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Selectivity and feeding behavior of Saanen goats subjected to three nutritional levels

Helen Fernanda Barros Gomes[1*], Samuel Figueiredo de Souza[2], Daiana de Oliveira[3], Bruno Biagioli[4], Izabelle Auxiliadora Molina de Almeida Teixeira[4], Kleber Tomás de Resende[4]

[1] Universidade Federal de Mato Grosso, Rondonópolis, MT, Brasil.
[2] Embrapa Tabuleiros Costeiros, Aracaju, SE, Brasil.
[3] Swedish University of Agricultural Sciences, Uppsala, Sweden.
[4] Universidade Estadual Paulista, Jaboticabal, SP, Brasil.

***Corresponding author:**
gomeshfb@gmail.com

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ABSTRACT - This study was conducted to investigate the effect of selective feeding habits on the quality of the ingested diet and the effect of feed restriction on the selectivity and behavior of goats in feedlots. Differences were found only in the amount of feed given to the animals, with a difference in the amount of feed rejected as a function of the nutritional level. Higher levels of orts were measured for those animals that received the *ad libitum* diet. For the composition of orts, differences were measured only in the ether extract fraction. Animals fed the *ad libitum* diet increased their intake of ether extract and energy, crude fiber, neutral detergent fiber, and acid detergent fiber. Thus, they had a preference for consuming the fibrous and energetic portions of the diet to the detriment of the mineral matter. The granulometry influenced the leftovers for the male and female treatments only in the diet that contained the 2.00- and 0.063-mm sized particles, with larger leftovers for the females. There were statistical differences as a function of feeding level for time spent in rumination, with stereotypical behavior, and in time spent standing up or lying down. As a function of sex, the differences were the same variables, including the time spent with agonistic behavior. Animals that received the *ad libitum* diet had a greater gain and final weight, whereas the animals that received the 60% restricted diet had the lowest performance, as did the females. Feed restriction changed the natural feeding behavior of goats, with smaller feed particles preferred. The feed restriction and sex also influenced the time spent on nonproductive activities, and the animals became more restless, with females having a higher social behavior than males.

Keywords: granulometry, intake, rumination, small ruminant

Introduction

The feeding habit of goats is conditioned by an intrinsic behavior of the species and, according to Aguirre (1986), this is associated with several factors including the nature of the diet, the form of the feed offered, the organoleptic qualities, and the presence or absence of anti-nutritional factors, as well as the body size of the animals and the capacity of the digestive tract. When the maximum opportunity for feed selection is provided, the nutritional value of the ingested feed and the amount ingested is higher, which positively affects performance.

In diets containing different particle sizes and physical densities between ingredients, segregation may occur at the mixing process and during transportation and utilization by animals that turn over the diet to select the appropriate feed.

The determination of particle size by granulometry can be used to study the selective habit of animals during feeding and is directly related to the amount of feed available. It can alter the feed intake pattern, and thus positively or negatively influence the performance of animals.

Adequate quantities of orts stimulate increased intake and avoid unnecessary waste, achieving higher performance. Likewise, there are acceptable levels of feed restriction that avoid any negative effects on the welfare and development of animals. However, under feedlot and other production systems, the constant search is for methods to increase the productive efficiency and reduce costs (Quintiliano and Paranhos da Costa, 2006). In general, the search for maximum productivity has given more attention to nutrition, breeding, and reproduction; however, essential aspects have been forgotten, including the behavior and physiology of animals.

Feed restriction, feedlot systems, and contact with animals of the other sex are factors that might contribute to changes in behavior, thus determining higher or lower energy expenditure for maintenance and deviation of energy gain to adapt to the environment or to confront these inadequacies. In feedlots, goats retain most of the behavioral characteristics of grazing animals; however, the supply of feed in limited quantity and/or frequency changes their behavior, resulting in greater agitation, aggression, and lower feed intake, which may interfere with performance.

To date, there are few scientific studies on the behavior and selectivity of goats, especially in feedlot conditions, because this species is still extensively produced. However, with increased demand for products of goat origin, given their distinct quality of milk and meat, it is necessary to learn more about the feeding habits of these animals and their selective capacity, with a view to increasing the efficiency of production systems.

In view of all the information about behavior that is necessary for the correct planning of goat production systems, and to complement the current literature, the present study focused on studying the effect of selective feeding habits on the quality of the ingested diet, and the effect of feed restrictions on the selectivity, behavior, and welfare of goats in feedlots.

Material and Methods

The trial was undertaken in Jaboticabal, SP, Brazil (21°14'05" S and 48°17'09" W, 615.01 m altitude), between April 2008 and August 2009.

A total of 36 Saanen goats were included in the study, 18 intact males and 18 females. When they reached 30 kg of live weight, the animals were housed in individual stalls of dimensions 0.50 × 1.0 m with slatted floors and had free access to water.

The diet was formulated according to the NRC (2006) to meet the nutritional requirements of animals with a live weight between 30 and 45 kg, considering a daily gain of 250 g. The feed was offered as a total mixed ration based on approximately 240 g of Tifton hay and 760 g of concentrate per kg of dry matter (Table 1).

After adaption to the diet, the animals were subdivided into three groups, in which they were allocated to the following treatments: *ad libitum*, 30%, and 60% restricted diet.

The experimental diet was administered daily, and feed intake was calculated as the difference between the amount offered and orts. The amount offered to the animals with restricted diets was calculated as a function of the intake of animals fed the *ad libitum* diet, in each group, for which orts of 150-200 g kg^{-1} of the offered diet on an organic matter basis was allowed. The diet was given twice daily, in the morning at 7.30 h and in the afternoon at 16.30 h, as a total mixed ration.

The orts were collected daily and stored fortnightly as a composite sample, with 60 days of collection. Subsequently, the samples were processed (pre-dried and ground in a knife mill) and stored at −18 °C until subsequent analysis.

Table 1 - Proportion of ingredients and chemical composition of the diet

Ingredient	g kg^{-1}	GE (kcal kg^{-1} DM)	g kg^{-1} DM				
			CP	EE	MM	ADF	NDF
Tifton hay	241.50	944.46	18.10	63.60	16.10	90.20	174.90
Corn	488.50	1996.40	38.90	10.40	6.60	19.30	79.10
Soybean meal	139.70	613.96	65.40	8.03	8.10	9.80	18.80
Wheat bran	88.70	367.98	14.20	7.90	4.40	9.90	34.30
Calcitic limestone	15.90	-	-	-	15.40	-	-
Ammonium chloride	11.40	-	-	-	10.20	-	-
Salt	4.50	-	-	-	4.00	-	-
Mineral supplement[1]	4.20	-	0.03	-	3.20	0.10	1.10
Sodium bicarbonate	4.50	-	-	-	4.10	-	-
Total	1000.00	3922.80	136.80	90.70	72.50	129.50	308.30

DM - dry matter, GE - gross energy, CP - crude protein, EE - ether extract, MM - mineral matter, NDF - neutral detergent fiber, ADF - acid detergent fiber.
[1] Composition of the mineral supplement (kg): 190 g of calcium, 73 g of phosphorus, 44 g of magnesium, 62 g of sodium, 92 g of chlorine, 30 g of sulfur, 1350 mg of zinc, 34 mg of copper, 940 mg of manganese, 1064 mg of iron, 3 mg of cobalt, 16 mg of iodine, 18 mg of selenium, 730 mg of fluorine.

Samples of ingredients and orts were oven dried at 60±5 °C for 72 h to constant weight and ground in a Wiley mill (Arthur H. Tomas Co., Philadelphia, PA) using a 1-mm sieve. The samples were analyzed according to AOAC (2007) to measure the dry matter (oven dried at 105 °C until constant weight, item 934.01), ash or mineral matter (complete combustion at 600 °C for 6 h in a muffle furnace, item 934.01), fat (based on weight loss of the dried sample after a 6-hextraction with petroleum ether in a Soxhlet apparatus, item 920.39), and protein (micro-Kjeldahl analysis, item 954.01). The neutral detergent fiber (NDF) content was analyzed using amylase without sulfite (Van Soest et al., 1991). Acid detergent fiber was analyzed according to the methodology described by Goering and Van Soest (1970), and gross energy was determined by a calorimetric pump (Parr Instrument Co., Moline, IL).

Subsequently, the dry matter intake and the intake of each nutrient (crude protein, ether extract, mineral matter, NDF, acid detergent fiber, and gross energy) were calculated in grams and in proportion (g kg^{-1}) to the observed dry matter intake, as well as the relation between the intake of each nutrient and quantity of each nutrient in the offered diet.

The granulometric analysis was performed according to the methodology of the Compêndio Brasileiro de Alimentação Animal (1998), in which 200 g of the pre-dried sample was weighed and conditioned in a set of automatic sieves of known weight, and agitated for 10 min. The samples were then weighed, subtracting the mass of the sieves. Six Tyler sieves with the following mesh sizes were used: 9, 11, 14, 32, 115, and 250, which represented in order: 1 = 3.35, 2 = 2.00, 3 = 1.19, 4 = 0.50, 5 = 0.125, and 6 = 0.063 mm, respectively, and bottom, which collected particles of less than 0.063 mm in powder form. The physically effective fiber ($_{pe}$NDF) was also determined according to the methodology proposed by Mertens (1997), calculated by a multiplication of the concentration of NDF on a dry matter basis of the feed and the percentage of particles retained on sieves larger than 1.18 mm. However, the methodology was adapted by replacing the 1.18 mm sieve with a 1.19 mm sieve.

Because the dietary restriction, selectivity, and percentage of $_{pe}$NDF ingested might alter the behavior of animals, observations at 10-min intervals were made to identify possible alterations using the methodology proposed by Johnson and Combs (1991) of scan sampling, adapted for a period of 24 h, repeated over three days at random.

Observations started at 6.00 h and lasted 24 h. The shed was maintained with the least amount of artificial lighting possible at night during the experimental period. The behavioral variables observed were feeding, ruminating, and idle, in addition to the agonistic interactions (interactions between animals) and stereotyped behavior (strange behaviors related to stress), which were evaluated according to the posture (standing up or lying down) to judge the agitation and energy demand spent, even within the pens. During the observations, drinking (evaluated as a separate event) was also recorded and the number of visits to the water trough was measured.

To evaluate the effect of selectivity and restriction on performance, the weight and weight gain of animals in each group were evaluated during the experimental period.

A randomized block design (groups) was used, with the effect of different nutritional levels (0, 30, and 60% restriction) and sex (males and females), according to Equation 1, which were evaluated in a 3 × 2 factorial scheme. The variables were evaluated by analysis of variance using the PROC MIXED software program (Statistical Analysis System, version 9.0) and the means compared by Tukey's test (P<0.05) using the SAS software.

$$Yijkl = \mu + Bi + NLj + Sk + NLj \times Sk + \varepsilon ijkl, \quad (1)$$

in which Yijkl = characteristics evaluated in animal l, sex k, and nutritional level j; μ = inherent constant in the data; Bi = block design effects; NLj = nutritional levels effects j, j = 1: *ad libitum*, 2: 30%, and 3: 60% of restriction; Sk = sex effects k, k = 1: male and 2: female; NLj × Sk = interaction effects between nutritional level j and sex k; and εijkl = random error Yijk, NID, $(0, \sigma_e^2)$.

Results

The same diet formulation was offered; therefore, there was no difference in the proportion of nutrients in the feed supplied, only in their amount (P = 0.0001), and there was no difference between males and females (P = 0.075) (Table 2).

There was a difference in the amount of feed rejected as a function of the nutritional level. Higher levels of orts were observed for animals fed the *ad libitum* diet (Table 2).

When the composition of orts was measured, there was a difference only for the fraction of ether extract (P = 0.0012) as a function of feeding level and sex (P = 0.0016), and for mineral matter as a function of sex (P = 0.0437). While there was a higher proportion of ether extract in the leftovers of males, females had a higher percentage of mineral matter (Table 2).

Differences were found for almost all variables observed as a function of treatment because the feeding level was different (P<0.05; Table 3).

Because they could select their feed, animals fed *ad libitum*, as expected, ingested dietary fractions of higher nutritional value, thus increasing their intake of ether extract and energy, as well as that of crude fiber, NDF, and acid detergent fiber. Therefore, when the animals could select their feed, they had a preference to consume the fibrous and energetic portions of the diet to the detriment of the mineral matter.

In agreement with that observed in orts, based on sex, differences were observed for mineral matter intake and its percentage of intake in relation to the dry matter offered (P = 0.0150). A lower percentage of mineral matter was ingested by females; in contrast, a higher percentage of ether extract intake was measured.

Observing the relationship between the amount of nutrients consumed and offered, there was a difference between treatments for all evaluated nutrients. The animals showed selective behavior related to the particle size of feed regardless of feeding level.

These differences were found for particles retained on sieves no. 2 and 4 as a function of feed restriction, with preference for particles larger than 2.00 mm by animals fed the *ad libitum* and 30% restricted diets, and preference for particles between 1.19 and 0.50 mm by animals subjected to the 60% restricted diet (Table 4).

In the present study, there was an influence of feeding restriction level on the particle size selection. Differences were observed as a function of treatment for particles retained on sieves no. 2 and 4, i.e., 2.0 and 0.5 mm, and as a function of sex for particles retained on sieves no. 2 and 6, i.e., 2.0 and 0.063 mm (Table 4). Therefore, animals subjected to the highest level of feeding restriction (60% restricted diet) had a preference for smaller particles, resulting in greater percentages of particles larger than 2.0 mm in the orts, and intake of a higher proportion of particles up to 0.5 mm. Females did not prefer particles larger than 2.0 mm or particles smaller than 0.12 mm.

The values of $_{pe}$NDF ingested by animals subjected to the 60% restricted diet (P = 0.049) and by females (P = 0.046) were the lowest (Table 4).

Differences were observed as a function of feeding level for time spent in rumination (P = 0.0003), with stereotypical behavior (P = 0.0011), and in time spent standing up (P = 0.0014) or lying down (P = 0.0014). As a function of sex, the differences were observed for the same variables (P<0.05), including time spent with agonistic behavior (P = 0.0020) (Table 5).

The animals that received the *ad libitum* diet had greater gain and final weight (P<0.05), whereas the animals fed the 60% restricted diet had the lowest performance. Females presented lower performances than males (P<0.05) (Table 6).

Table 2 - Amount offered and chemical composition of orts (average/day) according to the level of feeding restriction and sex

Variable[1]	Average	Restriction level (RL)			Sex (S)		P[2]	
		0%	30%	60%	Male	Female	RL	S
				Offered				
NM/day (kg)	1.01	1.66a	0.87b	0.50c	1.07	0.95	0.0001	0.0750
DM (g)	878.08	1441.75a	758.68b	433.80c	930.08	826.10	0.0001	0.0750
CP (g)	120.12	197.24a	103.79b	59.34c	127.23	113.01	0.0001	0.0750
EE (g)	24.66	40.49a	21.30b	12.18c	26.12	23.20	0.0001	0.0750
MM (g)	63.66	104.53a	55.00b	31.45c	67.43	59.89	0.0001	0.0750
ADF (g)	113.42	186.71a	98.24b	56.11c	120.45	106.98	0.0001	0.0750
NDF (g)	270.71	444.50a	233.90b	133.74c	286.74	254.70	0.0001	0.0750
GE (kcal)	3444.56	5655.80a	2976.15b	1701.72c	3648.51	3240.61	0.0001	0.0750
				Leftover				
NM/day (g)	171.82	432.73a	63.59b	18.95c	185.64	157.88	0.0001	0.2519
DM (g)	144.08	362.97a	53.55b	15.23c	156.63	131.21	0.0001	0.2207
DM (g kg^{-1})	828.00	838.50	793.30	852.30	814.20	841.90	0.1509	0.2777
CP (g)	20.62	51.30a	8.34b	2.09c	22.33	18.83	0.0001	0.2640
CP (g kg^{-1})	144.80	141.20	149.50	143.30	145.70	143.60	0.1300	0.4158
EE (g)	3.76	9.49a	1.44b	0.31c	4.30a	3.19b	0.0001	0.0300
EE (g kg^{-1})	25.50	26.10a	26.60a	24.00b	26.80a	24.30b	0.0120	0.0160
MM (g)	13.09	32.27a	5.44b	1.32c	12.88	13.15	0.0001	0.9120
MM (g kg^{-1})	94.3	89.40	94.10	99.40	86.70b	101.09a	0.8600	0.0437
ADF (g)	14.03	36.94a	3.90b	1.26c	15.68	12.39	0.0001	0.1290
ADF (g kg^{-1})	92.90	102.60	81.60	95.00	99.01	87.00	0.1560	0.1783
NDF (g)	35.67	93.47a	10.05b	3.44c	40.43	30.87	0.0001	0.0903
NDF (g kg^{-1})	233.50	255.30	216.60	228.70	249.20	217.90	0.2894	0.1318
GE (kcal)	561.35	1381.66a	218.35b	84.04c	620.20	502.51	0.0001	0.2694
GE (kcal kg^{-1})	3666.16	3746.10	3629.64	3622.75	3720.86a	3611.47b	0.0591	0.0224

NM - natural matter, DM - dry matter, CP - crude protein, EE - ether extract, MM - mineral matter, ADF - acid detergent fiber, NDF - neutral detergent fiber, GE - gross energy.
[1] (g) = quantity offered in grams, (g kg^{-1}) = quantity offered in relation to DM.
[2] P - significance level.
Means followed by different letters in the row differ by Tukey's test (P<0.05).

Table 3 - Intake of nutrients (g), as a relation of dry matter (g kg^{-1}) and in relation to the percentage of each fraction offered (R), according to the feeding restriction level and sex

Variable	Average	Restriction level (RL)			Sex (S)		CV	P[1]	
		0%	30%	60%	Male	Female		RL	S
					Intake				
DMI (g)	734.00	1078.20a	706.00b	417.81c	773.19	694.81	19.82	0.0001	0.1190
R_DM	88.28	74.49b	93.58a	97.00a	87.99	88.72	20.07	0.0001	0.8758
CPI (g)	99.49	145.75a	95.69b	57.03c	104.81	94.18	10.77	0.0001	0.1260
CPI (g kg^{-1})	135.60	134.90	135.50	136.50	135.60	135.60	20.29	0.0756	0.9770
R_CP	87.65	73.64b	92.73a	96.89a	87.41	88.09	18.65	0.0001	0.8700
EEI (g)	20.90	30.96a	19.91b	11.82c	21.79	20.01	19.77	0.0001	0.2183
EEI (g kg^{-1})	28.30	28.60a	28.20b	28.30b	28.10b	28.60a	24.27	0.0440	0.0100
R_EE	89.12	76.08b	93.86a	97.71a	88.30	90.13	20.04	0.0001	0.5956
MMI (g)	50.56	72.04a	49.95a	29.70b	54.41	46.72	5.85	0.0140	0.0580
MMI (g kg^{-1})	69.40	66.40b	70.60a	71.30a	70.60a	68.20b	21.68	0.0002	0.0150
R_MM	85.17	68.61c	91.49b	95.70a	86.16	84.37	32.51	0.0001	0.2803
ADFI (g)	99.57	149.77a	94.34b	54.91c	104.76	94.58	9.90	0.0001	0.0930
ADFI (g kg^{-1})	135.30	140.70a	133.90b	131.10b	134.70	135.70	9.81	0.0327	0.7500
R_ADF	91.52	80.13b	96.49a	97.95a	90.80	92.25	7.65	0.0001	0.4543
NDF (g)	235.05	351.03a	223.84b	130.30c	246.31	223.81	49.65	0.0001	0.1213
NDF (g kg^{-1})	319.30	328.80a	317.50b	310.90b	316.90	321.20	70.12	0.0350	0.2720
R_NDF	90.90	78.77	96.22	97.71	90.00	91.81	7.89	0.0001	0.1815
GEI (kcal)	3194.81	5045.78a	2864.72b	1674.28c	3336.86	3057.99	35.70	0.0001	0.2462
GEI (kcal/kg DM)	4262.78	4721.50a	4043.78b	4023.07b	4257.57	4268.00	19.82	0.0003	0.4248
R_GE	94.52	88.58b	96.58a	98.40a	93.80	95.24	7.80	0.0001	0.1674

DMI - dry matter intake, CPI - crude protein intake, EEI - ether extract intake, MMI - mineral matter intake, ADFI - acid detergent fiber intake, NDFI - neutral detergent fiber intake, GEI - grosso energy intake, R - relations between the nutrient intake and dry matter intake; CV - coeficient of variation.
[1] P - significance level.
Means followed by different letters in the row differ by Tukey's test (P<0.05).

Table 4 - Granulometry of orts as a function of the feeding restriction level and sex

Variable[1]	Average	Restriction level (RL)			Sex (S)		P[2]	
		0%	30%	60%	Male	Female	RL	S
Sieve 1	4.40	4.51	4.08	4.42	5.23	3.78	0.350	0.240
Sieve 2	30.34	28.34b	28.76b	35.12a	26.30b	33.17a	0.034	0.039
Sieve 3	19.53	19.83	19.04	19.71	20.16	18.89	0.970	0.680
Sieve 4	26.00	28.72a	25.25b	22.04c	27.61	26.40	0.047	0.660
Sieve 5	11.75	11.34	13.48	10.83	13.22	9.87	0.498	0.193
Sieve 6	4.82	4.50	5.70	5.05	3.75b	5.09a	0.220	0.030
Rest	0.54	0.41	0.69	0.51	0.52	0.56	0.456	0.823
peNDF	16.86	16.31b	16.06b	18.35a	16.31b	17.29a	0.049	0.046

peNDF - phisically effective neutral detergent fiber, according to Mertens (1997).
[1] Sieve 1 = 3.35, Sieve 2 = 2.00, Sieve 3 = 1.19, Sieve 4 = 0.50, Sieve 5 = 0.125, Sieve 6 = 0.063 mm.
[2] P - significance level.
Means followed by different letters in the row differ by Tukey's test (P<0.05).

Discussion

The need of animals subjected to a higher level of feed restriction to obtain energy may be justified by the greater search for dietary portions of high energy, leading to the lower percentage of ether extract in orts. This can be extrapolated to females, which had a similar intake to males but a higher energy demand, with females spending more energy on stereotypical and agonistic behaviors.

Table 5 - Time spent (in min) on activities observed and frequency of water intake according to the feeding restriction level and sex

Variable	Average	Restriction level (RL)			Sex (S)		P[1]	
		0%	30%	60%	Male	Female	RL	S
Eating	90.22	98.71	88.33	83.61	85.25	95.18	0.1879	0.1486
Ruminating	211.02	259.45a	206.11b	167.50c	235.37a	186.67b	0.0003	0.0048
Agonistic behavior	42.40	40.83	43.05	43.33	33.33b	51.48a	0.9137	0.0020
Estereotypic behavior	138.12	89.65c	139.72b	185.00a	112.92b	163.33a	0.0011	0.0110
Idleness	958.34	951.68	962.78	960.55	973.34	943.33	0.9004	0.1628
Lying	888.22	941.05a	874.44ab	849.17b	926.63a	849.82b	0.0014	0.0004
Standing	550.67	497.84b	564.44ab	589.72a	512.26b	589.07a	0.0014	0.0004
Frequency_water intake/day	5.00	5.16	4.58	5.25	5.16	4.83	0.6787	0.6224

[1] P - significance level.
Means followed by different letters in the row differ by Tukey's test (P<0.05).

Table 6 - Initial and final weight of animals during the experimental period and mean weight gain according to the feeding restriction level and sex

Variable	Restriction level (RL)			Sex (S)		CV	P[1]	
	0%	30%	60%	Male	Female		RL	S
Initial weight (kg)	29.95	29.25	29.25	29.50	29.35	1.94	0.8465	0.7648
Final weight (kg)	35.97a	32.48b	27.54c	33.33a	30.53b	7.96	0.0001	0.0037
Weight gain (kg)	6.02a	3.23b	−1.71c	3.83a	1.18b	20.70	0.0001	0.0001

CV - coefficient of variation.
[1] P - significance level.
Means followed by different letters in the row differ by Tukey's test (P<0.05).

The greatest rejection of mineral matter by females was in the percentage of particles less than 0.12 mm in size. The concentrated feeds coincidentally have higher mineral content in their composition, besides the mineral supplement, which was also a part of the total diet.

By observing the composition of the offered feed and orts, the selectivity by animals was measured, with increased intake of ether extract, energy, crude fiber, and neutral and acid detergent fiber fractions. These fractions had lower percentages in orts in relation to the composition of the diet offered. This means that feed restriction altered animal selectivity and intake.

In a study conducted by Branco et al. (2011), who used different fiber levels for dairy goats, the NDF intake increased linearly as the levels of dietary forage NDF increased. It was expected that the NDF intake would be stable up to approximately the maximum dry matter intake due to the physical limitations of the rumen, which was justified by the quality of forage used. This can be extrapolated to the present study because the higher fiber intake did not limit energy intake by animals fed *ad libitum.*

The preference of these animals may also have influenced the higher fiber intake, as they showed a preference for coarser particles. By extrapolating the information from the granulometry of orts, with a smaller proportion of orts retained on sieve no. 2 (2.0-mm mesh), there was a smaller proportion of particles larger than 2.0 mm in the orts, which had been consumed by the animals. The protein content consumed by the animals fed *ad libitum* (13.49%) was very similar to that offered in the diet (13.68%), with no difference for those animals fed the restricted diets. This can be attributed to the good balance and homogeneous diet.

In agreement with what was observed in the leftovers, in function of sex, differences were observed for mineral matter intake and its percentage of intake in relation to the dry matter offered, being ingested a smaller percentage of these fractions by females; on the other hand, a higher percentage of ether extract intake was observed. In the relation between the amount of nutrients consumed by the amount of nutrients offered, it was noted that for all evaluated nutrients, there was a difference between treatments, showing that the animals subjected to restriction ingested a higher percentage in relation to those that received the *ad libitum* diet based on that offered.

Therefore, feeding restriction altered the feeding behavior of the animals, leading to decreased selectivity, which is in agreement with results reported by Ribeiro et al. (2009). However, a different result was observed by Ribeiro (2006) with Moxotó and Canindé goats subjected to restricted feeding or fed *ad libitum*, with no influence of nutritional level on feeding behavior. This might have occurred because the highest restriction level was 30% in their study, which was lower than the 60% used in the present study.

Cavalcanti et al. (2008) studied sheep and goats and observed that goats had a higher capacity to select the most specific ingredients from their diet, thus modifying the proportion of dietary ingredients. In their study, there was an increase in dietary crude protein intake from 8.75 to 12.21% when the animals could select their feed; however, this was not observed in the present study for protein.

The selective behavior related to the particle size of feed was expected, considering the characteristic habit of the species. In contrast, in a previous study conducted by Ribeiro et al. (2009), varying only the amount of feed rejected, there was no influence of feed restriction on the granulometry selected by Moxotó and Canindé goats in feedlots.

According to Ribeiro et al. (2009), the feed selection strategy of goats appears to be a feeding choice when the protein content and digestibility are high. Therefore, this capacity would be more beneficial under conditions of greater variability in the available feed digestibility and more advantageous for animals that can select highly digestible parts and reject lower-quality parts. In the present study, however, the animals selected the fibrous and energetic fractions of the diet to the detriment of the protein fraction, which might have been minimized by the quality of the diet offered.

Associating this information with diet composition, feed-restricted animals searched more for smaller particles in their diet, which constitute concentrated feeds. This was seen for particles smaller than 0.5 or 0.12 mm, because they might have accumulated at the margins of the trough, thus making them difficult to access. It might also explain the fact that females had a higher percentage of mineral matter in their orts, because the concentrated feeds and mineral supplement had lower granulometry.

Barreto et al. (2011) observed that Moxotó and Canindé goats had a preference for the smaller particles in their diets, regardless of energy level, which was similar to what we observed in the present study. This can be explained in diets composed of ingredients that have heterogeneous particle size and physical density, as segregation may occur at mixing due to transportation and the animals turning over the diet in the trough using their muzzles, thus facilitating selective feeding. In addition, losses of concentrated ingredients might occur owing to the difficulty of animals ingesting or accessing the smaller particles.

The size of the particles ingested varies with the selective capacity of each species and aims to meet their nutritional needs, thus contributing to lower rumination time.

When maximum selection is allowed, the nutritional value of the ingested feed is higher, as is the amount consumed and, consequently, the performance. However, the cost can negatively influence the farmer's choice, with selectivity leading to a higher cost of orts. This corroborates the observation of Silva et al. (1999) in a similar study on the influence of the selective habit of goats on the chemical composition of ingested feed and orts.

Males were calmer in the present study than females, spending more time ruminating or lying down, whereas the females spent more time on nonproductive behaviors, which further intensified their energy demand, resulting in higher weight losses during the experimental period.

Animals subjected to feed restrictions were expected to ingest the feed offered faster than animals fed *ad libitum*, a behavior that was not observed in the present study. This might be because the animals on the restricted diets could have stayed longer in the feeding position, trying to reach the smaller portions of their diet, which might have segregated and accumulated in the sides and corners of the troughs. This possibly confused the observers at the time of data collection, but it means they were standing, wasting more energy.

Ruminants should consume minimum amounts of fiber daily to stimulate chewing, maintain saliva flow, and contribute to the development of rumen microorganisms that are responsible for the digestion of fibrous carbohydrates. Several factors may affect the fiber concentration of diets, including the carbohydrate type, percentage of fiber from forage, and particle size (Nussio et al., 2006). The smaller the particle size of the feed, the greater its contact with the ruminal fluid, and the easier it is for rumen microorganisms to access. This favors fermentation and absorption, which can directly affect the behavior of the animals, reducing the time spent chewing and on rumination, as observed in the present study.

These observations confirmed that animals subjected to feeding restrictions ruminated less and spent less time lying down, spending most of their time standing and with stereotypical behaviors. Females ruminated less and spent more time standing and with agonistic and stereotypical activities than males, which is harmful to the welfare and development of these animals.

Considering that the fermentation rate is an inherent property of the feed, whereas the passage rate might be regulated by the feed intake, processing or particle size, and by the type of feed consumed (Russell et al., 1992), animals under restricted diets in the present study spent less time ruminating because they ingested less feed. This was also influenced by the granulometry, because these animals, especially the females, had a preference for the smaller particles in the diet, thus consuming lower amounts of $_{pe}$NDF. This might have created difficulties in dealing physiologically with the higher proportions of concentrate ingested, because the stability of the ruminal environment would have been impaired, resulting in reduced time spent on rumination. This might have contributed to a lower buffering capacity of the rumen, leading to pH variations, which is in agreement with the results reported by Branco et al. (2011). These events might have led to a decreased intake, as with the high feed restriction they were subjected to should have meant that they did not have a representative quantity of orts.

In a study by Bezerra et al. (2004), their data revealed an effect of granulometry on the average retention time of dietary particles. A longer retention time was observed in the diet with a higher proportion of coarser particles. Particles with lower granulometry remained for a shorter time in the gastrointestinal tract, which is in agreement with the results obtained in the present study.

The intake of $_{pe}$NDF measurements agree with the results obtained in the evaluation of orts, because the animals fed *ad libitum* had a preference for the larger particles in the diet. These particles should be composed of more fibrous portions, leading to a greater intake of $_{pe}$NDF, and thus required a longer rumination time.

The animals in the present study had access to different amounts of feed; therefore, there was a lower intake of nutrients for those subjected to the restricted diets, and because of this lower feeding level, these animals experienced behavioral changes, including higher agitation of those subjected to the lower nutritional level diets, specially females. Thus, it is possible to predict that the performance of these animals was further impaired by the increased demand for these activities.

Despite the short time used to perform the present study, it was observed that the 60% restricted diet was very severe to the animals, as it might be below the minimum maintenance requirements and, therefore, should not be used. In a previous study by Yáñez et al. (2009), equal dietary restrictions were used. However, the this was not observed, possibly because the authors used Boer crossbred animals, which might have a lower maintenance requirement. Nevertheless, the observed weight loss may be due to the greater activity of animals subjected to the higher restricted diets. Besides ingesting less amounts of feed, these animals still had high energetic demands for their activities, resulting in greater weight loss. This may have been further intensified by the animals' limited intake of particles with greater fiber effectiveness, which could have resulted in damage to ruminal functions.

Conclusions

Feed restriction changes the natural feeding behavior of goats, triggering them to accept most of the feed available in the trough, and also influences the selected particle size, with smaller feed particles being preferred, which are also those with the highest energy value, thus limiting the ingestion of the fibrous portions. Feed restriction and sex also influence the time spent on nonproductive activities (stereotypical and agonistic behaviors) and animals become more restless, exacerbating the body energy loss and increasing its productive losses. Females, in general, have a higher social behavior than males.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: I.A.M.A. Teixeira and K.T. Resende. Data curation: H.F.B. Gomes, S.F. Souza, D. Oliveira and B. Biagioli. Formal analysis: K.T. Resende. Investigation: H.F.B. Gomes, S.F. Souza, D. Oliveira and B. Biagioli. Methodology: I.A.M.A. Teixeira and K.T. Resende. Project administration: H.F.B. Gomes and I.A.M.A. Teixeira. Supervision: I.A.M.A. Teixeira and K.T. Resende. Writing-original draft: H.F.B. Gomes. Writing-review & editing: H.F.B. Gomes and I.A.M.A. Teixeira.

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