a significant impact or that harm the sensory evaluation of the product. Attributes such as shiny appearance, spreadable, soft, and creamy texture, as well as Brazilian-cream-cheese flavour and milk flavour, along with yogurt aroma, cheese aroma and Brazilian-cream-cheese aroma were identified as essential for this type of product. On the other hand, characteristics such as firm texture and ricotta flavour had no significant effect on the sensory evaluation. In contrast, matte appearance, artificial cheese aroma, vegetable oil flavour and artificial cheese flavour were considered detrimental to the quality perception of cream cheese.

RATA test

The frequency graph of the attributes, Figure A2 of the Appendix, illustrates the attributes most frequently mentioned by the participants. Those evaluated by less than one-third of the participants (i.e., rated by less than 1/3 of tasters) were excluded from subsequent ANOVA and Fisher's test, generating unreliable data with a lot of residuals in ANOVA, mainly due to the insufficient representativeness of the sample.

Table 5 shows the average scores of the attributes evaluated by the participants and the significant differences between them. The penalty analysis of the CATA/RATA results made it possible to classify the

Table 5 Averages of attribute intensities evaluated by at least 1/3 of the panellists in the RATA test

	Intensity scores							
Attribute	**MB1**	**MB2**	**PB1**	**PB2**	**PB3**	**Pr > F(mod)**	***P*-value**	***n***
1.Yellow	2.52a	1.63b	1.81ab	2.61a	2.12ab	0.006	**0.001**	138
1.White	3.96b	4.19ab	4.39a	3.30c	4.13ab	<0.001	**<0.001**	343
1.Grey	1.00b	1.00b	1.75b	3.47a	2.21b	<0.001	**<0.001**	102
1.Matte	2.94b	3.50ab	3.65a	3.96a	3.00b	<0.001	**0.001**	186
1.Shiny	3.44b	4.06a	3.06b	2.50b	3.42b	0.000	**<0.001**	200
3.Creamy	4.24a	4.38a	4.06ab	3.50c	3.72bc	0.000	**<0.001**	262
1.Pasty	4.19a	3.72b	3.50b	3.76ab	3.33b	0.002	**<0.001**	213
1.Smooth	4.45a	4.40a	4.20ab	3.90b	3.90b	0.040	**0.014**	197
1.Grainy	2.00bc	1.00c	2.88ab	3.19a	2.94ab	0.011	**0.001**	86
3.Spreadable	4.22ab	4.47a	4.07bc	3.03d	3.75c	<0.001	**<0.001**	285
3.Firm	3.66b	3.50b	3.78ab	4.19a	3.74b	0.017	**0.006**	225
3.Soft	4.35a	4.24ab	3.90bc	3.91abc	3.50c	0.005	**0.001**	170
3.Gelatinous	2.00a	3.57a	3.22a	3.31a	3.48a	0.412	0.059	88
2.Acid	3.09a	3.19a	3.06a	3.45a	3.47a	0.770	0.305	127
2.Art.Cheese	3.17ab	1.75c	4.08a	3.43ab	2.86b	<0.001	**<0.001**	175
2.Margarine	3.24a	3.16a	3.07a	3.60a	2.92a	0.399	0.116	123
2.Cheese	3.36a	3.59a	3.59a	3.27a	2.14b	0.074	**0.006**	167
2.BR cream cheese	3.42a	3.55a	3.33a	3.35a	2.09b	0.021	**0.001**	137
2.Milk	3.14a	3.00a	2.89a	2.83a	2.29a	0.598	0.108	87
2.Yogurt	3.32a	3.37a	3.33a	2.50ab	1.80b	0.011	**0.002**	118
2.Vegetable oil	3.00ab	2.00b	3.75a	3.37ab	3.64a	0.134	**0.013**	77
4.Acid	3.09a	3.19a	3.06a	3.45a	3.47a	0.770	0.305	124
4.Art.cheese	2.64b	2.77b	4.07a	3.34b	3.39b	<0.001	**<0.001**	196
4.Salty	3.00a	3.03a	3.38a	3.02a	3.24a	0.367	0.095	240
4. BR cream cheese	3.64a	3.41a	3.76a	3.24a	3.00a	0.182	0.058	175
4.Milk	3.03a	3.17a	3.30a	2.38a	2.67a	0.561	0.146	89
4.Rancid	2.33a	3.00a	3.29a	3.05a	3.55a	0.370	0.125	91
4.Cream cheese	4.24a	3.87b	3.88ab	4.00ab	4.00ab	0.342	**0.048**	185
4.Vegetable oil	3.33a	3.88a	3.25a	3.43a	3.72a	0.525	0.147	105

Means on the same row followed by the same lowercase letter do not differ significantly by Fisher's test with a confidence level of 95% ($P \leq 0.05$).
1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavour.
Bold are variables that differ significantly ($P \leq 0.05$).

attributes with relevant citation (20% threshold) that have an impact on increasing or decreasing the average acceptability of the products, classifying them as 'must have'; 'nice to have', 'does not influence', 'does not harm' and 'must not have'. Among the attributes recognised as essential for the quality of cream cheese, shiny appearance significantly stood out in sample MB2. The creamy texture was more evident in MB1, MB2 and PB1, and less perceived in PB2, while the attributes yogurt aroma, cheese aroma, and BR cream cheese aroma were significantly lower in PB3. There was no significant difference between the samples for the attributes of milk flavour and BR cream cheese flavour. Regarding the attributes considered harmful to the product, the artificial cheese flavour was more prevalent in the sample PB2, while the artificial cheese aroma was less frequent in MB2. Although the vegetable oil flavour was mentioned as characteristic of plant-based formulations, no significant differences were observed among the samples for this attribute.

The RATA test indicated that the attributes most strongly associated with the samples MB1 and MB2 were those most appreciated and desirable for products with higher acceptance, such as spreadable and milk aroma and milk flavour.

The Pearson's correlation matrix (Table A2) and the biplot graph of the Principal Component Analysis (PCA) (Fig. 5) revealed that the attributes of firmness and spreadability were negatively correlated, confirming

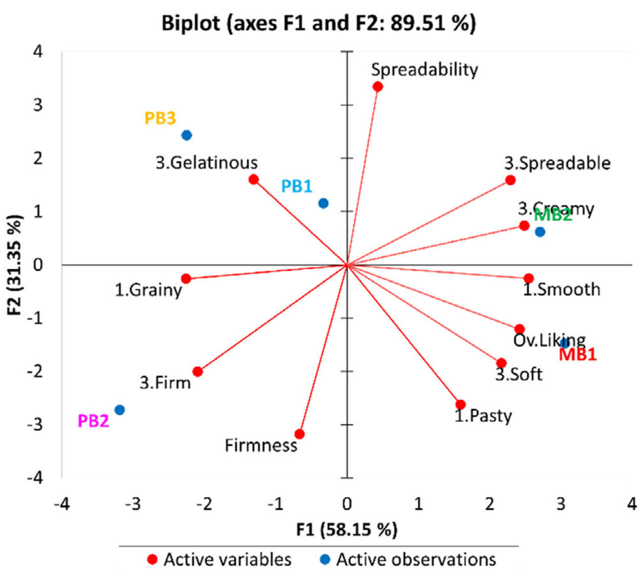

Figure 5 Principal component correlation (PCA) plot of instrumental analysis and RATA test; (● = Active variables; ● = Active observations). 1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavour.

that these parameters were inversely correlated and strongly related to the sensory attributes of firm texture and spreadable texture, respectively. The attributes associated with product acceptance were those expected for a quality cream cheese, such as soft texture, creamy texture and smooth appearance. Conversely, characteristics such as grainy and gelatinous texture were inversely correlated with product acceptability.

The PCA analysis was crucial both to confirm the predicted correlations between attributes and to establish new relationships between sensory attributes and product acceptance. For instance, gelatinous texture showed a negative relationship with acceptance, while pasty appearance had a positive correlation. Thus, there is an antagonism (inverse correlation) between variables, as well as a distinctive positioning of the samples. The sample MB2 was positioned close to the descriptors smooth and soft, indicating high acceptance, whereas in the opposite quadrant, the least accepted sample (PB3) was associated with gelatinous texture. The sample MB1 was located close to the attribute of spreadable by both instrumental and sensory analyses, while PB2 was close to the indicators of firmness also measured by both methodologies.

Conclusion

The results of this study showed that novel plant-based analogues still face barriers concerning consumer acceptance. The sensory attributes of coconut flavour, artificial cheese aroma and flavour, along with spreadable texture, marked the distinction between milk-based (MB1 and MB2) and plant-based (PB1, PB2 and PB3) products, contributing to the lower acceptance of the plant-based analogues. The complexity of stabilising the physicochemical system of cream cheese and the importance of protein–fat interactions highlight the technological challenge in producing plant-based cream cheese analogous to traditional formulations. The difference in formulations and, consequently, in the stabilisation of the physicochemical system, directly impacts the characteristics of the products, affecting both techno-functional and sensory properties. Therefore, overcoming these challenges is essential for improving the consumers' acceptance of plant-based analogues.

Acknowledgments

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-Brazil (CAPES)-Finance Code 001. The authors acknowledge the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for granted scholarships (grant 141775/2020-3 and grant 151640/2022-0) and financial support (grant 405616/2021-0).

Author contributions

Kívea Kássia de Paiva e Silva: Conceptualization; methodology; formal analysis; investigation; resources; writing – original draft; writing – review and editing; data curation. **Bruno Domingues Galli:** Methodology; formal analysis; data curation. **Michelle Alban:** Conceptualization; methodology; investigation. **Débora Parra Baptista:** Conceptualization; methodology; formal analysis; investigation; resources; data curation. **Elizabeth Harumi Nabeshima:** Methodology; formal analysis. **Paulo Henrique Mariano Marfil:** Methodology; formal analysis. **Mirna Lúcia Gigante:** Conceptualization; supervision; project administration.

Conflict of interest statement

The authors declare no conflict of interest.

Ethical guidelines

The present study was carried out after approval by the UNICAMP Research Ethics Committee, under registration CAAE 66975222.9.0000.5404.

Peer review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/ijfs.17484.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure A1. Flash-profile atributes Frequency. 1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavor.

Figure A2. Evaluated attributes frequency. * Excluded attributes (i.e. rated by less than 1/3 of tasters). 1 = Appearance, 2 = Aroma, 3 = Texture, 4 = Flavor.

Table A1. CATA Penalty analysis summary.

Table A2. Pearson's correlation matrix correlating data referring to samples of cream cheese and plant-based analogues.

Sheet A1.

Sheet A2.

Sheet A3.