Short communication: Antimicrobial activity of pequi (*Caryocar brasiliense*) waste extract on goat Minas Frescal cheese presenting sodium reduction

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ABSTRACT

Sodium chloride reduction in foods is a significant focus of the dairy industry; however, it can interfere with dairy product quality. Thus, researchers have carried out studies on alternatives to maintain dairy product safety when presenting reduced NaCl content, such as natural antimicrobial addition. *Caryocar brasiliense* (pequi) is a fruit with high phenolic compound concentrations in the pulp and peel and known antioxidant and antimicrobial properties. This study aimed to define the optimum stage for pequi waste extract addition during cheese manufacturing in order to maintain and prolong the shelf life of reduced-sodium goat Minas Frescal cheese. Four different goat Minas Frescal cheese treatments were carried out: control cheese (without extract; CC), pequi extract addition to milk (CM), pequi extract addition to mass (CS), and cheese immersion in pequi extract (CIE). The treatments were subjected to microbiological (*Staphylococcus* spp., *Escherichia coli*, *Enterobacteriaceae*, coliforms and fecal coliforms, *Lactococcus* spp., and lactic acid bacteria counts), textural (hardness and consistency), and instrumental color (luminosity, yellow intensity, red intensity, chroma, hue angle, and total color change) analyses. No *Enterobacteriaceae*, *Staphylococcus* spp., *E. coli*, or coliforms and fecal coliforms were detected during storage for any of the assessed samples, including CC. Regarding texture, all samples presented a trend for decreasing rigidity during storage. In addition, lower luminosity values were also observed in cheeses produced with added pequi extract (CM, CS, and CIE) when compared with CC. All cheeses produced with added pequi were stable regarding all evaluated parameters; however, pequi extract addition to milk (CM) was shown to be more

efficient, leading to higher textural parameters and better microbiological quality during storage. Thus, the CM treatment is the most recommended for pequi waste extract addition during Minas Frescal cheese manufacture.

Key words: natural antimicrobial, sodium chloride reduction, *Escherichia coli*, *Staphylococcus* spp.

Short Communication

Cheese manufacturing is an essential dairy industry activity (Dantas et al., 2016). According to the Brazilian Association of Cheese Manufacturers (ABIQ), Minas Frescal cheese is the third most consumed cheese by the Brazilian population and is considered a favorite cheese among Brazilian consumers (ABIQ, 2011). Goat milk is an alternative to cow milk in the production of Minas Frescal cheese (Costa et al., 2013). Moreover, goat product consumption is related to health maintenance and chronic disease prevention (Haenlein and Anke, 2011). However, sodium chloride is the most widely applied optional ingredient in cheese production (Cruz et al., 2011). This salt, when consumed in excess, is directly related to adverse health effects, such as increased blood pressure and decreased calcium absorption (Felicio et al., 2013).

Sodium reduction is a technological alternative for obtaining healthier dairy products (Cruz et al., 2011). Sodium can also be replaced by potassium chloride, as potassium presents lower consumer risks than sodium (Felicio et al., 2016). However, NaCl has been shown to display antimicrobial effects due to its ability to decrease water activity and increase osmotic pressure in dairy products, leading to bacteria dehydration or preventing microorganism growth and proliferation (McMahon et al., 2014), whereas KCl does not possess these attributes (Gomes et al., 2011). Thus, sodium substitution may lead to reduced microbiological dairy product safety. In this scenario, natural antimicrobials

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have appeared as enhancements to functional products, recognized as beneficial for consumers (Gyawali and Ibrahim, 2014; Caleja et al., 2015).

Pequi (*Caryocar brasiliense*) is a native fruit from Brazil containing high antioxidant concentrations (Faria et al., 2014). Pequi extracts present high antimicrobial activity, inhibiting or delaying microorganism growth, especially concerning spoilage and pathogenic bacteria. Moreover, pequi peels are considered a cost-effective natural antimicrobial source, and perhaps an economically attractive way to enhance food safety (de Paula-Junior et al., 2006; Amaral et al., 2014). In this context, we aimed to define the optimum stage of *Caryocar brasiliense* waste extract addition to cheese during processing in order to prolong the shelf life of reduced-sodium (75% NaCl and 25% KCl) goat Minas Frescal cheese.

Pequi fruits (*Caryocar brasiliense*) were obtained from the Pequi Nino Farm (Montes Claros, Minas Gerais, Brazil; 16°44'06"S, 43°51'42"W). Pequi epicarps and external mesocarps were separated and immediately frozen at -20°C to inactivate enzymes and maintain their general properties. The waste was then air-dried at 60°C until constant weight (16 h) in a forced-air circulation oven (330 drier, Fanem Ltda., São Paulo, Brazil), ground in a mill (A11 Bsic, IKA Werke, Staufen, Germany), and subsequently sieved through a 250- μ m mesh screen and stored at -20°C until further use.

The liquid extract was obtained by microwave-assistant extraction using a DGT 100 Plus system (Provecto Analytics Ltd., Jundiaí, SP, Brazil) according to Frasao et al. (2017), using a 94% aqueous ethanol solution (vol/vol) at 670 W microwave power for 110 s. Subsequently, the extract was concentrated in a rotaevaporator (Fisatom, model 801, Fisatom Scientific Equipment Ltd., São Paulo, SP, Brazil) and then diluted to 6.25 mL/L, defined by the MIC reported by de Paula-Junior et al. (2006) for *Escherichia coli* (6.25 μ g/mL) and *Staphylococcus* spp. (4 μ g/mL).

For the Minas Frescal cheese manufacture, goat milk (40 L) was obtained from a producer at Sítio da Água da Pedra (Niterói, Rio de Janeiro, Brazil; 22°52'58"S, 43°6'14"W), pasteurized at 65°C for 30 min, and then cooled to 37°C. Subsequently, 0.4 mL/L of calcium chloride 40% (Rica Nata Ltd., Piracema, MG, Brazil), 10 mL/L of *Lactococcus lactis* ssp. *lactis* and *Lactococcus lactis* ssp. *cremoris* bacteria (R-704; Chr. Hansen, Valinhos, Minas Gerais, Brazil), and 1 mL/L of liquid coagulant (Ha-La, Chr. Hansen) were added to the milk. The solution was then mixed for 2 min and left standing at 37°C for 40 min to coagulate. The curds were cut, the serum drained, and the remaining curds placed in 250-g plastic molds. The cheeses were dry

salted (0.8%) using a 75% NaCl (Sigma, São Paulo, Brazil) and 25% KCl (Sigma) ratio (Gomes et al., 2011), packed, sealed in polyethylene plastic bags, and stored at 4°C for 21 d.

Four treatments were developed to define the pequi waste extract addition moment to the goat Minas Frescal cheese: control cheese (without extract; **CC**), pequi extract addition to milk (**CM**), pequi extract addition to mass (**CS**), and cheese immersion in pequi extract (**CIE**; Figure 1). In the CM treatment, 6.25 mL/L of the pequi extract were added to the pasteurized milk after lactic acid bacteria (**LAB**) addition. In the CS treatment, 6.25 mL/L of the pequi extract was added after mass salting. In the CIE treatment, the pequi extract was added to the cheese by immersion in a 6.25 mL/L of extract concentration solution, remaining for 15 min, followed by packing.

Microbiological analyses (*Lactococcus* spp., *LAB*, *Staphylococcus* spp., *E. coli*, and coliforms and fecal coliforms) were performed during storage, on d 0, 7, 14, and 21. *Lactococcus* spp., *Staphylococcus* spp., *Enterobacteriaceae*, and LAB counts for the cheeses were performed according to the methodologies described in the Codex Alimentarius (2010). Briefly, 50 g of each sample were homogenized in 225 mL of sterile peptone water for 120 s in a Stomacher (Stomacher 80, Seward, London, UK). Decimal dilutions were then prepared by mixing 1 mL of sample and 9 mL of 0.1% (wt/vol) sterile peptone water (Oxoid, Unipath Ltd., Basingstoke, UK) based on standard 122B (FIL-IDF 1992). Bacteria were counted and expressed as log colony-forming units per gram. Coliforms and fecal coliforms were also analyzed, expressed as most probable number.

Color determinations [lightness (**L***), redness (**a***), and yellowness (**b***)] were carried out at a 10° observer angle using a Minolta CM-600D spectrophotometer (Minolta Camera Co., Osaka, Japan), with an illuminant D45 and reflected mode, at 7, 14, and 21 d of storage. Total color change (ΔE^*), hue angle (**h°**), and chroma (**C***) were also calculated. The **C*** value is obtained by using the **a*** and **b*** values. Hue angle values are expressed in degrees, starting at red (0°), with a gradual increase to yellow (90°), green (180°), and blue (270°). Regarding ΔE^* , values were obtained by fluctuations in **L***, **a***, and **b*** values compared with the CC (Incedayi et al., 2016).

Texture (hardness and consistency) was determined using a TA-XT2i equipment (Stable Micro Systems Ltd., Godalming, UK) at 7, 14, and 21 d, applying cylindrical sample compression (1 × 1 × 1 cm). An employed compression force of 5 g was applied at an initial height 1 cm at 25% compression, test speed of 5 mm/s, and constant temperature (15 ± 2°C). A

Figure 1. Schematic flowchart of goat Minas Frescal cheese production. CM = pequi extract addition to milk; CS = pequi extract addition to mass; CIE = cheese immersion in pequi extract.

cylinder probe (aluminum cylinder probe P/36R, 36 mm diameter; Stable Micro Systems Ltd.) and the Texture Expert software for Windows (version 1.20; Stable Micro Systems Ltd.) were used. Hardness was calculated by applying maximum force up to 25% compression. Hardness is also related to the force of food rupture (force 1). Consistency was calculated by the ratio between maximum deformation applied to the food and time (area $F - T1:2$, where F is force and T is time). Determinations were carried out in triplicate per sample.

Statistical analyses were performed using the XLSTAT version 2013.2.03 software (Addinsoft, Paris, France). The data were subjected to ANOVA to determine possible differences between treatments. Significant differences were compared using the Tukey test at the $P < 0.05$ level.

The LAB and *Lactococcus* spp. behavior throughout the storage period (0 to 21 d) for the different goat milk cheese treatments are displayed in Figure 2. The CC treatment presented a significant increase ($P < 0.05$) in LAB values until d 14, which was maintained until the end of the storage period, whereas CS and

CIE exhibited a significant decrease ($P < 0.05$) in LAB values on d 21. On the other hand, no significant difference ($P > 0.05$) was observed during storage for CM, which suggests no influence of the extract in the lactic culture over the storage period. At the end of the storage period, the CS displayed the lowest LAB count, suggesting that the pequi extract addition to the cheese mass inhibited LAB throughout the storage period, as antimicrobial activity can be influenced by many factors, such as the moment of extract addition (Ribeiro et al., 2013). In this case, it is desirable that the antimicrobial activity of the extract take effect on pathogenic and spoilage bacteria and that the lactic culture not be inhibited.

Lactococcus spp. presented similar behavior to LAB in all treatments. The starter culture also exhibited an increase ($P < 0.05$) throughout the 21 d of storage in CC and a decrease in CS, whereas CM and CIE showed no difference in *Lactococcus* spp. counts. Significant differences ($P < 0.05$) among treatments were detected. In the beginning, CS presented the highest counts, which decreased significantly until the end of the storage period. On the other hand, *Lactococcus*

spp. counts in CC increased significantly ($P < 0.05$) throughout the storage period, with the highest count detected on d 21. These results corroborate that pequi extract addition to the cheese mass caused detrimental effects on the lactic culture. A similar study was carried out by Mushtaq et al. (2018) with pomegranate peel extract incorporated to fresh Himalayan cheese, and those authors reported that the extract did not affect beneficial cheese microbiota.

Staphylococcus spp., *Enterobacteriaceae*, *E. coli*, and coliforms and fecal coliforms did not grow in any of the treatments, including the control group, during the storage period. This may be related to the efficiency of the pasteurization process, as these microorganisms, as well as coliforms, are prevalent in raw milk. Thus, the effect of different moments of extract addition in the inhibition of these microorganisms was not evaluated.

Figure 2. Changes in lactic acid bacteria (A) and *Lactococcus* (B) counts of Minas Frescal goat cheeses at 4°C during the storage period (21 d). CC = control cheese, without extract; CM = pequi extract addition to milk; CS = pequi extract addition to mass; CIE = cheese immersion in pequi extract. Similar lowercase letters (a–c) indicate no significant difference between treatments on the same day; different letters indicate significant differences ($P < 0.05$). Similar uppercase letters (A–C) indicate no significant difference between interday results; different letters indicate significant differences ($P < 0.05$).

Ribeiro et al. (2013) assessed Coalho cheese shelf life using essential rosemary oil and reported initial stability of *E. coli* counts for almost 3 d. Thus, future studies, such as *E. coli* inoculation, should be carried out, to evaluate pequi waste extract action on goat Minas Frescal cheese.

Color values are displayed in Table 1. A significant decrease in L^* values in the CC, CM, and CS treatments was observed after 7 d until the end of the storage period. On the other hand, L^* values in CIE were lower at the beginning, followed by an increase, but remained lower than CC and CS cheeses. At the end of the storage period (d 21), CS still displayed the highest ($P < 0.05$) L^* values. The lightness decrease during storage was probably due to higher protein hydration, leading to decreased moisture (whey) and reduced light scattering degree as light penetrates in the upper Minas Frescal cheese layers and is scattered by both whey and fat globules (Dantas et al., 2016).

Yellowness values (b^*) in CC, CM, and CS increased during storage. In contrast, cheese immersion in the pequi extract (CIE) presented high initial b^* values, decreasing throughout the storage period. On d 21, CS exhibited higher ($P < 0.05$) b^* values than CC, CM, and CIE. Lucas et al. (2008) related increased b^* values in raw milk farmhouse goat cheeses, which presented proteolysis and the Maillard reaction, leading to decreases in luminosity due to the production of browning compounds. Queiroga et al. (2013) reported increased b^* values and similar L^* values throughout 28 d of Coalho cheese storage produced from cow and goat milk and their mixture.

Redness values (a^*) were significantly different ($P < 0.05$) among treatments throughout the storage period. Both CC and CS displayed values close to zero. In contrast, a significant increase in a^* value was observed in CM; however, CIE presented the highest a^* values. High a^* values in goat dairy products have been mainly attributed to their fatty acid profiles (Queiroga et al., 2013).

In general, all assessed samples presented high luminosity (L^*) values, with a predominance of the yellow component (b^*) compared with the green component (a^*), suggesting that white-yellowness mostly contributed to cheese color characteristics. Nonetheless, CM cheese presented intermediary values for these 3 components (L^* , a^* , and b^*) between CC and CS and CIE, demonstrating that pequi extract addition to milk reduced sample lightness and increased redness-greenness when compared with the control cheese. This interference was more pronounced in CIE. This behavior can be explained by the manner in which the pequi extract is added in this treatment, as pequi extract contains compounds such as carotenoids, leading to the brown-

Table 1. Instrumental color and texture characterization (mean $\pm$ SD; $n = 3$) of Minas Frescal goat cheese treatments for 21 d of storage at 4°C

Cheese ¹	Day	Color parameters ²					Texture analysis		
		L*	a*	b*	C*	h°	ΔE^*	Hardness (g)	Consistency (g/s)
CC	7	94.80 $\pm$ 0.12 ^{B,c}	1.28 $\pm$ 0.04 ^{C,a}	9.22 $\pm$ 0.08 ^{A,ab}	9.30 $\pm$ 0.06 ^{A,a}	82.09 $\pm$ 0.14 ^{A,c}	—	70.4 $\pm$ 1.81 ^{C,a}	66.94 $\pm$ 1.05 ^{C,a}
	14	93.31 $\pm$ 0.26 ^{A,c}	0.93 $\pm$ 0.04 ^{B,a}	9.90 $\pm$ 0.13 ^{B,b}	9.94 $\pm$ 0.09 ^{B,b}	84.63 $\pm$ 0.12 ^{B,d}	—	27.76 $\pm$ 3.19 ^{B,b}	34.51 $\pm$ 4.19 ^{B,b}
	21	93.12 $\pm$ 0.14 ^{A,b}	0.84 $\pm$ 0.01 ^{A,a}	10.05 $\pm$ 0.10 ^{B,b}	10.09 $\pm$ 0.07 ^{B,a}	85.22 $\pm$ 0.09 ^{C,d}	—	9.73 $\pm$ 0.38 ^{A,a}	12.73 $\pm$ 0.40 ^{A,a}
CM	7	91.53 $\pm$ 0.52 ^{B,b}	2.83 $\pm$ 0.08 ^{A,b}	8.91 $\pm$ 0.03 ^{A,a}	9.35 $\pm$ 0.04 ^{A,ab}	72.38 $\pm$ 0.31 ^{B,b}	3.63 $\pm$ 0.44 ^{A,b}	217.11 $\pm$ 15.00 ^{C,c}	245.81 $\pm$ 20.92 ^{C,c}
	14	90.36 $\pm$ 0.71 ^{A,b}	3.17 $\pm$ 0.09 ^{B,c}	9.16 $\pm$ 0.04 ^{B,a}	9.69 $\pm$ 0.04 ^{B,a}	70.93 $\pm$ 0.32 ^{A,b}	3.78 $\pm$ 0.28 ^{A,b}	99.03 $\pm$ 4.55 ^{A,c}	115.63 $\pm$ 7.49 ^{A,c}
	21	90.13 $\pm$ 0.11 ^{A,a}	3.20 $\pm$ 0.13 ^{B,c}	9.45 $\pm$ 0.07 ^{C,a}	9.98 $\pm$ 0.02 ^{C,a}	71.29 $\pm$ 0.58 ^{A,b}	3.86 $\pm$ 0.19 ^{A,b}	131.82 $\pm$ 4.72 ^{B,b}	186.03 $\pm$ 8.34 ^{B,b}
CS	7	94.47 $\pm$ 0.11 ^{B,c}	1.27 $\pm$ 0.09 ^{A,b}	9.59 $\pm$ 0.06 ^{A,b}	9.67 $\pm$ 0.03 ^{A,b}	82.49 $\pm$ 0.41 ^{A,c}	0.50 $\pm$ 0.08 ^{A,a}	126.33 $\pm$ 8.21 ^{B,b}	126.12 $\pm$ 13.09 ^{B,b}
	14	94.34 $\pm$ 0.06 ^{B,d}	1.31 $\pm$ 0.13 ^{A,b}	10.04 $\pm$ 0.10 ^{B,b}	10.13 $\pm$ 0.08 ^{B,a}	82.57 $\pm$ 0.45 ^{A,c}	1.11 $\pm$ 0.27 ^{B,a}	18.48 $\pm$ 1.00 ^{A,a}	13.85 $\pm$ 0.84 ^{A,a}
	21	94.16 $\pm$ 0.04 ^{A,c}	1.30 $\pm$ 0.01 ^{A,b}	10.76 $\pm$ 0.05 ^{C,c}	10.83 $\pm$ 0.04 ^{C,b}	83.13 $\pm$ 0.00 ^{A,c}	1.34 $\pm$ 0.09 ^{B,a}	10.63 $\pm$ 0.24 ^{A,a}	13.69 $\pm$ 0.35 ^{A,a}
CIE	7	88.83 $\pm$ 0.26 ^{A,a}	5.05 $\pm$ 0.07 ^{B,c}	12.92 $\pm$ 0.40 ^{C,c}	13.87 $\pm$ 0.25 ^{C,c}	68.64 $\pm$ 0.62 ^{B,a}	7.98 $\pm$ 0.13 ^{C,c}	66.50 $\pm$ 3.54 ^{C,a}	89.01 $\pm$ 5.78 ^{C,a}
	14	89.18 $\pm$ 0.16 ^{A,a}	4.32 $\pm$ 0.04 ^{A,d}	10.81 $\pm$ 0.04 ^{B,c}	11.64 $\pm$ 0.02 ^{B,d}	68.24 $\pm$ 0.17 ^{B,a}	5.41 $\pm$ 0.03 ^{B,c}	25.22 $\pm$ 1.95 ^{C,ab}	30.76 $\pm$ 2.83 ^{B,b}
	21	90.03 $\pm$ 0.21 ^{B,a}	4.23 $\pm$ 0.04 ^{A,d}	10.08 $\pm$ 0.06 ^{A,b}	10.93 $\pm$ 0.03 ^{A,b}	67.22 $\pm$ 0.24 ^{A,a}	4.59 $\pm$ 0.02 ^{A,c}	10.08 $\pm$ 0.06 ^{A,a}	11.52 $\pm$ 0.20 ^{A,a}

^{a-d}Similar letters represent no difference between the treatments in the same day results within the analysis; different letters represent a difference ($P < 0.05$).

^{A-C}Similar letters represent no difference between day results within the analysis; different letters represent a difference ($P < 0.05$).

¹CC = control cheese, without extract; CM = pequi extract addition to milk; CS = pequi extract addition to mass; CIE = cheese immersion in pequi extract.

²L* = lightness value; a* = redness value; b* = yellowness value; C* = chroma value; h° = hue angle values; ΔE^* = total color change values.

ing of goat Minas Frescal cheese. When performing the cheese immersion in the extract, this carotenoid action may have been accentuated. In addition, a deposition of extract pigments during storage may have occurred, intensifying this process (Ribeiro et al., 2014).

Regarding C*, the observed increases ($P < 0.05$) in CM during storage are related to the same behavior observed for a* and b* values. In CC and CS, the increase in C* values is due to the increase in b* values. The CIE presented decreased ($P < 0.05$) C* values due to the behavior of a* and b* values, which also decreased. Nevertheless, when compared with other treatments at the beginning and end of storage, CIE displayed the highest ($P < 0.05$) values for C*. On the other hand, CM presented the lowest ($P < 0.05$) C* values during storage. Thus, this parameter behavior was related to a* and b* at this point.

During the storage period, CIE and CM displayed a significant decrease in h° ($P < 0.05$), whereas CC presented a significant increase ($P < 0.05$) and CS presented constant h°. Control cheeses exhibited the highest ($P < 0.05$) h° values throughout the storage, followed by CS, whereas CIE presented the lowest ($P < 0.05$) h° values. The lower values observed in CIE and CM are due to higher a* values, which slightly distanced the hue angle results from 90° (yellow) and can be explained by extract interferences, probably by pequi carotene, which can lead to orange color variations (Ribeiro et al., 2014; Incedayi et al., 2016). Thus, all treatments are classified as white cheese by nearness to 90°.

Regarding ΔE^* , CIE presented highest ($P < 0.05$) color change values during the entire storage period, even when taking into account the decrease ($P < 0.05$) observed from d 0 to 21. This behavior can be related to the a* and b* results. The CM showed no difference ($P > 0.05$) during the storage period due to the small variations in L*, a*, and b* values. A significant difference among treatments was observed ($P < 0.05$), with CS presenting lowest ($P < 0.05$) color change values, related to similar L*, a*, and b* values in the control cheese. In our study, the variations observed in treatments with pequi waste extract (CM, CS, and CIE) can be attributed to the presence of orange pigments, such as carotenoids (Ribeiro et al., 2014).

According to Cruz-Romero et al. (2007), ΔE^* values can be classified as small difference (values of 0.5–1.5), distinct difference (values of 1.5–3.0), very distinct (values of 3.0–6.0), great difference (values of 6.0–12.0), and very great difference (values ≥ 12.1). In the present study, when compared with the control cheese, CIE color change values were classified as great difference, whereas CM values were classified as very distinct and CS as small difference in color values.

The instrumental texture parameters of goat Minas Frescal cheese are summarized in Table 1. Hardness and consistency values presented significant differences ($P < 0.05$), both for kind of cheese and for storage time. Significant decreases ($P < 0.05$) in these parameters were observed in all treatments during storage. This may be related to increased proteolysis, probably due to the enzymatic hydrolysis of α -CN by the coagulant. This fact is also related to the decreased molar salt levels obtained when KCl was added during the salting step, as KCl displays decreased ionic strength compared with NaCl, leading to decreased protein solubility, with a direct effect on the cheese matrix (Gomes et al., 2011). Similar results were reported during storage of Minas Frescal cheese (Gomes et al., 2011) and Halloumi cheese (Ayyash et al., 2011) when replacing NaCl for KCl.

When comparing treatments, CM presented higher ($P < 0.05$) hardness values than CC, CS, and CIE, remaining higher than the other samples at the end of the storage period even though decreased values were observed. These higher hardness values may be related to lower moisture content and compact structure (Hasan et al., 2004). The significant difference between treatments may be due to changes in acidity during storage induced by the moment of extract addition, as well as to initial cheese moisture, as high initial moisture weakens the protein network, leading to a softer cheese matrix (Buriti et al., 2005). On the other hand, pequi extract addition to the cheese mass (CS) displayed values closer to the control for color parameters. However, regarding hardness and consistency results, marked decreases and loss of texture aspects and cheese characteristics during storage were observed. In relation to cheese immersion in the pequi extract (CIE), a remarkable difference in color and texture values was noted when compared with the other treatments; the lower level of α_{S1} -CN in goat milk, which makes the casein structure more fragile (Queiroga et al., 2013), may be a contributing factor.

In conclusion, the cheese with pequi extract addition to milk (CM) was the most stable in terms of bacteriological, textural, and instrumental color parameters. Furthermore, a lesser effect of the extract on the lactic culture was noted in this treatment, which is desirable. In addition, the CM treatment presented the best firmness and consistency throughout the storage period, as it was harder and stiffer than control cheese. Therefore, this is the most suitable moment for pequi extract addition in the manufacturing of this type of cheese. Finally, pequi waste should be considered as a potential antimicrobial and antioxidant that can be applied to ensure food safety.

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