

# Production, intake, and feeding behavior of dairy goats fed alfalfa via grazing and cassava

Raquel Ornelas Marques<sup>1</sup> , Heraldo Cesar Gonçalves<sup>1</sup> , Paulo Roberto de Lima Meirelles<sup>1</sup> , Reinaldo de Paula Ferreira<sup>2</sup> , Helen Fernanda Barros Gomes<sup>3\*</sup> , Raquel Vasconcelos Lourençon<sup>4</sup> , Evelyn Prestes Brito<sup>1</sup> , Gil Ignacio Lara Cañizares<sup>5</sup> 

<sup>1</sup> Universidade Estadual Paulista, Faculdade de Medicina Veterinária e Zootecnia, Botucatu, SP, Brasil.

<sup>2</sup> Embrapa Pecuária Sudeste, São Carlos, SP, Brasil.

<sup>3</sup> Universidade Federal de Rondonópolis, Rondonópolis, MT, Brasil.

<sup>4</sup> Lincoln University of Missouri, Jefferson City, MO, USA.

<sup>5</sup> Instituto Federal do Rio Grande do Sul, Bento Gonçalves, RS, Brasil.

\*Corresponding author:  
gomes.helen@ufr.edu.br

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**ABSTRACT** - This study examined the replacement of maize and soybean meal with cassava chips and alfalfa grazing, respectively. Twelve lactating Anglo-Nubian goats were kept on a *Panicum maximum* cv. Tobiata pasture. The experiment was laid out in a Latin square design in which the following diets were tested: ground maize + soybean meal, cassava chips + soybean meal, ground maize + alfalfa grazing, and cassava chips + alfalfa grazing. The evaluated variables were feed intake, daily weight gain, milk yield and composition, and feeding behavior of the goats as well as production costs. Cassava chips and grazed alfalfa influenced the intakes of dry matter, crude protein, neutral detergent fiber, and total digestible nutrients. However, milk yield, body weight, and body score did not change. There was no diet effect on the proportions of protein, solids-not-fat, somatic cell count, or urea nitrogen in the milk. Treatments influenced the levels of fat, lactose, and total solids in milk, with the highest fat levels achieved with diets containing alfalfa. Grazing, rumination, and idle times and time spent interacting with other goats were not influenced by diets. The evaluated feedstuffs improved feed efficiency and reduced production costs. Therefore, cassava chips and alfalfa can replace certain ingredients without impairing the production performance of goats, but rather improving the profit of the producer.

**Keywords:** goat, grass, milk composition, pasture

## 1. Introduction

Commercial production of goat milk and derivatives has grown in the southeastern region of Brazil. This expansion is due mainly to the establishment of dairy industries in these states and the growing marketing of such products, which have augmented competition and forced producers to become more efficient in the activity by increasing their revenue and/or reducing production costs.

The use of pastures is an option to reduce feed expenses. Maize and soybean meal are traditionally used as concentrate feeds—an essential element for the nutritional care of dairy animals—, representing energy and protein components, respectively. For dairy goats, the fluctuation in the price of these products on the international market, in certain years, makes their use unfeasible. Therefore, including

cassava chips as an energy substitute and alfalfa grazing as protein source is a possible strategy to be adopted by small goat-milk producers.

Alfalfa is a forage plant that contains high protein levels as well as the main minerals required by dairy herds. Additionally, it has the potential to increase the fat content of milk thanks to its long fibers that allow ruminal bacteria to produce large amounts of volatile fatty acids, precursors of milk fat. This roughage has high nutritional value, palatability, and digestibility, characteristics that provide an increase in intake and, consequently, in milk yield (Marques et al., 2020).

Cassava is considered a feed of good nutritional value, which is similar to maize in terms of energy content. In addition to having a lower purchase price, this tuber is also widely produced in Brazil (Fernandes et al., 2016).

When a farming system uses pasture as a roughage source, it also takes into account the feeding behavior of animals and assessment of pastures. This practice enables the adoption of appropriate management strategies aimed at improving dry matter intake and animal comfort and ultimately increase the efficiency of the dairy activity (Adami et al., 2013).

In view of the lack of information on dairy goat farming on pasture involving the use of alternative feeds, the present study was developed to examine the influence of replacing maize and soybean meal in the concentrate with cassava chips and alfalfa grazing, respectively, on the milk yield and composition, intake, and feeding behavior of Anglo-Nubian goats in a rotational grazing system on Tobiata grass pasture, as well as their production costs.

## 2. Material and Methods

The experiment was conducted in an experimental station in Botucatu, São Paulo, Brazil (22°53'08"S, 48°26'42" W, and 837 m asl), after approval by the local ethics committee (case no. 180/2012 - CEUA). According to the Köppen classification, the region has a Cwa climate type (mesothermal hot). The average annual precipitation is 1,479 mm (Cunha and Martins, 2009), and the period considered dry runs from May to September (30% of the annual precipitation).

Twelve multiparous Anglo-Nubian goats at post-lactation peak, with an average body weight of 60 kg, were distributed into three balanced Latin squares (4 × 4), according to milk yield, to evaluate the replacement of maize and soybean meal in the concentrate with cassava chips and alfalfa grazing, respectively. The following diets were thus established: ground maize + soybean meal, cassava chips + soybean meal, ground maize + alfalfa (*Medicago sativa* cv. Crioula), and cassava chips + alfalfa. Tobiata grass (*Panicum maximum* cv. Tobiata) was offered as a roughage feed for all diet groups, and so was alfalfa for the maize + alfalfa and cassava + alfalfa groups.

Goats fed the maize + soybean meal and cassava + soybean meal diets were kept on Tobiata grass pasture from 07.00 to 18.00 h. Those fed the maize + alfalfa and cassava + alfalfa diets, in turn, remained on alfalfa pasture from 07.00 to 07.30 h and from 07.00 to 08.00 h, respectively (times calculated based on bite rate and pre-determined amount of alfalfa in the diet). Animals fed the cassava + alfalfa diet remained twice as long on alfalfa to compensate for the lower protein content of the cassava relative to maize in the maize + alfalfa diet. After grazing on alfalfa, animals were moved to the Tobiata pasture, where they remained together with goats from the other diet groups until 18.00 h.

Rotational grazing was implemented with a fixed stocking rate. After grazing, animals were gathered into individual stalls with suspended slatted floors. In the stalls, animals received the experimental concentrate and had water and mineral salt freely available.

The area established with Tobiata grass pasture was approximately 0.6 ha, whose average dry matter (DM) yield is 8,650 kg/ha/cut and which was divided into 10 paddocks of approximately 500 m<sup>2</sup>. The paddock occupation and rest periods were three and 27 days, respectively. Each paddock had an automatic drinker and a free-access rest area with artificial shade provided by a black mesh cloth, located in the corridor to the paddocks, which retained 75% of solar radiation.

To form the alfalfa pasture, seeds of *Medicago sativa* variety Crioula were used. The alfalfa pasture area was approximately 400 m<sup>2</sup>, with an average DM yield of 5,500 kg/ha/cut, which was divided into 10 paddocks of approximately 40 m<sup>2</sup> and used in the months of October and November. The paddock occupation and rest periods were three and 27 days, respectively. A bucket of water with a capacity of 20 L was provided daily in the occupied paddock.

Cassava chips were made on the experimental farm using freshly harvested cassava roots (*Manihot esculenta*, Crantz) of the mixed varieties IAC 13 and IAC 15. The roots were washed, peeled, chopped to particles of approximately 2 to 3 cm, and dried in the sun until they reached 89% DM. Then, they were bagged and stored to be subsequently prepared for the experimental diets.

The experimental diets were formulated according to the NRC (2007) to meet the nutritional requirements of lactating goats with a live weight of 60 kg and the potential to produce 2-3 kg of milk with 4% fat per day. The chemical composition of the diet ingredients (Table 1) was determined in the laboratory.

Samples of Tobiata grass and alfalfa were harvested every 15 days, dried for 72 h in a forced-air oven at 55 °C, ground in a Wiley mill with a 1-mm sieve, and packed in plastic containers. For the analysis, a composite sample was used, which consisted of an aliquot of the individual samples. The following variables were determined in the analyses: mineral matter (MM), crude protein (CP), and ether extract (EE) according to AOAC International (2007); and neutral detergent fiber (NDF), and acid detergent fiber (ADF) according to the techniques described by Van Soest et al. (1991) (Table 2).

The experiment had a duration of 60 days, which were divided into four periods of 15 days, consisting of 10 days of adaptation to the diet and five days of data collection.

Body weight and body condition score were determined at the beginning of each period and at the end of the experiment, always after the afternoon milking. Body condition score was assessed using a scale of 0 to 5, by palpating the lumbar region (Ribeiro, 1997).

Voluntary intake of concentrate was calculated by the difference between the feed supplied andorts, during the five days of data collection. Forage intake was determined based on the estimates of fecal output, associated with the internal marker iNDF (indigestible neutral detergent fiber).

To estimate the fecal output, the external marker chromium oxide (Cr<sub>2</sub>O<sub>3</sub>) was administered orally, using gelatin capsules. The capsules contained 2.5 g of Cr<sub>2</sub>O<sub>3</sub> and were administered at 18.30 h over 10 days, the first five of which were used to stabilize the concentration of Cr<sub>2</sub>O<sub>3</sub> in feces and the last five for fecal collection. Feces were collected in plastic pots at the time of defecation, at 06.00 and 18.30 h. The concentration of marker in feces samples was determined in the laboratory using a colorimeter (Thermo Scientific®, model Evolution 60S - UV - Visible Spectrophotometer), after digesting the samples in nitric and perchloric acids, following a methodology adapted from Bremer Neto et al. (2005).

**Table 1 - Chemical composition of the ingredients used in the experimental diets and Tobiata grass**

| Composition (g/kg DM) | Ingredient |              |            |         |         |         |
|-----------------------|------------|--------------|------------|---------|---------|---------|
|                       | Maize      | Soybean meal | Wheat bran | Cassava | Alfalfa | Tobiata |
| DM (%)                | 87.9       | 88.6         | 88.0       | 87.7    | 25.0    | 18.1    |
| MM                    | 16.0       | 33.1         | 27.7       | 29.0    | 73.0    | 62.5    |
| CP                    | 98.2       | 446.0        | 148.0      | 3.28    | 241.0   | 137.5   |
| EE                    | 39.7       | 16.2         | 41.3       | 17.9    | 25.0    | 16.0    |
| NDF                   | 206.8      | 100.6        | 250.1      | 89.3    | 509.5   | 706.8   |
| ADF                   | 56.2       | 68.8         | 117.5      | 48.6    | 309.8   | 399.7   |
| TDN <sup>1</sup>      | 844.0      | 848.0        | 841.0      | 851.0   | 651.0   | 617.6   |

DM - dry matter; MM - mineral matter; CP - crude protein; EE - ether extract; NDF - neutral detergent fiber; ADF - acid detergent fiber; TDN - total digestible nutrients.

<sup>1</sup> Obtained from the equation proposed by the NRC (2001): TDN = DCP + DNFC + DNDF + (DFA × 2.25) - 7, in which DCP = truly digestible CP, DNFC = truly digestible non-fiber carbohydrates, DNDF = digestible NDF, and DFA = truly digestible fatty acids.

**Table 2** - Proportions of dietary ingredients and chemical composition of ingredients

| Ingredient (g/kg DM)                    | Diet <sup>1</sup> |       |       |       |
|-----------------------------------------|-------------------|-------|-------|-------|
|                                         | 1                 | 2     | 3     | 4     |
| <b>Grazing</b>                          |                   |       |       |       |
| Tobiatã grass                           | 400               | 550   | 300   | 300   |
| Alfalfa                                 | 0                 | 0     | 140   | 280   |
| <b>Concentrate</b>                      |                   |       |       |       |
| Cassava                                 | 0                 | 255   | 0     | 290   |
| Soybean meal                            | 50                | 65    | 0     | 0     |
| Ground maize                            | 420               | 0     | 430   | 0     |
| Wheat bran                              | 100               | 100   | 100   | 100   |
| Dicalcium phosphate                     | 10                | 10    | 10    | 10    |
| Mineral mix <sup>2</sup>                | 20                | 20    | 20    | 20    |
| <b>Composition (g/kg DM)</b>            |                   |       |       |       |
| Mineral matter                          | 36.1              | 46.7  | 38.6  | 50.4  |
| Crude protein                           | 134.3             | 129.1 | 132.0 | 133.0 |
| Ether extract                           | 28.0              | 18.5  | 29.5  | 21.1  |
| Neutral detergent fiber                 | 399.6             | 443.1 | 397.3 | 405.6 |
| Acid detergent fiber                    | 198.7             | 248.5 | 199.2 | 232.5 |
| Total digestible nutrients <sup>3</sup> | 728.0             | 695.9 | 723.4 | 698.5 |

DM - dry matter.

<sup>1</sup> Diets: 1 - maize + soybean meal; 2 - cassava + soybean meal; 3 - maize + alfalfa grazing; 4 - cassava + alfalfa grazing.

<sup>2</sup> Composition (amount/kg of product): Ca, 200 g; Co, 25 mg; Cu, 440 mg; Cr, 6 mg; S, 10 g; Fe, 340 mg; F, 700 mg; P, 70 g; I, 48 mg; Mg, 5,000 mg; Mn, 1,480 mg; Se, 20 mg; Na, 100 g; Zn, 3,010 mg; vitamin A, 250,000 IU; vitamin D3, 40,000 IU; vitamin E, 350 IU.

<sup>3</sup> Obtained from the equation proposed by the NRC (2001).

Fecal dry matter output (FDMO) was estimated as the ratio between the amount of marker supplied (AM supplied) and its concentration in feces (AM feces), according to the formula below:

$$\text{FDMO (g/day)} = [\text{AM supplied/AM feces}] \times 100 \quad (1)$$

To estimate the voluntary intake of DM, iNDF was used as an internal marker by *in situ* incubation of feed and feces samples in the rumen of fistulated goats, for 144 h (Berchielli et al., 2005). Samples were placed in nylon bags with 50 µm porosity, following the standardized technique mentioned by Vanzant et al. (1998). Each fistulated goat was adapted to one of the diets for 14 days, and bags of the respective treatment were incubated in each animal. After incubation, the bags were washed in a tank system with a propeller agitator, where water was renewed until it became colorless. Next, the material was dried in a forced-air oven at 55 °C for 72 h. Then, NDF analyses were performed according to the methodology proposed by Van Soest et al. (1991). Voluntary DM intake was calculated using the equation proposed by Detmann et al. (2001):

$$\text{DMI (kg/day)} = \{[(\text{FDMO} \times \text{iNDFFe}) - \text{iNDFIC}]/\text{iNDFFo}\} + \text{CDMI}, \quad (2)$$

in which DMI = dry matter intake; FDMO = fecal dry matter output (kg/day); iNDFFe = concentration of iNDF in feces (kg/kg); iNDFIC = iNDF intake from concentrate (kg/day); iNDFFo = concentration of NDFi in the forage (kg/kg); and CDMI = concentrate dry matter intake (kg/day).

Goats were milked twice daily, at 06.00 and 18.00 h, using a mechanical milking machine, in the milking parlor. Milk yield was determined on the last five days of each experimental period, by weighing the milk on a digital scale with a capacity of 15 kg and dividing the result by 5 g. Milk yield was estimated as the average production of the five test days with correction for 3.5% fat (3.5%FMY), using the formula of Gaines (1928) as suggested by the NRC (2001):

$$3.5\%FMY = (0.4255 \times \text{kg milk}) + [16.425 \times (\% \text{ fat}/100) \times \text{kg milk}] \quad (3)$$

To determine the components of milk, individual samples proportional to the milk production from the morning (1/2) and afternoon (1/2) milkings of the first test day were collected and packed in 30-mL plastic tubes containing the preservative bronopol (2-bromo-2-nitropropane-1,3-diol). In the

samples, contents of fat, protein, lactose, total solids, solids-not-fat (SNF), urea nitrogen (MUN), and somatic cell count (SCC) were determined using a Bentley® 2000 instrument.

For the assessment of feeding behavior, animals were observed every 10 min by the method of visual observation, for three consecutive days of paddock occupation, in each experimental period. For this procedure, goats were identified with colored collars. Times spent grazing, ruminating, idling, and interacting with other goats were recorded.

Diet production costs were computed using the following formulas:

$$\text{Total feed cost (BRL)} = [\text{Intake (kg DM)} \times \text{Cost (kg DM)}] \times \text{Lactation period (days)} \quad (4)$$

$$\text{Cost per liter of milk (BRL)} = \frac{\text{Total feed cost (BRL)}}{\text{Total milk production (kg)}} \quad (5)$$

$$\text{Gross revenue (BRL)} = \text{Total milk production (kg)} \times \text{Price received (BRL)} \quad (6)$$

$$\text{Net revenue per liter of milk (BRL)} = \text{Price received (BRL)} - \text{Cost per liter of milk (BRL)} \quad (7)$$

$$\text{Total net revenue per goat (BRL)} = \text{Total milk production (kg)} \times \text{Net revenue per liter of milk (BRL)} \quad (8)$$

In the calculation of the cost of a kilogram of forage DM, costs of labor and inputs for the formation and maintenance of pastures were taken into account.

The Latin square design (Model) was applied for traits: intake, body weight and score, milk yield and composition, and feeding behavior.

$$\text{Model: } Y_{ijkl} = u + S_i + p_{j(i)} + c_{k(i)} + T_l + T \times S_{li} + e_{ijkl} \quad (9)$$

in which  $Y_{ijkl}$  = trait observed in goat  $k$  in period  $j$ , treatment  $l$ , and square  $i$ ;  $u$  = average of the trait;  $S_i$  = effect of square  $i$  ( $i = 1, 2, \text{ and } 3$ );  $p_{j(i)}$  = effect of period  $j$  within square  $i$  ( $j = 1, 2, 3, \text{ and } 4$ );  $c_{k(i)}$  = effect of goat  $k$  within square  $i$  ( $k = 1, 2, 3, \text{ and } 4$ );  $T_l$  = effect of treatment  $l$  ( $l = 1, 2, 3, \text{ and } 4$ );  $T \times S_{li}$  = interaction effect between treatment  $l$  and square  $i$ ; and  $e_{ijkl}$  = random error regarding observation  $Y_{ijkl}$ .

Data were subjected to analysis of variance using SAS statistical software (Statistical Analysis System, version 9.0). In all analyses, the significance level adopted was  $\alpha = 0.05$ .

### 3. Results

There was an effect of diets on DM intake (Table 3). When maize was used as an energy feedstuff (maize + soybean meal and maize + alfalfa), the presence of alfalfa reduced DM intake, which led to lower intakes of CP, NDF, and TDN. When cassava was used (cassava + soybean meal and cassava + alfalfa), the same behavior occurred, except for TDN intake, which was similar. With soybean meal as a protein feedstuff (maize + soybean meal and cassava + soy), the group fed the diet containing cassava showed a reduction in DM intake and, consequently, in the intake of other nutrients. The use of alfalfa as a protein ingredient (maize + alfalfa and cassava + alfalfa) did not change the intakes of DM, NDF, or TDN, but the group fed cassava + alfalfa exhibited a lower CP intake.

The goats on the cassava + alfalfa and maize + alfalfa diets showed the lowest bite rates on Tobiata grass. The other feeding behaviors evaluated were not influenced by diets (Table 4).

The differences in DM intake between diets were not sufficient to influence weight gain or the body condition score of the animals (Table 5).

Diets did not influence milk yield, 3.5%FMY, protein content, SNF, MUN, or SCC (Table 6).

When alfalfa was present in diets, feed efficiency (FE) and FE corrected for 3.5%FMY were better than the control diet.

Goats fed the cassava + alfalfa diet produced milk with a higher total solids content than those fed the cassava + soybean meal, due to the higher fat content in the milk of the former. Goats on the cassava + alfalfa diet also had a higher fat and lactose content in their milk than those fed maize + soybean meal.

There was a higher fat content in the milk from the goats receiving the cassava + alfalfa treatment as compared with those that received the maize + soybean meal and cassava + soybean meal treatments, which did not eat alfalfa and which did not differ from the group fed the maize + alfalfa treatment. Lactose was higher in the milk from goats fed cassava + alfalfa than in the milk from the animals fed maize + soybean meal.

The milk from goats fed the maize + alfalfa and cassava + alfalfa diets had a lower cost per liter produced. Consequently, these diets provided a higher net income/L of milk, when compared with the maize + soybean meal diet (Table 7), as well as higher total net revenues per goat.

**Table 3 - Intake of chemical components of concentrates and roughages in each diet**

| Variable                         | Diet <sup>1</sup> |        |         |        | Mean  | CV (%) |
|----------------------------------|-------------------|--------|---------|--------|-------|--------|
|                                  | 1                 | 2      | 3       | 4      |       |        |
| Dry matter                       |                   |        |         |        |       |        |
| Concentrate (kg)                 | 1.07a             | 0.94ab | 0.88b   | 0.84b  | 0.93  | 17.26  |
| Alfalfa (kg)                     | -                 | -      | 0.27    | 0.35   | 0.31  | 27.08  |
| Tobiatã grass (kg)               | 0.94a             | 0.79b  | 0.43c   | 0.33c  | 0.62  | 14.01  |
| Total (kg)                       | 2.01a             | 1.74b  | 1.58bc  | 1.53c  | 1.71  | 9.72   |
| Total (% LW)                     | 3.37a             | 2.95b  | 2.68bc  | 2.58c  | 2.90  | 9.85   |
| Total (g DM/kg <sup>0.75</sup> ) | 93.48a            | 81.67b | 74.20bc | 71.34c | 80.17 | 9.74   |
| Crude protein                    |                   |        |         |        |       |        |
| Concentrate (kg)                 | 0.18a             | 0.16a  | 0.11b   | 0.08c  | 0.13  | 15.95  |
| Alfalfa (kg)                     | -                 | -      | 0.07    | 0.09   | 0.08  | 27.08  |
| Tobiatã grass (kg)               | 0.15a             | 0.13b  | 0.07c   | 0.05c  | 0.10  | 14.01  |
| Total (kg)                       | 0.33a             | 0.29b  | 0.25c   | 0.22d  | 0.27  | 8.02   |
| Neutral detergent fiber          |                   |        |         |        |       |        |
| Concentrate (kg)                 | 0.13a             | 0.12ab | 0.10bc  | 0.09c  | 0.11  | 16.57  |
| Alfalfa (kg)                     | -                 | -      | 0.12    | 0.16   | 0.14  | 27.08  |
| Tobiatã grass (kg)               | 0.59a             | 0.50b  | 0.27c   | 0.21c  | 0.39  | 14.01  |
| Total (kg)                       | 0.73a             | 0.62b  | 0.50c   | 0.46c  | 0.57  | 8.58   |
| Total digestible nutrients       |                   |        |         |        |       |        |
| Concentrate (kg)                 | 0.91a             | 0.77ab | 0.76b   | 0.71b  | 0.79  | 17.09  |
| Alfalfa (kg)                     | -                 | -      | 0.18    | 0.23   | 0.21  | 27.08  |
| Tobiatã grass (kg)               | 0.56a             | 0.48b  | 0.26c   | 0.20c  | 0.37  | 14.01  |
| Total (kg)                       | 1.48a             | 1.25b  | 1.19b   | 1.14b  | 1.26  | 10.59  |
| Roughage:concentrate             | 47:53             | 46:54  | 44:56   | 45:55  |       |        |

DM - dry matter; LW - live weight; CV - coefficient of variation.

<sup>1</sup> Diets: 1 - maize + soybean; 2 - cassava + soybean; 3 - maize + alfalfa grazing; 4 - cassava + alfalfa grazing. Means followed by different letters in the rows differ from each other (P<0.05) by Tukey's test.

**Table 4 - Feeding behavior of goats during the grazing period and bite rate (bites/min) on Tobiatã grass according to the diet**

| Variable              | Diet <sup>1</sup> |        |        |        | Mean  | CV (%) |
|-----------------------|-------------------|--------|--------|--------|-------|--------|
|                       | 1                 | 2      | 3      | 4      |       |        |
| Bite rate (bites/min) | 29.67b            | 34.00a | 20.92c | 17.08d | 25.42 | 7.35   |
| Grazing (%)           | 39.88             | 40.09  | 41.00  | 40.26  | 40.31 | 7.36   |
| Rumination (%)        | 23.72             | 23.26  | 23.47  | 20.27  | 22.68 | 22.19  |
| Idleness (%)          | 35.16             | 35.07  | 34.04  | 37.48  | 35.44 | 9.21   |
| Interaction (%)       | 1.24              | 1.58   | 1.49   | 1.99   | 1.58  | 64.35  |

CV - coefficient of variation.

<sup>1</sup> Diets: 1 - maize + soybean meal; 2 - cassava + soybean meal; 3 - maize + alfalfa grazing; 4 - cassava + alfalfa grazing. Means followed by different letters in the rows differ from each other (P<0.05) by Tukey's test.

**Table 5 - Daily weight gain and body score change according to the diet**

| Variable                  | Diet <sup>1</sup> |       |       |       | Mean  | CV (%) |
|---------------------------|-------------------|-------|-------|-------|-------|--------|
|                           | 1                 | 2     | 3     | 4     |       |        |
| Daily weight gain (g/day) | -90               | -49   | -107  | -95   | -85   | 13.54  |
| Body score (units)        | -0.13             | -0.06 | -0.19 | -0.17 | -0.14 | 27.47  |

CV - coefficient of variation.

<sup>1</sup> Diets: 1 - maize + soybean meal; 2 - cassava + soybean meal; 3 - maize + alfalfa grazing; 4 - cassava + alfalfa grazing.**Table 6 - Milk yield and components according to the diet**

| Variable                 | Diet <sup>1</sup> |         |         |        | Mean   | CV (%) |
|--------------------------|-------------------|---------|---------|--------|--------|--------|
|                          | 1                 | 2       | 3       | 4      |        |        |
| Milk yield (kg/day)      | 2.16              | 2.05    | 2.04    | 1.98   | 2.06   | 7.09   |
| 3.5%FMY (kg/day)         | 2.40              | 2.26    | 2.35    | 2.32   | 2.32   | 8.14   |
| FE                       | 1.08b             | 1.18ab  | 1.31a   | 1.33a  | 1.22   | 10.83  |
| FE <sub>3.5%FMY</sub>    | 1.19c             | 1.34bc  | 1.44ab  | 1.56a  | 1.38   | 11.26  |
| Protein (g/kg)           | 32.90             | 32.00   | 31.80   | 31.90  | 32.20  | 5.09   |
| Total solids (g/kg)      | 128.2ab           | 127.1b  | 129.4ab | 132.3a | 129.3  | 2.96   |
| Fat (g/kg)               | 42.60b            | 41.60b  | 44.00ab | 46.20a | 43.60  | 7.12   |
| Lactose (g/kg)           | 42.90b            | 44.20ab | 43.90ab | 44.70a | 43.90  | 3.21   |
| SNF (g/kg)               | 85.60             | 85.50   | 85.40   | 86.20  | 85.70  | 1.98   |
| MUN (mg/dL)              | 18.15             | 18.51   | 17.10   | 16.86  | 17.65  | 17.96  |
| SCC ( $\times 10^3$ /mL) | 2074.7            | 1546.7  | 1943.2  | 1912.3 | 1869.2 | 11.48  |

3.5%FMY - 3.5% fat-corrected milk yield; FE - feed efficiency; FE<sub>3.5%FMY</sub> - feed efficiency for 3.5% fat-corrected milk yield; SNF - solids-not-fat; MUN - milk urea nitrogen; SCC - somatic cell count; CV - coefficient of variation.<sup>1</sup> Diets: 1 - maize + soybean meal; 2 - cassava + soybean meal; 3 - maize + alfalfa grazing; 4 - cassava + alfalfa grazing.Means followed by different letters in the rows differ from each other ( $P < 0.05$ ) by Tukey's test.

## 4. Discussion

The decreasing intakes of the diets indicates that both the inclusion of cassava and alfalfa caused intake to decrease. This reduction in intake is more accentuated when we compare the cassava + alfalfa with the maize + soybean meal and cassava + soybean meal diets, in which cassava and alfalfa were included simultaneously (Table 3).

Cassava is a feedstuff known to reduce DM intake due to its lower palatability and powderiness caused by its light and fine powder, which bothers the animals during consumption (Silva et al., 2012).

In the present study, there was no difference in concentrate DM intake between the groups fed diets with the same protein base (maize + soybean meal vs. cassava + soybean meal; and maize + alfalfa vs. cassava + alfalfa), but they contributed to differences in total DM intake (Table 3). The high intake of DM from Tobiatã grass in the maize + soybean meal treatment group (Table 3) may be related to the higher intake of concentrate, which stimulated forage intake, as an additive effect (Adami et al., 2013).

The lower total DM intake from the diets with alfalfa with the same energy base (maize + soybean meal vs. maize + alfalfa; and cassava + soybean meal vs. cassava + alfalfa) (Table 3) can be attributed to the management strategy adopted in the experiment. After receiving 100 g of concentrate during the morning milking, goats were sent to the paddocks of Tobiatã grass (maize + soybean meal and cassava + soybean meal) or alfalfa (maize + alfalfa and cassava + alfalfa). Because goats were conditioned to graze on alfalfa for some time, coupled with its good acceptability (Comeron et al., 2015), they ingested this forage quickly and, later, when put to graze on Tobiatã grass, they reduced their intake due to momentary rumen fill. This, combined with the fact that alfalfa is richer in nutrients than Tobiatã grass, allowed the animals to meet their nutritional requirements with less DM intake. This behavior was

**Table 7 - Milk production costs for each diet**

| Variable                                    | Diet <sup>1</sup> |        |        |        |
|---------------------------------------------|-------------------|--------|--------|--------|
|                                             | 1                 | 2      | 3      | 4      |
| Concentrate intake (kg DM)                  | 1.07              | 0.94   | 0.88   | 0.84   |
| Alfalfa intake (kg DM)                      | -                 | -      | 0.27   | 0.35   |
| Tobiatã intake (kg DM)                      | 0.94              | 0.79   | 0.43   | 0.33   |
| Lactation period (days)                     | 60                | 60     | 60     | 60     |
| Total milk yield (kg)                       | 130               | 123    | 122    | 119    |
| BRL                                         |                   |        |        |        |
| Concentrate cost (BRL/kg DM) <sup>2</sup>   | 1.72              | 1.64   | 1.17   | 0.87   |
| Alfalfa cost (BRL/kg DM) <sup>2</sup>       | -                 | -      | 0.25   | 0.25   |
| Tobiatã cost (BRL/kg DM) <sup>2</sup>       | 0.15              | 0.15   | 0.15   | 0.15   |
| Diet cost (BRL/kg DM)                       | 1.09              | 1.00   | 0.61   | 0.48   |
| Total feed cost (BRL)                       | 119.10            | 94.38  | 72.88  | 52.20  |
| Cost/L milk (BRL)                           | 0.92              | 0.77   | 0.60   | 0.44   |
| Price of milk (BRL/L) <sup>3</sup>          | 2.50              | 2.50   | 2.50   | 2.50   |
| Gross revenue (BRL)                         | 325.00            | 307.50 | 305.00 | 297.50 |
| Net revenue/L milk (BRL)                    | 1.58              | 1.73   | 1.90   | 2.06   |
| Total net revenue/goat (BRL)                | 205.40            | 212.79 | 231.80 | 245.14 |
| USD <sup>4</sup>                            |                   |        |        |        |
| Concentrate cost (USD/kg DM) <sup>2</sup>   | 0.31              | 0.30   | 0.21   | 0.16   |
| Alfalfa cost (USD/kg DM) <sup>2</sup>       | -                 | -      | 0.05   | 0.05   |
| Tobiatã grass cost (USD/kg DM) <sup>2</sup> | 0.03              | 0.03   | 0.03   | 0.03   |
| Diet cost (USD/kg DM)                       | 0.20              | 0.18   | 0.11   | 0.09   |
| Total feed cost (USD)                       | 21.58             | 17.10  | 13.20  | 9.46   |
| Cost/L milk (USD)                           | 0.17              | 0.14   | 0.11   | 0.08   |
| Price of milk (USD/L) <sup>3</sup>          | 0.45              | 0.45   | 0.45   | 0.45   |
| Gross revenue (USD)                         | 58.88             | 55.71  | 55.25  | 53.89  |
| Net revenue/L milk (USD)                    | 0.29              | 0.31   | 0.34   | 0.37   |
| Total net revenue/goat (USD)                | 37.21             | 38.55  | 41.99  | 44.41  |

DM - dry matter.

<sup>1</sup> Diets: 1 - maize + soybean meal; 2 - cassava + soybean meal; 3 - maize + alfalfa grazing; 4 - cassava + alfalfa grazing.<sup>2</sup> Prices quoted in March 2021 (CEPEA, 2021).<sup>3</sup> Price paid to cooperative producers, quoted in March 2021 (EMBRAPA, 2021).<sup>4</sup> U.S. dollar quoted in March 2021 at BRL 5.52.

confirmed by the lower bite rate observed in goats fed the maize + alfalfa and cassava + alfalfa diets (Table 4) on Tobiatã grass, demonstrating that the previous grazing on alfalfa might have reduced the avidity for grazing on Tobiatã grass.

The fact that goats first grazed the alfalfa in the maize + alfalfa and cassava + alfalfa diet group during the early times of the day did not influence the time spent grazing, ruminating, idling, or interacting with other goats (Table 4). Nevertheless, the animals that grazed on alfalfa (maize + alfalfa and cassava + alfalfa) had a lower bite rate than those that did not graze.

Although diets did not influence weight gain or body condition score, the animals in all diets lost weight and body condition (Table 5). It is because goats usually lose weight and body condition in the first months of lactation due to a decreased DM intake, which has not yet reached its maximum. During this period, animals mobilize body reserves to meet their needs (Barbosa et al., 2016).

The results found in this study indicate that the inclusion of cassava and alfalfa does not interfere with the yield, protein, SNF, MUN, or SCC of milk from grazing goats (Table 6). These findings agree with Cameron et al. (2015), who did not observe differences in milk yield of cows receiving alfalfa when compared with their feedlot counterparts. Mouro et al. (2002) and Lourençon et al. (2013) also obtained similar results after replacing maize with cassava sweep meal for Saanen goats and cassava chips for Alpine goats, respectively.

However, alfalfa inclusion in the diets provided a better FE than control diet (Table 6), demonstrating that these diets induced similar milk production, but with less feed intake.

Milk protein levels were similar between the diet groups (Table 6), suggesting a similar provision of amino acids for the mammary gland to synthesize milk protein. This result is in line with those reported by Peres Netto et al. (2011) in the milk of cows receiving alfalfa when compared with feedlot cows, and by Mouro et al. (2002) and Lourençon et al. (2013), who did not observe an effect of replacing maize with cassava sweep meal and cassava chips, respectively.

The higher fat content found in the milk from the goats fed the cassava + alfalfa diet, in comparison with those that did not consume alfalfa, can be explained by the better synchronism between the energy from the cassava starch, which has immediate fermentation due mainly to its high amylopectin content (Wanapat and Kang, 2015), and the protein of alfalfa, which is rapidly degraded in the rumen (Comeron et al., 2015). This is coupled with the good-quality fiber of alfalfa, which provided a ruminal environment favorable to a large production of acetic acid, a direct precursor of 50% of milk fat (Santos et al., 2001).

Peres Netto et al. (2011) did not observe differences in the fat content of milk from cows fed diets with alfalfa. Mouro et al. (2002) and Lourençon et al. (2013) described similar findings in goats receiving diets in which maize was replaced with cassava sweep meal and cassava chips, respectively.

The lactose content was higher in the milk from the animals fed cassava + alfalfa than in the milk from those fed maize + soybean meal (Table 6), although it is considered the most stable component of milk and responsible for regulating osmotic pressure in the mammary gland (Madureira et al., 2017). Lactose is formed from glucose, which is synthesized from propionic acid, derived from the rumen fermentation of dietary carbohydrates (Madureira et al., 2017). Thus, the higher production of propionic acid in the milk from the goats fed the cassava + alfalfa diet, which resulted in the highest lactose content of milk, can be explained by the greater degradability of cassava relative to maize, which is due to the lack of pericarp, horny and peripheral endosperm, and protein matrix (Silva et al., 2015).

Milk urea nitrogen averaged 17.65 mg/dL, with no difference occurring between the diets (Table 6). This value is within the range of 11.9 to 67.5 mg/dL deemed adequate for the goat species (Rapetti et al., 2014) for maximum use of the dietary nitrogen. Higher MUN values, as found by Peres Netto et al. (2008) in cows that consumed alfalfa, were attributed to ruminal degradation of the protein from fresh forages, especially legumes, which is high and normally exceeds the microbial requirements of ammonia. These excesses are eliminated in the form of urea by the kidneys and mammary gland.

Somatic cell count is highly influenced by biological and environmental factors. Thus, in comparing results, one must be very careful by always taking into account the animal breed, physiological stage, and, mainly, its species (Madureira et al., 2017). Goats show apocrine-type milk secretion, in which part of the alveolar epithelial cells is eliminated together with milk. Because these cells are anucleated, they are counted as leukocytes in the standardized SCC test for cattle, generating high SCC values in goat milk (Madureira et al., 2017). The average 2.93 cells/mL obtained in this study (Table 6) is close to the 2.80 and 3.07 cells/mL reported by Lopez et al. (2020) and Marques et al. (2016) in goats, respectively.

The lower production cost per liter of milk produced and consequent higher net revenues in the treatments with the inclusion of alfalfa are due mainly to the fact that these diets have the lowest costs (Table 7) and provide the best FE (Table 6). These findings agree with Comeron et al. (2015), who evaluated milk production costs of cows fed alfalfa in comparison with those reared in a feedlot.

These results showed that the diets with alfalfa (maize + alfalfa and cassava + alfalfa) provided the best effects on milk quality and FE and the highest net revenue per liter of milk, generating more profit for the producer.

## 5. Conclusions

Cassava chips and alfalfa grazing can replace maize and soybean meal in the concentrate of the diet of lactating adult goats without changing their feeding behavior or milk yield. Rather, this replacement

improves feed efficiency and increases milk fat and lactose levels. Diets containing alfalfa have the lowest production costs per liter of milk.

### Conflict of Interest

The authors declare no conflict of interest.

### Author Contributions

Conceptualization: H.C. Gonçalves and P.R.L. Meirelles. Data curation: R.P. Ferreira. Formal analysis: R.O. Marques and R.V. Lourençon. Funding acquisition: R.P. Ferreira. Investigation: R.O. Marques, H.F.B. Gomes, R.V. Lourençon and E.P. Brito. Methodology: R.O. Marques, H.C. Gonçalves, P.R.L. Meirelles, R.P. Ferreira, R.V. Lourençon and E.P. Brito. Project administration: R.O. Marques and H.C. Gonçalves. Supervision: H.C. Gonçalves, P.R.L. Meirelles and G.I.L. Cañizares. Validation: R.P. Ferreira and G.I.L. Cañizares. Visualization: R.P. Ferreira and G.I.L. Cañizares. Writing-original draft: R.O. Marques and H.C. Gonçalves. Writing-review & editing: H.F.B. Gomes.

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