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Sensory profile and physicochemical parameters of cheese from dairy goats fed vegetable oils in the semiarid region of Brazil

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A B S T R A C T

The supplementation of vegetable oils in the diets of dairy goats may enhance to improve nutritional and sensory qualities of goat milk and cheese. Cheese was made from milk of crossbred Saanen × French Alpine goats fed diets containing 4% vegetable oils (faveleira oil, sesame oil or castor oil), and physicochemical parameters, texture profile, colour and fatty ... cheese were ... ilar physic- ... For cheeses made from the milk of goats fed sesame oil, the hardness was lower, and the cheeses were softer than the control ($P < 0.05$). Faveleira oil and sesame oil positively affected the fatty acid profile of the cheese. In general, the addition of different oils to the diets of dairy goats did not promote changes in the sensory quality of the cheese produced and can be used as a dietary supplement.

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1. Introduction

In Europe, goat cheese is much appreciated, and its consumption is part of the local culture, which is not the case in Brazil. Goat milk production is a dynamic and growing industry that is fundamental to the wellbeing of hundreds of millions of people worldwide and is an important part of the economy in many countries. In addition, the studies demonstrate that this milk is also rich in microcomponents (fatty acids, vitamins), in volatile compounds (flavours, terpenes), and phenolic compounds, favourable to human nutrition and health (Silanikove et al., 2010).

Because of its nutritional characteristics, researchers have attempted to improve the physicochemical characteristics of goat milk, especially by inducing changes through addition of different sources of fat in the diets of dairy

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goats (Queiroga et al., 2010). In this context, vegetable oils have been used to increase dietary energy density and to improve the quality of goat milk and its derivatives. However, there are limiting factors in the use of vegetable oils in the diets of ruminants. The oil content should not exceed 7% of the ethereal extract in dry matter (NRC, 2007).

Some studies have reported positive effects of lipid supplementation on milk quality in goats. Sanz Sampelayo et al. (2007) reported that lipid supplementation in dairy goats causes no changes in energy consumption or milk production but significantly increases the fat content of milk in most cases. In addition, the presence of unsaturated fatty acids in feed may have positive effects, such as inhibiting the production of methane and ammonia in the rumen and increasing the efficiency of microbial synthesis (Mohammed et al., 2004). Some studies have shown that dietary supplementation with fodder and oils improve the quality and sensory attributes of milk (Bernard et al., 2009; Chilliard et al., 2003; Palmquist and Griinari, 2006) and cheese (Cabiddu et al., 2006; Santos et al., 2012).

Among the existing lipid sources, faveleira oil (*Cnidoscolus quercifolius* or *C. phyllacanthus*), sesame oil (*Sesamum indicum* L.) and castor oil (*Ricinus communis* L.) have received special attention for their wide applicability, availability and high levels of unsaturated fatty acids, but their effects as supplements in animal diets and on changes in cheese attributes are still poorly understood. The seeds of faveleira (50–70% oil) stand out due to the presence of unsaturated fatty acids, especially linoleic acid (C18:2n6 *cis*), which accounts for 41.6% of linoleic (Santos et al., 2005). Castor seeds show crude oil levels ranging from 35 to 55%, where 90% is ricinoleic acid (C18:1 *cis*-9,12-OH), giving this oil typical features, such as high viscosity over a wide range of temperatures, oxidative stability, a low freezing point, and total solubility in low-molecular-weight alcohols (Berman et al., 2011). Sesame seeds, which contain up to 60% oil and 17–23% protein, produce oil rich in unsaturated fatty acids and the presence of antioxidants such as sesamin, sesamolin, and sesamol (Suja et al., 2004).

The objectives of the present study were as follows: to evaluate the effect of supplementation of three vegetable oils (faveleira, sesame and castor) on the milk composition of dairy goats raised in Brazilian semiarid region and to characterise rheological properties, colour, fatty acids and sensory properties of goat cheese produced from different dietary treatments.

2. Materials and methods

2.1. Animals and experimental rations

The cheese was made from the milk of crossbred Saanen × French Alpine goats, which were hand milked, kept in confinement and fed diets prepared according to NRC (2007) requirements (Table 1). Four diets were used in the study: Treatment 1, basal diet without the addition of vegetable oil to the dry matter; Treatment 2, basal diet plus 4% faveleira oil; Treatment 3, basal diet plus 4% sesame oil; and Treatment 4, basal diet plus 4% castor oil.

The trial lasted 76 days and followed a Latin square design (4 × 4) with 8 animals distributed into two for each treatments, with four treatments and four processing periods, being which the first 15 days of each period were used for adaptation to the diet and for the four days following the collection of milk samples.

2.2. Cheese samples and production technology

In each period, the cheeses were made using 10 L of goat milk per treatment, and they were pasteurised at 65 °C (±1 °C) for 30 min followed by cooling to 37 °C (±2 °C) and coagulation with additives in the following sequence: 0.25 mL L^{-1} 85% lactic acid solution; 0.1 g L^{-1} lyophilised lactic starter culture with *Lactococcus lactis* subsp. *cremoris* and *Lactococcus lactis* subsp. *lactis* (Christian Hansen Ind. & Com. Ltd., Valinhos, SP, Brazil); 0.5 mL L^{-1} 50% calcium chloride; and 0.9 mL L^{-1} commercial coagulant (Ha-La®, Christian Hansen Ind. & Com. Ltd., Valinhos, SP, Brazil). After 40 min of rest, the curd was gently cut into cubes, drained, and salted in brine (9 g L^{-1} NaCl). The cheese mass was then distributed into 250 g perforated moulds, pressed for 4–6 h at room temperature, vacuum packed and stored under refrigeration 4 ± 1 °C for 7 days. Four cheeses manufactured were 250 g for each treatment, in which a part was designed to sensory analysis and partly other analysis.

2.3. Physicochemical analysis

Physicochemical analyses were performed in accordance with the following procedures recommended by AOAC International (2000): 991.20 for protein; 989.04 for lipids; 935.42 for ash; 981.12 for pH; and 978.18 for water activity. The moisture content from the samples was determined following the international standard method (IDF, 1958).

2.4. Texture analysis

Texture profile analysis (TPA) were performed using a TA-XT2i texturometer (Stable Micro Systems, Survey, UK) coupled to a stainless steel spherical probe (P/1S) 1 inch in diameter (Extralab Brazil, São Paulo, Brazil). Cheeses were cut into cylindrical shapes (50 mm in diameter and 25 mm in height) and analysed in triplicate for each treatment.

The conditions for texture analysis based on the procedure of Andrade et al. (2007) were as follows: 1.0 mm/s speed, 50% compression, 5.0 g contact force, and 5 s between cycles. The texture parameters of hardness, cohesiveness, adhesiveness, springiness and chewiness were analysed using Texture Expert for Windows 1.20 software (Stable Micro Systems).

2.5. Colourimetric analysis

The determination of instrumental colour was performed on a CR-400 colourimeter (Minolta, Osaka, Japan) using the CIELAB system colour scale ($L^*a^*b^*$) with a D65 illuminant (standard daylight) and measuring angle of 10. The L^*, a^* and b^* parameters were determined according to the International Commission on Illumination (CIE, 1996). Using reference plates, the apparatus was calibrated in the reflectance mode with specular reflection excluded. A 10 mm quartz cuvette was used for the readings. Measurements were performed in triplicate on the external and internal of each piece of cheese immediately after unpacking.

2.6. Fatty acid analysis

For all the samples analysed, lipid extraction was performed according to the technique of Folch et al. (1957). For the analysis of fatty acids, saponification and esterification of the cheeses were performed according to the method of Hartman & Lago (1973).

The esterified samples were analysed with a gas chromatograph (Varian 430-GC) with a flame ionisation detector (FID) and fused silica capillary column (CP WAX 52 CB Varian; 60 mm × 0.25 mm, 0.25 μm film thickness). Helium was used as the carrier gas (flow rate of 1 mL min^{-1}). The initial oven temperature was 100 °C, and the temperature was programmed to reach 240 °C by increasing 2.5 °C per min for 20 min. The injector and detector temperatures were maintained at 250 and 260 °C, respectively.

An aliquot (1.0 μL) of each esterified extract was injected into a split/splitless type injector at 250 °C, and the chromatograms were recorded using Galaxie Chromatography Data System software. Fatty acids were identified by comparing the retention time of the methyl esters with Supelco ME19-Kit standards (Fatty Acid Methyl Esters C6-C24). The results were quantified by standardisation of the areas of methyl esters and are expressed as percentages of the area.

Table 1
Percentage and chemical composition of experimental diets.

Components	Experimental diets			
	Control without oil	"Faveleira" oil	Sesame oil	Castor oil
	Proportion of ingredients (% dry matter)			
Tifton hay	49.30	49.06	49.06	49.06
Ground corn	37.29	32.99	32.99	32.99
Soybean meal	10.79	11.34	11.34	11.34
Faveleira oil	0.00	4.00	0.00	0.00
Sesame oil	0.00	0.00	4.00	0.00
Castor oil	0.00	0.00	0.00	4.00
Core mineral[a]	1.37	1.47	1.47	1.47
Limestone	1.25	1.13	1.13	1.13
	Chemical composition (%)			
Dry matter[b]	86.99	87.42	87.42	87.42
Organic matter	91.91	91.96	91.96	91.96
Mineral matter	8.09	8.04	8.04	8.04
Crude protein	13.82	13.69	13.69	13.69
Ether extract	3.15	6.97	6.97	6.97
Neutral detergent fiber[c]	39.92	39.19	39.19	39.19
Acid detergent fiber[c]	18.70	18.48	18.48	18.48
Lignin	3.12	3.03	3.03	3.03
Total carbohydrates	74.95	71.31	71.31	71.31
Total digestible nutrients	61.61	69.68	69.05	69.19
Metabolisable energy (Mcal/kg)[d]	2.36	2.64	2.67	2.60

[a] Mineral supplement (nutrients/kg de supplement): Ca = 210 g; P = 70 g; Mg = 5 g; F = 700.00 mg; Zn = 3.010 mg; Cu = 440 mg; Mn = 1485 mg; Co = 25 mg; Fe = 340 mg; Cr = 6.00 mg; Se = 20 mg; I = 48 mg; S = 10 g; Vit. A = 250,000.00 UI/kg; Vit. D3 = 40,000.00 UI/kg; Vit E = 350.00 UI/kg.
[b] % on the basis dry matter.
[c] Free ash and protein.
[d] EM (Mcal/kg) = ED (Mcal/kg) × 0.86.

2.7. Sensory analysis

This study was approved by the Research Ethics Committee under protocol number 154/2009. The panellists were chosen from among a group prepared and trained for more than 150 h of sensory analysis of various types of cheese. Thirteen members were selected to define the descriptive terminology for the sensory attributes of goat cheese in more than three training sessions. The quantitative descriptive analysis (QDA) test was applied according to the methodology described by Faria and Yotsuyanagi (2002) and performed in three sessions with samples served refrigerated (4 ± 1 °C) in 2 cm × 2 cm × 2 cm. The sensory attributes, including external appearance, odour, texture (hardness and springiness), basic taste (sour and salty), flavour and aftertaste (intensity and persistence), were evaluated using a 5-point intensity scale ranging from less intense to more intense for most attributes, except for external appearance (dry to moist), hardness (soft to hard) and springiness (less elastic to more elastic) (Hossenlopp, 1995).

2.8. Microbiological analysis

The analyses were performed on the basis of Official Analytical Methods for Microbiological Analysis for Control of Animal Products and Water as required by National Health Surveillance Agency (ANVISA) for *Staphylococcus aureus*, total coliform in food, thermotolerant coliform in food, *Salmonella* and *Listeria monocytogenes* (Brazil, 2001).

The microbiological quality of cheeses was monitored during the maturation phase, and the presence of *S. aureus*, *Salmonella* spp. or *L. monocytogenes* was not detected at any time. Moreover, the total and thermotolerant coliform MPN (most probable number) remained less than 3 MPN/g indicating that the "curd type" goat cheese was pathogen-free and exhibited satisfactory microbiological quality, thereby allowing it to be used in the sensory analyses.

2.9. Statistical analysis

A simultaneous double Latin square (4 × 4) experimental design was used with eight animals randomly distributed into four treatments and four periods. The following statistical model was used in the analysis of the physicochemical data:

$$Yijkl = \mu + Qi + Tj + Pk + A(i)l + QTij + xijk$$

where *Yijkl* is the observation of goat *j* in period *k* submitted to treatment *i* with *i*, *j*, and *k* = 1, 2, 3, 4; μ is the general effect of the mean; *Qi* is the effect of the Latin square with *Q* = 1,2; *Ti* is the effect of treatment *i* with *i* = 1, 2, 3, 4; *Pk* is the effect of period *k*; *A* is the effect of goat *l* in square *i* with *l* = 1, 2, 3, 4; *QT* is the interaction of the effect of Latin square *i* with treatment *j*; and ξijk is the random error associated with each observation *Yijkl*.

The statistical model of the sensory analysis data contained only the fixed effect of the treatment. Treatment means were compared by Tukey's test at 5% error probability using statistical software (SAS, 1996). A principal component analysis (PCA) was performed using sensory data, rheological parameters, physicochemical parameters and fatty acids.

3. Results

The components chemical: moisture, protein, lipids, ash e aw of the cheeses were not affected ($P \geq 0.05$) by the addition of vegetable oils to the diets of the goats. There were significant differences among the four treatments ($P < 0.05$) for the pH, hardness, cohesiveness, colour a^* (internal) and colour b^* (external) parameters of goat cheese (Table 2). Lightness (L^*) did not affect ($P \geq 0.05$) the external or internal intensity of the white colour of cheeses from different treatments. The cheeses exhibited L^* values close to 100 ranging from 91.20 to 92.57.

In the fatty acid profile of the goat cheeses, the highest area percentages were found for the C16:0, C18:1, C18:0, C14:0, C10:0, C12:0, C18:2 and C8:0 acids with a total area average of 91%. The levels of saturated fatty acids, including palmitic and lauric acids, were reduced ($P < 0.05$) when

Table 2
Mean and standard error of the physicochemical parameters, texture and colour of cheese from goats fed different vegetable oils.

	Treatments[1] (cheese)				SEM	Significance
Parameters	Control without oil	Faveleira oil	Sesame oil	Castor oil		
Physicochemical						
Moisture (%)	48.80	48.45	49.65	49.74	0.464	ns
Protein (%)	26.60	25.31	26.00	26.54	0.292	ns
Lipids (%)	23.35	24.17	22.94	22.67	0.283	ns
Ash (%)	3.28	3.38	3.26	3.57	0.059	ns
Aw	0.951	0.950	0.960	0.956	0.003	ns
pH	5.80^{c}	6.11^{a}	5.95^{b}	6.10^{a}	0.031	*
Rheological						
Hardness (N)	67.84^{a}	56.47^{ab}	45.62^{b}	57.22^{ab}	4.255	*
Cohesiveness (g)	0.62^{b}	0.68^{a}	0.70^{a}	0.68^{a}	0.001	*
Adhesiveness (g)	−0.85	−0.93	−1.77	−0.62	0.002	ns
Springiness (g)	0.84	0.82	0.86	0.86	0.001	ns
Chewiness (N)	38.21	33.98	28.78	36.67	2.597	ns
Colour[2]						
L^*(e)	91.20	91.62	91.20	91.73	0.234	ns
a^*(e)	−2.90^{a}	−3.24^{ab}	−3.28^{b}	−3.62^{c}	0.081	*
b^*(e)	10.40^{b}	10.40^{b}	10.59^{b}	11.93^{a}	0.237	*
L^*(i)	92.33	92.44	92.02	92.57	0.169	ns
a^*(i)	−2.57^{a}	−2.81^{ab}	−3.11^{bc}	−3.45^{c}	0.092	*
b^*(i)	9.45^{c}	9.47^{c}	10.53^{b}	11.55^{a}	0.246	*
Fatty acids						
C8:0	2.15	1.88	2.07	2.02	0.048	ns
C10:0	8.68^{a}	6.90^{ab}	6.38^{b}	8.02^{ab}	0.315	*
C12:0	4.44^{a}	3.08^{b}	3.28^{b}	3.73^{ab}	0.143	*
C14:0	11.03^{a}	8.35^{c}	9.14^{bc}	10.17^{ab}	0.268	*
C16:0	28.13^{a}	26.45^{ab}	24.66^{b}	27.62^{ab}	0.485	*
C18:0	11.88^{b}	15.13^{ab}	16.64^{a}	11.63^{b}	0.607	*
C18:1	22.70^{ab}	25.61^{a}	25.70^{a}	18.88^{b}	0.875	*
C18:1 n9*cis*, 12-OH	nd	nd	nd	6.56	0.346	*
C18:2	2.77^{b}	3.48^{a}	3.35^{a}	2.57^{b}	0.095	*
Others saturated fatty acid	3.69	3.60	3.68	4.09	0.012	ns
Others unsaturated fatty acid	4.53^{b}	5.52^{a}	5.10^{a}	4.41^{b}	0.097	*
Total saturated fatty acid	69.46	64.27	64.92	66.46	0.801	ns
Total unsaturated fatty acid	30.54^{b}	35.73^{a}	35.08^{a}	33.54^{ab}	0.115	*

SEM = standard error of the mean; ns = non-significant; nd = non-detected.
Means followed by different lowercase letters in the same row indicate significant differences according to Tukey's test at a 5% significance level.
[1] 0% oil (control); 4.0% faveleira oil; 4.0% sesame oil; 4.0% castor oil.
[2] L^*(e), a^*(e) and b^*(e) correspond to the external colour parameters of the cheese, and L^*(i), a^*(i) and b^*(i) correspond to the internal colour parameters.
[*] $P < 0.05$.

sesame and faveleira oils were added to the diet of lactating goats. The total concentration of unsaturated fatty acids showed a significant difference ($P < 0.05$) among the cheese samples, especially when sesame and faveleira oils were added to the diets with a similar percentage of 35%.

The sensory attributes analysed did not vary between treatments ($P \geq 0.05$), showing differences ($P < 0.05$) among treatments for hardness and external appearance (dry/moist) (Table 3). The sensory attributes of quality, which contribute to the intensity of the parameters studied, had an average score of 2.55 on a scale from 1 to 5, thus indicating cheeses of intermediate quality.

To identify the sensory attributes, physicochemical properties, rheological properties and fatty acids that contributed most to distinguish the differences among the samples of cheese from goats fed with diets containing different vegetable oils, a principal component analysis (PCA) was performed using the average values of the repetitions in a correlation matrix (Fig. 1), revealed 87.8% of the variability among the parameters analysed in the cheese samples.

4. Discussion

The physicochemical composition of the cheeses was not affected by the addition of vegetable oils to the diets of the goats (Table 2). Similar results have been reported for cheese made from the milk of Saanen goats (Seifu et al., 2004) and for semi-hard cheese made from the milk of Alpine goats (Zeng et al., 2007). Santos et al. (2012) reported that goats' diets with soybean oil supplementation increased the fat and total solids content (%, w/w, total matter) of milk. Similar results concerning changes in milk composition as a consequence of with soybean oil supplementation of goats diet were reported by Bouattour et al. (2008), particularly the increase in fat level and the maintenance of protein content.

Cheeses with lower pH values, mainly values close to the casein isoelectric point, possess textures with high gumminess, and cheeses with higher pH values present a more plastic texture (Bhaskaracharya and Shah, 2001). In this context, the pH of the cheeses analysed varied among treatments with higher pH values observed in cheeses from

Table 3
Mean and standard error of quantitative descriptive analysis (QDA) of cheese from goats fed different vegetable oils.

Attributes	Treatments[1] (cheese)				SEM	Significance
	Control without oil	Faveleira oil	Sesame oil	Castor oil		
External appearance	2.63[b]	3.15[a]	2.74[b]	3.20[a]	0.105	*
Odour						
Overall intensity	2.54	2.62	2.62	2.59	0.048	ns
Goat milk	2.38	2.41	2.49	2.44	0.042	ns
Rancid	1.93	1.91	1.97	2.02	0.042	ns
Aromatic	2.43	2.43	2.44	2.41	0.043	ns
Texture						
Hardness	2.92[ab]	2.83[b]	2.74[b]	3.26[a]	0.125	*
Springiness	2.57	2.63	2.62	2.67	0.040	ns
Taste						
Sour	2.99	2.75	2.66	2.74	0.065	ns
Salty	2.46	2.53	2.40	2.65	0.045	ns
Flavour						
Overall intensity	3.17	2.88	2.91	3.08	0.059	ns
Rancid	2.38	2.17	2.15	2.32	0.057	ns
Goat	2.89	2.58	2.61	2.71	0.067	ns
Aromatic	2.53	2.49	2.47	2.51	0.044	ns
After taste						
Intensity	3.07	2.82	2.80	3.01	0.070	ns
Persistence	2.94	2.65	2.72	2.85	0.068	ns

SEM = standard error of the mean; ns = non-significant.
Means followed by different lowercase letters in the same row indicate significant differences according to the Ryan–Einot–Gabriel–Welsch test at a 5% significance level.
[1] 0% Oil (control); 4.0% Faveleira oil; 4.0% sesame oil; 4.0% castor oil.
* $P < 0.05$.

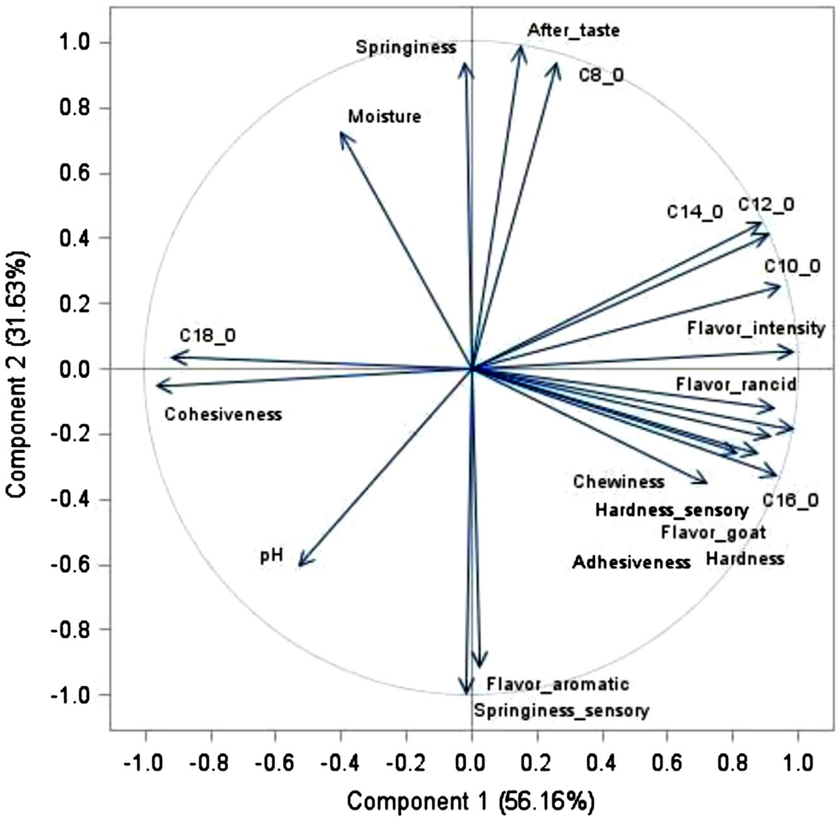

Fig. 1. Principal component analysis of cheese from goats fed different vegetable oils.

goats fed faveleira oil or castor oil. The goat milk also presented a more pronounced alkalinity and buffering capacity in comparison to cow milk, which is mainly related to the associated casein and phosphate systems (Galina et al., 2007). Low pH values make calcium phosphate micelles more soluble increasing the loss of soluble calcium of whey during the draining of curdled milk (Park, 2006).

There were significant differences in the hardness of the cheeses. The cheese from the sesame oil treatment was softer compared to the control treatment, and the cheese from the faveleira oil and castor oil treatments exhibited intermediate values compared to the control and sesame oil treatments. The cohesiveness of the cheeses from the faveleira oil, castor oil and sesame oil treatments were not significantly different, but the cohesiveness values were higher than the cohesiveness value of the cheese from the control treatment, indicating that cheeses from the oil treatments were more cohesive. Nevertheless, the variation in hardness observed cannot be unequivocally attributed to the addition of oils to the diet and may be caused by variations in the final pH, which can affect cheese hardness. There were no significant differences among the treatments for the other texture attributes analysed (adhesiveness, springiness and chewiness). The springiness values observed in the present study were similar to those observed for probiotic Minas fresh cheese studied by Buriti et al. (2005).

The analysed goat cheeses exhibited high lightness values (L^*) with component b^* predominant over component a^*. These values are associated with a more intense white colour most likely resulting from the lower diameter of fat globules in goat milk (3.5 μm in goat milk vs. 4.5 μm in cow milk) and the full conversion of β-carotene into vitamin A, which occurs in the metabolism of goats, as reported by Lucas et al. (2008).

The addition of vegetable oils to the diets may have positively influenced the instrumental colour parameters a^* and b^*, especially in sesame oil and castor oil treatments. Cheese from the castor oil treatment exhibited the highest values for b^* (yellowness). In fact, castor oil was the most yellow of all of the oils studied due to the presence of carotenoids in the oil (Famelart et al., 2006). Buffa et al. (2001) and Santos et al. (2011) reported similar L^*, a^* and b^* values for the control treatment in a study of "curd type" goat cheese. The lightness (L^*) value of the control treatment in the present study was higher than the one reported by Sheehan et al. (2009) for goat cheese (86.70), and the a^* values were similar in these studies. Pizzillo et al. (2005) studied ricotta cheese made from the milk of different goat breeds (Girgentana, Siriana, Maltese and Italian), and they reported results similar to those observed in the present study for lightness and component b^*.

The levels of saturated fatty acids, including palmitic and lauric acids, in the fatty acid profile of the goat cheeses, were reduced when sesame and faveleira oils were added to the diet of lactating goats. Similar results were observed by Chilliard et al. (2007) and Pereira et al. (2010), who reported that some vegetable oils in the diet of lactating goats, regardless of the fibre source, reflect a fatty acid profile of *novo* synthesis in mammary epithelial cells.

Only the total concentration of unsaturated fatty acids showed a significant difference among the cheese samples (Table 2) revealing that supplementation with 4% vegetable oils in the diet of dairy goats increased the percentage of fatty acids in cheese to a level considered beneficial to human health (Williams, 2000); this observation was especially detectable when sesame and faveleira oils were added to the diets. According to Jenkins and McGuire (2006), unsaturated fatty acids can alter the rumen fermentation of fibre by the toxic action of fibrolytic bacteria, which are involved in the biohydrogenation of polyunsaturated fatty acids. In the present study, the inclusion of oils rich in C18:2, such as faveleira oil (63.87%) and sesame oil (48.18%) (Medeiros et al., 2012), increased the rate of saturation stearic acid and, consequently, monounsaturated C18:1. However, this result differed from the result observed by Chilliard et al. (2007) and Bernard et al. (2009), who reported that a greater amount of linoleic acid inhibits the saturation of monounsaturated.

Significant differences among treatments were observed for hardness and external appearance (dry/moist) (Table 3). The other sensory attributes analysed did not vary between treatments. For the external appearance, panellists thought cheeses from the castor oil and faveleira oil treatments appeared moister than those from the control and sesame oil treatments, but this perception could not be attributed to measurable differences in moisture among cheeses because the moisture content was not significantly different among treatments. Although there were no significant differences among treatments in aftertaste, panellists reported a marked persistence of goat flavour but did not attribute this flavour to the addition of vegetable oils to the diets of dairy goats. Using a 5-point sensory scale, Gonzalez et al. (2003) reported similar results for the aftertaste quality and intensity of goat cheese with starter culture.

Pereira et al. (2010) reported that the inclusion of castor oil as a supplement in goat feed modifies the physicochemical characteristics of the milk, especially fat content, aside from accentuating the rancid flavour in the sensory profile. In contrast, the supplementation of vegetable oils in the diets of dairy goats did not affect the goat cheese sensory characteristics, which may have been due to technological factors resulting from the manufacturing process.

The results of the correlation matrix with the 2 components together accounted for 87.8% of the variability among the attributes and parameters analysed in the cheese samples, which indicated a high correlation between the intensity of goat flavour and aftertaste with the medium chain fatty acids (C10:0, C12:0 and C14:0) and short chain fatty acids, such as caprylic acid (C8:0). These results suggested that the goat flavour may be associated with the hydrolysis of these fatty acids, which is known to cause rancid flavour in these foods, but the rancid flavour is not sensorially perceived in cheeses due to the influence of the fermentation process. The presence of long chain fatty acids, such as C18:0, caused no significant differences in the sensory attributes of the cheeses; this finding is important because these fatty acids are essential in evaluating the nutritional quality of products.

According to component 1, the texture parameters were positively correlated among the samples. Interestingly, the rheological parameters and sensory hardness inversely interacted with moisture in component 2 although they were not significantly different from the moisture parameter in the cheeses as shown in Table 2, indicating that firmer cheese samples had the lowest moisture. The correlation of the cohesiveness of the cheeses supplemented with the addition of oils in the diet was confirmed by the principal component analysis. The pH of the control cheese (without oil) showed that the final pH was lower in the control compared to the other cheeses, which may have affected the hardness of the cheese and, consequently, attributed to the improved softness of the cheeses from the faveleira, sesame and castor oil treatments compared to the control cheese.

5. Conclusions

The inclusion of faveleira, sesame or castor oils had no effect on the physicochemical composition, but the addition of faveleira and sesame oils positively affected the fatty acid profile of cheese with a reduction of saturated fatty acids and an increase of unsaturated fatty acids. However, the addition of such oils did not cause a change in the rheological parameters and perceived sensory quality. The use of vegetable oils in the manipulation of goat diets may improve fat composition of dairy animals and, consequently, may increase the nutritional value without affecting the sensory characteristics of the cheese.

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