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Full Length Research Paper

Diet with detoxified castor meal increase unsaturated fatty acids in goat milk and cheese

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By-products of industrial processes nutritionally rich as castor meal have been used as an energy source in feed for goats in order to increase the lipid characteristics of milk and dairy products. The present study was conducted to evaluate the physicochemical, microbiological and sensory properties of goat cheese "Coalho Type" made from milk of goats submitted to diets with increasing levels (33, 67 and 100%) of detoxified castor meal, replacing soybean meal. The cheeses produced showed no changes in sensory attributes (P>0.05). However, the diet with different levels of detoxified castor meal promoted an increase in the levels of unsaturated fatty acids in milk and cheese, especially the C6:0; C10:0; C14:0; C16:0; C18:1 and C18:3 profile, whereas reduced contents of saturated fatty acids were observed (P<0.05). The results suggest detoxified castor meal as a promising alternative for use in the diet of dairy goats in total replacement of soybean meal.

Key words: By-product, goat milk products, *Ricinus communis.*

INTRODUCTION

The quality and chemical composition of goat milk are directly related to breed, lactation stage and physiological and genetic aspects of the animal. In addition, goat milk characteristics may vary as a result of diet composition and environmental conditions of each country and micro regions (Park et al., 2007; Hernandez - Ladesma; Ramos, Ruiz - Gomez, 2011; Garcia et al., 2014).

The world consumption of goat milk and milk products, especially cheese, has increased considerably in recent years, boosted by corporate actions that encourage goat production and dairy industries (Pimenta et al., 2009; Paula et al., 2009). Among dairy goat products, "Coalho Type" cheese stands out, a typical product of Northeastern Brazil, appreciated for its organoleptic

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characteristics and commonly made by hand using simple technology (Queiroga et al., 2013).

The feeding of dairy goats represents high cost for livestock farming, especially in the period of food scarcity, when there is need for diet supplementation, usually by the use of soybean meal. Despite the high nutritional quality, the inclusion of soy results in an increase in milk production costs. A promising alternative to minimize the production cost is the use of alternative sources of nutrients such as industrial byproducts, which are commonly generated in large amounts and discarded into the environment (Silva et al., 2010; Pompeu et al., 2012).

Castor meal is a byproduct from biodiesel production, resulting from the removal of bark and extraction of the seed oil by pressing or with the use solvents. Generated in large amounts, when improperly disposed into the environment, castor meal can cause environmental damage and health problems due to the presence of bioactive metabolites that cause toxicity and allergenic effects. However, when submitted to detoxification by denaturation of ricin, this byproduct can be used as source of proteins for ruminants, without compromising the milk produced by these animals (Silva et al., 2011, 2010). Still, the use of this byproduct can affect the lipid composition of milk and therefore of derivatives (Santos et al., 2011).

The lipid profile of goat milk obtained from goats usually fed with Tifton hay has on average 35% of short- and medium-chain fatty acids in its composition, which is higher than bovine milk fat (Zambom et al., 2011). Among the short-chain fatty acids present in goat milk, caproic, caprylic and capric stand out, which are related to the characteristic flavor of milk and derivatives (Haenlein, 2004).

In this context, the use of castor meal detoxified to replace soybean in diet of dairy goats could be a low-costs alternative for supplementation of the goat’s diet in the period of food scarcity, however studies with focus in the changes associated with this replacement still unknown. Considering these aspects, this study aimed to evaluate the effects caused by replacing soybean meal by detoxified castor meal in the diet of dairy goats on the nutritional and sensory characteristics of milk and "Coalho Type" cheese, especially regarding the fatty acid profile.

MATERIAL AND METHODS

Experimental design and preparation of "Coalho Type" cheese

The experimental group consisted of 24 Saanen and Alpine dairy goats with healthy clinical characteristics at about 80 days of lactation. The goats were distributed according a completely randomized design (CRD) into control group and three groups fed with diets containing increasing levels of detoxified castor meal (0, 33, 67, 100%) to replace soybean meal in a feedlot system. The milk produced by each goat in the different treatments was weighed, sieved and 10 kg were packaged in sterilized and sealed bags. Shortly after packaging, the packages with milk were submitted to pasteurization at 65°C for 30 min (Brazil, 2000) and subsequently used for the preparation of cheeses.

“Coalho Type” cheeses were produced as Queiroga et al. (2013), with minor modifications. Briefly, milk heated to 35°C was added of 10 ml of mesophilic culture R 704 previously dissolved into 200 ml of mineral water. About 9 ml of liquid rennet was dissolved for each 10 L of milk stirring gently.

After milk coagulation, the solution was mixed and left to rest for subsequent partial syneresis and mass cooking at 45°C. Then, sodium chloride was directly added to the mass, which was placed in molds and submitted to mechanical pressing for 5 h. Cheeses of approximately 1 kg were vacuum packed, weighed and refrigerated at temperature around 10 ± 2°C for 10 days.

Microbiological analyses

Milk and cheese samples made with milk produced by goats submitted to different diets were analyzed for the most probable number of total and fecal coliforms (MPN/mL), mesophilic bacteria, molds and yeasts, presence of *Salmonella* and coagulase positive *Staphylococcus* count (Vanderzant and Splittstoosser, 1992; Brazil, 2001)

Physical and chemical analyses

Proximate composition and acidity were determined in triplicate according to AOAC methods (2005). Moisture (925.09) and extracted total solids (990.19) were determined by gravimetric assay at 105°C, fat was assessed using Gerber centrifugation (2000.18), total protein was estimated by Kjeldahl method (939.02) using a conversion factor of 6.38, ash content was obtaining by incineration at 550°C (930.30) and acidity index was performed by titration using lactic acid (expressed as g/100 g lactic acid) (920.124).

Fatty acids profile

After extraction of total lipids by the Folch et al. method (1957), followed by saponification and esterification steps according Hartman and Lago (1973), esterified fatty acids

(1 µL) from milk and cheese samples were injected into Varian 430-GC gas chromatograph with flame ionization detector (FID) split/ splitless type injector at 250°C and fused silica capillary column (CP WAX 52 CB Varian), with dimensions of 60 × 0.25 × 0.25 mm of film thickness. The initial temperature program was 100°C, increasing 2.5°C / min to reach the temperature of 240°C, remaining for 20 min, totaling 76 min. Helium was used as carrier gas (flow rate of 1 mL/min), the injector temperature was maintained at 250°C and the detector at 260°C. The chromatograms were recorded on a Galaxie Chromatography Data System software and fatty acids were identified by comparing the retention times of methyl esters of samples with Supelco ME19 - Kit (Fatty Acid methyl Esters C6 - C24) standards. The fatty acid results were quantified by normalization of areas of methyl esters and expressed as area percentage (%) (QUEIROGA et al., 2013).

Sensory analysis

The project was submitted to the Ethics Research Committee of the "Lauro Wanderley" University Hospital (HULW) - Center of Health Sciences / UFPB and approved according to Protocol 424/10. The samples were submitted to sensory Quantitative Descriptive Analysis (QDA) (Stone and Sidel, 1993). Fifty questionnaires were distributed to people who showed interest in participating in the sensory tests. Candidates recruited for the pre-selection had affinity, availability to participate in sections, understanding of descriptive terms and ability to work with an unstructured scale. In the pre-selection, tasters were evaluated for discriminative power using the test of recognition of basic tastes and odors (Recognition Threshold Test). Moreover, difference tests were applied (triangular tests) and the confirmation in 75% of tests (Meilgaard et al., 2006) was the criterion for the selection of judges. Sixteen panelists were pre-selected and participated in the step of development of the descriptive terminology. The procedure described by Damasio and Costell (1991) was used to formulate a list of descriptive terms that characterize the products in terms of appearance, aroma, flavor and texture in open discussion and under the supervision of a moderator. Several training sessions were conducted, with the presentation of reference samples that represent the extremes of the scale. A 9 cm unstructured scale ranging from 0 (weak) to 9 (strong) was used (Richter et al., 2010) for attributes softness, elasticity, adhesiveness, juiciness, flavor, aroma, color and overall assessment, which was based on liked or disliked. Analyses were carried out in individual booths with white illumination and samples being served at refrigeration temperature in disposable plates coded with three random digits, accompanied by mineral water and crackers.

Statistical analysis

The results were analyzed using the SAS 9.1 (2006) software. The data of physicochemical and fatty acid analyses were submitted to analysis of variance (ANOVA) and Turkey test at $P < 0.05$.

RESULTS AND DISCUSSION

The microbiological quality of goat milk and cheeses analyzed met all the standards set by current law. The counts of total and fecal coliforms were less than 0.3 MPN/g, and no coagulase-positive *Staphylococcus* and *Salmonella* sp were found. These results characterize the samples as of satisfactory microbiological quality according to current Brazilian legislation (Brazil, 2001). It is noteworthy that the Mesophilic bacteria counts was below 6.0 log CFU/g, and complies with the European Union Directives (92/46 and 94/71 EU Directives) for mesophilic bacteria counts in dairy goats produced with thermally treated milk.

The physicochemical composition of milk and cheese showed that the replacement of soybean meal by detoxified castor meal at different levels did not change ($P>0.05$) parameters of acidity, moisture, protein, and total dry extract (TDE), even when soybean meal was completely replaced by detoxified castor oil (Tables 1 and 2). Similar results in these physicochemical characteristics were previously report for goat milk used for goat minas cheese (Sant'ana et al., 2013) and goat creamy ricotta (Borba et al., 2013), obtaining from goats submitted to diet that included soybean meal. Still, milk quality may be indicated by changes in physicochemical parameters such as high acidity due to lactic acid production by microbial action as a result of the use of available lactose. In this study, the acidity observed (Table 1) is similar to those reported for goat milk by Araujo et al. (2009) and Fernandes et al. (2008) which observed acidity of 0.18% for goat milk.

Regarding the moisture, protein and fat contents observed in cheese samples obtaining with control diet (Table 2), the results agree with previous report of Souza et al. (2011) for goat coalho-type cheese (moisture 46,49%; protein 26,92% and fat 25,33%). The mean lipid values of goat milk in different treatments ranged from 2.8 to 3.2% and in cheese, these values ranged from 31.2 to 45.5%, with the highest levels ($P < 0.05$) observed in diet where soybean meal was completely replaced (Tables 1 and 2). Studies show that the concentration of lipids in milk may vary with factors such as breed, milking shift and lactation. According Costa et

Table 1. Results of physicochemical analyses of milk from goats fed with diet containing increasing levels of detoxified castor meal in replacement to soybean meal.

Variables	Increasing levels of castor meal (%)			
	0	33	67	100
TDE* (%)	11.37 ± 1.49	10.71 ± 0.79	11.06 ± 0.97	11.11 ± 0.77
Protein (%)	3.05 ± 0.41	2.86 ± 0.29	3.05 ± 0.28	2.87 ± 0.23
Fat (%)	2.80 ± 0.20	2.93 ± 0.21	2.97 ± 0.28	3.20 ± 0.41
Acidity (%)	0.15 ± 0.10	0.15 ± 0.10	0.15 ± 0.10	0.16 ± 0.20

Table 2. Results of physicochemical analyses of "Coalho Type" cheese made with milk from goats fed with diet containing increasing levels of detoxified castor meal in replacement to soybean meal.

Variables	Increasing levels of castor meal (%)			
	0	33	67	100
Moisture (%)	46.47 ± 1.51	49.90 ± 2.99	49.09 ± 2.76	49.55 ± 3.31
Protein (%)	24.88 ± 0.40	23.89 ± 1.93	24.07 ± 1.36	24.79 ± 1.01
Fat (%)	31.20 ± 3.25	40.04 ± 2.41	41.87± 4.59	45.50 ± 2.42
Acidity (%)	0.06 ± 0.01	0.05 ± 0.02	0.05 ± 0.02	0.05 ± 0.02

al. (2009), fiber content in the diet of goats is directly related to fat content in milk obtaining. Additionally, it has been reported (Morand et al., 2007; Queiroga et al., 2010; Ribeiro et al., 2011) reported that the lipid composition of goat milk is strongly influenced by the feeding, considered a determinant factor in milk composition and production. In this context, the increase in fat content observed in this study for milk is related to the castor meal, which consequently increases the fat content in cheeses samples.

Analyses of fatty acid profile obtained for goat milk and cheese showed differences ($P<0.05$) between profiles obtained with diet containing only soybean meal and diets where this component had been completely replaced by detoxified castor meal. Torii et al. (2004) evaluated the physicochemical characteristics and fatty acid profile of milk from Saanen goats in response to different sources of forage (alfalfa hay, oat hay and corn silage) and the results indicated that the source of forage in diets of lactating goats affects the fatty acid composition without changing the physicochemical characteristics of milk, which was also observed in this study where soybean meal was replacement by detoxified castor meal.

The increase of unsaturated fatty acids in milk and cheese, observed in the present study possibly were caused by variations in the metabolic processes of ruminal biohydrogenation which directly interfered in milk production, and therefore in cheeses. According previous report (Queiroga et al., 2009; Zervas and Tsiplakou, 2011) it is known that the ruminal biohydrogenation in goat varying with the type and volume of feed ingested by goats. In this way, composition of castor meal used in the goats diet showing a better profile of fatty acids when considered the saturation index.

Eighteen fatty acids were identified, twelve saturated, four monounsaturated and two polyunsaturated fatty acids. The inclusion of different detoxified castor meal levels altered ($P<0.05$) the lipid composition for acids C6:0; C10:0; C14:0; C16:0; C18:1 and C18:3 and the highest average values were observed for C16:0 and C18:1 *cis* 9. The percentage of acids C6:0, C10:0 and C14:0 detected in cheese were inversely proportional to the increase in detoxified castor meal in the diet of goats, in contrast, for C10:0 and C14:0, total replacement showed no differences from the replacement of 67% soybean meal.

The lowest concentration of acid C16:0 was found in goat cheese made with milk from diet containing 33% detoxified castor meal in replacement to soybean meal. However, even with complete replacement of soybean meal, the amount of acid C16:0 did not differ from control (Table 3). The increase in the content of acid C18:1 was directly proportional to the replacement of soybean meal by detoxified castor meal, suggesting that its use in the diet can improve the levels of this unsaturated fatty acid. In addition, the concentration of C18:3, an essential fatty acid for human health, increased significantly in cheeses made with milk from diet with 67% soybean meal replacement. The reduction in the amount of saturated

Table 3. Fatty acid profile of "Coalho Type" cheese made with milk from goats fed with diet containing increasing levels of detoxified castor meal in replacement to soybean meal.

Fatty acids (%)	Increasing levels of castor meal (%)			
	0	33	67	100
C6:0 (caproic)	1.31[a] ± 0.36	0.45[b] ± 0.46	0.53[b] ± 0.13	0.00[b] ± 0.00
C8:0 (caprylic)	2.07 ± 0.43	4.33 ± 1.05	2.15 ± 0.47	3.63 ± 1.93
C10:0 (capric)	12.19[a] ± 0.88	12.24[a] ± 1.78	8.26[b] ±1.70	9.42[ab] ± 1.14
C11:0 (undecanoic)	0.27 ± 0.08	0.20 ± 0.22	0.21 ± 0.11	0.21 ± 0.19
C12:0 (lauric)	4.38 ± 1.08	6.21 ± 1.62	3.53 ± 0.67	4.11 ± 0.71
C13:0 (tridecanoic)	4.72 ± 0.34	6.84 ± 1.37	4.76 ± 0.98	4.89 ± 0.47
C14:0 (myristic)	14.39[a] ± 0.94	12.3[ab] ± 0.69	10.88[b] ± 0.94	10.94[b] ± 0.80
C14:1 (myristoleic)	0.39 ± 0.03	0.14 ± 0.14	0.54 ± 0.13	0.26 ± 0.26
C15:0 (pentadecanoic)	0.78 ± 0.03	0.56 ± 0.66	1.25 ± 0.23	1.19 ± 0.28
C16:0 (palmitic)	26.95[a] ± 1.53	23.75[b] ± 1.64	28.5[ab] ± 1.35	26.4[ab] ± 1.65
C16:1 (palmitoleic)	1.04 ± 0.02	1.88 ± 0.35	1.53 ± 0.27	1.01 ± 0.89
C17:0 (margaric)	1.20 ± 0.64	0.30 ± 0.31	0.71 ± 0.11	0.49 ± 0.44
C18:0 (stearic)	7.75 ± 0.44	7.30 ± 7.87	7.49 ± 0.33	7.80 ± 1.50
C18:1 *cis* 9 (oleic)	19.95[b] ± 0.44	20.34[b] ± 1.49	24.37[a] ± 1.16	26.93[a] ± 1.42
C18:1 *cis* 9. 12-OH (ricinoleic)	0.00 ± 0.00	0.19 ± 0.19	0.23 ± 0.40	0.58 ± 0.17
C18:2 *cis* 9. *cis* 12 (linolenic)	2.05 ± 0.20	2.53 ± 0.49	2.52 ± 0.49	1.81 ± 0.55
C18:3 n3 (linolenic)	0.37[ab] ± 0.03	0.16[b] ± 0.17	0.30 [a] ± 0.12	0.28[ab] ± 0.24
C20:0 (arachidonic)	0.10 ± 0.11	0.21 ± 0.23	0.45 ± 0.10	0.33 ± 0.29

In rows, means followed by the same letter do not differ significantly by the Tukey test at 5 % probability.

Table 4. Results of sensory analysis of "Coalho Type" cheese made with milk from goats fed with diet containing increasing levels of detoxified castor meal in replacement to soybean meal.

Sensory attributes	Increasing levels of castor meal (%)			
	0	33	67	100
Softness	5.57 ± 1.95	5.53 ± 1.72	6.10 ± 1.66	5.87 ± 1.81
Elasticity	4.65 ± 1.60	4.32 ± 1.52	4.47 ± 1.59	4.98 ± 2.69
Adhesiveness	3.78 ± 1.59	3.74 ± 1.87	4.04 ± 1.60	4.11 ± 1.87
Succulence	4.66 ± 1.96	4.84 ± 1.98	5.04 ± 1.58	4.65 ± 1.69
Flavor	5.57 ± 1.73	5.39 ± 1.91	4.96 ± 1.89	5.16 ± 1.65
Aroma	4.73 ± 2.09	4.91 ± 2.24	4.75 ± 2.05	4.53 ± 2.06
Color	1.28 ± 0.59	1.40 ± 0.83	1.34 ± 0.84	1.56 ± 1.02
Overall assessment	5.23 ± 2.22	5.24 ± 2.07	5.96 ± 1.75	5.98 ± 1.62

fatty acids as a function of the increased concentration of unsaturated fatty acids resulting from supplementation with castor bran observed in this study agrees with a previous study on the addition of castor oil in the diet of goats (QUEIROGA et al., 2010). According to Eknaes et al. (2005), short-chain fatty acids, particularly C6:0, influence the flavor and aroma of goat cheeses, important factors associated to sensory acceptance.

The results of sensory analysis showed no difference (P>0.05) among cheeses made with milk from goats submitted to different diets for attributes analyzed (Table 4). Moreover, the modification of the lipid profile of goat milk may have positively influenced the sensory characteristics of cheeses, even changing consumer's acceptance. In the sensory evaluation, mean scores higher than 5 were observed for levels of replacement of soybean meal by detoxified castor meal of 67 % (5.96) and 100% (5.98), showing that cheeses produced with high levels of castor meal showed appreciable sensory characteristics by panelists. Thus, the total replacement of soybean meal by castor meal did not compromise the acceptance of "Coalho Type" goat cheese.

Conclusion

The results showed that the replacement of soybean meal by detoxified castor meal, a low cost industrial by-product, in goat's diet improves the fatty-acids profile of goat milk and cheese, increasing their unsaturated fatty acids content. Additionally, castor meal in goat's diet did not negatively affects the physicochemical and sensory characteristics of cheese indicating it as a viable alternative for goat's feeding in replacement of soybean meal.

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