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RESEARCH ARTICLE OPEN ACCESS

TOTAL REPLACEMENT OF CORN BY POPCORN RESIDUE ON INTAKE, DIGESTIBILITY AND INGESTIVE BEHAVIOR OF LAMBS

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ABSTRACT

It was aimed to assess the effect of substitution of corn by popcorn residue on intake, digestibility and ingestive behavior of lambs. Four male, non-castrated Morada Nova lambs were utilized, with a mean body weight of 28 kg. Treatments consisted of different levels of substitution of corn by popcorn residue: 0, 333, 666 and 1000 g/kg of dry matter. The intake of dry matter and nutrients was obtained from the amount of feed offered and orts. Behavioral pattern measurements were carried out through the scan sampling method during 12 hours over two consecutive days. It was verified the number of times that animals sought water and urinated and the number of times that animals defecated. The experimental design used was a 4x4 Latin square. There were no significant differences in intake and nutrient digestibility, eating time, ruminating time, idling time, eating efficiency, rumination efficiency, physiological variables, and water intake. The popcorn residue can fully replace corn in the diet of confined ram lambs without altering intake, nutrient digestibility, or ingestive behavior.

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INTRODUCTION

Brazil has a sheep inventory of 17.6 million head, mostly concentrated in the Northeast region (57.5%), whose trends are targeted at meat production. Throughout decades sheep production has been considered a marginal or livelihood activity in the Northeast region, normally having low productivity and undertaken by producers lacking financial and technological resources. However, production of small ruminants has been distinguished by its significant social, economic, and cultural role in this region, thus being crucial for development of the Northeast. According to Nobre *et al*. (2016), sheep production represents a good alternative of employment and income for the northeasterner producer, as it provides food of high biological value (meat and entrails), besides high-quality sheep leather, making this activity profitable for small, medium or large producers. Despite the great importance of sheep production in the Brazilian Northeast, the adverse soil and climate attributes of the northeasterner semi-arid compromise the development of that activity, especially in periods of drought, when there is water deficit and, consequently, a deficit of forage resources. Thus, satisfactory meat production is jeopardized, since quantity and quality of feeding are reduced. As a consequence of irregularity on quantitative and qualitative offer of forage resources in the Brazilian semi-arid region, the inclusion of grains and cereals in sheep rations, mainly corn, is a common practice among ranchers in the northeasterner semi-arid. Despite the nutritional quality of corn, many researches are carried out with the goal of finding alternatives for its substitution in diets of ruminants, since corn is frequently an on-viable option and the rainfall regime in the northeasterner semi-arid does not enable sufficient production to meet the regional demand. Hence, it is necessary to import corn from other production regions, thereby raising production costs. Among alternatives available, there are residues generated from food processing in the industry. Normally, byproducts are included in rations for substitution of other traditional ingredients such as corn and soybean. Nonetheless, whatever the reasons for utilization of byproducts, the main factor to be considered is certainly an economic advantage, either related to a direct reduction in feeding costs or to obtaining a better animal performance, as a result of optimization of feed efficiency.

The byproduct of popcorn manufacturing or popcorn residue is one of prominence as it is little utilized and studied but has similar potential to well-known and employed ingredients. As stated by Imaizumi *et al.* (2006), the popcorn residue contains 94.40% of dry matter, 0.25% of ash, 5.35% of crude protein, 1.67% of ether extract, and 82.51% of total digestible nutrients, demonstrating the nutritional potential of that product for replacement of corn in sheep feeding. The popcorn residue is composed of particles of smaller size that pass through a sieve, before addition of salt, sugar, or other additives, and are not commercialized. It is worth noting that this residue is not seasonal (since the popcorn production is constant throughout the year), which is a paramount feature. The study of ingestive behavior has the purpose of verifying whether certain behavioral action is a characteristic of the animal or whether there is environmental or dietetic interference, thus promoting a better understanding of feeding habits, which can bring superior productive results. The study of behavioral patterns of ruminants is an important tool to adjust feeding, in order to obtain satisfactory animal productivity, whether it is meat, milk or any other product. Factors that may affect ingestive behavior are linked to the feed, the environment and the animal. In this context, it was aimed to evaluate the effect of the substitution of corn by popcorn residue on intake, digestibility, and ingestive behavior of sheep.

MATERIALS AND METHODS

This study was carried out in strict accordance with the recommendations of the Guide of the National Council for the Control of Animal Experimentation. The experiment was carried out in Serra Talhada, Pernambuco, Brazil, in an experimental barn at the Agronomic Institute of Pernambuco (IPA), approximately three kilometers away from the Federal Rural University of Pernambuco, Academic Unit of Serra Talhada - UFRPE/UAST. The facilities allowed lateral airflow; it was covered with ceramic roof tiles; and had a concrete floor with aslight declivity, which facilitated cleaning. Four male, non-castrated Morada Nova lambs with a mean initial body weight of 28 kg were used in the study. The animals were kept tied by halters and had free and individual access to water and feed. Before the onset of the trial, all animals were dewormed. The experiment lasted 48 days, being divided into four periods of 12 days each (seven days for adaptation and five days for collecting samples and data). Experimental diets consisted of Tifton hay, ground corn, popcorn residue, soybean meal and mineral salt, whose chemical-bromatological composition is presented in Table 1. Feeds were given twice daily (8:00 and 16:00 hours) as a total mixed ration, and the amount of feed offered was adjusted daily to allow 15% refusals and promotevoluntary intake.Treatments consisted of different levels of substitution of corn by popcorn residue: 0, 333, 666 and 1000 g/kg of dry matter (Table 2). The popcorn residue was obtained from the manufacturer *Pipocas e SalgadinhosBrotinho*located in Serra Talhada, Pernambuco. This residue was acquired before the addition of salt, sugar or any other flavoring additive. Prior to being offered to animals, this byproduct was ground on a feed chopper machine.

Intake of dry matter and other nutrients was estimated from the amount of feed offered and total of orts. Production of fecal dry matter (PFDM) was quantified through total fecal collection by using sampling bags. The bags were made of cotton with the interior lined with a fabric made of laminated polyvinyl chloride plastic (PVC) and polyester. The nutrient digestibility coefficient (CD) was calculated as percentage of absorbed nutrients by the percentage of ingested nutrients, where CD = (Nutrient ingested - nutrient excreted/nutrient ingested) x 100. During three consecutive days of the sampling period, samples of Tifton hay, ground corn, popcorn residue, soybean meal, mineral salt, orts, and feces were taken, weighed and packed in plastic bags previously identified, and stored in freezer at -20ºC. Subsequently, samples were pooled according to period and treatment to obtain a composite sample. All samples were dried in an air-forced oven at 55ºC for 72 hours and ground in a Wiley mill using a 1-mm sieve for further determination of chemical composition.

For determination of the chemical composition, samples were sent to the Animal and Plant Nutrition Laboratory (LANAV) at the Academic Unit of Serra Talhada (UFRPE/UAST) and analyzed for dry matter (DM) (method 967.03), mineral matter (MM) (method 942.05), organic matter (OM), crude protein (CP) (method 988.05) and neutral detergent fiber (NDF) (method 937.18) contents following the recommendations of the Association of Official Analytical Chemists (AOAC 1990). Total digestible nutrients (TDN) was estimated by the equation proposed by Weiss (1999), where TDN = dCP + dEE*2.25 + dNFC + dNDF, being dCP = (CP ingested - CP feces), dEE (EE ingested - EE feces), dNFC = (NFC ingested - NFC feces) and dNDF = (NDF ingested - NDF feces).

Measurements of behavioral patterns were carried out through the scan sampling method proposed by Martin & Bateson (1988) in five-minute intervals during 12 hours in two consecutive days. Each animal was individually observed to avoid excessive laborby observers and improve the efficiency of observation. Animal behavior was assessed by the following aspects: eating time, rumination time, and idling time. Behavioral activities were determined as: standing eating (the animal was in an upright position ingesting feed), standing ruminating (the animal was in an upright position in rumination activity), lying down ruminating (the animal was ruminating with its body on the floor), and idling time (the animal showed no apparent physiological activity).

The physiological variables urination, defecation, and number of times that animals sought water were recorded during the observation days in different periods. Total chewing time (TCT) was assessed by the sum of time spent on eating and rumination. The number of ruminating chews per bolus was recorded by using a digital stopwatch for each animal, as well as the mean time spent on ruminating chews per bolus. These latest evaluations were carried out in two periods comprised of two hours each (from 5:30 to 7:30 a.m. and from 10:00 to 12:00 a.m.) over a 12-hour period of observation. The amount of rumination bouts and ruminal boluses were also recorded. The number of chews per minute was calculated by sampling of four 15-second intervals of chewing per animal and later multiplying the number of chews within each interval by four to total one minute. Eating efficiency was expressed on DM (FE_{DM}, g DM/min) and NDF ((FE_{NDF}, g NDF/min) basis by dividing DM intake and NDF intake by eating time (DMI/ET e NDFI/ET); rumination efficiency was expressed as a function of DM and NDF intake and rumination time (min/day) (RE_{DM}, g DM/min e RE_{NDF}, g NDF/min).

Water intake was determined in three consecutive days of the sampling period. In these days, buckets (waterers) were filled and weighed twice daily, to prevent evaporation, approximately at the times of feed delivery (8:00 and 16:00 hours). The buckets had capacity of 10 liters. The water intake was calculated by difference of the weight of the buckets before and after consumption. The buckets were always washed before filling. Apart from the buckets used for water intake determination, two other buckets were used to check the daily amount of water evaporated; one bucket was placed in the shade and the second bucket kept under sunlight. Animals were not allowed access to these buckets. Respiratory rate (number of times that animals contracted and relaxed their abdomen within one minute) was assessed through visual observation of each animal, repeating this procedure three times for each animal. In addition, rectal temperature of lambs was checked over the sampling period by using a digital thermometer.

The experimental design employed was a 4 x 4 Latin Square (four diets and four periods). Data were analyzed by variance and regression analysis using the statistical package of Systems Statistical Analysis (SAS, version 9.1). The statistical model used for analyses was $Yijk = \mu + Ti + Pj + Ck + \varepsilon ijk$, where Yijk is the observation, μ the population mean, Ti the treatment, Pj the period, Ck the random effect of the animal, and εijk is the residual error. The criteria adopted for model selection were significance of regression coefficients at 5% of probability, the coefficient of determination (R^2), and the biological phenomena.The standard error of the mean was obtained from original data.

RESULTS AND DISCUSSION

No significant differences (*P*>0.05) were found in intakes of dry matter (g/day and % BW), organic matter, crude protein, neutral detergent fiber (g/day and % BW), total carbohydrates, non-fiber carbohydrates, and total digestible nutrients; therefore, popcorn residue can fully replace corn (Table 3). The reason for the lack of significant differences among diets may be explained by the similar bromatological composition of the experimental diets, as it was shown in Table 2, since a number of factors control feed intake, such as physical (digestive tract capacity), physiological (feed intake regulation by energy density of the diet), and psychogenic (response of the animal towards inhibiting or stimulating factors), besides feed-related factors (palatability). Zarpelon *et al*. (2015) tested the replacement of corn by increasing levels of soybean hulls and did not detect significant differences on nutrient intake. The data behavior shown in this study indicate that popcorn residue was well accepted by the animals and, consequently, can completely replace corn meal in rations of confined lambs, in addition to representing a lower-cost feed. Considering that feeding costs account for 50 to 75% of total costs in ruminant production and has a great influence on its profitability, it becomes essential to search for alternatives that can minimize the financial impact of this factor in the production system.

In practical terms, two rations composed of Tifton hay, soybean meal, and mineral salt (Table 1) but differing in the inclusion of popcorn residue (0% or 100%) would cost approximately R$1.04/kg if no popcorn residue was used to replace corn in the formulation, and R$0.95/kg if corn was completely replaced by the popcorn residue. This example was based on the assumption that the market price of soybean meal would be R$1.20/kg; Tifton hay R$1.10/kg; corn 0.85/kg; popcorn residue R$ 0.38/kg; and mineral salt R$2.00/kg). Moreover, if taken into account an average dry matter intake of 1.058 kg (Table 2), these rations would cost R$1.10/animal/day and R$0.95/animal/day, respectively, at the 0 and 100% substitution levels. Hence, this alternative feed source may promote a 13.5% reduction in feeding costs when used as an energy source in sheep rations.

No significant statistical differences (*P*>0.05) were found in digestibility coefficients of dry matter, organic matter, crude protein, neutral detergent fiber, total carbohydrates, non-fiber carbohydrates, and total digestible nutrients (Table 4). The fact that digestibility was not influenced by the treatments may be explained by the composition of the diets, which were similar in fiber, crude protein, ether extract, and total digestible nutrient content; had the same roughage : concentrate ratio; and animals, which were at similar age and belonged to the same species. Feed digestibility represents the highest or lowest ability of the animal in utilizing nutrients present in the feed depending on amount consumed, bromatological composition, and processing, being a characteristic inherent to the feed itself, not the animal. However, digestibility may be affected by animal-related factors such as species and age, and feeding management and environment (Marques *et al*., 2013). Together, these factors indicate the great potential of inclusion of the popcorn residue in sheep feeding.

Silva *et al*. (2014) tested the effects of substitution of corn by pearl millet in diets of confined steers and did not find significant differences on nutrient digestibility as well. Nonetheless, Hashimoto *et al*. (2007) tested the replacement of corn by increasing levels of soybean hulls and observed a linear decreasing relationship in energy intake and a linear increasing relationship in neutral detergent fiber. It is possible that the similar nature of the feeds as for digestion rate and rate of passage in the present study have contributed to the lack of differences in utilization of nutrients by the animals, as decreases in digestibility are often seen as a result of competition between rate of digestion and rate of passage. Both variables are affected by an increment in feed intake, which leads to increases in the rate of passage, thereby reducing the digestibility of nutrients. There was no significant difference (*P*>0.05) in the behavioral patterns total eating time, total idling time, standing ruminating, lying down ruminating,

Table 1. Bromatological composition of feeds from experimental diets

Nutrients	Ingredient			
	Tifton hay	SoybeanMeal	GroundCorn	PopcornResidue
Dry matter, g/kg FM[a]	927	910	900	916
Organic matter, g/kg DM[b]	947	936	986	987
Ash, g/kg DM	52.8	64.0	13.8	12.8
Crude Protein, g/kg DM	47.3	512	79.8	71.8
Total carbohydrates, g/kg DM	878	396	855	865
Neutral detergent fiber, g/kg DM	799	137	143	85.3
Non-fiber carbohydrates, g/kg DM	79.0	259	712	780
Ether extract, g/kg DM	21.1	27.4	50.8	50.0

[a]Fresh matter. [b]Dry matter.

Table 2. Proportion of ingredients and bromatological composition of experimental rations

Ingredient	Substitution levels of corn (g/kg DM)			
	0	333	666	1000
Ground corn	30.0	20.0	10.0	0.0
Popcorn residue	0.0	10.0	20.0	30.0
Soybean meal	12.6	12.0	11.0	11.0
Tifton hay	56.4	57.0	58.0	58.0
Mineral mixture[a]	1.0	1.0	1.0	1.0
Nutrient, g/kg	Bromatological composition			
Dry matter	917	919	920	931
Organic matter	966	968	967	967
Ash	52.0	51.8	51.6	51.5
Crude protein	115	111	106	105
Total carbohydrates	802	806	811	812
Neutral detergent fiber	511	511	514	510
Non-fiber carbohydrates	290	294	297	302
Ether extract	30.6	30.5	30.3	30.3

[a]Mineral mixture composition: Ca 132.72 (g/kg); P 96.86; (g/kg); S 38.00 (g/kg); Co 66.42 (mg/kg); Cu 1.810.44 (mg/kg); Fe 2.846.46 (mg/kg); I 89.55 (mg/kg); Mn 1774.63 (mg/kg); Se 14.92 (mg/kg); Zn 4.298.51 (mg/kg); F 968.60 (mg/kg).

Table 3. Effect of substitution of corn by popcorn residue on nutrient intake of confined lambs

Nutrients	Substitution levels of corn (g/kg DM)						
	0	333	666	1000	$\hat{Y}$	SEM[a]	*p*value
Dry matter							
kg/day	1.08	1.05	1.02	1.07	1.06	0.39	0.79
% BW	3.26	3.17	3.03	3.15	3.15	0.13	0.58
Organic matter							
kg/day	1.05	1.02	0.99	1.04	1.03	0.38	0.79
Crude protein							
kg/day	0.14	0.13	0.12	0.12	0.13	0.05	0.24
Total carbohydrates							
kg/day	0.85	0.83	0.82	0.86	0.84	0.03	0.87
Neutral detergent fiber							
kg/day	0.48	0.48	0.48	0.49	0.48	0.02	0.93
% BW	1.43	1.46	1.43	1.45	1.44	0.06	0.95
Non-fiber carbohydrates							
kg/day	0.37	0.35	0.34	0.36	0.35	0.01	0.79
Total digestiblenutrients							
kg/day	0.75	0.75	0.75	0.76	0.74	0.04	0.96

[a]Standard error of the mean.

Table 4. Effect of substitution of corn by popcorn residue on nutrients digestibility coefficients in confined lambs

Items	Substitution levels of corn (g/kg DM)				$\hat{Y}$	SEM[a]	*p* value
	0	333	666	1000			
Dry matter	679	720	695	700	689	18.6	0.82
Organic matter	695	732	710	715	713	17.8	0.84
Crude protein	734	758	711	714	729	17.4	0.57
Total carbohydrates	677	720	700	707	701	18.3	0.81
Neutral detergente fiber	536	596	568	560	565	24.8	0.60
Non-fiber carbohydrates	864	891	887	898	885	14.4	0.88
Total digestible nutrients	682	717	697	700	699	42.1	0.85

[a]Standard error of the mean.

Table 5. Effect of substitution of corn by popcorn residue on ingestive behavior of confined lambs

Variables	Substitution levels of corn (g/kg DM)				Ŷ	SEM[a]	*p* value
	0	333	666	1000			
Eating total time							
Minutes	171.67	167.86	173.13	218.33	181.48	7.82	0.10
%	23.84	23.31	24.04	30.32	25.2	1.08	0.11
Idling total time							
Minutes	368.33	346.43	362.5	310	347.96	12.4	0.11
%	51.16	48.12	50.35	43.06	48.33	1.73	0.12
Standing ruminating							
Minutes	55	55	40	66.67	53.15	4.86	0.07
%	7.64	7.64	5.56	9.26	7.38	0.66	0.08
Lying down ruminating							
Minutes	125	149.29	140.63	120.83	135	9.03	0.24
%	17.36	20.73	19.53	16.78	18.75	1.26	0.25
Rumination total time							
Minutes	180	204.29	180.63	187.5	188.15	8.80	0.47
%	25	28.37	25.09	26.04	26.13	1.22	0.48
Chewing total time							
Minutes	351.67	372.14	353.75	405.83	369.63	12.4	0.15
%	48.84	51.69	49.13	56.37	51.34	1.73	0.16
Eating efficiency							
DM[b], g DM/min	6.29	6.61	6.01	5.89	6.21	0.25	0.14
NDF[c], g NDF/min	2.46	2.84	2.72	2.35	2.59	0.12	0.19
Rumination efficiency							
DM, g DM/min	6.37	5.37	5.94	6.26	6.03	0.37	0.55
NDF, g NDF/min	2.50	2.86	2.68	2.82	2.71	0.16	0.69

[a]Standard error of the mean.
[b]Dry matter.
[c]Neutraldetergente fiber.

Table 6. Effect of substitution of corn by popcorn residue on time spent on rumination, ruminal boluses, rumination bouts, ruminating chews, and number of rumination bouts and ruminal boluses in confined lambs

Items	Substitution levels of corn (g/kg DM)				Ŷ	SEM[a]	*p* value
	0	333	666	1000			
Number of ruminal boluses	47.25	50.71	42.13	39.86	44.97	2.42	0.22
Time per ruminal bolus, min	0.99	0.91	1.02	0.96	0.97	0.03	0.31
Ruminating chews, min	86.88	91.50	88.25	85.57	88.13	1.44	0.22
Ruminating chews, min/bolus	0.97	0.92	0.98	0.98	0.96	0.02	0.89
Number of rumination bouts	2.50	2.50	1.83	1.94	2.22	0.12	0.08
Time per rumination bout, min/bout	19.15	19.73	20.92	18.09	19.42	1.57	0.86

[a]Standard error of the mean.

Table 7. Effect of different levels of substitution of corn by popcorn residue in rations of lambs on water intake and number of times that animals defecated, urinated or sought water

Items	Substitution levels of corn (g/kg DM)				Ŷ	SEM[a]	*p* value
	0	333	666	1000			
Wateringestionfrequency	3.19	3.94	3.63	3.69	3.61	0.21	0.61
Defecation frequency	7.63	7.69	5.94	7.25	7.13	0.49	0.11
Urination frequency	4.44	4.25	5.75	5.25	4.92	0.31	0.17
Water intake via feed (g)	97.9	92.4	88.0	79.7	89.5	3.94	0.09
Water intake via drinking (kg)	2.26	2.84	3.13	3.25	2.87	0.19	0.15
Total intake (g)	2.36	2.93	3.22	3.33	2.96	0.19	0.16
Waterintake/DMI (g H_2O/g DM)	2.29	2.81	3.13	3.16	2.89	0.18	0.26

total rumination time, and total chewing time (Table 5). This probably occurred in response to the close percentual values of dry matter and neutral detergent fiber among the rations (Table 2). Rumination time is affected by the content of structural carbohydrates in the diet. Fontenele *et al.* (2011) reported that high-energy diets have low NDF levels and decrease rumination time, whereas fibrous diets have lower energy values and result in longer periods of rumination. Missio *et al.* (2010) verified the response of confined young bulls to increasing levels of NDF in the diet and observed a linear reduction in rumination time as concentrate was added and the NDF content decreased. Forages with a high NDF content induce longer eating, ruminating and chewing periods, as well as raise the need of a more effective processing of dietary fiber, so it can pass through the ruminant digestive tract. This fact corroborates with Branco *et al.* (2011), who evaluated five forage NDF concentrations forage on performance of lactating goats and found a linear positive effect in eating and rumination time. According to Argôlo *et al.* (2013), factors that may affect ingestive behavior are related to the feed (type and quality), the environment, and the animal. Argenta *et al.* (2013) reported that confined animals spend about one hour consuming energy-rich feeds or even more than six hours for sources with low energy content. This author also stated that rumination time is influenced by the nature of the diet and seems to be proportional to the cell wall content of roughages; in other words, the higher the amount of roughage fed, the longer the time spent on rumination.

It was also observed that the animals spent a considerable amount of time idling. However, they spent the largest portion of the day in chewing activity (eating and ruminating). This behavior is consistent with the consulted literature, as ruminants spend most of the day engaged in chewing activities (Magalhães *et al*., 2012).

Magalhães *et al*. (2012) found similar results when evaluating the ingestive behavior of sheep fed with sugar cane that had been ensiled with calcium oxide or urea, where no significant differences were seen in time spent ruminating or eating. The replacement of corn by the popcorn residue in the ration of lambs did not influence (*P*>0.05) the number of rumination bouts and ruminal boluses, time per ruminal bolus, ruminating chews, nor the ruminating time per rumination bout (Table 6), which possibly occurred in response to similar amounts of physically effective fiber present in the experimental rations. These results were confirmed by Azevedo *et al*. (2013) for the number of ruminating chews per bolus and time of ruminating chews per ruminal bolus when these authors studied the ingestive behavior of sheep fed with increasing proportions of “macauba” cake (*Acrocomiaaculeata* (lacq) Lood. ex Mart) in isonitrogenous diets containing 15% of crude protein.

No significant effect (*P*>0.05) of treatments were detected on eating efficiency and rumination efficiency of DM and NDF, which was certainly caused by the close values of NDF intake among treatments (455.20 g/day on average), as NDF intake may influence feeding and rumination efficiency. As stated by Vieira *et al*. (2011), ruminating and feeding efficiency is related to chewing activity, the latest tending to decrease depending on roughage:concentrate ratio and reduction of NDF in the diet. Thus, this statement reinforces the results observed in the present study, which can be verified in the variables total chewing time and ruminating chews (Tables 5 and 6). The number of times that animals sought water, defecated or urinated was not significantly different (*P*>0.05) among treatments (Table 7). This outcome is coherent with the homogeneous water content of the experimental diets. There was also no effect of treatments on the number of times that animals urinated, as urination is proportional to water consumption. It can be observed that different levels of substitution of corn by the popcorn residue did not influence water intake in any of the variables tested (*P*>0.05), either via feed or drinking. This is related to the similarity in the percentage of water, crude protein, and mineral salt among treatments; according to Souza *et al*. (2015), voluntary water intake by sheep is linked to dry matter intake, crude protein, and mineral salt content in the diets. Neto *et al*. (2016), evaluating water balance and renal excretion of metabolites by sheep fed prickly pear and Tifton hay, verified that water consumption was not affected by feeding. As stated by these authors, animals that consumed Tifton hay plus prickly pear showed lower water consumption. Since animals can meet their water requirement directly via water ingestion or feed, or via metabolic water, this observation is coherent. Succulent feeds, characterized by high concentration of water and low dry matter content such as the prickly pear, the “mandacaru” (*Cereus jamacaru*), fresh grass and legume species, and the forage watermelon (*Citrulluslanatus* cv. Citroides) may constitute valuable sources of water for animals raised in regions of low water availability, as are goats and sheep in the Brazilian semi-arid region.

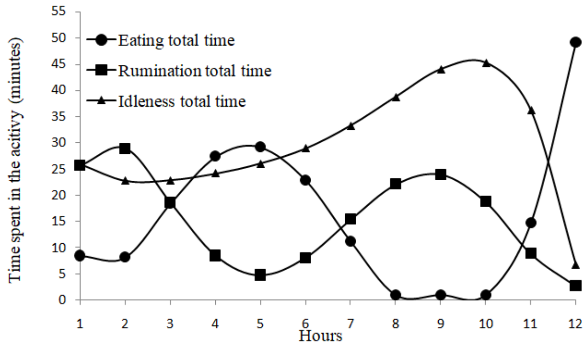

Figure 1. Effect of substitution of corn by popcorn residue oneating total time, rumination total time, and idling total time in confined lambs

Figure 1 confirms that behavioral patterns chnage throughout the day (*P*>0.05). The lambs showed more rumination activity in the first and second hours of observation (from 5:30 to 7:30), and eighth, ninth, and tenth hours of observation (from 12:30 to 15:30). Eating time was affected by feed delivery, where more eating activity was detected in the first hours after feed offer (8:00 and 16:00 hours). These are consistent observations, as ingestive activities are dictated by feed delivery, which driveanimals to eat. The time spent on ingestion are interspersed with one or more periods of rumination or idleness (Argenta *et al*., 2013). These authors also reported highest peaks of rumination at night; nonetheless, the rumination periods are determined by feeding, time of feeding and its frequency.

Conclusion

The substitution of corn by popcorn residue represents a viable alternative, as it had no effect on intake and digestibility of nutrients, as well as on the ingestive behavior of the animals, demonstrating the potential of the popcorn residue for replacing corn in the diet of sheep.

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