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*Research Article*

# Evaluation of the food safety of vegan almond-based cream cheese analogue produced in an artisanal way in Jaraguá do Sul, Brazil

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**Abstract -** In recent years, the demand and preference for artisanal foods, including cheeses, have increased even in industrialized countries. The objective of this work was to present a plant-based cream cheese which, although similar to dairy products, is new and specially created based on almond milk. To evaluate its safety, microbial and physicochemical analyses were performed. Almond milk was prepared manually and mechanically. Analysis of thermotolerant coliforms and *Escherichia coli* | , *Salmonella* spp., determination of viable aerobic mesophiles and mold/yeast count, and positive coagulase *Staphylococcus aureus* count were carried out. The physicochemical determinations as pH, moisture, ashes, and fat content, were carried out. Sensory evaluation was carried out by a non-trained panel. There was an absence of *Salmonella* spp. and coagulase-positive *Staphylococcus aures*. All samples analyzed showed <3 MPN/g of thermotolerant coliforms. The count of viable aerobic mesophiles presented values of 6.27 - 6.47 $Log_{10}$ for almond-based type cream cheese and 2.41 $Log_{10}$ for traditional cream cheese. pH values of 5.2 and 5.4, fat content of 24.04 % and 26.44 % were obtained for almond-based type cream cheese and traditional cream cheese, respectively. Ash values of 2.5% and 71.44% of moisture content were obtained with the manual extraction, which were higher than with the mechanical extraction. Most of the panelists approved the almond-based cream cheese. Results demonstrated that the vegetarian

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product type "cream cheese" is suitable for consumption and meets the demand of vegetarian or vegan consumers and consumers who choose not to consume meat.

**Keywords:** Vegan almond cheese, microbial quality vegan cheese, Brazilian processed cheese, food safety

## 1. Introduction

In recent years, the consumer profile has transformed, and a range of new products have appeared in the Brazilian market. Among the differentiated products, we can mention foods that meet the demand of the vegetarian and vegan public and those who are lactose intolerant. Products developed for this market can also be consumed by consumers with non-strict habits, but who avoid consuming animals (Prabhakaran, 2005; Taffarel, 2012; Nobrega et al., 2020). In Brazil, there has been an increase from 9% to 14% in the number of Brazilians who declare themselves vegetarian and around 29.2 million Brazilians declare themselves vegetarian (IBOPE Inteligência, 2018). According to the Brazilian Vegetarian Society, Brazilians are reducing their meat consumption on their own (Sociedade Vegetariana Brasileira, 2021). Plant-based products (PBPs) are defined as food or drink products in which the main ingredient (or ingredients) are substitutes for meat or dairy products. The PBPs market, therefore is gaining prominence since an increasing number of consumers globally are adopting a plant-based diet or incorporating plant-based products into their diets. It has been considered as a potentially profitable sector for new entrants and current plant-based food and beverage producers (Beacom et al., 2021; Beacom et al., 2022)

It is estimated that 65% of the human population has a reduced ability to digest lactose after childhood due to a partial or total decrease in the lactase enzyme (Branco et al., 2017). Symptoms of lactose intolerance can range from simple malaise to anaphylactic shock. In Brazil, the southeast region has a higher prevalence of lactose intolerance (60%) followed by the southern region with 44.1% with the prevalence higher among non-whites (91%) compared to whites, 53.2% (Barbosa et al., 2020). Sweet almond (*Prunus dulcis*) is the fruit of the almond tree, belonging to the *Rosaceae* family. Almonds are considered a valuable source of lipids and protein in the diet and their contents of dietary fiber, vitamin E, phytosterols and several key micronutrients contribute to a healthy nutrient profile (King et al., 2008).

With the growing demand for consumption and sustainable production of products rich in protein, interest in alternative, lower-cost vegetable proteins are also increasing. Among the alternatives to bovine milk or animal milk, whose demand has been increasing in recent decades, "non-dairy alternatives" such as soluble almond extract or almond "milk" stand out. Almond "milk" is a colloidal dispersion obtained after mixing water with almond powder or almond paste. From this mixture, a white liquid is obtained, which is then filtered, homogenized (by high pressure) and finally pasteurized (van Mastrigt et al., 2018) From "almond milk" it is possible to produce cheeses of non-animal origin. Thus, in this way, we meet the demand of vegetarian/vegan consumers, those who are lactose intolerant and even consumers who no longer wish to consume meat.

Studies show that milk is one of the foods that vegans miss the most on the market and the demand for artisanal cheeses has increased significantly and, even with industrialization, individuals have preferred artisanal foods, on the grounds that they are more appetizing and consider them "natural" foods, due to their manual preparation. Artisanal cheeses are those that, to obtain them, use traditional manufacturing methods, being produced using rudimentary techniques, which do not have quality control (Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, 2008). And because they are heavily handled, they are susceptible to contamination, especially of bacteriological origin.

The elaboration of vegetarian or vegan "cheese" products using vegetable sources has increased recently and products similar to "cheese" have been prepared using white beans (Santo et al., 2022), cassava (Souza & Oliveira, 2016), soybeans (Silva et al., 2020) and Brazil nuts (Braga et al., 2020) as vegetable sources. The objective of the present work is to evaluate the food safety of an almond-based type cream cheese produced in an artisanal way in Jaraguá do Sul, Brazil, through microbiological analyses, physicochemical parameters and sensory evaluation.

## 2. Materials and methods

### 2.1 Samples

The samples of artisanal vegan almond-based cream type cheese were kindly donated by a local producer in the city of Jaraguá do Sul, Brazil. For analytical and microbial analysis, 120 g of artisanal vegan almond-based cream type cheese, packed in plastic food container samples, were used. Creamy traditional cheese: Traditional creamy processed cheese (milk-based) samples were purchased in supermarkets. For each analytical and microbial analysis, 200 g of creamy traditional cheese packed in plastic food containers was used.

For analytical and microbial analysis, three (3) and five (5) samples were used, respectively.

The samples were identified and sent to the Microbiology Laboratory at the Unisociesc Faculty, Jaraguá Parking Campus, Brazil and kept under refrigeration until the moment of analytical procedures.

### 2.2 Preparation of almond milk

Method A: Almonds were soaked in distilled water for 12 h at room temperature, drained and peeled. Then, almonds were ground with water in a blender in an optimized ratio of 1:4 for 2 min. The obtained slurry was strained through a two-layer cotton cloth to obtain almond milk (Kundu et al., 2018). Method B: A second method for preparation of almond milk was used through an industrial fruit depulper machine (650W), specially designed for this purpose by the local producer. The manufacturing process takes 30 minutes at room temperature. A ratio of 1:4 of almonds and water was used to extract the pulp at 1500 rpm for 2 min, separating it from the almonds and then used in the fermentation

The milky liquid obtained from both methods was subjected to a thermal process by heating at 95°C for 5 min and used for the fermentation process.

### 2.3 Fermented almond milk processing

For the fermentation process, *Penicilium candidum* was used as the inoculum. A commercial fungus for vegan camembert and brie cheese composed of selected strains of *Penicillium candidum*, freeze-dried, grown in a plant-based medium was added. For the fermentation process, 20 g of the inoculum containing 10 UFC/g was added to 80 L of almond milk according

to the manufacturer's instructions. In addition *to Penicilium candidum* as inoculum, acid lactic bacteria were used in the fermentation process. A commercial blend of freeze-dried cultures of the following bacteria was used: *Lactococcus lactis* ssp. *lactis*, *Lactococcus lactis* ssp. *cremoris*, *Lactococcus lactis* ssp. *lactis biovar.diacetylactis*, and *Leuconostoc mesenteroides* ssp. *mesenteroides*. These blends of mixed bacteria are commonly used by the cheese industry. For the fermentation process, 20 g of of freeze-dried cultures containing 10 UFC/g were used in 80 L of almond milk according to the manufacturer's instructions.

This process was performed in 10 batches and from these batches, 5 of them were selected for microbial and physicochemical analyses. When the heated almond milk reached the ideal temperature, around 38 °C, probiotic cultures (*Peniciulium candidum* and lactic acid bacteria) were added. The fermentation process occurs spontaneously for a period of 24 hours at room temperature. After this period, the final pH is checked, which is around 5.0.

Data for the processing operations were provided under a nondisclosure agreement, and thus the primary data are not included in this article.

### 2.4 Analytical determinations

Physicochemical determinations were carried out in accordance with the Analytical Standards of the Adolfo Lutz Institute (Instituto Adolfo Lutz, 2008). All analyses were carried out in triplicates.

*2.4.1 pH, moisture content and ashes determination*

For pH determination, the electrometric method was followed. The IAL standard method was chosen to determine the pH, moisture content and ashes determination (Instituto Adolfo Lutz, 2008) in samples. For moisture content determination the direct drying method in an oven at 105ºC until constant weight was used and ashes determination was carried out through incineration in a muffle furnace at 550°C.

*2.4.2 Fat content*

The Gerber method was used. The lactobutyrometers were weighed with their respective stoppers (to check whether they had equivalent weights), then 10 mL of sulfuric acid (D = 1.5) was slowly transferred, with the aid of an automatic pipettor, to the butyrometer. Approximately 1 g of the sample was weighed and slowly stirred until the sample was completely dissolved. Then, 1 mL of isoamyl alcohol was added. The butyrometers were corked and gently shaken to completely dissolve, placed in a water bath at 60ºC for 15 min in the vertical position (cork down). The reading (inferior meniscus) of the light yellow, transparent layer (fat) was taken directly within the graduated scale of the lactobutyrometer. The value obtained on the scale corresponds directly to the fat percentage.

### 2.5 Microbiological analysis

The sampling plans and microbiological criteria for microbiological determinations were in accordance with Resolution No. 331/2019 (Agência Nacional de Vigilância Sanitária., 2019) and the International Commission on Microbiological Specifications for Food (International Commission on Microbiological Specifications for Foods, 1986). To determine *Salmonella*, the 2-attribute plan was followed, with absence or presence criteria. To determine thermotolerant coliforms, the 3-attribute plan was followed.

The methodologies used were traditional according to the Compendium of Methods for the Microbiological Examination of Food – APHA. (Salfinger & Tortorello, 2015).

*2.5.1 Viable aerobic mesophiles count*

To count viable aerobic mesophiles, the Pour Plate technique was used. From the serial dilution, 1 mL aliquots were inoculated onto plates containing Standard Counting Agar (PCA), incubated inverted at 35°C for 48 h. Results expressed in CFU/g (colony forming units) of the sample were converted to $Log_{10}$.

*2.5.2 Thermotolerant coliform*

For the determination of thermotolerant coliforms the standard most probable number (MPN) technique was used.

*2.5.3 Coagulase-positive staphylococci*

From the serial dilution, 1 mL aliquots of the serial dilutions ($10^{-1}$ to $10^{-2}$) were inoculated on plates (in duplicates) containing Baird Parker (BP) agar using the surface technique. Then, incubated inverted at 35°C for 48h. Colonies considered typical (circular, black, smooth, small, with perfect edges and the formation of a transparent halo or opaque color around them) were subjected to the coagulase test, using rabbit plasma. Results expressed in CFU/g (colony forming units) of the sample were converted to $Log_{10}$.

*2.5.4 Mold and yeast count*

To count molds and yeasts, the surface plating technique was used. From the serial dilution, 1 mL aliquots were inoculated on plates containing Standard Agar for Counting Sabouraud Dextrose Agar with chloramphenicol. Incubated at 25 °C for 3-5 days for colony counting.

**2.6 Statistical analysis**

After obtaining the results, the count values were transformed into $log_{10}$, correlated and subjected to one-way (ANOVA) analysis of variance using the Minitab Statistical Software program (Minitab® 21). The significance level used in all tests was 95% confidence ($p < 0.05$). The significance of difference between means was determined by the Tukey test.

**2.7 Sensory evaluation**

Sample preparation and presentation were carried out in accordance with the Analytical Standards of the Adolfo Lutz Institute (Instituto Adolfo Lutz, 2008). Sensory evaluation of almond cream cheese was carried out using the 9-point hedonic scale (1 = extremely dislike, 5 = neither liked nor dislike, 9 = extremely like) to assess the appearance, texture, flavor and taste. Sensory evaluation was carried out by 30 untrained panelists of varied aged (20 to 50 years old), comprising men and women of the faculty, including teachers, students and staff were recruited. The samples were presented to the consumers in individual plastic pots containing 10 - 20 g of the product at 4 ± 1°C.

## 3. Results and discussion

In this study, a comparison was made between the almond-based type cream cheese with the Brazilian creamy processed cheese. In Brazil the creamy processed cheese has a great commercial value. It is processed from mechanical, chemical and thermal treatment of protein mass (Silva e Alves et al., 2015) According to the Brazilian legislation, the processed creamy cheese is obtained by the fusion of the curd mass, cooked or not, drained and washed, which is obtained by acid and/or enzymatic coagulation of milk and has consistency that can be spread with a knife at room temperature (Brasil. Ministério da Agricultura e do Abastecimento, 1997). In this study, an almond-based type cream cheese was evaluated using physicochemical parameters and microbiological quality. Almond milk is a plant-based alternative derived from maceration of plant material and soaked in water through homogenization and its appearance and consistency is similar to

the mammalian milk. (Kundu et al., 2018)

### 3.1 Physicochemical analysis

The values found for the physico-chemical parameters for almond-based type cream type cheese and traditional creamy processed cheese are shown in (Table 1).

**Table 1.** Physicochemical parameters for almond-based type cream cheese and traditional creamy processed cheese.

| | Almond-based cream cheese (Method A) Manual extraction | Almond-based type cream cheese (Method B) Mechanical extraction | Traditional creamy processed cheese |
|---|---|---|---|
| pH | 5.22 ± 0.03 [a] | 5.25 ± 0.04 [a] | 5.4 ± 0.21 [a] |
| % Moisture content | 71.44 ± 2.86 [a] | 56.05 ± 4.8 [b] | 61 ± 2.94 [a,b] |
| % Ashes | 2.5 ± 0.04 [a] | 1.7 ± 0.16 [b] | 1.8 ± 1.96 [b] |
| % Fat content | 23.91 ± 0.87 [a] | 24.04 ± 3.73 [a] | 26.44 ± 0.42 [a] |

**Note:** All analyses were performed in triplicate. Data are expressed as the mean ± SD (standard deviation). For each parameter, the mean followed by the same letter represents that they are not significantly different ($p \leq 0.05$) according to the Tukey test.

#### 3.1.1 *pH and moisture content*

The pH values for almond-based type cream cheese presented close values and did not differ significantly from traditional creamy cheese ($p > 0.05$). pH values vary greatly depending on the origin from which the cheese was produced. Higher values of 6.18 were found by Souza and Oliveira (2016) when evaluating cheeses made from cassava. Silva et al. (2020) found values of 6.07 and 6.36 for two commercialized brands of vegan cheese-type tofu. Values like those found in this study were found when evaluating the effect of coagulants in cheeses similar to tofu made from soybeans, whose values varied between 5.6 and 5.95 (Prabhakaran, 2005). Mefleh et al. (2022) obtained an average pH of 5.6 for spreadable plant-based cheese containing dry-fractioned pea protein and inulin–olive oil. In this study, the lowest value for moisture content ($p \leq 0.05$) was obtained when the extraction was mechanically processed. In this study, the moisture content for the traditional creamy cheese was higher ($p \leq 0,05$) than the almond-based cream type cheese when almond milk was mechanically extracted (method B).

High levels of moisture content confer high perishability to the product and are directly related to the stability and quality of the food. Higher values for moisture content were found for vegetable-based cheese. Souza and Oliveira (2016) obtained an index of 63.38% for cassava-based cheese-type food. In products like tofu, produced with soybeans, studies reported values varying between 82 and 87% (Ciabotti et al., 2006).

According to the Brazilian legislation (Brasil. Ministério da Agricultura, Pecuária e Abastecimento, 1996), cheeses with a moisture content of not less than 55% are classified as high-moisture cheeses, also known as soft cheeses. The high moisture content and relatively high pH make the product highly perishable due to the development of spoilage microorganisms, with a short shelf life and it must be consumed quickly once opened (Silva et

al., 2020).

According to Hasan (2012), proteins in almond composition act as emulsifiers, which are fundamental for obtaining almond milk. In this study, during the mechanical process of extraction is possible to control the pressure applied at the homogenization operation, since the emulsion stability is one of the most important factors governing the shelf-life of colloidal foods such as the almond milk (Hasan, 2012). Thus, with the mechanical process of extraction, it is possible to obtain a fine emulsion with precise properties of texture and a high degree of stability. Furthermore, the mechanical method may enhance both nutritional and sensory properties, besides is fast and easy to perform.

The almond milk extraction method employed might have influenced the percentage yield since the yield was 50 % higher when the mechanical method was used. Furthermore, the type of processing might influence the extractability of solid content. Soaking, as in the manual extraction, probably influenced the extractability of total solids. In this study, when the almond milk was mechanically processed, it displayed a lower moisture content as almond milk contained higher total solids content (Kundu et al., 2018).

*3.1.2 Ash content*

The values obtained for ash content for almond-based type cream cheese (method A) in the present study are in alignment with the value reported by Santo et al. (2022), which reported ash content values of 2.27 in the preparation of a vegetarian "cheese" product based on white beans (*Phaseolus vulgaris*), adding prebiotics such as inulin. The lowest ($p \leq 0.05$) values for ash content were obtained when the extraction was mechanically processed and a higher mineral content when extracted manually. Higher values of 6.18 were found by Souza and Oliveira (2016) when evaluating cheeses made from cassava. The ash content may vary depending on the plant source used in food production and the percentage mineral content is considered a quality criterion for the nutritional adequacy of foods for well-being. (Ndife et al., 2021) Higher values for ash content were found by Souza and Oliveira (Souza & Oliveira, 2016) in cassava-based cheese with values of around 8% and lower ash content of 1.00 was found in tofu cheese (Elmahi & Zubeir, 2020). Studies have reported that almond milk exhibits high contents of ash as potassium, calcium, zinc and magnesium (El-Hossainy et al., 2022). It has been postulated that the mineral composition of plant based milk samples varies with the level of minerals in the seed of extraction, extraction method, seed/extractant ratio, among others (Onweluzo & Nwakalor, 2009).

*3.1.3 Fat content*

The fat content for the three types of cheese did not vary significantly ($p \geq 0.05$), with values varying between 23 and 26%. According to the Brazilian legislation (Brasil. Ministério da Agricultura, Pecuária e Abastecimento, 1996), vegan cheeses obtained from almonds, as well as the traditional creamy cheese, can be classified as semi-fat (fat content between 25.0 and 44.9%). The variation in fat content may vary according to the source from which the product was obtained. For example, commercial plant-based milk substitutes as almond-based samples, contained lower fat content, as 3.3 to 4.4% (Jeske et al., 2017) and 10% in tofu cheese (Elmahi & Zubeir, 2020).

### 3.2 Microbiological analysis

In this study, from 10 batches of the processed almond milk, 5 batches were randomly selected to ensure microbiological quality. Our results showed that all batches using the same processing during the

production of the almond-based type cream cheese presented a good microbiological quality. In (Table 2), the results of the evaluation of the *Salmonella* sp, thermotolerant coliforms, positive coagulase-positive staphylococci, viable mesophilic aerobic bacteria and molds and yeasts' populations are shown.

**Table 2.** Analysis of thermotolerant coliforms, count of viable mesophilic aerobic bacteria, Count of molds and yeasts, *Salmonella* sp. and coagulase-positive staphylococci in almond-based type cream cheese and traditional creamy cheese.

| | **Almond-based type cream cheese (Method A)** | **Almond-based type cream cheese (Method B)** | **Traditional creamy cheese** |
|---|---|---|---|
| Thermotolerant coliforms MPN/g | <3 | <3 | <3 |
| *Salmonella* spp. | Absence | Absence | Absence |
| Estafilococos coagulase positive | Absence | Absence | Absence |
| Count of viable mesophilic aerobic bacteria (arithmetic mean) $Log_{10}$. (standard deviation in parentheses) | $6.27^{a} \pm 0.66$ | $6.47^{a} \pm 0.71$ | $2.41^{b} \pm 0.51$ |
| Mold and yeast count (arithmetic mean) $Log_{10}$. (standard deviation in parentheses) | $4.63^{a} \pm 0.48$ | $5.53^{a} \pm 0.72$ | Absence |

**Note:** Data are expressed as the mean ± SD (standard deviation). For each parameter, the mean followed by the same letter represents that they are not significantly different ($p \leq 0.05$) according to the Tukey test.

*3.2.1 Salmonella and thermotolerant coliforms determination*

According to Brazilian legislation (Agência Nacional de Vigilância Sanitária, 2019), nuts, almonds and edible seeds (for direct consumption), the microorganisms researched are *Salmonella*/25g and *Escherichia coli*. However, there is no specification for products obtained from almonds, walnuts and other seeds. These products are relatively new on the market, as is their consumption by the general population. To compare data already established by law for nuts, almonds and edible seeds for direct consumption were used. In this study, the following microorganisms were evaluated: *Salmonella* spp., thermotolerant coliforms, coagulase-positive staphylococci, standard count of viable mesophilic organisms and count of molds and yeasts. The microbiological criteria as well as the sampling plans were followed in accordance with the ICMSF (International Commission on Microbiological Specifications for Foods, 1986; International Commission on Microbiological Specifications for Foods, 2018). In this study, all cheeses analyzed are in accordance with the parameters established.

Thermotolerant coliforms (MPN/g) had their values below the maximum limit allowed by the Brazilian legislation, with values of <3 MPN/g for all cheeses analyzed. Results like those found in this

study were found by Santo et al. (2022), who reported the result of <10 MPN/ g and absence of *Salmonella* spp. in the formulation of vegetarian product type "cheese" based on white beans (*Phaseolus vulgaris*), added with prebiotics.

*3.2.2 Coagulase-positive staphylococci*

In the Brazilian legislation, there is no specification for coagulase-positive staphylococci for edible nuts, almonds and edible seeds. In fact, in this study, in all samples, the presence of *Salmonella* sp. and coagulase-positive staphylococci was not detected. Regarding the presence of *Salmonella* spp., the specification of the Brazilian legislation is absent in all samples analyzed. Thus, all samples analyzed are in accordance with Brazilian legislation. The presence of *Salmonella* spp. in food characterizes it as a product unsuitable for human consumption. Nazim et al. (2013) reported the absence of *Salmonella* spp. in soy-based cheese (tofu). However, Santo et al. (2022) reported the presence of coagulase-positive staphylococci with a low count in the order of $< 10^2$ CFU/g when preparing a cheese-like product based on white beans and added inulin.

*3.2.3 Viable mesophilic aerobic bacteria and mold/yeast counts*

Viable mesophilic aerobic bacteria and mold/yeast counts for the vegan almond-based type cheese were relatively high. Traditional creamy cheese presented viable mesophilic aerobic bacteria counts at significantly lower levels than the almond-based type cream cheese ($p \leq 0.05$). Mesophilic microorganisms are not directly related to human health; their presence or count is an indicator of deterioration or excessive environmental contact. It provides information about the hygienic-sanitary characteristics of product processing and storage. Regarding mold/ yeast count, the traditional creamy cheese did not present fungi, thus demonstrating its quality.

It is well known that the thermal process of pasteurization eliminates pathogenic microorganisms and reduces the microbial load. In this study, the milk almond was subject to a thermal process before fermentation to ensure safety and delay spoilage. A temperature of 95°C for 5 min was chosen to ensure the microbial quality of the vegan almond-based type cheese. After cooling the almond milk to 38 °C, the inoculum was added. The levels of mesophilic microorganisms found in this study are consistent with the use of fermentation processes during the production of the vegan almond-based type cheese (Willis et al., 2024). The acid environment created by the fermentation selectively favors the lactic acid bacteria in the starter and potential pathogens are unable to flourish (Johnson, 2014). The almond-based type of cream cheese is produced in an artisanal way, followed by strict control over the ingredients at all stages of fermentation to prevent cross-contamination and potential microbial growth.

In the production of almond-based type cream cheese, dairy bacteria and fungi are added. Dairy bacteria are part of a group of Gram-positive, catalase-negative, non-spore-forming organisms that generally grow under microaerophilic or strictly anaerobic conditions (Bruno & Carvalho, 2009). *Lactobacillus*, *Lactococcus*, *Enterococcus*, *Streptococcus*, *Pediococcus*, *Leuconostoc*, *Weissela*, *Carnobacterium*, *Tetragenococcus* and *Bifidobacterium* are considered the most important genera (Djadouni & Kihal, 2012).

In the product analyzed in this study, the main dairy bacteria added were *Lactococcus lactis*, which has been considered one of the most important starter bacteria used in dairy technology with great economic importance (Yerlikaya, 2019) Species and subspecies *lactis* and *cremoris* have been considered as the central

components of starter cultures used in commercial cheese production (McAuliffe, 2018). Some probiotic properties of *Lactococcus lactis* spp. have been demonstrated. For example, Yerlikaya (2019) reported that certain strains of *Lactococcus lactis* showed antimicrobial activity. Another positive characteristic that the authors reported was no decarboxylation activity, which led to biogenic amines that are undesirable in commercial foods. Furthermore, studies have shown the viability of *Lactobacillus* for 21 days when used as starter culture in fermented plant-based milk as soy and almond milk (Al Zahrani & Shori, 2023).

The fermentation of dairy milk by lactic bacteria is well documented and fermentation improves the flavor and texture of dairy fermented products. *Lactococcus lactis* has been widely used in the production of dairy and non-dairy foods, as well as in the health sector. It is a fermenting organism, and its main product is lactic acid, resulting from the fermentation of carbohydrates. In addition to reducing the pH, it adds flavor and conservation to the product. As a preservative, it has been used as a control bioagent and studies indicate its potential to inactivate certain strains of *L. monocytogenes* in milk (Bukvicki et al., 2020). Furthermore, it is an organism with great potential to produce flavor in the products to which it is added. Studies by van Mastrigt et al. (2018) demonstrated the production of 82 volatile compounds with flavours like butter or cheese when using cultures simulating cheese ripening conditions. Another important aspect of *Lactococcus lactis* is its potential as a probiotic and many studies have evaluated its biochemical and probiotic potential. The benefits of probiotic bacteria to human health include improving the intestinal microbiota and defense against pathogens (Yerlikaya, 2019) Studies indicate that certain species have been shown to have anti-inflammatory and anti-cancer activities (Han et al., 2015) and can be used as probiotics to combat cancer and pro-inflammatory cytokines.

In the current study, no sugar or acidity regulators were added to decrease the pH and then convert to lactic acid. Although the fermentation of plant-based products as the almond milk used in this study is still not completely understood, it can be implied that the *Lactococcus lactis* added was able to break down the carbohydrate present in the almond milk. Besides this, *Penicilium candidum* played an important role due to its known proteolytic activity, which supplies a carbon source. (Aziza & Amrane, 2012) Indeed, studies have shown the ability of certain strains of *Lactobacillus acidophilus* to grow and convert sugars to lactic acid in different plant substrates (Harper et al., 2022). Although there are differences in plant proteins and carbohydrate structure which may affect the fermentation process, studies have shown that plant proteins can be broken by the proteolytic system of lactic acid bacteria (Harper et al., 2022).

Fungi play an important role in the maturation and development of flavor, contributing to flavor. In this study, *Penicilium candidum* (or *P. camemberti*) was used in the starter culture in the production of the almond-based type cream cheese. Its colonization in cheese prevents the colonization of undesirable fungi and bacteria (Laich et al., 2002) This fungus is also known as white mold, being responsible for the aroma and flavor of cheeses and is involved in the ripening of cheeses such as Camembert and Brie, which are characterized by superficial growth, giving the cheese a whitish appearance. It is also used in cheeses such as Roquefort and Gorgonzola, characterized by bluish "veins' ', a striking feature in these types of cheese.

In addition to its pronounced characteristics in the production of flavor, aromas, and texture, *Penicilium candidum* has characteristics of intense lipolytic and proteolytic activity. And under favorable conditions, lipolysis of triglycerides present in fat occurs (Galli et al., 2016). It is an organism with intense enzymatic activity, as demonstrated by Aziza and Amrane (2012) who reported the ability of *Penicilium candidum* (*P. camemberti*) to assimilate three groups of amino acids (cysteine, histidine and lysine) as a carbon source. The authors also report a continuous proteolysis and assimilation of peptides by *Penicilium candidum.*

### 3.3 Sensory evaluation

The means of the responses of the acceptance test of the sensory analysis of the almond-based type cream cheese and traditional processed cheese are presented in (Table 3). In this study, the 9-point hedonic structured category scale was chosen to get insights into drivers of preference and liking of potential consumers, and the product successes or failures. Untrained panelists, comprising men and women of the faculty, including teachers, students and staff, were recruited to evaluate the attributes of appearance, texture, flavor, and taste. Regarding taste and appearance, the traditional processed cheese had a higher score ($p \leq 0.05$) when compared to the almond-based type cream cheese, however there was no difference ($p \geq 0.05$) for the attributes of flavor and texture between both cheeses. It has been pointed out that sensory profile is the most important characteristic that contributes to the overall quality of a product and is the property by which consumer first identifies and associate their likability to a particular product (Kundu et al., 2018).

**Table 3**. Means of the scores of the panelists for the liking attributes of products, almond-based type cream cheese and traditional processed cheese, using a 9-point hedonic scale.

| Attributes | Almond-based type cream cheese | Traditional processed cheese |
|---|---|---|
| Appearance | 7.76 ± 0.01 | 8.16 ± 0.11 |
| Texture | 7.7 ± 0.15 | 7.9 ± 0.17 |
| Flavour | 7.67 ± 0.16 | 7.93 ± 0.17 |
| Taste | 7.56 ± 0.01 | 8.16 ± 0.11 |

**Note:** Data are expressed as the mean ± SD (standard deviation). Student's t-test was used to determine whether the differences between means are significantly different ($p \leq 0.05$).

Figure 1 shows the preference and acceptance by the panelists of almond-based type cream cheese (a) and traditional processed cheese (b). In all attributes evaluated (appearance, texture, flavor, and taste) most of the panelists approved the almond-based type cream cheese. Overall, there was a good acceptability for the almond-based type cream cheese and between 60 and 73% of the panelists really liked or moderately liked all attributes evaluated, while for the traditional processed cheese, approximately 46-49% really liked or moderately liked. However, approximately 16-23% extremely liked the almond-based type cream cheese and 43-49% extremely liked the traditional processed cheese for all attributes evaluated.

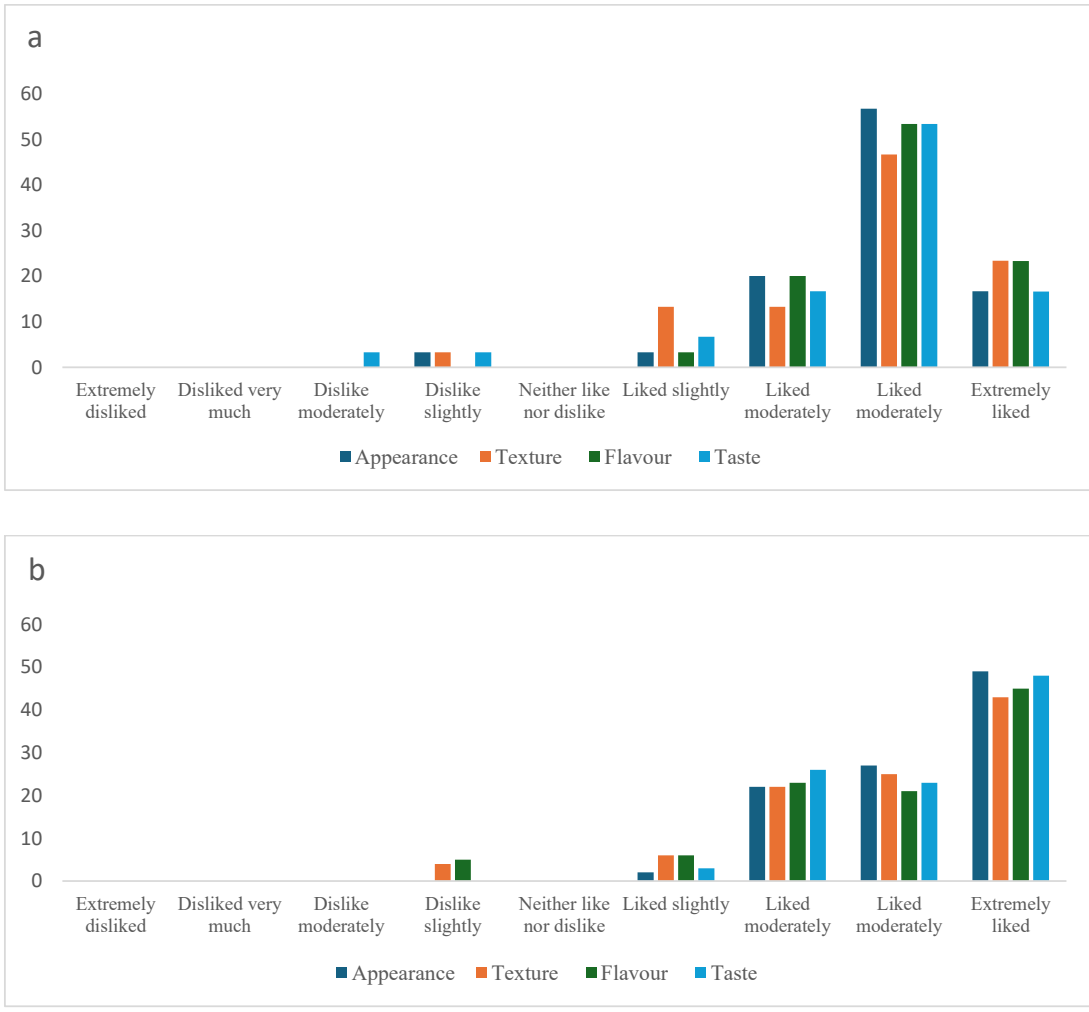


**Figure 1.** Acceptance and preferences of almond-based type cream cheese (a) and traditional processed cheese (b) by untrained panelists for appearance, texture, flavor and taste using a 9 hedonic scale.

In this current study, a sensory evaluation of an almond-based type of cream cheese was performed and compared with the traditional processed cheese. In Brazil, the traditional processed cheese is a dairy product with great acceptability by consumers and is easy to prepare; its elaboration allows variations during its process as well as technological changes. It is a product with great usefulness in various ways, including use in cooking.

Plant-based cheeses are generally considered to have low to satisfactory acceptability in terms of texture, as they do not completely mimic the sensorial attributes of traditional cheeses (Kamath et al., 2022). In this study, however, the panelists considered the attribute of texture as good as the traditional processed cheese.

In this study, regarding flavor the almond-based type cream cheese most of the panelists (48%) preferred the almond-based type cream cheese while the traditional processed cheese was preferred by 24- 43% by the panelists. Generally, texture and flavor development

in plant-based cheese is achieved with the use of texturizing and flavoring agents (Masiá et al., 2023). In this study, no flavoring or texturizing agents were used, but instead probiotic organisms such as lactic bacteria and *Penicilium candidum*, which improved the sensorial attributes. Indeed, it has been postulated that fermentation is a powerful tool in the improvement of the flavor profile of plant-based cheeses (Masiá et al., 2023). The authors pointed out that fermentation can reduce the off-flavor from the raw material, and it can boost the intensity of acid and dairy-like notes reminiscent of animal milk products. Regarding taste, 73% of the panelists really liked the almond-based type cream cheese. Pritulska et al. (2021) pointed out that taste is one of the crucial factors in choosing plant-based milk analogues by the consumers. The authors investigated the perception of plant-based milk analogues by real and potential consumers and the largest share of consumers (20.4%) preferred almond milk, and 15.3% of consumers preferred oat milk.

According to our results the almond-based cream cheese is suitable for consuming within the food quality standards established by the legislation and moreover presents a good acceptability. In addition to almond-based cream cheese, this product has been used to produce filling for pizzas and snacks, pastries and pies. Also, as a base to produce bakeable cheddar-flavored cream for use in burgers. Other potential applications are the use to produce white mold cheese such as Brie, Camembert and Creamy Brie–type cheese.

The microbial composition of fermented products such as the almond-based type of cream cheese, plays a fundamental role in nutritional and sensorial attributes. The microorganisms used in the fermentation process enable the creation of unique flavors and textures and nutritional enrichment of the final product. Moreover, the potential health benefits are provided with the presence of probiotic strains in plant-based cheeses.

## 4. Conclusions

This product developed in this study, although it has been similar to dairy products, is a new and different product which was specially created to meet the demand of vegetarian/vegan consumers, those who are lactose intolerant and those who wish no longer to consume meat. This study demonstrated the good quality of vegan cheese produced from almonds in an artisanal way, and its excellent microbiological quality guarantees food safety, in addition to providing health benefits as it is probiotic. A sensory analysis demonstrated that vegan cheese has excellent consumer acceptability. Traditional cream cheese, obtained industrially, also presents excellent quality, guaranteeing the consumer the quality of the product. Given this, it can be said that vegan cheese obtained from almonds is a good alternative for consumers.

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