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Textural properties of faba bean-based Camembert analogue

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As global food systems evolve toward sustainability, the demand for plant-based alternatives to traditional animal-derived products is growing. Faba beans (*Vicia faba*), known for their versatility and agricultural benefits, offer a promising solution in the development of vegan cheese analogues. This study explores the potential of using faba beans to produce a Camembert-like cheese. The Camembert analogues were formulated with fat contents of 15% and 30% and varying proportions of coconut and rapeseed oils in triplicate. The proportions of coconut and rapeseed oils were 40:60, 50:50, and 60:40. Generally, the Camembert analogues with the higher fat content (30%) resulted in higher hardness, springiness, chewiness, and dry matter content compared to the analogues with 15% fat. This suggests that fat content is more important for these parameters than proportions of coconut and rapeseed oil. Future research should focus on optimising texture to more closely replicate traditional dairy Camembert and meet consumer sensory expectations. Incorporating sensory evaluations and consumer feedback is essential to validate instrumental findings and ensure the product meets consumer expectations.

Key words: *Vicia faba,* plant-based food, dairy analogue, vegan

Introduction

Production of plant-based foods is rapidly gaining popularity today due to a variety of reasons related to environmental sustainability, animal welfare, health benefits, and market demand (Batista et al. 2023, Boukid 2024). The transition from traditional dairy cheese to plant-based alternatives represents a significant shift towards more ethical, sustainable, and health-conscious food systems. Health benefits of consuming plant-based cheese-like products include lower saturated fats, which can be beneficial for cardiovascular health (Kamath et al. 2022). Moreover, plant-based cheese-like products are naturally lactose-free, which makes them suitable for people with lactose intolerance or dairy allergies. Finally, plant-based cheese-like products are characterised by a high content of dietary fibre as well as vitamins and minerals (Kamath et al. 2022).

The production of plant-based cheese-like products, however, encourages innovation in food technology to make the products attractive to a wide range of consumers. Several attempts were made to develop healthy and tasty cheese analogues (Ferawati et al. 2021, Dobson and Marangoni 2023, Grasso et al. 2024, Jaeger et al. 2024). These studies used various plant materials such as soybean, peas and faba beans, and tried to mimic the unique flavours, textures, and mould-ripened qualities of the classical dairy products while following vegan standards. However, such products often lack texture and nutritional value compared to traditional dairy cheeses (Short et al. 2021, Sözeri Atik and Huppertz 2025). Camembert is a soft, creamy, surface-ripened cheese which is characterised by a fat content of 45–60% of dry matter and a NaCl content of below 2% (McClements and Grossmann 2022). Camembert analogues, based on fermenting flaxseed oil cake (Łopusiewicz et al. 2020), soy flour, chickpea flour, pea protein, pumpkin protein, hemp protein, cashews, pistachios, and spirulina powder (Fabiszewska et al. 2024) have been developed. Among these, cashews, pistachios and flaxseed oil cake showed the highest potential to serve as a raw material for Camembert analogues as they had the best taste and appearance and served as good matrices for mould and lactic acid bacteria starter cultures (Fabiszewska et al. 2024). In the present study, we used faba beans (*Vicia faba* minor) as a base as this crop is adapted to the cool, temperate climate of Scandinavia, with nutritional value and economic viability (Tidåker et al. 2021).

Texture plays a crucial role in determining consumer preference and overall satisfaction with cheese and cheese analogues. Traditionally, cheese texture analysis has relied on either sensory evaluation or instrumental measurements or both. While sensory evaluation provides valuable insights, it is often time-consuming and requires extensive

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panellist training. Consequently, instrumental measurements have become increasingly popular for routine texture analysis in the cheese industry (Kim et al. 2009, Zheng et al. 2016). Among instrumental methods, Texture Profile Analysis (TPA) is a particularly effective tool for analysing and predicting sensory attributes of cheese and cheese analogues that have demonstrated strong correlations between instrumental TPA results and sensory evaluation data of the texture (Drake et al. 1999, Di Monaco et al. 2008, Silva et al. 2024).

Faba bean (*Vicia faba*) is gaining attention as a sustainable and protein-rich ingredient for plant-based food applications, including dairy analogues. With a protein content ranging from 23% to 35%, it offers a promising alternative to soy and other legume-based proteins (Auer et al. 2023). Fortifying cereal-based foods with faba beans has been intensively investigated (Verni et al. 2019). Some research explored faba beans as a base for fermentation to create new products (Fernandez Castaneda et al. 2024). Garcia-Fontanals et al. (2023) used faba bean flour to partially replace dairy protein. Despite its potential, faba bean protein is currently used sparingly in food products. This limited use is primarily due to two factors: its low solubility and its restricted functionality when compared to animal-derived proteins such as those found in egg whites and milk (Yang et al. 2018). Additionally, its functional and sensory properties, such as texture, mouthfeel, and flavour, remain key challenges in food formulation.

Generally, faba beans contain 23–35% protein, 55–71% carbohydrates and only 0.7–3.2% fat (Auer et al. 2023), which is quite low for Camembert production. During the production and ripening of cheese, the fat content and subsequent lipolysis are important, as fat influences the main sensory characteristics: texture, solubility of aromatic components, as well as flavour compounds and flavour precursors (Leclercq-Perlat et al. 2007).

Coconut oil is a popular choice in plant-based cheese production due to its high saturated fat content, which contributes to a creamy texture and helps mimic traditional dairy cheese (Fresán and Rippin 2021). However, concerns about the health implications of saturated fat and the sustainability of coconut oil have led researchers to search for alternative fats or fat combinations. Recent studies have shown that blending coconut oil with unsaturated oils, such as sunflower oil, can improve the nutritional profile of plant-based cheeses while maintaining desirable textural qualities (Sanders et al. 2025). For example, it has been found that a combination of 25% coconut oil and 75% sunflower oil, along with pea protein, created a cheese alternative with satisfactory melt and stretch properties comparable to those made with 100% coconut oil (Sanders et al. 2025). Rapeseed oil, known for its high content of unsaturated fatty acids, especially polyunsaturated fatty acids, offers a nutritionally valuable alternative and contribute to various health benefits, including anti-inflammatory, antimicrobial, antidiabetic, and anticancer properties (Shen et al. 2023).

By combining the textural benefits of coconut oil with the nutritional advantages of unsaturated oils like rapeseed or sunflower oil, our aim was to create plant-based cheeses that are not only satisfying in texture and flavour but also healthier and more sustainable. This approach allows for a reduction in saturated fat content while maintaining the desired functionality, addressing both consumer demands and health concerns. The aim of this study was to develop a prototype of a Camembert analogue based on Nordic-grown faba beans and evaluate texture in relation to fat content and fat source. In this study, the term "texture" refers to instrumental measurements obtained through TPA, which provides quantitative data on mechanical properties such as hardness, cohesiveness, adhesiveness, springiness, chewiness, and gumminess. Sensory evaluations, while valuable for assessing texture as perceived by consumers, were not conducted as part of this research.

Material and methods

Materials

Swedish-grown faba beans cv. "Tiffany" were supplied by the Research Institute of Sweden (RISE), Uppsala, Sweden. Rapeseed oil ('Rapsona') was supplied from AAK, Karlshamn, Sweden. Coconut oil (Virgin coconut oil from the brand Kung Markatta) was purchased from a supermarket chain in Uppsala, Sweden. Starter culture and white mould culture (containing *Penicillium camembertii*) were supplied by SACCO System Nordic AB company (Skurup, Sweden).

Preparation of Camembert analogue

Based on earlier studies by Fogelberg et al. (2017), a production protocol was set up as follows (Fig. 1). Dry, de-hulled faba beans (500 g) were soaked in water for 10–12 h at room temperature, swelling to approximately twice their original size and weight. Soaked beans were then washed and tap water was added to reach a total weight of 3000 g. This resulted in a bean-water ratio (BWR) of 1:6 (W/W) on a dry bean weight basis. Then, 0.05% of ascorbic acid was added to the mixture to stabilise colour. The faba beans and water were blended in a standard household blender until a homogenous structure was achieved (3 min). The mixture was then filtered through a muslin cloth and pressed to extract the filtrate and obtain faba bean base referred to as "bean milk".

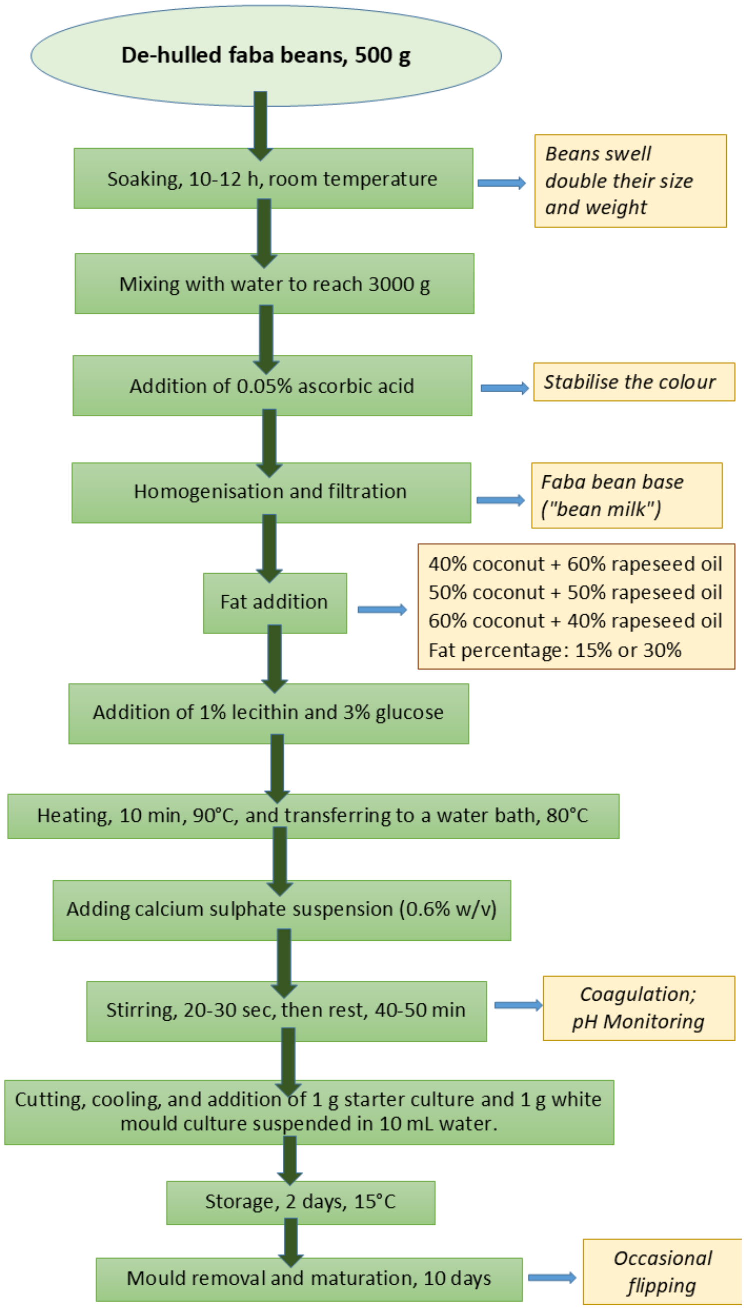

Fig. 1. Faba bean-based Camembert analogue processing flowchart

Faba bean milk was mixed with an appropriate amount of one of the three combinations of fat 1) 40% coconut + 60% rapeseed oil, 2) 50% coconut + 50% rapeseed oil and 3) 60% coconut + 40% rapeseed oil to reach a total fat of either 15% or 30%. Then, emulsifier lecithin (1%) and glucose (3%) were added to ensure the binding of the oil with the water in the next stages and to provide the appropriate amount of glucose necessary for the start culture activity in the fermentation stage. After combining the ingredients, the mixture was transferred to a stainless-steel pot, heated to 90 °C, and maintained at this temperature for 10 min with stirring to prevent sticking. The mixture was then transferred into a water bath at 80 °C and left until it reached this temperature. After this, a suspension of the coagulant calcium sulphate dihydrate in 100 ml of water was added to the mixture. The final concentration of calcium sulphate dihydrate in the mixture was 0.6% (w/v). The mixture was stirred manually for 20–30 seconds to distribute the coagulant evenly and then left for 40–50 min to allow coagulation. Following coagulation, the pH of the faba bean milk was 6.1 ± 0.3, which was optimal for coagulant activity, while the pH of the resulting curd decreased to 4.7 ± 0.1. Then, the curd was cut and cooled in a cold-water bath until it reached to the temperature of 30 °C. The selected starter culture (1 g) and white mould culture (1 g), both suspended in 10 ml of water, were added to the curd and gently stirred. The curd was placed in round plastic Camembert moulds and stored in a refrigerator at 15 °C for two days. After two days, the moulds were removed, and the product was left to mature for at least 10 days, with occasional flipping, to complete fermentation and allow *Penicillium camembertii* growth.

Experimental design

Camembert fat content varies significantly between producers. Adamska et al. (2017) examined eight samples of Camembert-type and six samples of Brie-type cheese available on the Polish market and found that the cheeses differed in fat content, 13.07–33.81% in Camembert-type and 22.05–36.0% in the Brie-type. Based on these findings and previous studies by Fogelberg et al. (2017) indicating problems with high fat content using coconut oil, we selected two lower levels of fat, 15% and 30%, including different proportions of coconut and rapeseed oils in triplicate.

Dry matter content

The dry matter content of the faba bean Camembert analogue was analysed as previously described (Nielsen and Hui 1994). The representative samples of the final Camembert analogues, representing all layers, were taken, weighed (approximately 5 g), and dried in small aluminium containers in an oven for 18–24 h at 105 °C. After drying, the samples were weighed again, and the dry matter content (DM) was calculated.

Texture profile analyses (TPA)

Before testing, all samples were kept at ambient temperature for 1 h. The samples of Camembert analogues were cut into 4 cm cubes and analysed using a texture analyser TA-XT plus (Stable Micro Systems, TA-HDi, Surrey, UK) equipped with a 500 N load cell and a 36 mm cylindrical aluminium probe with a 1.0 mm diameter probe at a falling speed of 1.0 mm s^{-1}, testing speed of 1.0 mm s^{-1}, return rate of 1.0 mm s^{-1}, compression ratio of 50%, two compression cycles, and trigger force of 5 g. Hardness, cohesiveness, adhesiveness, springiness, chewiness, and gumminess were calculated in triplicate following the procedure used by Johansson et al. (2022).

Mould growth and visual appearance

Camembert and Brie cheese develop a white mould on the outside, causing these cheeses to ripen from the outside in as a result of the enzymes the mould produces. In this study, mould growth was only assessed visually. Visual appearance was evaluated qualitatively based on photographic documentation of the samples under standardised lighting conditions.

Statistical Analysis

Data were analysed with SAS Version 9.4 (SAS Institute Inc., Cary, NC, USA). The effect of fat content, proportions between coconut and rapeseed oil, and interactions between fat content and ratios on texture parameters and dry matter content were evaluated using two-way ANOVA. Post-hoc Tukey's test was used to determine differences between the samples prepared with different fat content and different proportions of coconut and rapeseed oil. The level of statistical significance was set at $p < 0.05$. Data are presented as least squares means (LS means) ± standard errors. As no significant interactions were observed, interaction effects were not presented.

Results

The visual appearance of the Camembert analogues differed due to variations in fat content and the proportions of coconut and rapeseed oil (Fig. 2).

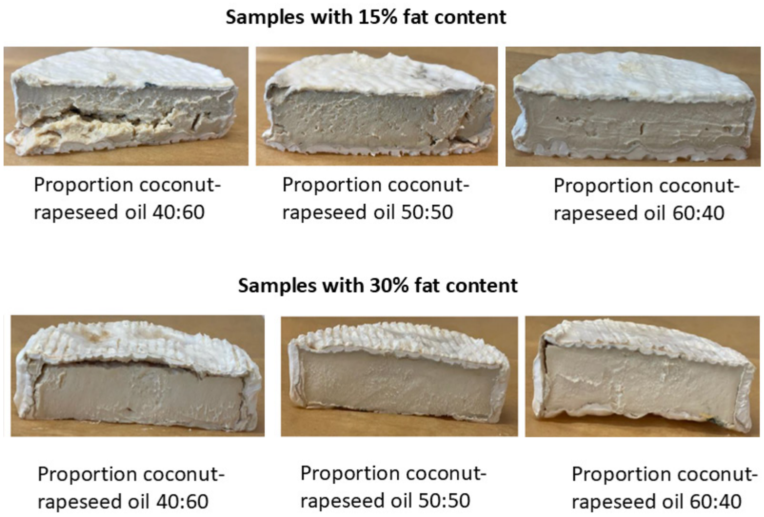

Fig. 2. The appearance of representative samples from each group

Higher fat content generally resulted in a smoother, creamier surface, while lower fat levels led to a drier look, with the samples often falling apart more easily. Additionally, the different oil proportions influenced colour and texture, with more coconut giving the analogues a whiter, more uniform appearance, while higher rapeseed oil content contributed to a slightly yellower hue surface. The texture of the Camembert analogues was described using the attributes of hardness, adhesiveness, springiness, cohesiveness, chewiness and gumminess, all of which were measured using TPA (Tables 1 and 2).

Table 1. Instrumental texture profile analysis of faba-based Camembert analogues with 15% and 30% fat content.

Parameter	Faba-based Camembert analogues		*p-value,* fat content
	Fat 15%	Fat 30%	
Hardness, N	1.7 ± 0.19	2.4 ± 0.16	0.016
Adhesiveness, N·s	-1.4 ± 0.19	-1.47 ± 0.15	0.902
Springiness	13.84 ± 0.88	18.86 ± 0.73	0.001
Cohesiveness	0.14 ± 0.01	0.13 ± 0.01	0.501
Chewiness, N·m	3.25 ± 0.68	6.16 ± 0.56	0.007
Gumminess, N	0.23 ± 0.03	0.32 ± 0.03	0.070
Dry matter, %	33.04 ± 3.79	57.1 ± 3.14	0.001

Data are presented as LS (least squares) means and standard error (n=3 in each group, measured in triplicate).

Hardness was significantly higher in the samples with 30% fat levels (Table 1; $p < 0.05$). No differences in the hardness between analogues with different fat sources were observed. Springiness was also higher in the samples with 30% fat levels (Table 1; $p < 0.05$), meaning that it takes longer for the samples with 15% fat to recover its properties after compression, and they are more sensitive to deformation. Samples with 30% fat has higher chewiness compared to other samples with 15% fat (Table 1, $p = 0.007$). A marginal effect of the proportions of coconut and rapeseed oil was observed ($p = 0.053$). The detailed Post-hoc Tukey's test revealed that the only significant differences were observed between the samples with a coconut-rapeseed oil proportion of 50:50 and those with a proportion of 60:40 at fat levels of 30%, with the latter exhibiting higher values (Table 2, $p = 0.035$). The higher dry matter content in the samples with 30% fat compared to those with 15% fat was observed.

Table 2. Instrumental texture profile analysis of faba-based Camembert analogues with different proportions of coconut and rapeseed oil

Parameter	Faba-based Camembert analogues						*p-value*, proportion between fat sources
	Fat 15%			Fat 30%			
	Proportion coconut-rapeseed oil 40:60	Proportion coconut-rapeseed oil 50:50	Proportion coconut-rapeseed oil 60:40	Proportion coconut-rapeseed oil 40:60	Proportion coconut-rapeseed oil 50:50	Proportion coconut-rapeseed oil 60:40	
Hardness, N	1.6 ± 0.35	1.4 ± 0.29	2.1 ± 0.35	2.2 ± 0.29	2.1 ± 0.29	2.7 ± 0.25	0.126
Adhesiveness, N·s	-1.24 ± 0.32	-1.44 ± 0.26	-1.65 ±0.32	-1.56 ± 0.26	-1.07 ±0.26	-1.78 ± 0.23	0.267
Springiness	13.79 ± 1.61	13.75 ± 1.32	13.99 ± 1.62	18.34 ± 1.32	16.09 ± 1.32	22.16 ± 1.14	0.109
Cohesiveness	0.16 ± 0.01	0.14 ± 0.01	0.12 ± 0.01	0.14 ±0.01	0.11 ±0.01	0.15 ±0.01	0.207
Chewiness, N·m	3.6^{b} ± 1.25	2.6^{b} ± 1.01	3.56^{b} ±1.25	5.66^{ab} ±1.018	3.97^{b} ±1.02	8.86^{a} ± 0.88	0.053
Gumminess, N	0.26 ± 0.06	0.19 ± 0.05	0.25 ±0.06	0.31 ±0.05	0.24 ± 0.05	0.4 ± 0.04	0.136
Dry matter, %	39.23 ± 6.95	37.51 ± 5.68	22.36 ± 6.95	59.13 ± 5.68	59.05 ± 5.68	53.11 ± 4.91	0.155

Data are presented as LS (least squares) means and standard error (n=3 in each group, measured in triplicate). LS means within a row followed by different letters are significantly different according to Tukey's test ($p < 0.05$).

Discussion

Texture plays a significant role in consumer satisfaction and perception of food quality. Deviations from consumers' expectations for the texture of foods (e.g., creaminess of soft cheeses and crispiness of chips) can lead to negative feedback. In the development of new food products, understanding texture is essential for creating items that appeal to consumers. Measuring texture can guide adjustments to ingredients, processing methods, or formulations to achieve desired properties.

Texture Profile Analysis (TPA) is an instrumental technique used to assess the textural properties of food products, such as hardness, cohesiveness, springiness, and chewiness. It gives insights into the mechanical properties of food, which are influenced by its molecular structure, processing conditions, and ingredients (Peleg 2019). By quantifying texture, food producers can ensure their products meet both sensory and practical expectations, improving the overall food experience. TPA offers several advantages in the evaluation of cheese and cheese analogue texture. It provides quantitative, reproducible data on texture, overcoming limitations of time and panel training. It simultaneously measures various textural properties including hardness, springiness, cohesiveness, adhesiveness, and chewiness, providing a comprehensive texture profile. Dobson and Marangoni (2023) used TPA on a range of cheese analogues, showing that the analogues could reach hardness levels of 15–90 N, which allowed samples to be tailored to a broader range of dairy products. However, TPA method has several limitations, including a lack of standardisation across products, dependence on sample preparation, and inability to fully mimic human chewing behaviour. Additionally, TPA may not capture microstructural differences or the behaviour of fragile or adhesive samples, and the results can be influenced by compression conditions, especially in high-fat or highly elastic foods (Chen and Opara 2013). To gain a more comprehensive understanding of texture properties, complementary methods such as rheological measurements or microscopy could be considered in future studies.

The observed higher hardness in our samples with 30% fat levels can be attributed to fat content contributing to a firmer texture in plant-based products, mainly because fats, particularly saturated fats, remain solid at room temperature (Kilcast and Clegg 2002). This effect may also be due to the lower moisture content in the higher-fat samples. The results indicate that adjusting the fat content is an effective approach for increasing hardness where a denser texture is desired. As our composition of rapeseed oil and coconut oil will be less stable at room temperature compared to animal-based fat compositions, we suggest that further work should be carried out using vegetable-based fats that have a higher melting point.

Interestingly, in traditional dairy cheese, hardness usually decreases with higher fat content, likely due to the high protein content and the stable, firm network formed by dairy proteins (Romeih et al. 2002, Koca and Metin 2004). Additionally, fat tends to disrupt the protein structure and acts as a lubricant, resulting in a smoother and softer texture in dairy cheese (Romeih et al. 2002). In the present study, the hardness of Camembert analogues was generally lower compared to traditional dairy soft cheeses, which varies from 6.9 (Szkolnicka et al. 2024) to 9.3 (Abdeen et al. 2021). The higher springiness in samples with 30% fat levels can be explained by higher viscosity of the samples with 15% fat compared to these with 30% fat. Higher fat content can disrupt the protein matrix leading to a more elastic and springy texture (Faber et al. 2017). The observed significant differences in hardness and springiness are important, as they are usually well correlated with sensory measurements (Meullenet et al. 1997, Breuil and Meullenet 2001).

Higher chewiness in samples with 30% fat can be attributed to the fact that increased fat content contributes to a creamier texture, making the cheese more enjoyable to chew. The fat can also help create a smoother mouthfeel, enhancing the perception of chewiness (Pang et al. 2022).

Generally, fat content, dry matter and hardness of the samples with 30% fat were similar to commercial dairy Camembert cheese (Fang et al. 2016). However, other TPA parameters differed. The adhesiveness was −0.21 N·s, springiness was 0.44, cohesiveness was 0.39, and chewiness was 0.44 N for commercial dairy Camembert cheese (Fang et al. 2016), which differed from the corresponding values in faba bean-based Camembert analogues in the present study. Lower springiness might be a result of a less elastic protein network in dairy Camembert cheese (Logan et al. 2017). Chewiness in the present study (6.2) was rather similar to commercial young Cheddar (7.19) (Fang et al. 2016).

Cheese analogues are gaining increasing acceptance among both food manufacturers and consumers due to their numerous potential benefits (Rinaldoni et al. 2014, Berta et al. 2016, Farahat et al. 2021). However, it is obvious that formulating foods with ingredients that reduce health risks, such as replacing animal fats with vegetable fats, presents a challenge for the food industry. Differences in texture between dairy cheese and plant-based cheese analogues are commonly criticised by consumers (Grossmann and McClements 2021, Short et al. 2021).

There are several cheese analogues on the market today, mainly based on starch and coconut fat. Although these are considered vegan-friendly, it can be discussed if coconut oil, a product not originating from Europe, is suitable from a sustainable point of view. Moreover, rapeseed oil has less saturated fats than coconut oil and a higher content of monounsaturated and polyunsaturated fats, indicating that rapeseed oil would be preferred from a health perspective. However, as coconut oil hardens at higher temperatures, it will create a more stable/firm structure compared to most rapeseed oils. Further studies are needed to optimise the production of cheese analogues, focusing on improving texture, flavour, and overall sensory qualities to better meet consumer preferences. Optimal balance of fat content, protein sources, and alternative oils, as well as the impact of processing methods on the final product's quality and shelf life, should be explored.

Conclusion

This study offers a foundational contribution to both the development of Camembert-style cheese analogues from Swedish-grown faba beans and the characterisation of their texture. There is clear potential for producing and further developing such analogues using Swedish-grown faba beans. In this study, we focused on texture and mould growth, rather than on sensory qualities or shelf-life. Our findings suggest that a combination of rapeseed oil and coconut oil is feasible, although other fats that are solid at room temperature may also be suitable. Using a solid fat may help reduce the risk of the Camembert analogue melting in consumer settings. Overall, the analogues with higher fat content (30%) exhibited increased hardness, springiness, chewiness, and dry matter content compared to those with 15% fat. This indicates that fat content had a greater influence on texture attributes than the specific ratio of coconut to rapeseed oil. This insight is valuable for mimicking the texture of traditional Camembert cheese.

Further research is needed to optimise texture and to include sensory evaluations and consumer acceptance, with the ultimate goal of creating a viable, appealing non-dairy alternative. Incorporating sensory evaluations and consumer feedback is essential to validate instrumental findings and ensure the product meets consumer expectations.

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References

Abdeen, E.-S.M.M., Ibrahim, O.A. & Kholif, A.M.M. 2021. Utility of *Moringa oleifera* waste as a coagulant in goat soft cheese production. Heliyon 7: e07536. https://doi.org/10.1016/j.heliyon.2021.e07536

Adamska, A., Rasińska, E., Rutkowska, J. & Antoniewska, A. 2017. Fatty acid profile of commercial Camembert- and Brie-type cheeses available on the Polish market. CyTA - Journal of Food 15: 639–645. https://doi.org/10.1080/19476337.2017.1331266

Auer, J., Östlund, J., Nilsson, K., Johansson, M., Herneke, A. & Langton, M. 2023. Nordic Crops as Alternatives to Soy-An Overview of Nutritional, Sensory, and Functional Properties. Foods 12: 2607. https://doi.org/10.3390/foods12132607

Batista, L.F., Rocha, F., Dias, M.M. d. S., Pires, A.C.d.S. & Vidigal, M.C.T.R. 2023. Comfort plant-based food: What do consumers want? - A focus group study with different consumers group. International Journal of Gastronomy and Food Science 34: 100810. https://doi.org/10.1016/j.ijgfs.2023.100810

Berta, M., Muskens, E., Schuster, E. & Stading, M. 2016. Rheology of natural and imitation mozzarella cheese at conditions relevant to pizza baking. International Dairy Journal 57: 34–38. https://doi.org/10.1016/j.idairyj.2016.02.038

Boukid, F. 2024. Holistic benefits of plant-based foods for sustainable agrifood systems. Current Opinion in Food Science 58: 101184. https://doi.org/10.1016/j.cofs.2024.101184

Breuil, P. & Meullenet, J.-F. 2001. A comparison of three instrumental tests for predicting sensory texture profiles of cheese. Journal of Texture Studies 32: 41–55. https://doi.org/10.1111/j.1745-4603.2001.tb01033.x

Chen, L. & Opara, U.L. 2013. Approaches to analysis and modeling texture in fresh and processed foods - A review. Journal of Food Engineering 119: 497–507. https://doi.org/10.1016/j.jfoodeng.2013.07.026

Di Monaco, R., Cavella, S. & Masi, P. 2008. Predicting sensory cohesiveness, hardness and springiness of solid foods from instrumental measurements. Journal of Texture Studies 39: 129–149. https://doi.org/10.1111/j.1745-4603.2008.00134.x

Dobson, S. & Marangoni, A.G. 2023. Methodology and development of a high-protein plant-based cheese alternative. Current Research in Food Science 7: 100632. https://doi.org/10.1016/j.crfs.2023.100632

Drake, M.A., Gerard, P.D., Truong, V.D. & Daubert, C.R. 1999. Relationship between instrumental and sensory measurements of cheese texture. Journal of Texture Studies 30: 451–476. https://doi.org/10.1111/j.1745-4603.1999.tb00230.x

Faber, T.J., Jaishankar, A. & McKinley, G.H. 2017. Describing the firmness, springiness and rubberiness of food gels using fractional calculus. Part II: Measurements on semi-hard cheese. Food Hydrocolloids 62: 325–339. https://doi.org/10.1016/j.foodhyd.2016.06.038

Fabiszewska, A., Wierzchowska, K., Dębkowska, I., Śliczniak, W., Ziółkowska, M., Jasińska, K., Kobus, J., Nowak, D. & Zieniuk, B. 2024. Plant-Based Alternatives to Mold-Ripened Cheeses as an Innovation among Dairy Analogues. Foods 13: 2305. https://doi.org/10.3390/foods13142305

Fang, X., Rioux, L.-E., Labrie, S. & Turgeon, S.L. 2016. Commercial cheeses with different texture have different disintegration and protein/peptide release rates during simulated in vitro digestion. International Dairy Journal 56: 169–178. https://doi.org/10.1016/j.idairyj.2016.01.023

Farahat, E.S.A., Mohamed, A.G., El-Loly, M.M. & Gafour, W.A.M.S. 2021. Innovative vegetables-processed cheese: I. Physicochemical, rheological and sensory characteristics. Food Bioscience 42: 101128. https://doi.org/10.1016/j.fbio.2021.101128

Ferawati, F., Hefni, M., Östbring, K. & Witthöft, C. 2021. The Application of Pulse Flours in the Development of Plant-Based Cheese Analogues: Proximate Composition, Color, and Texture Properties. Foods 10: 2208. https://doi.org/10.3390/foods10092208

Fernandez Castaneda, L.A., Auer, J., Leong, S.-l. L., Newson, W.R., Passoth, V., Langton, M. & Zamaratskaia, G. 2024. Optimizing Soaking and Boiling Time in the Development of Tempeh-like Products from Faba Bean (*Vicia faba* L.). Fermentation 10: 407. https://doi.org/10.3390/fermentation10080407

Fogelberg, F., Östlund, J. & Feng, X. 2017. Vegetarian cheese from faba beans. In: Proceedings of the NJF Conference Legumes from Field to Fork - a Nordic-Baltic Perspective on Production, Development and Marketing of Legumes, Tartu, Estonia 28-30th November 2017. 28 p.

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

Grasso, N., Roos, Y.H., Crowley, S.V. & O'Mahony, J.A. 2024. Physicochemical properties of plant-based cheese alternatives fortified with calcium. LWT 193: 115657. https://doi.org/10.1016/j.lwt.2023.115657

Garcia-Fontanals, L., Llorente, R., Valderrama, J., Bravo, S. & Talens, C. 2023. Hybrid Spreadable Cheese Analogues with Faba Bean and Mealworm (*Tenebrio molitor*) Flours: Optimisation Using Desirability-Based Mixture Design. Foods 12: 1522. https://doi.org/10.3390/foods12071522

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 & Technology 118: 207–229. https://doi.org/10.1016/j.tifs.2021.10.004

Jaeger, I., Köhn, C.R., Evans, J. D., Frazzon, J., Renault, P. & Kothe, C.I. 2024. Nutritional and microbial profiles of ripened plant-based cheese analogs collected from the European market. Food Research International 191:114724. https://doi.org/10.1016/j.foodres.2024.114724

Johansson, M., Johansson, D., Ström, A., Rydén, J., Nilsson, K., Karlsson, J., Moriana, R. & Langton, M. 2022. Effect of starch and fibre on faba bean protein gel characteristics. Food Hydrocolloids 131: 107741. https://doi.org/10.1016/j.foodhyd.2022.107741

Kamath, R., Basak, S. & Gokhale, J. 2022. Recent trends in the development of healthy and functional cheese analogues-a review. LWT 155: 112991. https://doi.org/10.1016/j.lwt.2021.112991

Kilcast, D. & Clegg, S. 2002. Sensory perception of creaminess and its relationship with food structure. Food Quality and Preference 13: 609–623. https://doi.org/10.1016/S0950-3293(02)00074-5

Kim, E.H.-J., Corrigan, V.K., Hedderley, D.I., Motoi, L., Wilson, A.J. & Morgenstern, M.P. 2009. Predicting the sensory texture of cereal snack bars using instrumental measurements. Journal of Texture Studies 40: 457–481. https://doi.org/10.1111/j.1745-4603.2009.00192.x

Koca, N. & Metin, M. 2004. Textural, melting and sensory properties of low-fat fresh kashar cheeses produced by using fat replacers. International Dairy Journal 14: 365–373. https://doi.org/10.1016/j.idairyj.2003.08.006

Leclercq-Perlat, M.N., Corrieu, G. & Spinnler, H.E. 2007. Controlled production of Camembert-type cheeses: part III role of the ripening microflora on free fatty acid concentrations. Journal of dairy research 74: 218–225. https://doi.org/10.1017/S0022029906002329

Logan, A., Xu, M., Day, L., Singh, T., Moore, S.C., Mazzonetto, M. & Augustin, M.A. 2017. Milk fat globule size affects Cheddar cheese properties. International Dairy Journal 70: 46–54. https://doi.org/10.1016/j.idairyj.2016.11.003

Łopusiewicz, Ł., Drozłowska, E., Tarnowiecka-Kuca, A., Bartkowiak, A., Mazurkiewicz-Zapałowicz, K. & Salachna, P. 2020. Biotransformation of Flaxseed Oil Cake into Bioactive Camembert-Analogue Using Lactic Acid Bacteria, *Penicillium camemberti* and *Geotrichum candidum*. Microorganisms 8:1266. https://doi.org/10.3390/microorganisms8091266

McClements, D.J. & Grossmann, L. 2022. Dairy Alternatives - Cheese, Yogurt, Butter, and Ice Cream. In: McClements, D.J. & Grossmann, L. (eds.). Next-Generation Plant-based Foods: Design, Production, and Properties. Springer International Publishing. p. 443–521. https://doi.org/10.1007/978-3-030-96764-2_9

Meullenet, J.F.C., Carpenter, J.A., Lyon, B.G. & Lyon, C.E. 1997. Bi-cyclical instrument for assessing texture profile parameters and its relationship to sensory evaluation of texture. Journal of Texture Studies 28: 101–118. https://doi.org/10.1111/j.1745-4603.1997.tb00104.x

Nielsen, S.S. & Hui, Y.H. 1994. Government Regulations and Recommendations Related to Food Analysis. In: Nielsen, S.S. (ed.). Introduction to the Chemical Analysis of Foods. Jones and Bartlett Publishers, Inc., Boston, US.

Pang, Z., Bourouis, I. & Liu, X. 2022. Function of saliva in creaminess perception during food oral processing: In perspective of lubrication. Journal of Agriculture and Food Research 10: 100377. https://doi.org/10.1016/j.jafr.2022.100377

Peleg, M. 2019. The instrumental texture profile analysis (TPA) revisited. Journal of Texture Studies 50: 317–327. https://doi.org/10.1111/jtxs.12387

Rinaldoni, A.N., Palatnik, D.R., Zaritzky, N. & Campderrós, M.E. 2014. Soft cheese-like product development enriched with soy protein concentrates. LWT - Food Science and Technology 55: 139–147. https://doi.org/10.1016/j.lwt.2013.09.003

Romeih, E.A., Michaelidou, A., Biliaderis, C.G. & Zerfiridis, G.K. 2002. Low-fat white-brined cheese made from bovine milk and two commercial fat mimetics: chemical, physical and sensory attributes. International Dairy Journal 12: 525–540. https://doi.org/10.1016/S0958-6946(02)00043-2

Sanders, C., Stobbs, J.A., Dobson, S. & Marangoni, A.G. 2025. Impact of protein sources on the functionality of plant-based cheeses formulated with saturated and unsaturated fat. Physics of Fluids 37: 011913. https://doi.org/10.1063/5.0238556

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

Shen, J., Liu, Y., Wang, X., Bai, J., Lin, L., Luo, F. & Zhong, H. 2023. A Comprehensive Review of Health-Benefiting Components in Rapeseed Oil. Nutrients 15: 999. https://doi.org/10.3390/nu15040999

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

Sözeri Atik, D. & Huppertz, T. 2025. Plant-based cheese analogs: structure, texture, and functionality. Critical Reviews in Food Science and Nutrition. https://doi.org/10.1080/10408398.2024.2449234

Szkolnicka, K., Dmytrów, I., Mituniewicz-Małek, A. & Meghzili, B. 2024. Camembert-type cheese with sweet buttermilk: The determination of quality properties and microstructure. Foods 13: 2515. https://doi.org/10.3390/foods13162515

Tidåker, P., Karlsson Potter, H., Carlsson, G. & Röös, E. 2021. Towards sustainable consumption of legumes: How origin, processing and transport affect the environmental impact of pulses. Sustainable Production and Consumption 27: 496–508. https://doi.org/10.1016/j.spc.2021.01.017

Verni, M., Coda, R. & Rizzello, C.G. 2019. Chapter 37 - The Use of Faba Bean Flour to Improve the Nutritional and Functional Features of Cereal-Based Foods: Perspectives and Future Strategies. In: Preedy, V.R. & Watson, R.R. (eds.). Flour and Breads and their Fortification in Health and Disease Prevention (Second Edition) Academic Press. p. 465–475. https://doi.org/10.1016/B978-0-12-814639-2.00037-X

Yang, J., Liu, G., Zeng, H. & Chen, L. 2018. Effects of High Pressure Homogenization on Faba Bean Protein Aggregation in Relation to Solubility and Interfacial Properties. Food Hydrocolloids 83: 275–286. doi: 10.1016/j.foodhyd.2018.05.020.

Zheng, Y., Liu, Z. & Mo, B. 2016. Texture profile analysis of sliced cheese in relation to chemical composition and storage temperature. Journal of Chemistry 2016: 690380. https://doi.org/10.1155/2016/8690380