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Sensory analysis and physicochemical characterization of Boursin cheese from milk of goats fed increasing levels of cassava chips

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ABSTRACT - The objective of this study was to examine the physicochemical composition and sensory properties of Boursin cheese made from the milk of goats fed diets with increasing levels of cassava chips replacing corn. Eight lactating Alpine goats were distributed into two 4 × 4 Latin squares, where they were subjected to diets in which 0, 33, 66, and 100% of corn was replaced with cassava chips. The cheeses were prepared with individual milk of each goat for physicochemical, yield, and texture analyses. Sensory analysis consisted of flavor and texture appraisal by 50 untrained tasters, using the difference-from-control test and the acceptance test. The cheeses from the four treatments did not differ in their fat, protein, and total solid contents; acidity; moisture; ash; pH; yield; or the texture parameters of gumminess, cohesiveness, hardness, and chewiness. They also showed no difference in the sensory acceptance of flavor and texture, indicating that the panelists did not perceive the replacement of corn with cassava chips.

Keywords: acceptability, alternative food, cost, proximate composition, texture, yield

1. Introduction

In the last decade, there has been an increase in the number of dairy industries that process goat milk in the southeast and south regions of Brazil. This increase implies a need for regular supply of the product, with an adequate level of quality, from goat farmers who have noticed the increase in demand from the consumers.

To meet this industry challenge and increase profitability, as an alternative, it is up to the producer to include high-quality unconventional feedstuffs whose price is lower than that of traditional ingredients in the animal diet. This strategy allows a reduction in milk production costs and/or increased profits for small farms, since feeding accounts for around 60% of the cost of the product. Cheese production is a viable alternative for producers to add value to the milk sold.

To enable the use of byproducts in feeding goats, it is necessary to understand their possible influence on milk production and the characteristics of the cheeses produced.

Corn is the most commonly used energy feedstuff in animal diets, but price fluctuations in recent years in Brazil have driven the search for alternative sources, such as roots and tubers, as well as agro-industrial byproducts. Among the various alternative energy sources available, cassava and its byproducts can be used as substitutes for corn. Cassava is highly adaptable to different ecosystems, which enables its cultivation practically across the entire Brazilian territory (Silva, 2011).

Little research has been done on the use of cassava and its byproducts in goat feeding (Menezes et al., 2004) and its effect on yield of dairy products, mainly cheeses, like Boursin, which is one of the most produced cheeses with goat's milk in Brazil. Therefore, the present study proposed to evaluate the cost, physicochemical parameters, and sensory traits of flavor and texture of Boursin cheese produced with milk of goats fed diets with increasing levels of cassava chips replacing corn.

2. Material and Methods

The research project was conducted in Botucatu, SP, Brazil (22°52' S and 48°26' W; 800 m above sea level), after approval by the local ethics and animal experimentation committee (approval no. 154/ 2012 – CUS).

The milk used for the manufacture of the Boursin cheese originated from an experiment that evaluated the effects of replacing 0, 33, 67, and 100% of corn with cassava (*Manihot esculenta* Crantz) chips on the intake, digestibility, and production performance of lactating goats kept on tobiatã grass (*Panicum maximum* cv. Tobiatã) pasture.

Four treatments were used to evaluate the effects of replacement levels of corn with cassava chips in the diet, in the following proportions: 100% corn; 66% corn + 33% cassava chips; 33% corn + 66% cassava chips; and 100% cassava chips.

The experimental diets were formulated according to the NRC (2007) to meet the nutritional requirements of goats at 45 days in milk, with 50 kg of live weight and the potential to produce 3.5 kg of milk per day. The diets were formulated to be isoproteic and isoenergetic, based on the protein and metabolizable energy contents (Table 1).

Table 1 - Proportion of ingredients and chemical composition of diets for lactating goats

Ingredient (%)	Replacement level (%)			
	0	33	66	100
Corn	39.59	26.44	13.24	0.00
Soy bran	42.03	44.86	46.27	47.74
Cassava chips	0.00	13.03	26.18	39.29
Wheat bran	11.05	8.33	6.96	5.60
Limestone	4.01	4.02	4.02	4.03
Mineral[1]	2.25	2.25	2.25	2.26
Dicalcium phosphate	1.08	1.08	1.08	1.08
Dry matter	90.9	90.3	91.0	91.3
Organic matter	88.6	89.6	88.9	90.3
Metabolizable protein	6.6	6.3	5.9	5.9
Ether extract	9.7	7.3	8.9	7.2
Neutral detergent fiber	16.3	15.4	12.0	11.8
Acid detergent fiber	6.9	7.0	6.1	6.4
Non-fibrous carbohydrates	39.3	41.8	44.7	49.0
Total carbohydrates	55.6	57.3	56.7	60.9
Total digestible nutrients	86.5	84.6	86.5	85.9
Net energy	3.1	3.1	3.1	3.1

[1] g/kg: limestone, 200 g; cobalt, 25 mg; copper, 440 mg; chrome, 6 mg; sulphur, 10 g; iron, 340 mg; fluorine, 700 mg; phosphorus, 70 g; iodine, 48 g; magnesium, 5000 mg; manganese, 1480 mg; selenium, 20 mg; sodium, 100 g; vitamin A, 250,000 IU; vitamin E, 350,000 IU; vitamin D3, 40,000 IU; zinc, 3010 mg.

Following the methodology proposed by AOAC (1995), the chemical composition of the concentrates was analyzed by determining the contents of dry matter (DM), crude protein (CP), ash, ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, lignin, total carbohydrates (TC), and non-fibrous carbohydrates (NFC). Total digestible nutrients (TDN) were estimated by the following equations:

$$\text{TC (\%)} = 100 - (\%\text{CP} + \%\text{EE} + \%\text{ASH});$$

$$\text{NFC (\%)} = 100 - (\%\text{NDF} + \%\text{CP} + \%\text{EE} + \%\text{ASH}); \text{ and}$$

$$\text{TDN (\%)} = \%\text{Digestible CP} + (2.25 \times \%\text{Digestible EE}) + \%\text{Digestible TC}.$$

To calculate the metabolizable energy (ME) values, the TDN and digestible energy (DE) values were used in the following equations, as suggested by the NRC (1981):

$$\text{DE (Mcal/kg)} = 0.04409 \times \text{TDN (\%)}; \text{ and}$$

$$\text{ME (Mcal/kg)} = 0.82 \times \text{DE (Mcal/kg)}.$$

The experimental period consisted of two stages. The first, related to milk production, lasted 72 days, after the goats reached the peak of lactation, which were divided into four 18-day periods: 12 for adaptation to the diet and six for data and milk collection. The second stage consisted of the manufacture of the cheeses and analyses.

Eight Alpine goats with an average body weight of 47 ± 1.5 kg were distributed into two balanced Latin squares (4 × 4), according to nutritional replacement levels and milk yield production. The goats were milked mechanically, twice a day, at 06:00 and 18:00 h. Milk yield was measured daily in the last six days of each period, after summing the weight of milk obtained from the morning and afternoon milking events. Milk samples from each animal, in the proportion of 2/3 of the morning milking and 1/3 of the afternoon milking, were collected in 30-mL plastic tubes containing the preservative bronopol and sent for component analysis (Table 2).

Table 2 - Goat milk yield and composition as a function of increasing levels of replacement of corn with cassava chips in the diet

Trait	Mean	Replacement level (%)				P<0.05	CV
		0	33	66	100		
Milk production (kg/d)	2.09	2.16	2.11	2.06	2.02	ns	14.50
Fat (%)	2.63	2.82	2.47	2.53	2.71	ns	19.48
Protein (%)	2.91	2.44	2.86	3.02	3.35	ns	23.66
Lactoses (%)	3.72	3.78	3.80	3.85	3.46	ns	13.55
Total solids (%)	10.17	10.03	10.08	10.10	10.50	ns	7.06
Defatted dry extract %	7.55	7.21	7.61	7.57	7.79	ns	7.62
Urea nitrogen (mg/dL)	33.25	32.54	33.55	31.98	34.94	ns	21.04

CV - coefficient of variation; ns - non significant.

After the afternoon milking, the animals were housed in individual 3.5-m^2 stalls in a covered shed, where they had access to drinkers, salt troughs, and feed troughs. One kilogram of concentrate per goat was supplied daily at 19:00 h, observing the roughage:concentrate ratio of 60:40, on a DM basis.

In the last six days of each experimental period, the milk from each goat was frozen individually for production of the cheeses and for analyses.

To manufacture the cheeses, 2 L of milk from each goat were thawed, individually pasteurized at 60 °C for 30 min, and immediately cooled to 36 °C. Then, for each processing case, 30 g/L of curd (Borá brand) were added, to help the fermentation start, and was left to rest for 30 min. Next, 0.7 mL/L of liquid rennet (Estrela brand) was added, mixed, and left to rest for approximately 6 h at a temperature of 25 °C, until reaching an acidity of 60 °D. After this period, the mass was placed in a sterile cloth filter with a not very fine mesh, allowing the curds slowly drain in a refrigerator (±10 °C) for approximately 16 h. The cheese was then mashed, salted (1.5% salt), and stored in a sterile container at ± 4 °C, to acquire a good consistency (adapted from Barros et al., 2009).

Inputs such as fabrics, thermometers, cutlery, and containers for packaging the final product were sterilized with boiling water at a temperature of 100 °C for 5 min. Additionally, 70% ethyl alcohol was applied in the cleaning of the utensils to prevent microbiological interference in the final result of the study.

The chemical composition of the cheeses, which included acidity (°D) and total solids, was determined according to the methodology of Instituto Adolfo Lutz (IAL, 2005). The pH was measured by a digital potentiometer in a 10-g sample of cheese, which was crushed with a glass pestle, transferred to a beaker containing 50 mL of water at 40 °C, and then homogenized.

To determine water activity, five cheese samples from each goat were analyzed on the same day of manufacture using the Aqualab CX-2 Decagon instrument, and the three results with the least variation were considered.

The yield of each cheese was calculated as the number of liters of milk needed to make one kilogram of cheese (L/kg). In this case, the volume of milk used was divided by the weight of the mass of cheeses obtained (Rossi et al., 1998).

For texture analysis, three cheese samples from each goat were analyzed on the same day of manufacture using a Brookfield texturometer. The samples were stored in cylindrical plastic containers (30 cm high × 5 cm in diameter). The test consisted of double compression using a 2.5-cm-diameter acrylic cylinder, adopting a sample deformation rate of 20%. The distance traveled by the cylinder to the sample was 10 mm, at a speed of 2 mm/s.

The sample was subjected to two compressions symbolizing the 1st and 2nd "bites". A force-compression curve was drawn following the deformation of the sample by the equipment software. This curve was then used to obtain the primary (hardness and cohesiveness) and secondary (chewiness and gumminess) parameters that make up the mechanical characteristics of cheeses (Fox et al., 2000).

For sensory analysis, a cheese was made with the set of 15 L of milk from each of the four treatments. After one day of manufacture, the difference-from-control sensory test (flavor and texture parameters) was applied to determine whether the panelists would perceive a difference in the samples with alterations in the levels of cassava chips in relation to the standard (without addition of cassava chips). Acceptance tests were also carried out using a nine-point structured hedonic scale (1- dislike very much, 5- neither like/dislike, and 9- like extremely) and the spreadability test (Dutcosky, 1996; Chaves, 2005).

Each test was performed with 50 untrained tasters. The sensory tests were approved by the institutional Research Ethics Committee (CEP; approval no. 341/2012).

The samples were coded with three-digit numbers and presented randomly in transparent disposable containers with lids containing approximately 10 g of Boursin cheese, which were analyzed the day after manufacture.

For the spreadability test adapted from Dutcosky (1996) and Chaves (2005), the tasters were given a toast and a sample of each of the four treatments. Then, they were asked to spread the cheese with a spatula and assess the degree of difficulty or ease using a nine-point structured scale. Additionally, the tasters were asked whether they had the habit of consuming Boursin cheese and their purchase intention was evaluated.

The traits of proximate composition, texture, yield, water activity, and pH were analyzed in a Latin square design, by analysis of variance. Results of sensory analysis were analyzed by the Kruskal-Wallis test. In all analyses, the significance level adopted was 5% probability (Model I). Data analyses were processed using the SAEG (System of Statistical and Genetic Analysis) computer program version 9.0 (UFV, 2000).

Model I:

$$Y_{ijkl} = \mu + Q_i + p_{j(i)} + c_{k(i)} + T_l + T{*}Q_{li} + e_{ijkl},$$

in which Y_{ijkl} = goat characteristics k for period j, in the treatment l and square i; μ = means charactristics; Q_i = square effect i, in which i = 1 and 2; $p_{j(i)}$ = period effect j, in the square i, in which j = 1, 2, 3, and 4; $c_{k(i)}$ = goat effect k, in the square i, in which k = 1, 2, 3, and 4; T_l = treatment effect l, in which l = 1, 2, 3, and 4; $T{*}Q_{li}$ = effect of the interaction between treatment l and square i; and e_{ijkl} = random error referring to observation Y_{ijkl}.

For the cost analysis of the cheeses, the prices of curds, liquid rennet, and commercial refined salt, and selling price of Boursin cheese made from goat milk packed in plastic were obtained from the local market, which amounted to a value close to BRL 2.20/kg of cheese produced.

The costs of the cheeses as a function of treatments were calculated using the following formulae:

Cost per kg of cheese (BRL) = Liters of milk (L) × Cost of one liter of milk (BRL) + Total cost of ingredients used in the manufacture of the cheese (BRL/kg);

Net income per kilogram of cheese (BRL) = Price received per kilogram of cheese (BRL) – Cost per kilogram of cheese (BRL); and

Net income per kilogram of milk (BRL) = Net income per kilogram of cheese (BRL) / Liters of milk to make one kilogram of cheese (L).

3. Results

There was no difference in the physicochemical traits of Boursin cheese (Table 3) made with the milk of goats fed diets in which corn was replaced with increasing levels of cassava shavings.

In terms of acidity (Table 3), the cheeses showed pH values ranging from 5.47 to 5.49, and ash contents that ranged from 5.45 to 5.51%. The ash content of cheese can be influenced by its pH as it decreases.

The average moisture content of 66.17% (Table 3) complies with the Regulamento Técnico de Identidade e Qualidade de Queijo ("Technical Regulation on Identity and Quality of Cheeses") by the Brazilian legislation, according to which the cheeses would be classified as very-high-moisture or soft (Brasil, 1996).

The composition of a cheese is one of the main factors that affect its production yield, with higher water contents translating into greater yields (Furtado and Lourenço Neto, 1994). The four formulations resulted in similar cheese yields, which, as seen for the moisture values, were not changed by the dietary replacement of corn with cassava chips, averaging 6.08 L/kg of cheese produced.

Table 3 - Physicochemical traits of Boursin cheese made with goat milk as a function of increasing levels of replacement of corn with cassava chips in the diet

Trait	Mean	Replacement level (%)				P<0.05	CV
		0	33	66	100		
pH	5.47	5.47	5.48	5.46	5.49	ns	1.90
Acidity (°D)	20.13	20.13	20.25	20.00	20.13	ns	0.12
Water activity	0.98	0.98	0.98	0.98	0.98	ns	6.29
Fat (%)	43.05	43.81	42.13	42.63	43.62	ns	6.29
Protein (%)	39.85	40.49	39.41	39.83	39.69	ns	2.00
Moisture (%)	66.17	66.33	66.17	65.99	66.19	ns	0.58
Total solids (%)	33.83	33.67	33.83	34.01	33.82	ns	1.13
Ash (%)	5.48	5.51	5.48	5.45	5.49	ns	1.27
Cheese yield (L/kg)	6.08	6.15	5.98	6.02	6.18	ns	0.54

CV - coefficient of variation; ns - non significant.

In terms of physicochemical traits, the cheeses showed mean values of 39.85% protein, 43.05% fat, and 33.83% total solids. None of these traits differed in response to the use of cassava chips in the diet.

The main factors that affect the texture of cheese are milk composition (casein, fat, calcium, and water contents), the type of lactic ferment, rennet, time, temperature, pH during coagulation, draining, and salting (Pinto Júnior, 2012). As was found for the physicochemical traits of milk, there were no differences in the texture parameters of the produced cheeses as a function of the increasing levels of dietary replacement of corn with cassava chips (Table 4).

Hardness results remained between 26.80 and 28.05 MJ and are related to cheese moisture. Because of its high moisture content, Boursin cheese is considered creamy and is less firm than cheeses such as "Minas frescal", "prato", and mozzarella.

Hardness has a high positive correlation with chewability, which is determined as the number of bites needed to get the food ready to be swallowed. Accordingly, harder cheeses have greater chewability, whereas the softer ones, such as Boursin, require less energy to disintegrate to the point of swallowing. In the present study, the chewiness of the cheeses was between 30.86 and 31.31 MJ, proving them to be an easy-to-eat food (Table 4).

The degree of gumminess is judged by the amount of manipulation required before the food disintegrates, and is the term used for a product with a low degree of hardness and a high degree of cohesiveness (Santos, 2011). The gumminess values obtained ranged from 0.92 to 0.94 J. For cohesiveness, which is the degree of deformation of the sample compressed between the teeth before it breaks (Szczesniak, 2002), the values found ranged between 0.69 and 0.71 (Table 4).

Table 4 - Texture of Boursin cheese made with goat milk as a function of increasing levels of replacement of corn with cassava chips in the diet

Trait	Mean	Replacement level (%)				P<0.05	CV
		0	33	66	100		
Gumminess (J)	0.93	0.93	0.92	0.94	0.93	ns	1.90
Cohesiveness	0.70	0.71	0.69	0.69	0.70	ns	4.27
Hardness (MJ)	27.60	28.05	27.71	27.84	26.80	ns	7.14
Chewability (MJ)	31.09	31.31	30.86	31.15	31.05	ns	6.52

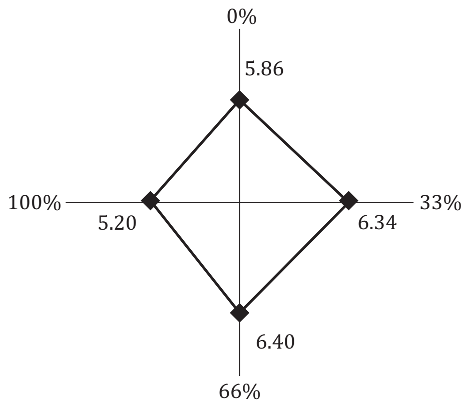
CV - coefficient of variation; ns - non significant.

Spreadability values (Figure 1) were between 5 and 7, which represent "neither difficult/nor easy" and "moderately easy". The average scores obtained for the acceptance of the cheeses as attributed by the tasters through the structured hedonic scale remained between 6 and 7, which mean "like slightly" and "like moderately", respectively (Figure 2).

In the difference-from-control test, there was no difference in flavor or texture between the standard (0% replacement) and the other levels of replacement (33, 66, and 100%).

Regarding the evaluated attributes, although most tasters (72%) declared they had never tried Boursin cheese, only six percent would not buy the analyzed cheeses. Although the cheeses had a flavor acceptance between 71.33 and 75.78%, the results indicate that they are still little known to the population.

To add value to the product and increase the income of producers, the transformation of milk into derivatives, such as cheese, is a way to keep the activity profitable, since the selling price of cheese is BRL 38.92 higher than that of milk (Table 5), with a profit of BRL 37.83/kg of cheese produced and sold.



[1] Further away from the point of intersection the sample shows better spreadability.

Figure 1 - Sensory profile of spreadability[1] of Boursin cheese made with goat milk as a function of increasing levels of replacement of corn with cassava chips.

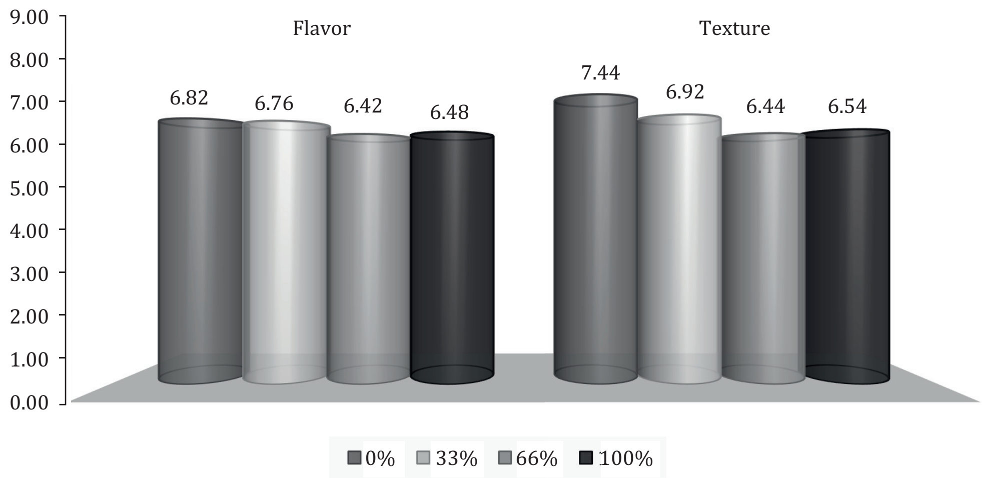


Figure 2 - Acceptance score profile of Boursin cheese made with goat milk as a function of increasing levels of replacement of corn with cassava chips.

Table 5 - Cost and revenue per kilogram of cheese as a function of increasing levels of replacement of corn with cassava chips in the diet

Variable	Mean	Replacement level (%)			
		0	33	66	100
Milk (L/kg)	6.08	6.15	5.98	6.02	6.18
Milk production cost (R$/L)	0.82	0.82	0.82	0.83	0.83
Cost of ingredients (R$/kg)	2.19	2.21	2.16	2.17	2.22
Cheese cost (R$/kg)	7.17	7.25	7.06	7.17	7.35
Cost difference (R$/kg)			−0.19	−0.08	+0.10
Cheese price (R$/kg)	45.00	45.00	45.00	45.00	45.00
Net income of cheese (R$/kg)	37.83	37.75	37.94	37.83	37.65
Net income of milk (R$/kg)	6.22	6.14	6.34	6.28	6.09

4. Discussion

The pH values found in this study are higher than those described by Santos (2011) in Boursin cheese made with milk of Alpine goats, which remained at 4.2 to 4.3, with Dornic acidity from 20.00 to 20.25 °D. The pH and acidity values of the cheeses indicate an acidic condition due to the natural process resulting from continuous lactic acid production caused by the culture added during manufacture. On the other hand, these values are within the expected range for this cheese, which is considered characteristically acidic.

In addition to pH, another relevant aspect to bacterial development is the water activity (Aw) of the cheese, in which cheeses with higher Aw values have a greater tendency to deteriorate, since they have more favorable conditions for microorganisms. Most fresh cheeses have Aw between 0.94 and 0.98, which is in line with the average value of 0.98 measured in the cheeses of this study.

Fat is the component of milk—and, consequently, of cheese—with the greatest range of variation, and the feed provided to the animals is the factor that most contributes to this (Ishler and Varga, 2001). To a lesser extent than milk fat, protein can also change with diet alterations (Vilela, 2003). However, replacing corn in the diet with up to 100% cassava chips did not influence the mean fat or protein contents in the cheeses, which ranged from 42.13 to 43.81% and 39.41 to 40.49%, respectively, and did not differ among treatments. These values differ from those published by Santos (2011), who found mean values of 37.22% fat and 50.06% protein in Boursin cheese made with milk of Alpine goats. Thus, the manufactured cheeses can be classified, according to MAPA Ordinance No. 146 of 1996 (Brasil, 1996), as semi-fat (solids fat content between 25 and 44.9%).

Disagreeing with the present results, the Boursin cheeses evaluated by Santos (2011) showed chewability values between 11.48 and 10.60 MJ.

The cohesiveness values obtained in this study are in agreement with those described by Piccolo (2006), who worked with cream cheese made with cow milk and found mean cohesiveness results of 0.68 to 0.74. This result is consistent with the type of cheese analyzed, which, due to its softness and high moisture, is less resistant to breaking and, therefore, has low cohesiveness.

There was no difference between the spreadability means attributed by the panelists in the present study (Figure 1), indicating that the presence of cassava chips in the diet of the goats did not change the spreadability characteristics of the studied cheese. They also indicate that there are no perceptible differences by the consumer in terms of flavor or texture between cheeses made with milk of goats fed diets with different levels of cassava chips replacing corn. In other words, cassava can fully replace corn without there being any perceptible sensory differences in Boursin cheese.

In the cheese manufacturing stage, milk expenses represented an average cost of BRL 4.99 per kilogram of cheese produced (Table 5), that is, almost 70% of the total cost. This demonstrates the importance of using quality unconventional foods such as cassava and its byproducts—which have lower costs compared with traditional feedstuffs (corn) and are easily produced on small farms—in the diet of ruminants. This practice can lead to a better cost/benefit ratio in the production of goat milk and its derivatives and represent an alternative at certain times in the Brazilian economy.

The transformation of milk into Boursin cheese allowed an average increase of 78.8 times in profitability, denoting the importance of milk processing for the activity.

According to Rohenkohl et al. (2011), based on data from the United States Department of Agriculture, Brazil has increased its cheese production at a rate of 5.5% per year. The treatments involving 33 and 66% replacement of corn in the diet with cassava chips provided higher cheese yields and lower production costs and, therefore, a higher net income per kilogram of cheese.

Production yield is one of the most important aspects in the manufacture of a cheese, as it is fundamental in the calculation of the cost of the product and the profitability of the activity. Despite the reduction in the cost of feed concentrate with the increasing replacement of corn with cassava, the cheese yield did not differ, which translated into little difference in profitability among treatments (Table 5).

5. Conclusions

Cassava chips can partially or fully replace corn in the diet of dairy goats without altering the physicochemical composition or sensory characteristics of Boursin cheese made with their milk. The use of cassava chips to replace corn in the diet of dairy goats does not significantly alter the production cost of Boursin cheese. The replacement of 33 and 66% corn with cassava chips provides higher cheese yields and, consequently, higher net incomes for the producer.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: Gonçalves, H. C. **Data curation:** Marques, R. O. and Gonçalves, H. C. **Formal analysis:** Marques, R. O.; Brito, E. P.; Meirelles, P. R. L.; Rodrigues, L. and Gonçalves, H. C. **Funding acquisition:** Gonçalves, H. C. **Investigation:** Marques, R. O.; Cañizares, G. I. L.; Rodrigues, L. and Betelli, R. G. L. **Methodology:** Brito, E. P.; Cañizares, G. I. L.; Meirelles, P. R. L.; Rodrigues, L. and Betelli, R. G. L. **Supervision:** Gomes, H. F. B. **Writing – review & editing:** Gomes, H. F. B.

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