Physicochemical and sensory characteristics of milk from goats supplemented with castor or licuri oil

R. A. G. Pereira,* C. J. B. Oliveira,* A. N. Medeiros,* R. G. Costa,† M. A. D. Bomfim,‡ and R. C. R. E. Queiroga§¹

*Department of Animal Science, Federal University of Paraíba, Areia-PB 58397-000, Brazil

†Department of Agriculture, Federal University of Paraíba, Bananeiras-PB 58220-000, Brazil

‡National Centre for Goat Research, Embrapa, Sobral-CE, 62011-970, Brazil

§Department of Nutrition, Federal University of Paraíba, João Pessoa-PB 58051-900, Brazil

ABSTRACT

The purpose of this study was to evaluate the influence of castor and licuri palm oils supplemented to milking goats on the physical, chemical, and sensory characteristics of milk. A double Latin square experimental design (5×5) using 10 confined crossbred Moxotó-Alpine goats was performed according to the following treatments: nonsupplemented (control), 3% castor oil, 5% castor oil, 3% licuri oil, and 5% licuri oil. Oils in each treatment were supplemented in the dry matter. Castor oil supplementation reduced the fat content and increased the lactose and density of milk. Considering the sensory analysis, a lower acceptability was observed for milk from goats supplemented with castor oil. On the other hand, licuri oil supplementation led to higher acceptability scores for flavor and odor of goat milk.

Key words: acceptability, chemical composition, *Syagrus coronata*, *Ricinus communis*

INTRODUCTION

The effects of dietary fats on milk composition have been widely studied (Delacroix-Buchet and Lamberet, 2000; Morand-Fehr et al., 2007; Vasta et al., 2008). Although it is known that ruminant diets must not contain high fat percentage because this could inhibit ruminal fermentation by cellulolytic microorganisms (Jenkins, 1993), even low levels of fat in ruminant diets could lead to major changes in composition and physicochemical traits of milk. Such changes depend predominantly on the fat amount and its fatty acid profiling (Chilliard et al., 2003).

Lipid composition plays an important role in the nutritional quality of goat milk. Lipids are involved in the color and flavor of dairy products, in the yield and

firmness of cheese, and in the sensory characteristics of yogurt (Vargas et al., 2008). The presence of small fat globules and high amounts of short- and medium-chain fatty acids in goat milk leads to major changes in the content of free fatty acids during lipolysis, which influences the flavor of products (Chilliard et al., 2003; Haenlein, 2004; Bernard et al., 2009). Flavor and odor are known to be important milk quality traits; they are especially important for goat milk because the sensory attributes play an important role in the acceptability of milk and dairy products.

Of the several factors that might be associated with the sensory attributes and quality of goat milk, feeding is considered to be a key factor. Animal feeding systems are shown to be very important in giving particular features to the milk used in the production of certain cheese types (Alonso et al., 1999; Scintu and Piredda, 2007). Therefore, it is plausible to think that the inclusion of some oils in the diet of goats could add value to goat milk. Although fat supplementation could have a major effect on chemical and sensory characteristics of goat milk, little attention has been paid to the development of feeding strategies using vegetable oils to produce desirable quality traits in goat milk.

Licuri (*Syagrus coronata*) is a palm tree that is well adapted to semiarid areas of Brazil. Licuri oil is predominantly made up of saturated fatty acids and particular sensory attributes. It has been increasingly used for cooking purposes and might become an important economic commodity for local extractive communities and regions with agricultural limitations.

The cultivation of the castor bean (*Ricinus communis* L.) also presents an economical opportunity for family agriculture in semiarid northeast Brazil because this plant is very resistant to drought, presents good market value, and can be cultivated together with other vegetables, especially beans. Castor oil has a high polyunsaturated fatty acid profile, and byproducts of oil extraction from castor beans have a high content of protein (Azevedo and Lima, 2001) and could be used in animal feeding after detoxification.

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¹Corresponding author: rqueiroga@uol.com.br

Table 1. Percentage composition of ingredients in the diets¹ and chemical composition of rations according to licuri oil or castor oil supplementation levels

Item	Control	Licuri oil		Castor oil	
		3%	5%	3%	5%
Ingredient (%)					
Ground corn ²	25.00	21.00	18.50	21.00	18.50
Soybean meal	15.00	16.00	16.50	16.00	16.50
Licuri oil	—	3.00	5.00	—	—
Castor oil	—	—	—	3.00	5.00
Limestone	1.50	1.50	1.50	1.50	1.50
Mineral salt ³	1.50	1.50	1.50	1.50	1.50
Cactus pear	10.00	10.00	10.00	10.00	10.00
Buffel hay (<i>Cenchrus ciliaris</i> L.)	47.00	47.00	47.00	47.00	47.00
Nutritional composition (g/kg unless noted)					
DM	57.20	57.36	57.46	57.36	57.46
Mineral matter	10.56	10.51	10.46	10.51	10.46
CP	11.41	11.46	11.43	11.46	11.43
Ether extract	3.17	5.80	7.56	5.80	7.56
NDF	47.03	46.37	45.94	46.37	45.94
ADF	31.88	31.52	31.29	31.52	31.29
Metabolizable energy (Mcal/kg of DM)	2.17	2.27	2.34	2.27	2.34

¹Diets: nonsupplemented (control), 3% castor oil, 5% castor oil, 3% licuri oil, and 5% licuri oil. Oils in each treatment were supplemented in the DM.

²Byproduct of corn flakes.

³Composition per kilogram: 180 g of Ca; 90 g of P; 10 g of Mg; 900 mg of F; 3,600 mg of Zn; 1,000 mg of Cu; 1,500 mg of Mg; 80 mg of Co; 12 mg of Se; 150 mg of I; 93 g of Na; 145 g of Cl; 15 g of S; 15,000 IU/kg of vitamin A; 27,000 IU/kg of vitamin D₃; 421 mg of vitamin E.

Based on the fatty acid profiles of licuri and castor oils and the potential of these plants to improve the agricultural development of semiarid regions in north-east Brazil, this study evaluated the effects of including licuri or castor oils in the diet of goats on physicochemical and sensory attributes of milk.

MATERIALS AND METHODS

Experimental Design

The experiment was performed at the Field Station for Small Ruminant Research of the Federal University of Paraíba (João Pessoa, Brazil). Ten multiparous crossbred Moxotó × Alpine goats, at d 51 of lactation and weighing 40 kg on average, were penned individually; drinking water and feed were provided ad libitum. Diets were formulated according to NRC (1981) to meet the nutritional requirements of goats producing 2 kg of milk daily with 4% fat. Feed was supplied as a TMR twice daily in excess (20%) to ensure ad libitum intake. Buffel hay and sliced cactus pear leaves were mixed into the experimental diets. The treatments consisted of the following 5 groups: nonsupplemented (control), 3% castor oil, 5% castor oil, 3% licuri oil, and 5% licuri oil. Oils in each treatment were supplemented in the DM. Experimental diet compositions are shown in Table 1.

The trial lasted 75 d and comprised 5 experimental periods of 15 d each. The first 12 d of each period was

used for adaptation to the diets and the following 3 d were used for data collection.

The goats were manually milked twice daily. Before milking, the udder was cleaned and the strip-cup test was performed to detect mastitis. Postdipping was performed after milking using a commercial iodine solution. Milk yield (kilograms/day) was determined during the last 3 d of each experimental period. A composed sample per animal was collected using proportional amounts from morning and afternoon milkings and used for physicochemical and sensory analyses. Previously sterilized stainless steel bottles (500 mL) were used for milk storage.

Physicochemical Determinations

Physicochemical analyses were carried out on 50 composed milk samples from 5 treatments and 5 periods in a double Latin square design (5 × 5 × 2). Protein content was determined according to AOAC (1998) methods 991.20 and 991.23. Milk DM was obtained according to AOAC (1998) method 925.23. Fat content of milk samples was determined by the Gerber method according to IAL (2005) protocol 433/IV. Lactose was determined by the Fehling reduction method according to IAL (2005) protocol 432/IV, and ashes were determined by milk incineration at 550 to 570°C. Density was measured by a thermolactodensimeter at 15°C and acidity was determined by endpoint titration and expressed as lactic acid.

Table 2. Glossary of quality descriptors of goat milk developed in consensus by the sensory panel

Descriptor	Definition
Goatish odor	Characteristic odor (aroma) of goat milk perceived by the sensory (olfactory) cells in the nasal cavity while volatile substances are inhaled.
Goatish flavor	Typical property of goat milk given by a complex sensation of taste (gustatory sense) together with odor or aroma (olfactory sense).
Rancid flavor	Noncharacteristic taste of goat milk given by the rank smell of decomposition of fat or oils.
Sweet flavor	Taste sensation that is induced by disaccharides and is mediated especially by receptors in taste buds at the front of the tongue.

Sensory Analysis

Composed milk samples from the 5 periods in each treatment were pasteurized at 65°C for 30 min, transferred to sterile amber glass containers, and kept under refrigeration until analyses. Sensory analyses were performed according to Stone and Sidel (1993) in individual booths isolated from noise and odors. Samples (50 mL) were served at 7°C in glasses coded with 3-digit random numbers. Between samples, crackers and plain water were served to cleanse the palate. Quantitative descriptive analysis (QDA) was performed in triplicate using 12 trained panelists (50% women, 50% men; 22–38 yr of age). Intensity of goatish odor, goatish flavor, rancid flavor, and sweet flavor was assessed based on a nonstructured 9-cm intensity scale ranging from 1 (extremely weak) to 9 (extremely strong). A glossary of these descriptors is presented in Table 2. Because each sample was related to a given treatment, the panelists tasted 5 samples 3 times (repetitions) each.

For the acceptance test, the attributes flavor and odor were evaluated by 48 nontrained panelists (42% women, 58% men; 20–40 yr of age) according to a hedonic scale ranging from 1 (dislike very much) to 9 (like very much). Panelists were frequent goat milk consumers that were recruited from students, employees, and professors at the Federal University of Paraíba, Brazil.

Statistical Analysis

A simultaneous double Latin square (5×5) experimental design was used, with 10 animals randomly distributed into 5 treatments and 5 periods. The statistical model used in the analysis of the physicochemical data was the following:

$$Y_{ijkl} = \mu + Q_i + T_j + P_k + A_{(i)l} + QT_{ij} + \xi_{ijk},$$

where Y_{ijkl} is the observation of goat j in period k submitted to treatment i , with i, j , and $k = 1, 2, 3, 4, 5$; μ is the general effect of the mean; Q_i is the effect of the Latin square, with $Q = 1, 2$; T_i is the effect of treatment i , with $i = 1, 2, 3, 4, 5$; P_k is the effect of period k ; A is the effect of goat l in square i , with $l = 1, 2, 3, 4, 5$;

QT is the interaction of the effect of Latin square i with treatment j ; and ξ_{ijk} is the random error associated with each observation Y_{ijkl} .

The statistical model of sensory analysis data contained only the fixed effect of the treatment. Treatment means were compared by Tukey test at 5% error probability using statistical software (SAS, 1999).

RESULTS AND DISCUSSION

According to the proposed model, no square effect was observed, but significant differences ($P < 0.01$) between treatments were observed for fat, lactose, dry extract, and density. No differences ($P > 0.05$) were observed in the composition of milk from goats supplemented with licuri oil compared with control animals (Table 3). On the other hand, the addition of 3% castor oil decreased ($P < 0.05$) milk fat content by about 17% (Table 3). This finding could be explained by the high amount of ricinoleic acid, a monounsaturated acid, found in castor oil; the increase of unsaturated fatty acid concentrations led to partial biohydrogenation of fat (Lana et al., 2005; Silva et al., 2007). The decrease in the content of milk fat in cows is most likely caused by 2 conditions in the rumen: 1) abnormal fermentation with pH decrease and 2) an acetate:propionate ratio less than 3 caused by concentrate excess as well as the presence of unsaturated fat in the diet (NRC, 2001). Moreover, Cenkvar et al. (2005) reported that the supplementation of linseed oil with Ca-soap (Ca-Agcl) decreased fat in goat milk. It must also be considered that in case of intense biohydrogenation, the proportion of saturated fatty acids will be greater, which can reduce their availability in the intestines. This could explain the decrease in fat when using castor oil. In this sense, the high percentage of saturated fatty acids in licuri oil, mostly lauric acid (C12:0), might explain the consistency in the fat contents of milk from goats supplemented with licuri oil, which is in accordance with previous findings (Jenkins et al., 2008; Bernard et al., 2009).

Conversely, Chilliard et al. (2003) reported an increase in the fat contents of milk from goats fed different types of unsaturated oil. Moreover, a significant increase in the percentage of fat in milk from crossbred Moxotó

Table 3. Physicochemical composition of milk of crossbred Moxotó-Alpine goats without oil supplementation (control group) and supplemented with licuri oil or castor oil at levels of 3 and 5% in the DM

Item (g/100 g unless noted)	Control	Licuri oil		Castor oil		CV (%)	P-value
		3%	5%	3%	5%		
Fat	4.03 ^{ab} ± 0.45	4.42 ^a ± 0.51	4.30 ^a ± 0.53	3.36 ^c ± 0.56	3.43 ^{bc} ± 0.33	11.98	0.0001
Protein	3.14 ± 0.27	3.24 ± 0.17	3.19 ± 0.28	3.12 ± 0.25	3.24 ± 0.34	7.35	0.6917
Lactose	4.61 ^b ± 0.42	4.65 ^{ab} ± 0.27	4.61 ^b ± 0.33	4.81 ^a ± 0.47	4.71 ^a ± 0.40	2.77	0.0087
DM	12.55 ^{abc} ± 0.50	12.76 ^{ab} ± 0.60	12.83 ^a ± 0.61	12.16 ^c ± 0.45	12.27 ^{bc} ± 0.62	3.21	0.0024
Ash	0.75 ± 0.04	0.75 ± 0.05	0.73 ± 0.09	0.76 ± 0.04	0.76 ± 0.06	7.04	0.5364
Acidity	15.9 ± 0.14	16.6 ± 0.01	16.2 ± 0.02	15.0 ± 0.02	15.7 ± 0.01	9.32	0.1684
Density (g/cm ³)	1,029.8 ^{bc} ± 1.74	1,029.3 ^{bc} ± 1.57	1,029.1 ^c ± 1.98	1,032.3 ^a ± 3.78	1,031.5 ^{ab} ± 1.48	0.17	0.0008

^{a-c}Means followed by different superscript letters in the same line differ by Tukey test at 5%.

goats fed 5% sunflower oil was observed (Fernandes et al., 2008).

It is noteworthy that the fat decrease in milk from goats supplemented with 5% castor oil was not statistically different ($P > 0.05$) from the control group. In view of the knowledge already available, the results shown herein support the hypothesis that the percentage of fat in milk might vary according to the fat sources and concentrations. Indeed, it has been shown that fat contents in goat milk differ considerably in studies using different fat sources, soluble carbohydrates, and fiber levels (Chilliard et al., 2003).

Castor oil supplementation increased milk lactose contents ($P < 0.05$) compared with the control and licuri oil-supplemented groups, which is in accordance with previous studies evaluating fat supplementation in goats receiving isocaloric diets (Sklan, 1992; Fernandes et al., 2008). Furthermore, a strong correlation between

lipid supplementation and lactose production was observed in goats fed protected fat (Sanz Sampelayo et al., 2002). The increase in lactose contents in milk could be associated with the spare of some fatty acids normally used in the fat synthesis or acetyl CoA derived from fatty acids used in the lactose synthesis in mammary glands (Bauman et al, 2006). On the other hand, no effect of licuri oil supplementation on milk lactose contents was observed ($P > 0.05$). Indeed, Chilliard et al. (2003) observed no significant differences in lactose contents between milk samples from nonsupplemented and supplemented goats using different types of vegetable oils.

Castor oil supplementation increased milk density significantly ($P < 0.05$) as shown in Table 3. This could be explained by the increase in lactose and the decrease in fat in milk from goats supplemented with castor oil because fat has lower density than other milk constitu-

Figure 1. Principal component analysis of the milk of Moxotó crossbred goats fed diets containing licuri or castor oils. F1 and F2 refer to principal components 1 and 2, respectively.

Table 4. Average sensory scores¹ of quantitative descriptive analysis for milk of crossbred Moxotó-Alpine goats without oil supplementation (control group) and supplemented with licuri oil or castor oil at levels of 3 and 5% in the DM

Attribute	Control	Licuri oil		Castor oil		CV (%)
		3%	5%	3%	5%	
Goatish odor	3.5 ^b ± 1.7	3.6 ^b ± 1.7	3.6 ^b ± 1.6	4.4 ^a ± 1.7	4.3 ^a ± 1.9	31.6
Goatish flavor	5.5 ^{ab} ± 1.5	5.3 ^{ab} ± 1.5	5.1 ^b ± 1.2	5.8 ^{ab} ± 1.3	6.0 ^a ± 1.4	19.6
Rancid flavor	4.1 ^b ± 1.9	4.5 ^b ± 1.7	4.0 ^b ± 1.8	5.3 ^a ± 1.7	5.5 ^a ± 1.7	26.6
Sweet flavor	4.6 ± 1.6	4.4 ± 1.7	4.3 ± 1.6	4.5 ± 1.9	4.7 ± 1.9	25.6

^{a,b}Means followed by different superscript letters in the column differ by Tukey test at 5%.

¹Scored based on a nonstructured 9-cm intensity scale ranging from 1 (extremely weak) to 9 (extremely strong).

ents. No differences ($P > 0.05$) were observed between treatments regarding protein, ashes, and acidity.

Results of QDA are shown in Table 4. There was no effect ($P > 0.05$) of licuri oil supplementation on the sensory attributes of goat milk. Supplementation with 3 and 5% of castor oil led to a slightly stronger ($P < 0.05$) goatish odor. Rancid flavor was more intense ($P < 0.05$) when castor oil was included in the animal diet; scores were 5.3 and 5.5 for 3 and 5% of castor oil inclusion rates, respectively. It is known that higher amounts of fat in milk can lead to high rates of lipolysis and proteolysis and therefore promote more intense rancid flavor (Chilliard et al., 2003). However, it is important to consider that the more evident rancid flavor was seen in milk samples with decreased fat contents (3% castor oil). Furthermore, physicochemical and sensory properties and sensory acceptability were not affected by the percentage of vegetable oil (3 and 5%) when milk samples from the same type of oil were considered. Therefore, the present findings suggest that the rancid flavor could be linked to the lipid composition of the oil because unsaturated fatty acids are much more reactive than saturated fatty acids (Attaie and Richter, 1996; Soryal et al., 2005). In fact, castor oil shows high contents of polyunsaturated fatty acids. It must be considered that hydrolytic reactions of triglycerides produce fatty acids of low molecular weight (butyric, caproic, and caprylic acids), which lead to unpleasant odor and flavor (Zan et al., 2006).

To identify the sensory attributes that most contributed to distinguishing the differences between the

samples of milk from the goats fed diets containing licuri or castor oils, a principal component (PC) analysis was performed using the mean values given by the panelists and the repetitions using a correlation matrix (Figure 1).

The first 2 components together were able to explain 98.66% of the variability between the samples. According to the PC chart, PC1 discriminated castor oil samples that were stronger in all descriptors, and PC2 discriminated 3 and 5% samples from each other and control from licuri samples by sweet flavor. It is interesting because there was no significant difference in the sweet flavor of milk from oil-supplemented goats in QDA analysis (Table 4). The correlation matrix results (data not shown) indicate a positive correlation between sweet flavor and goatish flavor. The high correlation between rancid flavor and goatish odor (Figure 1) could indicate the fact that goatish odor of goat milk could be linked to the hydrolysis of fatty acids, which is known to cause rancid flavor.

Considering the acceptance test (Table 5), no differences ($P > 0.05$) between milk from goats supplemented with licuri oil and control animals were observed regarding odor and flavor traits. The smaller odor score ($P < 0.05$) seen in milk samples from goats supplemented with 5% licuri oil when compared with castor oil supplementation is probably a result of the higher intensity of goatish odor observed for those samples (Table 4).

There was a significant reduction ($P < 0.01$) in the palatability (flavor) of milk from goats supplemented

Table 5. Average acceptance scores¹ for milk of crossbred Moxotó-Alpine goats without oil supplementation (control group) and supplemented with licuri oil or castor oil at levels of 3 and 5% in the DM

Attribute	Control	Licuri oil		Castor oil		CV (%)
		3%	5%	3%	5%	
Odor	6.1 ^{ab} ± 1.4	5.9 ^{ab} ± 1.6	6.2 ^a ± 1.5	5.6 ^b ± 1.5	5.6 ^b ± 1.7	15.0
Flavor	6.0 ^a ± 1.9	5.6 ^{ab} ± 2.0	5.9 ^a ± 1.7	4.9 ^{bc} ± 1.7	4.6 ^c ± 1.9	27.9

^{a-c}Means followed by different superscript letters in the column differ by Tukey test at 5%.

¹Scored according to a hedonic scale ranging from 1 (dislike very much) to 9 (like very much).

with castor oil when compared with milk from the control group, which could be attributed to fat rancidity. In fact, the flavor of goat milk is highly correlated to the lipid contents and lipolysis in milk. According to Jaubert et al. (1997), the intensity of flavor varied significantly because of lactation period, fat, and free fatty acid contents and somatic cell counts. On the other hand, factors such as breed, herd size, pH, acidity, and protein concentration have not been shown to play an important role in the sensory attributes. Despite these statements, it can be noted that even though the milk from animals supplemented with licuri oil presented a higher fat percentage compared with the animals receiving castor oil, no differences regarding the sensory characteristics (flavor and odor) were detected by the assessors. This is possibly because of the richness of saturated fatty acids in licuri oil.

CONCLUSIONS

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 flavor in the sensory profile. On the other hand, licuri oil did not influence any of the parameters studied. Further studies on the characterization of fatty acid profiles and volatile compounds in milk from goats supplemented with vegetable oils could contribute to understanding the physical, chemical, and sensory changes in milk and, consequently, to developing animal feeding strategies aimed at improving goat milk quality attributes.

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