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RESEARCH ARTICLE

Fat substitution by inulin in goat milk ice cream produced with cajá (*Spondias mombin*) pulp and probiotic cultures: influence on composition, texture, and acceptability among consumers of two Brazilian regions

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ABSTRACT

The production of a goat milk ice cream with a typical Brazilian fruit, probiotic cultures and with the fat substitution by inulin could be an opportunity of products' diversification for the growing goat dairy sector in Brazil and also to attend the consumers' demand of healthy indulgence products. However, the probiotic stability and texture could be affected by the fat replacement in a frozen product, and sensory acceptability can vary according to the country region. The objective of this study was to investigate the effect of substitution of goat milk cream by inulin on the stability and quality parameters such as fat content, fatty acid profile, lactobacilli viability, hardness and melting rate of goat milk ice cream produced with cajá pulp and probiotic cultures of *Lactobacillus rhamnosus* or *Lactobacillus paracasei*. Focusing on the opportunity of spreading food products containing regional ingredients, a sensory evaluation was conducted with consumers of two distinct Brazilian regions (São Paulo and Sobral, south-eastern and north-eastern cities, respectively). Formulations with inulin fitted requirements for low fat and low saturated fat products. Probiotic cultures survived well in all tested formulations since added probiotics maintained viability levels above 8.00 log cfu/g during storage. The full-fat ice creams achieved significant higher acceptability among the consumers of Sobral when compared with those of São Paulo, reinforcing that familiarization with goat milk can influence the acceptability of caprine dairy products. Inulin added ice creams showed lower overrun, with hardness and melt-down profile increased in comparison with milk cream formulations. Nonetheless, inulin successfully substituted milk cream in goat milk ice creams with cajá as their scores of sensory acceptability were above 7.00 and similar within both consumer groups. The multi-functional character of the inulin added ice creams indicate their potential contribution for good health if consumed as part of a well-balanced diet.

Keywords: Goat milk ice cream; Fatty acid profile; Melting rate; Probiotics; Acceptability test

INTRODUCTION

Ice creams are traditionally consumed as dessert, and associated with moments of leisure and indulgence due to their sensorial attributes (Vega, 2013; Topcu, 2015; Cruxen et al., 2017). These widely appreciated products can also be part of a healthy diet, contributing to the supply of essential nutrients and bioactive compounds, depending on the ingredients used in their formulations. The development of ice cream formulations that meet the requirements for functional foods, conferring health benefits beyond the basic nutrition, has been reported in several studies (Cruz et al., 2009; Kumar et al., 2016; Cruxen et al., 2017).

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Milk is one of the main ingredients used in the manufacture of ice cream. Alternatively, goat milk has also been used in the formulation of ice creams, resulting in products differentiated by taste and nutritional value. Compared to bovine, goat milk has unique physicochemical and sensory properties, distinguished by the higher digestibility, lower cholesterol content and high calcium content, which is also better absorbed (Martín-Diana et al., 2003; Haenlein, 2004; Park, 2009). Goat milk has lower fat globules than bovine milk, which is advantageous regarding better digestibility and efficiency of lipid absorption. The low allergenic potential of goat milk is also an important feature related to its lower proportion of α-s1 casein, a protein generally associated with the allergic response to cow milk, one of the most frequent causes of food allergy among children (Park, 2009). In Brazil, goat milk production has increased in recent years and most of the goat herd is concentrated in the north-eastern Brazilian states. Particularly in the Brazilian Northeast region, this growth was most a result of government programs designed to encourage this activity (Cavicchioli et al., 2015; SIDRA-IBGE, 2017).

Fruit pulp is another ingredient commonly used in the formulation of ice creams, imparting different flavours and colours to the product (Patel et al., 2015). The addition of fruits rich in vitamins and bioactive compounds can also contribute for the nutritional and functional value of ice cream (Cruxen et al., 2017). Cajá (*Spondias mombim*) is a small yellow fruit with exotic flavour, typical of the Northeast Region of Brazil. It is widely used in juices, ice creams, nectars and jellies, and has been well studied regarding its properties to human health. This fruit is known for the high content of carotenoids and phenolic compounds, besides presenting antifungal and antiviral capacity. The consumption of 100 g of cajá pulp exceeds by about 37% the daily recommendation of retinol activity equivalents (RAE) and contains twice the concentration of total phenolic compounds of açaí - *Euterpe oleracea* (Tiburski et al., 2011). According to Gomes da Silva et al. (2012) and Lavrinha e Silva et al. (2018), the total phenolic compounds of this fresh pulp fruit can vary around 60 mg/100 g in its harvest period and, among these compounds, flavonoids (from 1 to 5 mg/100g fresh pulp) and condensed tannins (from 3 to 17 mg/100 g) can be found. Despite some polyphenols, particularly the tannins, are generally related to antinutritional factors, such as low protein digestibility, it is also known that microbial metabolism in the gut can undergo transformations in these compounds, improving the nutrient digestibility, especially for proteins, and the phenolic bioactivity, such as antioxidant properties (Velickovic and Stanic-Vucinic, 2017).

In this case, the addition of probiotic cultures in a goat milk ice cream produced with cajá pulp, and in which the goat milk fat is substituted by inulin, could generate a beneficial product to the human health. The first benefit would be the contribution to the maintenance of the microbial balance in the gut (Salva et al., 2011; Senaka Ranadheera et al., 2012). The second benefit would be the reduction of the fat content of the product (Costa et al., 2016). Nonetheless, the texture of the ice cream can be modified by the use of fat replacers, generally as a result of low overrun and increased hardness (Akalın et al., 2008). Even though inulin has been reported to be a good fat replacer in low fat ice cream formulations (Akbari et al., 2016), its addition impact the product texture and deserve investigation. Moreover, since goat milk and cajá are mostly consumed in the Brazilian northeast states, where their production is predominant, the acceptability of an ice cream with these foods as ingredients may vary among other regions, particularly in the areas where the consumption of these foods are only sporadic. Due to the nutritional benefits of goat milk and cajá previously described, it is desirable that a product with these ingredients reach a large audience in the country.

The aim of the present study was to evaluate the influence of the substitution of goat milk fat by inulin on the composition and texture parameters of goat milk ice cream produced with cajá pulp and lactobacilli probiotic cultures, and to investigate the viability of these microorganisms. Focusing on the opportunity of spreading the food products containing regional ingredients, typical of smaller areas, to other localities, this study also included a sensory evaluation test with the purpose of to compare the sensory acceptability of the ice cream formulations studied by consumers (untrained volunteers) from two different regions of Brazil: Sobral, Ceará State (Brazilian Northeast) and São Paulo, São Paulo State (Brazilian Southeast).

MATERIAL AND METHODS

Production of ice creams

Four ice cream formulations were produced at the Pilot Plant of the Laboratory of Food Science and Technology of Embrapa Goats and Sheep (Sobral, Ceará State, Brazil), in two batches of 7 kg each. Two formulations were prepared with the addition of goat milk cream (C) and two formulations were produced substituting this ingredient by inulin (I). One formulation of each group (C and I) was supplemented with the probiotic strains *Lactobacillus rhamnosus* HN001 (Lr) or *Lactobacillus paracasei* LBC82 (Lp). These formulations were denoted CLr (C + Lr), CLp (C + Lp), ILr (I + Lr), and ILp (I + Lp), as described in Table 1. The proportions of ingredients used in these formulations are listed in Table 2.

Table 1: Description of ice cream formulations studied, according to the addition of goat milk cream or inulin and to the probiotic strain employed

Ice cream formulations	Goat milk cream[a]	Inulin[b]	Probiotic strain
CLr	+	−	*Lactobacillus rhamnosus*[c]
CLp	+	−	*Lactobacillus paracasei*[d]
ILr	−	+	*Lactobacillus rhamnosus*[c]
ILp	−	+	*Lactobacillus paracasei*[d]

[a]At 10% (50% fat, produced at Embrapa Goats and Sheep,Sobral, Brazil), [b]At 5%, Beneo GR (Orafti, Oreye, Belgium), [c]HN001 HOWARU® Rhamnosus Probiotics (Danisco, Madison, WI, USA). [d] LBC 82 Choozit (Danisco, Dangé, France), + = present, − = absent

Table 2: Proportion of ingredients used in the ice cream formulations (two batches each)

Ingredients (g/100 g)	Ice cream formulations (n=2)			
	CLr	CLp	ILr	ILp
Fixed ingredients				
Cajá pulp[a]	33.26	33.26	33.26	33.26
Sucrose [b]	12.00	12.00	12.00	12.00
Skimmed goat milk powder*	6.65	6.65	6.65	6.65
Glucose[c]	4.65	4.65	4.65	4.65
Emulsifier[d]	0.66	0.66	0.66	0.66
Citric acid[e]**	0.29	0.29	0.29	0.29
Stabilizer[f]	0.19	0.19	0.19	0.19
Variable ingredients				
Skimmed goat milk (0.5 g/100 g fat)*	32.24	32.24	37.24	37.24
Goat milk cream (50 g/100 g fat)*	10.00	10.00	-	-
Inulin[g]	-	-	5.00	5.00
Lactobacillus rhamnosus[h]	0.06	-	0.06	-
Lactobacillus paracasei[i]	-	0.06	-	0.06
Total ingredients	100.00	100.00	100.00	100.00

Ingredients: [a]Frute (Antonio Vander Almeida Vieira e EPP, Caucaia, Brazil); [b] Estrela (Biosev, Maracaju, Brazil); [c] Marvi (Ourinhos, Brazil); [d]Selecta (Duas Rodas, Jaguará do Sul, Brazil); [e] Kerry (Campinas Brazil); [f]Neutral stabilizer G3 (Kerry, Campinas, Brazil); [g] Beneo-GR (Orafti, Oreye, Belgium); [h]HN001 HOWARU® Rhamnosus Probiotics (Danisco, Madison, WI, USA); [i]LBC 82 Choozit (Danisco, Dangé, France), *Produced at Embrapa Goats and Sheep **Citric acid diluted in water in a 1:1 proportion

For the production of ice creams, a mix base was prepared with the ingredients (except the cajá pulp and citric acid), which were pasteurised at 70 °C for 10 min in a continuous ice cream machine (Finamac model PP12 Plus, Santo André, Brazil), and cooled up to 37° C in an ice bath. For the addition to the pasteurised mix base, the probiotic cultures were activated in skimmed goat milk, previously heated at 90° C for 3.5 min and cooled up to 37° C, remaining in this temperature for 2.5 h in the presence of the microorganisms added. Next, the bases supplemented with the probiotic strains were aged at 4° C for 4 h and then mixed with the cajá pulp and the citric acid solution during 5 min. In the following step, the flavoured bases were maintained under dynamic whipping and freezing for 7 min until reaching −6° C. The ice creams were packed in polyethylene pots for static hardening at −20 ± 3° C during 24 h. The final products were transferred to a commercial freezer and stored at −18 ± 3° C for 84 days.

Microbiological and pH determinations

Viability of probiotic lactobacilli were monitored in the ready product (day 1) and during 84 days of storage, in duplicate samples of two batches for each formulation. Samples of 25 g were diluted in 225 ml of peptone water (0.1 g/100 ml), and serial dilutions were subsequently prepared. Populations of *L. rhamnosus* and *L. paracasei* were determined by pour-plating 1 ml of each dilution in MRS agar (Oxoid, Basingstoke, United Kingdom) acidified to pH 5.4 with acetic acid, followed by anaerobic incubation (Anaerobic System Anaerogen, Oxoid) at 37° C for 72 h (Buriti et al., 2005).

The pH values were determined in duplicate for each batch of ice cream using two pots of 70 ml each batch, at 1, 28, 56 and 84 days of storage, with a pH meter Tecnal (model TEC 3 MPp, Piracicaba, Brazil) equiped with a penetration electrode model HI-1131B (Hanna Instruments, Leighton Buzzard, UK).

Mean composition

For proximate composition determinations the analyses were carried out for each batch of ice cream formulation, in duplicates, at 14 days of storage. Total solids (by drying 5 g samples at 70° C under vacuum up to constant weight) and ash (by ashing 5 g samples at 550 °C) were determined following the analytical procedures of the Institute Adolfo Lutz (IAL, 2005). Fat content was assessed using the adapted Bligh-Dyer method (IAL, 2005), and protein was obtained by measuring the nitrogen of samples through the micro Kjeldahl method and multiplying by the conversion factor 6.38 (AOAC International, 2003). The total carbohydrates content was obtained by difference in order to achieve 100 g/100 g of total composition (FAO, 2003).

Fatty acids analysis

Fatty acid (FA) profile of goat milk cream and ice cream fat extracted by Bligh-Dyer method was obtained by gas chromatography, according to AOCS Official Method Ce 1-62.(AOCS, 1990), after conversion of FAs into their corresponding methyl esters (Hartman & Lago, 1973). Analyses of FA methyl esters (FAME) were performed on a Varian GC gas chromatograph (model 3400CX, Varian Ind. Com. Ltda., São Paulo, Brazil). The chromatograph was equipped with split-injection port, flame-ionization detector, Workstation Star Chromatography (version 5.5, Varian Inc., Palo Alto, CA, USA) and 30 m fused silica capillary column (ID = 0.25 mm) coated with 0.25 mm of CP-Wax 52CB (Chrompack, Minnesota, MN, USA). Qualitative FA composition was determined by comparing the retention times of the peaks with the respective FA standards. Quantitative composition was accomplished by area normalization. The proportion of each individual

FA (*FAi*) in goat milk cream and ice cream samples was estimated according to the Equation (1):

$$FAi\ (g/100\ g) = \frac{FAMEi \times \left(\frac{FAi_{MW}}{FAMEi_{MW}}\right) \times FAT \times 0.933}{\sum FAMEi \times \left(\frac{FAi_{MW}}{FAMEi_{MW}}\right)} \quad (1),$$

where *FAMEi* is the percentage of each individual FAME (g/100 g total FAME), FAi_{MW} and $FAMEi_{MW}$ are the corresponding FA and FAME individual molecular weights, *FAT* is the percentage of total fat in samples (g/100 g) and 0.933 is the coefficient for the mean FA proportion in total milk fat described by Glasser et al. (2007).

Overrun, instrumental hardness, and meltdown measurements

The overrun measurement (in %) was taken per formulation during the production, as described by Muse and Hartel (2004), by comparing the weight of the mix base (w_{MB}) and the weight of the final ice cream (w_{IC}) in a fixed volume (250 ml), as described in the Equation (2):

$$Overrun\ (\%) = \frac{(w_{MB} - w_{IC})}{w_{IC}} \times 100 \quad (2)$$

The hardness of each ice cream formulation was determined in samples at 14 days of storage using a TA-XTplus texture analyser (Stable Micro Systems, Surrey, UK). Ten samples of each formulation were used for the measurements. The tests were performed using the knife edge HDP/BS probe on 300 ml samples inside their original pots. The pots with ice cream samples were removed from the freezer and maintained at 26 ± 1 °C during 10 min before the analyses. The knife edge sheared the samples to a depth of 5 mm at 3 mm/s speed, and returned at 10 mm/s speed. The hardness measured in the ice cream samples (in N) were obtained by using the Exponent Lite© 2007 software - version 4.0.13 (Stable Micro Systems).

The melting rate was measured at 14 days of storage using the method adapted from Muse and Hartel (2004), with some modifications, using ice cream samples of 100 ± 10 mL each. The measurements were done in septuplicate. Removed from the frozen storage (−18 ± 3°C), the samples were immediately placed on a wire screen (2 holes/cm) on top of a funnel that was attached to a graduated cylinder at room temperature (26 ± 1° C). The beginning of melting and the time to drip the first 10.0 ml of product were recorded. From this step, the dripped volume was recorded every 3 min up to obtain 10 recorded volume points. A plot of dripped volume versus the elapsed time was constructed to calculate the meltdown rate (ml/min), according to Cavender and Kerr (2013).

Sensory evaluation

The sensory evaluation was approved (Approval decision CEP/FCF/126/2010; CAAE: 5015.1.00.018.10; Protocol CEP/FCF/560) by the Ethics Research Committee of University of São Paulo – School of Pharmaceutical Sciences (USP/FCF, São Paulo, São Paulo State, Brazil). The samples were evaluated 7 days after storage, simultaneously, at the laboratories of Sensory Analysis of Embrapa Goats and Sheep (Brazilian Northeast) and of USP/FCF (Brazilian Southeast), through acceptability test using a 9-point hedonic scale (9 = "liked extremely", 1 = "disliked extremely") (Lawless and Heymann, 2010). The samples were in agreement with the Brazilian regulatory standards regarding sanitary quality (ANVISA, 2001), since coliforms at 45 °C, coagulase positive *Staphylococcus*, and *Salmonella* spp. were not detected. Samples served, monadically, in 20 g portions codified with three random digits, being evaluated by 40 and 35 adult consumers (untrained volunteers), respectively, at the Embrapa Goats and Sheep and at the USP/FCF.

Statistical analysis

Statistical analysis was performed for probiotic viability, mean composition, hardness, dripping and meltdown parameters, and for sensory evaluation data. Differences between trials were statistically analysed using analysis of variance (ANOVA), followed by the post hoc Tukey test, with $p < 0.05$. Before ANOVA evaluation, data were checked for the normality and homogeneity of variances using the Shapiro-Wilk and Levene tests, respectively. Samples with normal results and homogenous variance were analysed using SAS (Statistical Analysis Systems) software version 9.2 (SAS Institute Inc., Cary, NC, USA). The non-normal and non-homogeneous data were compared using the Kruskal-Wallis test followed by Mann-Whitney test, with $p < 0.05$, using STATISTICA v.8.0 software (Statsoft Inc., Tulsa, OK, USA).

RESULTS AND DISCUSSION

Microbiological parameters and pH of ice creams

The viability of the probiotic lactobacilli studied, *L. rhamnosus* (for CLr and ILr) and *L. paracasei* (for CLp and ILp) in ice cream formulations are shown in Table 3. During the 84 days of frozen storage, the viability of lactobacilli remained above 8.00 log cfu/g, both in products with goat milk cream (CLr and CLp) and with inulin (ILr and ILp), with no significant difference observed between formulations ($p > 0.05$) (Table 3). These probiotic lactobacilli, therefore, remained above the minimum recommended level of 6 log cfu/g, suggested for beneficial health effects in the gut (Salva et al., 2011; Martinez et al., 2015). A slight decrease in the lactobacilli populations, however, was observed throughout the storage; significant differences were detected for CLp ice creams ($p < 0.05$), from day 1 to 7, and from the day 28 to 42 (Table 3).

The pH values of ice creams during storage are shown in Table 4. All ice creams formulations showed pH values ranging between 4.00 and 4.50 during the storage period, with no significant differences detected between the first and the last day of storage ($p > 0.05$). Ice cream CLp showed the lowest pH values at the beginning of storage (day 1) and differed significantly from ILr and ILp ($p < 0.05$). Formulations with inulin showed slightly higher pH values, between 4.28 and 4.49 for ILr, and between 4.26 and 4.43 for ILp, and a slight increase in the pH was registered during the storage for both formulations with inulin ($p < 0.05$). The low pH values, however, did not threaten the survival of the probiotic lactobacilli in the products, although some authors recommended pH values between 5.5 and 6.5 to guarantee the viability of the added probiotics during the product's shelf life (Cruz et al., 2009). A good viability of probiotic strains from *L. casei* group has been observed in low pH values, particularly in fruit juices, for e.g. *L. paracaasei* NFBC4338, *L. casei* DN-114 001 and *L. rhamnosus* GG in pineaple (pH 3.40) and orange (pH 3.65) juices, as well as for *L. rhamnosus* Lc705 and *L. rhamnosus* VTT E-97800/E800 also in orange juice (pH 3.8 ± 0.2) (Suomalainen et al., 2006; Sheehan et al., 2007). Moreover, other studies also reported favourable survival of probiotics (6 log cfu/g or above) in ice creams with pH 5.0 or lower and with pulp of tropical fruits added (Favaro-Trindade et al., 2006; Favaro-Trindade et al., 2007; Cruxen et al., 2017).

Mean composition of ice creams

The mean composition of the ice creams is shown in Table 5. The ice cream formulations did not differ significantly concerning total solids, protein, and ash content. On the other hand, ice creams ILr and ILp, with inulin substituting goat milk cream, showed fat content significantly lower than CLr and CLp, with goat milk cream added ($p < 0.05$). With this reduction in the fat content, ice creams ILr and ILp fitted the requirement to be classified as low fat products in accordance to the Codex Alimentarius (2013), with less than 1.5 g total fat per 100 ml (around 86 g for ice creams with inulin added). The ice creams were also in accordance to the Brazilian regulatory standards for low fat products (ANVISA, 2012), with less than 3 g total fat per 60 g, which is the reference serving portion customarily consumed of this kind of product (ANVISA, 2003). Moreover, the addition of inulin increased significantly the

Table 3: Populations of probiotic lactobacilli (during the manufacture process and throughout the 84 days of storage period at −18±3°C, log cfu/g) of ice cream formulations

Parameter	Sampling periods	Ice creams			
		CLr	CLp	ILr	ILp
	Ice cream base*	8.56±0.20^{Aa}	8.58±0.17^{Aa}	8.56±0.31^{Aa}	8.56±0.04^{Aa}
	1st day	8.50±0.36^{Aa}	8.53±0.06^{Aa}	8.42±0.39^{Aa}	8.53±0.14^{Aa}
	7th day	8.30±0.31^{Aa}	8.33±0.06^{Abc}	8.26±0.41^{Aa}	8.35±0.15^{Aa}
Lactobacilli (log cfu/g)	14th day	8.40±0.36^{Aa}	8.35±0.08^{Abc}	8.15±0.24^{Aa}	8.37±0.05^{Aa}
	21st day	8.38±0.32^{Aa}	8.46±0.12^{Aac}	8.19±0.38^{Aa}	8.28±0.12^{Aa}
	28th day	8.37±0.25^{Aa}	8.43±0.08^{Aac}	8.31±0.41^{Aa}	8.43±0.23^{Aa}
	42nd day	8.35±0.43^{Aa}	8.22±0.10^{Ab}	8.37±0.54^{Aa}	8.49±0.37^{Aa}
	56th day	8.29±0.32^{Aa}	8.37±0.15^{Abc}	8.14±0.36^{Aa}	8.34±0.20^{Aa}
	84th day	8.27±0.30^{Aa}	8.31±0.05^{Abc}	8.02±0.31^{Aa}	8.34±0.18^{Aa}

*n=4 (two batches × two replicate samples). Means±standard deviation (*SD*). CLr=goat milk cream+*L. rhamnosus* HN001. CLp=oat milk cream+*L. paracasei* LBC82. ILr=inulin+*L. rhamnosus* HN001. ILp=inulin *L. paracasei* LBC82. ^{A,B} In a row, different superscript capital letters denote significant differences between ice cream formulations evaluated in a same storage period ($p < 0.05$). ^{a,b,c} In a column, different superscript lowercase letters denote significant differences for a same ice cream formulation during the different storage periods ($p < 0.05$)

Table 4: Values of pH (after 1, 28, 56 and 84 of storage at −18±3°C) of ice cream formulations

Parameter	Sampling periods	Ice creams			
		CLr	CLp	ILr	ILp
	1 day	4.18±0.10^{ABa}	4.08±0.07^{Ba}	4.28±0.01^{Ac}	4.26±0.03^{Ab}
pH	28 days	4.36±0.14^{Aa}	4.35±0.09^{Aa}	4.39±0.03^{Ab}	4.38±0.06^{Aab}
	56 days	4.23±0.14^{Aa}	4.23±0.14^{Aa}	4.26±0.05^{Ac}	4.29±0.07^{Aab}
	84 days	4.25±0.23^{Aa}	4.27±0.24^{Aa}	4.49±0.05^{Aa}	4.43±0.10^{Aa}

*n=4 (two batches×two replicate samples). Means±standard deviation (*SD*). CLr=goat milk cream+*L. rhamnosus* HN001. CLp=goat milk cream+*L. paracasei* LBC82. ILr=inulin+*L. rhamnosus* HN001. ILp=nulin+*L. paracasei* LBC82. ^{A,B} In a row, different superscript capital letters denote significant differences between ice cream formulations evaluated in a same storage period ($p < 0.05$). ^{a,b,c} In a column, different superscript lowercase letters denote significant differences for a same ice cream formulation during the different storage periods ($p < 0.05$)

total carbohydrates content in both ice creams with this ingredient (p <0.05). This result was already expected since inulin is a fructan-type carbohydrate (Roberfroid, 2008).

Fatty acid (FA) composition of goat milk cream and ice creams formulations

The FA content of goat milk cream used as ingredient in CLr and CLp formulations and of the four ice cream studied are shown in Table 6. In decreasing order, oleic (C18:1), palmitic (C16:0), estearic (C18:0), myristic (C14:0), and capric (C10:0) acids were the fatty acids found in higher concentrations in goat milk cream as well as in ice cream samples, including those with inulin added (Table 5). According to Park et al. (2007), these FA account for more than 75% (m/m) of total FA in goat milk. Regarding fatty acids by group, saturated fatty acids (SFA) predominated in all samples analysed; nonetheless, SFA content was lower than 0.75 g/100 ml in ice creams ILr and ILp, with inulin added. In this case, ice creams ILr and ILp met the requirements for low saturated fat products according to the Codex Alimentarius (2013). Lauric (C12:0), caprilic (C8:0), and caproic (C6:0) FA were found in all samples studied, even in ice creams with inulin added. According to Alférez et al. (2001), the medium chain FA (MCFA) (6–12 carbon atoms) achieve twice the amounts in goat milk (or higher, in the case of C10:0) than those observed in cow milk, and are more rapidly metabolized to produce energy compared to long-chain FA. In addition, according to Sankararaman and Sferra (2018), the MCFA are preferably released from the triacylgycerol structure by gastrointestinal lipases or they may be absorbed intact. MCFA are, therefore, directly transferred from the small intestinal cells into the portal vein and reach the liver by binding to albumin (Sankararaman and Sferra, 2018). Moreover, C6:0, C8:0, and C10:0 FA are associated with the characteristic flavours of goat dairy products and may also be used to detect mixtures of milk from different species (Park et al., 2007).

Overrun, meltdown profile, and instrumental texture of ice creams

The substitution of the goat milk cream by inulin reduced the overrun by half in ice creams ILr and ILp (17% and 16%, respectively), compared to CLr and CLp containing the full amount of fat (29% and 28%, respectively). These results for the formulations with inulin added are justifiable

Table 5: Mean composition in 100 g of whole sample of the ice creams studied

Parameters*	Ice creams formulations			
	CLr	CLp	ILr	ILp
Total solids (g/100 g)	36.80±0.05^{A}	36.61±0.03^{A}	35.34±0.09^{A}	35.69±0.34^{A}
Ash (g/100 g)	1.08±0.01^{A}	1.04±0.04^{A}	1.00±0.01^{A}	1.02±0.01^{A}
Fat (g/100 g)	5.95±0.01^{A}	5.94±0.25^{A}	0.84±0.01^{B}	0.93±0.06^{B}
Protein (g/100 g)	2.99±0.03^{A}	2.99±0.08^{A}	2.90±0.09^{A}	3.12±0.11^{A}
Carbohydrates (g/100 g)	26.78±0.09^{B}	26.64±0.23^{B}	30.60±0.17^{A}	30.62±0.33^{A}

*n=4 (two batches×two replicate samples). Means±*SD*. CLr=goat milk cream+*L. rhamnosus* HN001. CLp=goat milk cream+*L. paracasei* LBC82. ILr inulin+*L. rhamnosus* HN001. ILp=inulin+*L. paracasei* LBC82. ^{A,B} In a row, ice cream formulations sharing a same superscript capital letter did not differ significantly (p >0.05)

Table 6: Distribution of fatty acid (FA) content in 100 g of whole samples of goat milk cream and ice cream formulations

Fatty acids (g/100 g of whole sample)	Goat milk cream sample	Ice cream formulations			
		CLr	CLp	ILr	ILp
Butiric (C4:0)	0.639	0.059	0.089	0.017	0.013
Caproic (C6:0)	0.686	0.101	0.083	0.013	0.013
Caprilic (C8:0)	0.764	0.116	0.096	0.013	0.015
Capric (C10:0)	2.45	0.355	0.297	0.041	0.047
Lauric (C12:0)	1.12	0.138	0.107	0.031	0.016
Miristic (C14:0)	4.03	0.400	0.407	0.055	0.066
Palmitic (C16:0)	11.9	1.22	1.39	0.190	0.223
Palmitoleic (C16:1)	0.356	0.042	0.021	0.000	0.004
Estearic (C18:0)	5.77	1.08	1.08	0.153	0.153
Oleic (C18:1)	17.59	1.81	1.82	0.257	0.298
Elaidic (C18:1t)	0.000	0.000	0.000	0.000	0.000
Linoleic (C18:2)	1.09	0.159	0.108	0.012	0.016
Linolenic (C18:3)	0.264	0.067	0.035	0.001	0.004
Total SFA*	27.35	3.47	3.56	0.513	0.546
Total UFA*	19.30	2.08	1.99	0.271	0.322

CLr=goat milk cream+*L. rhamnosus* HN001. CLp=goat milk cream+*L. paracasei* LBC82. ILr=nulin+*L. rhamnosus* HN001. ILp=inulin+*L. paracasei* LBC82. SFA= saturated fatty acids. UFA = unsaturated fatty acids. *Total SFA=C4:0+C6:0+C8:0+C10:0+C12:0+C14:0+C16:0+C18:0. **Total UFA=C16:1+C18:1+C18:2+C18:3

since, according to Clarke (2012), it is difficult to achieve and stabilise a similar overrun of ice cream with the whole amount of protein and fat in products which had one of these ingredients removed or added in substantial lower levels. Alternatively, since the air incorporation into the ice creams occurs throughout the dynamic whipping and freezing step, a higher overrun percentage could be achieved setting lower temperatures in this stage. However, Ferraz et al. (2012) recommended lower overrun levels in the production of probiotic ice creams focusing on the maintenance of viability of the microorganisms added in adequate amounts during the entire storage of these products. These authors observed a reduction of up to 2 log cycles in the viability of *Lactobacillus acidophilus* DOWARU™ added in vanilla ice creams with 60% and 90% overrun within a 60 days period of storage at −18°C. Due to this fact and focusing on a lower overrun in the ice creams produced, the final temperature of the dynamic whipping and freezing stage was limited to −6°C in the present study.

Table 7 shows the results of instrumental hardness and meltdown profile (time of first dripping, time to drip the first 10 ml of product, complete melting time, and melting rate) obtained for the formulations of ice creams studied on the 14th day of storage at −18 ± 3 ºC. The instrumental hardness was significantly increased with the substitution of the goat milk fat by inulin in ice creams ILr and ILp in comparison with CLr and CLp formulations (p <0.05), probably due to the overrun achieved in these products. In fact, the hardness of ice creams is inversely correlated with their overrun: a larger volume of a compressible disperse phase in ice creams with higher overruns led to less resistance to an applied force (Muse and Hartel, 2004). Similarly, other studies also reported increased hardness values in ice creams with inulin added in partial substitution of milk fat when compared to the whole fat product (El-Nagar et al., 2002; Akalın et al., 2008).

In general, the substitution of goat milk cream by inulin caused ice creams to melt faster (Fig. 1 (a) and (b)). After 60 min of exposure at room temperature, the inulin added ice creams ILr and ILp were completely melted, while a smaller portion of the ice creams CLr and CLp still remained above the wire screen (Fig. 1 (b)). As seen in the Table 6, the time to drip the first 10 ml of product and the complete melting time were significantly lower in ILr and ILp samples (p <0.05). The time of first time dripping also tended to be faster in both ice creams with inulin added, although significant differences were only verified between CLr and ILp samples (p <0.05). Similarly, the melting rate tended to be higher in inulin added ice cream, with ILp samples differing significantly from CLr (p <0.05). According to Akalın et al. (2008), milk fat slows the rates of heat transfer through ice creams and it leads fat containing ice cream to melt more slowly than non-fat ice creams with similar amounts of total solids containing fat substitutes. El-Nagar et al. (2002) and Akalın et al. (2008) also verified a faster meltdown in ice creams with inulin added in partial substitution of fat.

Sensory evaluation of ice creams

The scores of sensory acceptability obtained for the ice creams studied are shown in Table 8. No significant differences were observed between the ice cream formulations (p >0.05) either in the sensory evaluation performed in Sobral (a Brazilian north-eastern city) or in the one carried out in the city of São Paulo (a Brazilian south-eastern city). On the other hand, the ice creams CLr and CLp, with goat milk cream added, obtained scores significantly higher by the consumers in Sobral in comparison with those received by the consumers of São Paulo (p <0.05). As previously mentioned, the amounts of C6:0, C8:0, and C10:0 FA in goat milk fat are higher than those present in cow milk fat. These FA are responsible for the distinctive taste of caprine dairy products, which, according to Costa et al. (2014) turn them to be not well accepted among the consumers unfamiliarised with this kind of milk, as the panellists in São Paulo. Nonetheless, according to these authors, the increased exposure of consumers to caprine dairy products tends to increase their acceptability, as verified in their study for goat milk yogurt supplemented with the probiotic strain *L. acidophilus* LA-5. The authors concluded that when the panellists became more familiarized with the product, the attributed scores increased, after participating in consecutive sensory analysis sections with the same product. Conversely, the acceptability scores of ice creams ILr and ILp in São Paulo were similar to those in Sobral, without any significant differences (p <0.05).

Table 7: Hardness, dripping, and melting rate measurements obtained for the ice creams studied at 14 days of storage (–18±3 °C)

Parameters	Ice cream formulations			
	CLr	CLp	ILr	ILp
Hardness (N)	49.52±4.31^{B}	55.60±7.45^{B}	125.62±10.79^{A}	125.92±6.67^{A}
Time of first dripping (min)	15.86±1.46^{A}	15.71±2.06^{AB}	13.57±1.98^{AB}	13.00±1.91^{B}
Time to drip the first 10 ml (min)	23.71±1.11^{A}	23.57±2.30^{A}	20.43±0.97^{B}	20.14±1.35^{B}
Complete melting time (min)	62.71±1.38^{A}	62.71±2.29^{A}	55.71±1.11^{B}	55.57±1.81^{B}
Melting rate (mL/min)	2.14±0.09^{B}	2.22±0.13^{AB}	2.25±0.06^{AB}	2.35±0.35^{A}

Means±*SD*. CLr=goat milk cream+*L. rhamnosus* HN001. CLp=goat milk cream+*L. paracasei* LBC82. ILr = inulin+*L. rhamnosus* HN001. ILp=inulin+*L.paracasei* LBC82. ^{A,B} In a row, ice cream formulations sharing a same superscript capital letter did not differ significantly (p >0.05)

Despite the differences observed for the ice creams with goat milk cream added, the percentages of scores ranging from 6 to 9 in both regions was above 88% for all formulations, reaching 100% for the ice creams CLr, CLp, and ILr evaluated in the city of Sobral (Fig. 2). These scores are equivalent to the opinions varying between "liked slightly" and "liked extremely" in the nine-point hedonic scale (Lawless and Heymann, 2010).

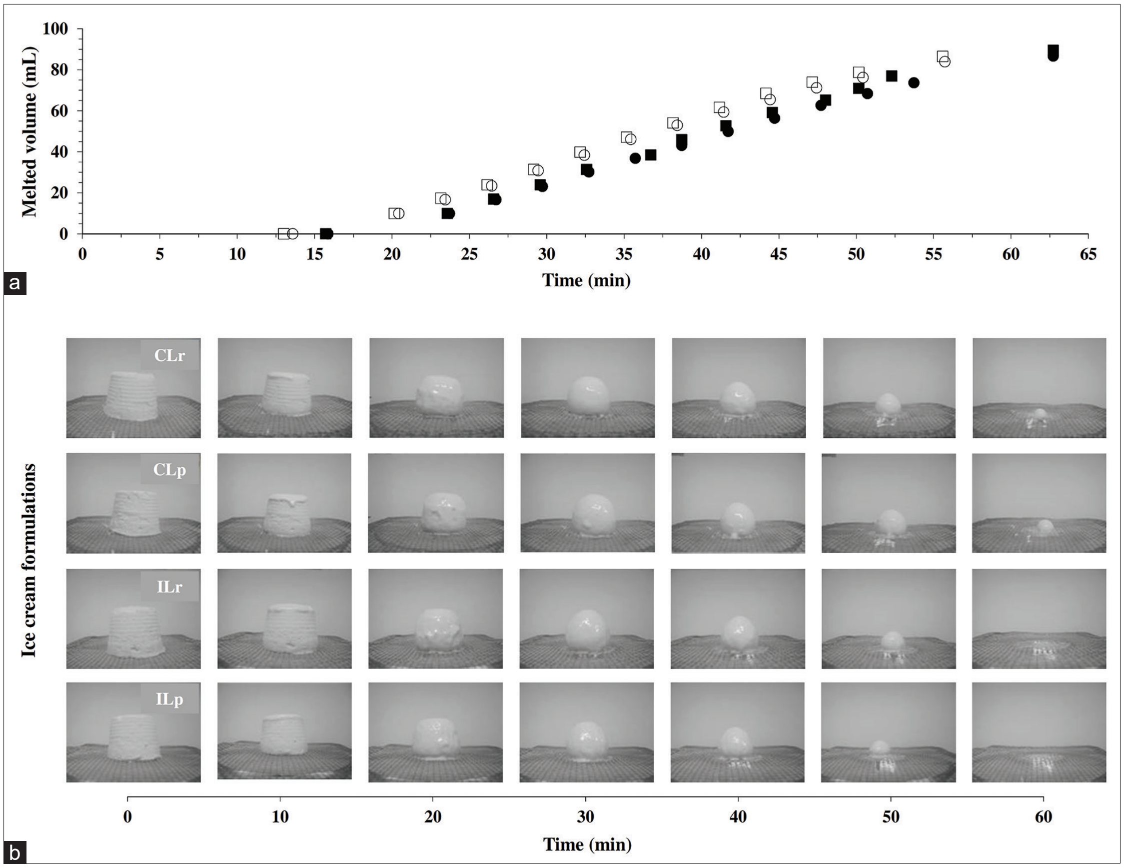

Fig 1. Meltdown profile of ice cream formulations at 14 days of storage (a) and behaviour of the ice cream formulations during the meltdown test with pictures taken every 10 min interval within 60 min (b). Ice creams: CLr = goat milk cream + L. *rhamnosus* HN001 (●); CLp = goat milk cream + L. *paracasei* LBC82 (■); ILr = inulin + L. *rhamnosus* HN001 (○); ILp = inulin + L. *paracasei* LBC82 (□).

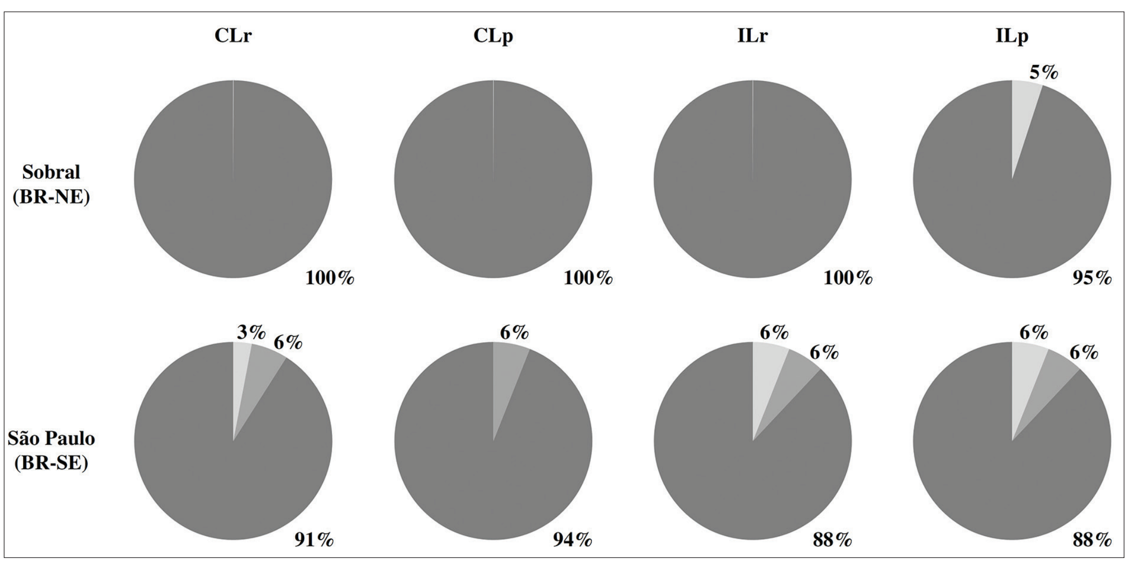

Fig 2. Frequency of the scores (= 1 to 4; = 5; = 6 to 9) attributed to the ice cream formulations at 7 days of storage (−18 ± 3°C) by the consumers in the cities of Sobral (Ceará State, Brazilian Northeast, BR-NE) and São Paulo (São Paulo State, Brazilian Southeast, BR-SE). See Table 1 for description of formulations.

Table 8: Acceptability scores obtained for the ice creams studied at 7 days of storage (–18±3°C) by the consumers in the cities of Sobral (Ceará State, Brazilian Northeast, BR-NE) and São Paulo (São Paulo State, Brazilian Southeast, BR-SE)

City	Ice cream formulations			
	CLr	CLp	ILr	ILp
Sobral (BR-NE)	7.95±0.64^{Aa}	8.03±0.73^{Aa}	7.55±0.93^{Aa}	7.68±1.38^{Aa}
São Paulo (BR-SE)	7.60±1.26^{Ab}	7.46±1.20^{Ab}	7.46±1.40^{Aa}	7.46±1.31^{Aa}

Means±*SD*. CLr=oat milk cream+*L. rhamnosus* HN001.CLp=goat milk cream+*L. paracasei* LBC82. ILr=inulin+*L. rhamnosus* HN001. ILp=inulin+*L. paracasei* LBC82. ^{A}In a row, scores sharing a same superscript capital letter did not differ significantly between ice cream formulations evaluated within a same city (p >0.05). ^{a,b}In a column, scores sharing a same superscript lowercase letter did not differ significantly (p >0.05) for a same ice cream formulation evaluated in two different cities

CONCLUSIONS

This study showed that inulin may be used as fat substitute in goat milk ice cream produced with cajá pulp and the probiotic cultures *L. rhamnosus* HN001 or *L. paracasei* LBC 82 to obtain low fat and low saturated fat products. These nutritional features allied to the presence of inulin, cajá pulp, and probiotic microorganisms in levels above 8 log cfu/g may contribute for a good health condition if consumed as part of well-balanced diet. Despite the fact that the fat substitution by inulin modified the texture of ice creams in comparison with the fat added products, similar sensory acceptance was found for all formulations studied, and particularly for inulin added products, the acceptance was also similar in both public of consumers studied. Moreover, it was also verified that the full fat ice creams achieved the highest scores in the sensory evaluation among the consumers of Sobral (a north-eastern Brazilian city, as the most of goat milk production in Brazil concentrate in the Northeast Region) in comparison with those of São Paulo (a south-eastern Brazilian city, where the goat milk products are still not part of a habitual diet). Those ice creams contained higher proportions of fatty acids responsible for the characteristic goat milk flavour. Therefore, this study reinforced that the acceptability of caprine dairy products is probably related with the familiarization of consumers with goat milk, as already demonstrated in the scientific literature by other authors.

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Author's contributions

C. M. de Paula performed the research, collected the data, interpreted the results, and prepared the manuscript. K. M. O. dos Santos collaborated with the development of the project plan and the tracking of the research progress, and also assisted with the review of the manuscript. L. Silva Oliveira and J. da Silva Oliveira assisted in the execution of the practical experimental aspect. F. C. Alonso Buriti assisted with the interpretation, discussion and presentation of the results, and with the review of the manuscript. S. M. I. Saad worked as an advisor guiding the research, tracking the research progress, assisting in the interpretation and discussion of the results, and also reviewing the manuscript.

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