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ARTICLE

Ingestive Behavior and Nutritional and Physiological Parameters of Sheep Fed Diets Based on Cashew Byproduct

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ABSTRACT

Objective of this study was to evaluate the ingestive behavior, feed efficiency, and nutritional and physiological parameters of sheep that were fed diets based on byproducts from the processing of cashew. The experiment was conducted in a completely randomized design with a 4 × 2 factorial arrangement with four levels of inclusion (6 %, 11 %, 16 %, and 21 % of cashew byproduct) and two forms of processing—with chemical treatment (CT) and without chemical treatment (NCT). The interaction levels of inclusion of the byproduct of cashew versus chemical treatments was not (P>0.05) for the dry matter intake, consumption of organic matter. No effect was observed (P>0.05) for the intake of dry matter in function of the type of chemical treatment used in the byproduct of cashew. There was no effect of interaction (P<0.05) between levels of inclusion and chemical treatment applied or not on the byproduct of cashew for the coefficients of digestibility of dry matter, organic matter and crude protein (P>0.05). The inclusion of the byproduct of cashew did not influence the behavioral parameters, intake and digestibility of the diets of sheep, being recommended to use up to the level of 21%.

1. Introduction

Raising sheep in the Northeast region of Brazil is of great social and economic relevance for to supply meat that is easily accessible/available to rural populations and populations at the peripheries of large cities. In this region, forage production shows strong seasonal variation mainly because of the poor distribution of rainfall and long periods of drought. Combined with low forage production, the seasonality of rainfall has a strong influence on the production of green mass per hectare and the nutritional value of fibrous sources of fodder provided

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to ruminants. This explains, in part, the sharp decrease in the productivity of herds of ruminants in traditional systems, particularly in periods of drought [1].

In an effort to reduce input costs, the use of agroindustrial byproducts to replace fiber sources in the diets of ruminants is increasing owing to an increase in the production of the national fruit. However, these byproducts have a high content of polyphenolic compounds that hinder the utilization of nutrients by animals [2].

Urea application is widely employed to increase the bioavailability of nutrients and improve the nutritional value of byproducts [3,4], however, its effects on animal behavior are still unknown.

The addition of urea to byproducts modifies the ingestive behavior of animals, as it is correlated with the physical and chemical characteristics of food and consequently the transit time of digestion, motility of the pre-stomachs, and feed grinding fineness and power level required. Chewing, in turn, is related to the size of the particles that reach the rumen and this interferes with the digestion of food and consequently influences consumption [5]. Rumination time is influenced by the nature of the diet and is proportional to the cell wall content of the byproduct in the feed [6]. Thus, the assessment of eating behavior, composed of the time of feeding, rumination, and leisure and efficiencies of feeding and rumination, can assist in evaluations of diets and allow the adjustment of food management for improved productive performance [7].

The objectives of this study were to evaluate the ingestive behavior, feed efficiency, and nutritional and physiological parameters of sheep that were fed diets based on byproducts from the processing of cashew, with and without the addition of urea.

2. Materials and Methods

The experiment was performed from March 22 to April 22, 2006, in the sector of animal digestibility, at Vale do Acaraú, experimental farm, Universidade Estadual Vale do Acaraú - UVA, in Sobral, Ceará. The physiographic zone of the Sertão region of Ceará is 3º36′S, 40º18′W, at an altitude of 56 m.

The region has BSh type climate (Köppen classification), dry weather, and receives approximately 888.9 mm during the rainy season (January to June), corresponding to 92.6 % of the total yearly rainfall. The annual maximum, average, and minimum temperatures are approximately 33.3, 26.6 and 22.0 °C, respectively, and the annual average relative humidity is 67.9 %.

The agroindustrial byproduct of cashew (*Anacardium occidentale* L.) was obtained from Cajubrás-SA, located in Pacajus-CE and was composed of bagasse of cashew pseudofruit after extraction of the juice and drying in the sun. The hay was prepared from Aruana grass (*Panicum maximum* "Aruana"). The cotton pie and maize grain were obtained from Sobral in sufficient quantity for the realization of the entire experiment.

The cashew byproduct was treated with urea before the start of the experiment. The amount of urea added was calculated as 5 % of the weight of the dry byproduct (5 kg urea per 100 kg byproduct) diluted with water at a 1:4 ratio. The cashew byproduct was treated by distributing the urea solution using a watering can, then covered with plastic for 20 days, without adding a urease source [8].

The experiment was conducted in a completely randomized design with a 4 × 2 factorial arrangement with four levels of inclusion (6 %, 11 %, 16 %, and 21 % of cashew byproduct) and two forms of processing—with (CT) and without chemical (NCT) treatment. Three animals per treatment were used, and the experiment lasted 34 days, with 27 days corresponding to the period of adaptation (when the leftovers were between 15 % and 20 %) and seven days for collection. The supply of the ration was divided over two feeding times (08:00 and 17:00).

For the determination of consumption, food and orts were collected before the supply during the collection period; moreover, feces were collected and aliquots of 20 % of the total weight were weighed, stored in plastic bags, and stored at -20 °C. At the end of the experiment, the material was thawed and ground to pass through 1 mm sieve for chemical analysis.

For determination of dry matter (DM), organic matter (OM) and ash, ether extract, and crude protein (CP), the methodology proposed by [9] was followed. Quantification of the neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, hemicellulose, and lignins was performed according to the methodology proposed by [10]. These analyses were performed at the Center of Agricultural and Biological Sciences of the Universidade Estadual Vale do Acaraú (Sobral - Ceará) (Table 1, 2).

For calculation of the TDN of the experimental diets, we used the equation recommended by the [11]. The percentage of total carbohydrates (CHOT) was calculated using the equation proposed by [12] and that of non-fibrous carbohydrates (NFC) was calculated using the equation suggested by [13]. The coefficients of digestibility of DM, OM, CP, and NDF were determined using the following formula: [(consumption of nutrient in grams - quantity of the nutrient in feces)/consumption of nutrient in grams]/100 [14].

The collection of ruminal fluid for measurements of ruminal pH in 4 pre-established times (0 h or prior to the delivery of the diet, 2, 5, and 8 h postprandial) was per-

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formed using an esophageal probe. The pH was measured immediately after the collection of ruminal fluid. Samples of approximately 50 ml of rumen fluid were acidified in 1 ml of sulfuric acid (1:1) and stored at -5 °C for future analysis of $N\text{-}NH_3$, which were carried out at the Laboratory of Animal Nutrition, Universidade Estadual Vale do Acaraú -UVA.

Ammoniacal nitrogen in the rumen fluid was determined by distillation with magnesium oxide, using boric acid containing a mixed indicator of methyl red and bromocresol green and titrating with 0.1N HCl.

Blood collection was performed by puncturing the jugular vein at the same time as the ruminal fluid was collected. The dosage of urea was measured using Bioclin kits at the Laboratory of Animal Nutrition, Universidade Estadual Vale do Acaraú -UVA and Bromatology Laboratory of the Center of Technological Education (CENTEC - Unidade Sobral).

The behavioral assessments of sheep were performed by recording time spent on food, rumination, idle, and other activities, through visual observation of the animals every 5 min, for 24 h [15]. The average number of chewing merícicas by ruminal boli, and the average time spent chewing merícica by ruminal boluses were obtained in three periods of 2 h, registering three values distributed in zones of 10–12 h, 14–16 h, and 18–20 h, by using a digital chronometer. For observations at night, the environment was maintained with artificial lighting. The results regarding factors of ingestive behavior were obtained using the following equations: FE = DMI/FT; RE = DMI/RT; ERndf = NDFI/RT; CTT = FT+ RT; BOL = RT/TCB; NCB = BOL/TCB, where FE (grams of DM h^{-1}) is feed efficiency, DMI (g day^{-1}) is dry matter intake, FT (h day^{-1}) corresponds to the time of feeding, RE (g DM h^{-1}; g NDF h^{-1}) is rumination efficiency, RT (h day^{-1}) is rumination time, CTT (h day^{-1}), total time spent chewing, BOL (No. day^{-1}) is the number of boli, TCB (s per bolus) is the time spent chewing per bolus (POLLI et al., 1996), NC (No day^{-1}) is the number of chews, and NCB (No dia^{-1}) is the number of chews per bolus. The boli was considered as the portion of food that returns to the mouth to undergo the process of rumination.

Data were initially subjected to normality (Cramer–von Mises) and homoscedasticity (Levene) tests. When the assumptions were met, analysis of variance was performed using F-test. In case of significant differences, means were compared by Student–Newman–Keuls (SNK) test at the 5 % probability level. Statistical analyses were run using the GLM procedure of SAS 9.0 software (2002).

For consumption data, digestibility and behavior were analyzed by using the following statistical model:

$$Y_{ijk} = \mu + H_j + G_k + HG_{jk} + e_{ijk}$$

where,

Y_{ijk} = Value for the observation of the repetition of the level of inclusion j versus chemical treatment k; μ = Overall average; H_j = Effect of level of inclusion j (j = 1, 2, 3, 4); G_k = Effect of chemical treatment k (k = 1, 2) HG_{jk} = Interaction of the effects of the inclusion level j to chemical treatment k; e_{ijk} = Random error associated with the observation.

For the data pertaining to pH, ammonia nitrogen in the rumen fluid and blood urea were analyzed by using the following statistical model:

$$Y_{ijklm} = \mu + H_i + G_j + (H \times Gj) + \alpha_{ijk} + T_l + (H \times T_{il}) + (G \times T_{jl}) + (H \times G \times T_{ijl}) + \varepsilon_{ijklm},$$

where Y_{ijklm} This is the dependent variable; μ Overall average; H_i Effect of level of inclusion; Gj Effect of chemical treatment; (H x Gij) Interaction of the effects of the inclusion level to chemical treatment; α_{ijk} Effect of random error, where the variance of animals within the treatments (H + G + H x G); T_l It is the fixed effect of time of collection; (H x T) It is the fixed effect of the interaction between the level of inclusion and the time of collection; (G x T) It is the fixed effect of the interaction between the chemical treatment and the time of collection; (H x G x T) It is the fixed effect of the interaction between the levels of inclusion, chemical treatment and the time of collection; is ε_{ijklm} It is the effect of random error.

3. Results and Discussion

The interactions between levels of inclusion of the cashew byproduct and chemical treatments were not significant ($P > 0.05$) for dry matter intake (DMI) or intake of organic matter. No effect was observed ($P > 0.05$) on DMI by type of chemical treatment used in the cashew byproduct (Table 3).

The average daily consumption of dry matter intake was 1045, 1 g day^{-1}, greater than that observed by [16] when providing diets containing ammoniated elephant grass, cocoa meal, and palm kernel cake (928 g day^{-1}). [17] evaluated the inclusion of cane sugar *in natura* or ensiled with calcium oxide and urea in sheep diets and observed higher DMI in g day^{-1} for sugar cane diet treated with 0.5 % urea (748.86 g day^{-1}) than supplied *in natura* (618.07 g day^{-1}). The average consumption of experimental treatments was 683.47 g day^{-1}, which is lower than that found in the present study (1045.10 g day^{-1}).

No differences were observed ($P > 0.05$) in the consumption of organic matter between the diets. Consumption might not have differed between diets because the

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nutrient levels of the diets were not affected, making the diets isonutritive. Consumption was lower than that observed by [18] who also evaluated byproducts. Reductions in consumption might be associated with odors or unpleasant tastes and/or digestive effects on the rate of passage, which is due to the different profiles of each byproduct [19]. Animals might also adjust DMI and organic matter intake according to their energy intake [20].

The inclusion of different levels of cashew byproduct with chemical treatment (CT) and without chemical treatment (NCT) did not influence the consumption of protein. The average values of consumption were higher than those recommended by the [21]. Additional research is required to evaluate the form of chemical treatment required for the cashew byproducts and the consumption of metabolizable protein in diets that contain these byproducts should be measured to ascertain the most efficient use and absorption of dietary protein.

There was a significant interaction ($P > 0.05$) between levels of inclusion of cashew byproduct with CT and NCT byproduct on the consumption of ether extract (g day ^{1}) (Table 3). The consumption of ether extract in the diet containing 21 % of byproduct and NCT was higher (60.31 g day^{-1}) than the same level of inclusion of byproduct with CT (29.66 g day^{-1}). These data demonstrate that caution must be taken before adding chemically treated cashew byproduct at high levels of inclusion (above 11 %).

There was no ($P > 0.05$) interaction between the levels of inclusion of the cashew byproduct with CT or NCT on NDF intake (g day ^{1}). The average NDF intake of animals that received the cashew byproduct with CT was always higher than that of animals that received the cashew byproduct with NCT. There were differences between the levels of inclusion on the consumptions of NDF (g day ^{1}). According to [22], fiber can be defined as the structural components of plants (cell walls), the fraction of less digestible food, the fraction of the food that is not digested by enzymes in mammals, or the fraction of the food that promotes rumination and the health of the rumen.

The [21] does not specify values of minimum fiber consumption for sheep. However, Santa Inês sheep with an average live weight of 45 kg require at least 28.05 % NDF for adequate ruminal function [23]. In our study, all values exceeded this minimum recommendation.

There was no interaction ($P < 0.05$) between levels of inclusion of the cashew byproduct and CT or NCT of the byproduct on the coefficients of digestibility of DM, OM, and CP ($P > 0.05$) (Table 4). No differences were observed between the averages of inclusion and CT or NCT of the cashew byproduct for these parameters.

We observed interaction ($P < 0.05$) between levels of inclusion of cashew byproduct and CT or NCT of the byproduct (Table 4). A diet that included 21 % of the NCT cashew byproduct presented higher ether extract digestibility (86.82 %) than 21 % of the CT byproduct diet (67.73 %) ($P < 0.05$). The other levels of inclusion did not differ significantly ($P > 0.05$). This probably compromised the consumption of ether extract at this level for diets with CT, given the high correlation between digestibility and consumption of ether extract.

Consistent with our results, [16] also observed no statistical differences for the coefficients of digestibility of DM, OM, and CP when sheep were fed with diets containing ammoniated elephant grass, cocoa meal, and palm pie. The ammoniation did not interfere in the coefficient of digestibility of ether extract, differing from the results obtained in our study, but despite this, the average coefficient of digestibility observed here (81.76 %) was higher than that found by [16] (72.87 %). The average coefficient of digestibility of MS (58.83 %) was similar to the average values obtained by [24] (58.58 %) when sheep were provided with ammoniated rice straw. For the digestibility of the OM, values were similar to those reported by [16], being 65.07 % and 65.93 % respectively.

No interaction ($P > 0.05$) was observed between levels of inclusion of the cashew byproduct with CT or with NCT (Table 4). The material treated with urea showed higher digestibility of NDF, which can be coupled to the fact that the technique of ammoniation improved the quality of the fiber. [25] proposed that the effect of treatment with urea on digestibility of NDF was due to its effect of breaking the ester links between the components of the cell walls and the phenolic acids and the depolarization of lignin. Ammoniation promotes the increased fermentable carbohydrate content, which results in an increase in the digestibility and consumption of CT fibrous materials [6].

No interaction was observed ($P < 0.05$) between treatments and collection times (Table 5). Eight hours postprandial the pH levels of inclusion of 16 % and 21 % of the NCT cashew byproduct presented higher values that that of 16 % CT byproduct; these were similar to other levels of inclusion with or without chemical treatment. Collection of ruminal fluid 8 h postprandial presented an average pH of 8.01, higher than at other times of collection. The average pH values obtained in this study remained within the average recommended by [26], i.e., between 6.0 and 8.0, compatible with the action of the enzymes of these microorganisms. [27] pointed out that the pH is the factor with the most influence on the ruminal ecosystem. The bacteria that degrade cellulose and produce methane are quite sensitive to pH lower than 6.0.

The adjustment of the pH depends on the transit of

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fatty acids through the ruminal wall and the secretion of bases inside the wall [6]. According to this author, the urea can be rapidly hydrolyzed to ammonium bicarbonate.

We observed a significant interaction (P < 0.05) between the time of collection and level of inclusion of the byproduct and between the time of collection and level of inclusion and CT or NCT (Table 5). After 2 h, the postprandial levels of 11, 16, and 21 % CT cashew byproduct showed higher concentrations of NH_3-N in relation to the other collection times. The lowest concentration was observed in the level of 16 % NCT byproduct, similar to the levels of 6, 11, and 21 % NCT cashew byproduct.

These data revealed the possible imbalance in the dietary energy to protein ratio that elevated concentrations of ammoniacal nitrogen in the rumen fluid. [28] emphasized that it is of utmost importance to optimize ruminal microbial protein synthesis. For this to be possible, the most important factor, besides soluble nitrogen and a certain amount of pre-formed amino acids, is the available amount of fermentable organic matter for microorganisms, i.e., the availability of energy.

The lowest concentration of microbial protein was obtained when provided 16 % of NCT cashew byproduct. The highest concentration was obtained in the second hour postprandial hyperglycemia (15.39 mg dL^{-1}) and the lowest was for the time zero. A minimum concentration of 10 mg/100 ml of ammonia in the rumen is necessary to allow adequate microbial fermentation [6]. Moreover, [29], evaluating the effect of ammonia concentration on the production of microbial protein, concluded that 5 mg of ammonia per 100 mL of rumen contents is sufficient for the maintenance of the ruminal microorganisms.

There was no interaction (P > 0.05) between inclusion level, time of collection, and CT or NCT on the levels of plasma urea (P > 0.05). There were no significant differences between the times of collection. As for the levels of inclusion, considering the chemical treatment or not with urea, 6 % with CT had the highest concentration of serum urea. The 6 % level of inclusion of the cashew byproduct had the second largest concentration of NH_3-N in relation to the 21 % with CT level, with both being similar to other experimental treatments.

Ammonia is a primary derivative of amino acid catabolism by ruminal bacteria, removed by the liver, and incorporated into the urea cycle, resulting in the formation of urea and eventual excretion by kidneys [30]. The concentrations of serum urea can give evidence of ruminal protein availability and adequate supply of protein in the diet. Below normal values may indicate a deficiency in supply or pathological states; normal values of urea for sheep are between 18 and 31 mg dL^{-1} of serum.

There was no interaction (P > 0.05) between levels of inclusion and the chemical treatment for the time spent with food (TF), rumination (TR), idle, (TI) and other activities (TOA) (Table 6).

For the TF the 21 % level of inclusion provided greater time than the 11 and 16 % levels, these three were similar to the 6 % level. This increase in TF observed in the 21 % level of inclusion of byproduct could have been caused by the increase in the fiber content of the diet, as increasing the amount of fiber in diets stimulates the masticatory activity [31]. A fact evidenced by [32], who evaluated the effect of five levels of NDF (20, 27, 34, 41, and 48 %) in the diet of goats, and found an increase in the time of ingestion and rumination and reduction of idleness with the elevation of levels of NDF in the diet.

[32] described rumination as a physiological feature for the best utilization of food, which begins when the time of feed supply decreases. This was not observed in our study, perhaps because the efficiency of rumination (DM and NDF) (Table 7) was not affected by the levels of inclusion or by CT or NCT of the cashew byproduct. The TI and TOA also showed no differences between the levels of inclusion or between CT and NCT.

[32] evaluating the ingestive behavior of sheep fed diets composed of elephant grass silage ammoniated or not and agroindustrial byproducts, observed that the animals that consumed ammoniated elephant grass silage presented a shorter time spent with rumination.

[5] also observed differences in rumination time between experimental treatments, with a shorter rumination time at a greater level of inclusion of cashew byproduct (5.33) than the lower level of inclusion (4.19).

There was no interaction (P < 0.05) between levels of inclusion and chemical treatment on power efficiency (Table 7). The 16 % NCT level of inclusion (366.40) provided a better power efficiency than the same level of inclusion with CT (307.64) and was superior to other levels of inclusion with NCT. The diets containing 11 and 16 % of cashew byproduct promoted better efficiency of supply in relation to the levels of inclusion of 6 and 21 %. This probably occurred because these levels (11 and 16 %) presented shorter supply, since there was a high negative correlation between the time of food and energy supply (r = -0.8512; P < 0.0001).

There was no interaction (P > 0.05) between levels of inclusion and chemical treatment for the rumination efficiency parameters (DM and NDF), chewing time, total number of ruminal boli per day, the number of chews per day, the number of chews per boli, and chew times for boli (Table 7). The number of chews per day were higher in CT cashew byproduct (20.947) than in NTC byproduct

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(20.201). This may have occurred due to the higher value of NDF and ADF present in diets containing CT cashew byproducts.

4. Conclusions

Chemical treatment improved the digestibility of fiber, consequently improved the consumption of fibrous constituents, and did not alter the intake of dry matter, organic matter, or crude protein.

The levels of inclusion of byproduct did not affect ingestive behavior, feed efficiency, or efficiency of rumination. The chemical treatment increased the time spent chewing.

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Appendixes: Tables

Table 1. Chemical composition of ingredients menus offered to sheep

Component	*By-product of cashew without chemical treatment*	*By-product of cashew with chemical treatment*	*Hay of Aruana*	*Grain of corn*	*Cotton cake*
Dry matter[a]	88.32	90.52	87.26	88.39	92.70
Crude protein[b]	15.28	23.88	9.09	11.24	27.63
NDIN[b]	2.36	3.60	1.33	1.65	1.27
ADIN[b]	2.30	3.74	1.27	0.08	1.16
Ether extract[b]	4.00	0.76	2.94	3.85	9.24
NDF[b]	68.34	86.97	85.26	31.68	55.93
ADF[b]	47.89	62.45	45.73	3.90	38.94
Hemicelluloses[b]	20.45	24.52	39.54	27.77	16.99
Cellulose[b]	22.70	6.49	38.81	3.73	28.32
Lignin[b]	21.84	62.08	4.22	0.31	10.58
Ash[b]	5.18	4.25	8.73	1.60	4.34
Ca[b]	0.80	0.77	1.19	0.88	1.09
TC[b]	75.54	71.11	79.24	83.31	58.79
NFC[b]	21.58	7.69	1.92	52.13	10.11
TDN[b]	44.67	8.65	55.44	77.22	71.06

Note: [a] % natural matter; [b]% the dry matter; DM=Dry matter; CP=Crude protein; NDIN = Neutral detergent insoluble nitrogen; ADIN = acid detergent insoluble nitrogen; NDF = neutral detergent fiber; ADF = acid detergent fiber; CT = Total Carbohydrates; NFC = non-fibrous carbohydrates; NDT = total digestible nutrients as NRC (2001)

Table 2. The chemical composition of the experimental diets

Componentes	**Experimental diets**							
	6		11		16		21	
	Without chemical treatment	With chemical treatment	Without chemical treatment	With chemical treatment	Without chemical treatment	With chemical treatment	Without chemical treatment	With chemical treatment
Dry matter[a]	89.42	89.54	88.80	89.04	88.98	89.33	89.35	89.81
Crude protein[b]	15.86	16.35	13.87	14.84	14.68	16.03	14.37	16.18
NDIN[b]	1.50	1.57	1.58	1.72	1.61	1.80	1.67	1.93
ADIN[b]	0.82	0.90	0.84	1.01	0.94	1.17	1.02	1.32
Ether extract[b]	5.25	5.07	4.52	4.16	4.74	4.23	4.58	3.90
NDF[b]	54.10	55.17	54.85	56.95	55.59	58.53	56.55	60.48
ADF[b]	27.10	27.93	26.44	28.09	28.26	30.55	29.11	32.19
Hemicelluloses[b]	27.00	27.23	28.40	28.86	27.33	27.97	27.44	28.29
Cellulose[b]	20.73	19.81	19.80	17.97	20.36	17.80	20.30	16.88
Lignin[b]	5.57	7.86	5.57	10.11	6.75	13.09	7.51	16.00

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Ash[b]	4.36	4.31	4.45	4.35	4.48	4.33	4.54	4.34
Ca[b]	1.01	1.01	0.99	0.99	0.99	0.98	0.98	0.97
TC[b]	74.55	74.29	77.16	76.66	76.11	75.41	77.11	76.18
NFC[b]	25.55	24.75	27.59	26.00	26.40	24.19	26.31	23.34
TDN[b]	65.79	78.08	67.35	60.07	57.41	65.81	64.64	62.39

Note: [a] % natural matter; [b]% the dry matter; DM=Dry matter; CP=Crude protein; NDIN = Neutral detergent insoluble nitrogen; ADIN = acid detergent insoluble nitrogen; NDF = neutral detergent fiber; ADF = acid detergent fiber; CT = Total Carbohydrates; NFC = non-fibrous carbohydrates; NDT = total digestible nutrients as NRC (2001)

Table 3. Daily intake of dry material and nutrient requirements of sheep fed levels of inclusion of the byproduct of cashew with or without chemical treatment

Chemical treatment	**Levels of inclusion of the byproduct of cashew (%)**				**Means**
	6	11	16	21	
Dry matter intake (g day^{-1}) (CV=17.88%)					
Without chemical treatment	921.93	1001.41	1090.28	1093.43	1026.76^{A}
With chemical treatment	1011.79	1184.21	1068.10	989.66	1063.44^{A}
Means	966.86^{a}	1092.81^{a}	1079.19^{a}	1041.55^{a}	
Organic matter intake (g day^{-1}) (CV=17.92%)					
Without chemical treatment	894.80	972.56	1057.80	1059.28	996.11^{A}
With chemical treatment	976.00	1143.45	1029.30	952.06	1025.20^{A}
Means	935.40^{a}	1058.01^{a}	1043.01^{a}	1005.67^{a}	
Crude protein intake (g day^{-1}) (CV=16.80%)					
Without chemical treatment	158.03	169.84	181.55	188.45	174.47^{A}
With chemical treatment	197.97	191.26	168.14	149.03	176.60^{A}
Means	177.10^{a}	170.55^{a}	174.81^{a}	168.74^{a}	
Ether extract intake (g day^{-1}) (CV=16.24%)					
Without chemical treatment	50.77	54.17	58.30	60.31	55.89^{A}
With chemical treatment	54.91	52.87	39.34	29.66	44.19^{B}
Means	52.84^{a}	53.52^{a}	48.82^{a}	44.99^{a}	
Neutral detergent fiber intake (g day^{-1}) (CV=18.90%)					
Without chemical treatment	477.89	520.77	567.52	546.74	528.23^{B}
With chemical treatment	564.76	686.11	652.22	658.61	640.43^{A}
Means	521.33^{a}	603.44^{a}	609.87^{a}	602.67^{a}	

Note: Means followed by different letters uppercase and lowercase letters columns in the lines differ by SNK test at 5% probability.

Table 4. Coefficients of digestibility of dry material and nutrients in sheep fed with levels of inclusion of the byproduct of cashew with or without chemical treatment

Chemical treatment	**Levels of inclusion of the byproduct of cashew (%)**				**Means**
	6	11	16	21	
Digestibility of dry matter (%) (CV=10.14%)					
Without chemical treatment	59.22	62.69	52.77	59.99	58.67^{A}
With chemical treatment	60.62	54.90	62.24	58.17	58.98^{A}
Means	59.92^{a}	58.80^{a}	57.50^{a}	59.09^{a}	
Digestibility of organic matter (%) (CV=8.17%)					
Without chemical treatment	66.53	68.53	59.17	65.36	65.23^{A}
With chemical treatment	66.49	62.04	67.49	64.92	64.90^{A}
Means	66.51^{a}	65.28^{a}	63.33^{a}	65.14^{a}	

Digestibility of crude protein (%) (CV=11.76%)					
Without chemical treatment	60.72	56.71	49.27	56.49	55.80^{A}
With chemical treatment	68.57	50.63	60.54	59.02	59.69^{A}
Means	64.65^{a}	53.67^{a}	54.91^{a}	57.76^{a}	
Digestibility of ether extract (%) (CV=6.54%)					
Without chemical treatment	82.83^{Aa}	86.82^{Aa}	82.54^{Aa}	86.82^{Aa}	85.35
With chemical treatment	84.15^{Aa}	83.37^{Aa}	77.38^{Aa}	67.73^{Bb}	78.16
Means	83.49	85.09	79.96	78.47	
Digestibility of neutral detergent fiber (CV=20.51%)					
Without chemical treatment	46.49	47.79	31.57	35.63	40.37^{B}
With chemical treatment	50.36	43.97	53.60	50.60	49.39^{A}
Means	48.42^{a}	42.38^{a}	42.59^{a}	43.12^{a}	

Note: Means followed by different letters uppercase and lowercase letters columns in the lines differ by SNK test at 5% probability.

Table 5. Average values of pH, ammoniacal nitrogen (NH_3-N) in the ruminal fluid and blood urea (mg dL^{-1}) of sheep fed levels of inclusion of the byproduct of cashew with or without chemical treatment

Levels of inclusion (%)	Treatment	Collection times (Hours)				
		0	2	5	8	Means
pH						
6	Without chemical treatment	7.53^{Aa}	7.13^{Aa}	7.50^{Aa}	7.93^{Aa}	7.53^{AB}
	With chemical treatment	7.47^{Aa}	7.17^{Aa}	7.53^{Aa}	8.60^{Aa}	7.69^{AB}
11	Without chemical treatment	7.83^{Aa}	7.53^{Aa}	6.53^{Aa}	7.40^{ABa}	7.33^{AB}
	With chemical treatment	7.50^{Aa}	7.30^{Aa}	7.70^{Aa}	8.07^{ABa}	7.64^{AB}
16	Without chemical treatment	7.83^{Aa}	7.53^{Aa}	8.23^{Aa}	8.70^{Aa}	8.08^{A}
	With chemical treatment	6.60^{Aa}	7.97^{Aa}	7.47^{Aa}	6.73^{Ba}	7.04^{B}
21	Without chemical treatment	7.80^{Aa}	7.33^{Aa}	8.03^{Aa}	8.40^{Aa}	7.09^{A}
	With chemical treatment	7.70^{Aa}	7.00^{Aa}	7.40^{Aa}	8.27^{ABa}	7.59^{AB}
Means		7.53^{b}	7.30^{b}	7.55^{b}	8.01^{a}	
NH_3-N (mg dL^{-1})						
6	Without chemical treatment	2.99^{Ab}	11.95^{BCa}	8.46^{Ba}	10.21^{Ba}	8.40^{CD}
	With chemical treatment	5.27^{Ab}	14.49^{Ba}	16.03^{Aa}	12.01^{ABa}	11.95^{AB}
11	Without chemical treatment	4.74^{Ab}	11.98^{BCa}	11.23^{ABa}	9.97^{Ba}	9.48^{BCD}
	With chemical treatment	3.48^{Ac}	19.86^{Aa}	12.64^{ABb}	15.90^{Aab}	12.97^{A}
16	Without chemical treatment	5.77^{Aa}	8.02^{Ca}	8.00^{Ba}	6.01^{Ba}	6.95^{D}
	With chemical treatment	3.21^{Ab}	24.96^{Aa}	8.16^{Bb}	5.42^{Bb}	10.44^{ABC}
21	Without chemical treatment	4.89^{Ab}	11.02^{BCa}	11.54^{ABa}	8.97^{Bab}	9.11^{BCD}
	With chemical treatment	2.76^{Ac}	20.79^{Aa}	9.77^{Bb}	6.01^{Bbc}	9.83^{BCD}
Means		4.14^{c}	15.39^{a}	10.73^{b}	9.31^{b}	
Urea plasm (mg dL^{-1})						
6	Without chemical treatment	38.82^{Aa}	39.25^{Aa}	26.48^{Ba}	38.42^{Aa}	35.74^{B}
	With chemical treatment	39.83^{Aa}	48.63^{Aa}	49.66^{Aa}	34.97^{Aa}	43.27^{A}
11	Without chemical treatment	28.99^{Aa}	27.41^{Aa}	32.39^{Aba}	37.31^{Aa}	31.53^{BC}
	With chemical treatment	22.35^{Aa}	29.62^{Aa}	24.72^{Ba}	31.46^{ABa}	27.04^{BC}
16	Without chemical treatment	28.94^{Aa}	33.74^{Aa}	27.08^{Ba}	36.89^{Aa}	31.66^{BC}
	With chemical treatment	23.01^{Aa}	34.17^{Aa}	33.62^{Ba}	33.84^{Aa}	31.16^{BC}

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21	Without chemical treatment	32.74[Aa]	30.17[Aa]	27.83[Ba]	18.13[ABa]	27.22[BC]
	With chemical treatment	16.55[Aab]	33.54[Aa]	30.45[ABab]	13.73[Bb]	23.57[C]
Means		28.90[a]	34.57[a]	31.53[a]	30.59[a]	

Note: [1] Letters equal in the same column indicate statistical similarity to 5% (SNK) [2] Lowercase equal in the same line indicate statistical similarity to 5% (SNK) CV= 23.06%

Table 6. Feeding behavior of sheep receiving different levels of inclusion of the byproduct of cashew with or without chemical treatment

Chemical treatment	**Levels of inclusion of the byproduct of cashew (%)**				**Means**
	6	11	16	21	
Feeding Time (CV=16.95%)					
Without chemical treatment	4.56	4.08	3.06	5.61	4.33[A]
With chemical treatment	5.14	3.94	4.64	4.94	4.67[A]
Means	4.85[ab]	4.01[b]	3.85[b]	5.28[a]	
Ruminantion time (CV=22.44%)					
Without chemical treatment	6.08	6.67	6.47	5.78	6.25[A]
With chemical treatment	5.69	6.67	7.19	7.00	6.64[A]
Means	5.89[a]	6.67[a]	6.83[a]	6.39[a]	
Idle time (CV=18.66%)					
Without chemical treatment	7.64	9.86	8.64	7.06	8.30[A]
With chemical treatment	6.97	7.06	7.97	6.44	7.11[A]
Means	7.31[a]	8.46[a]	8.31[a]	6.75[a]	
Others activities time (CV=21.62%)					
Without chemical treatment	5.72	3.39	5.83	5.56	5.13[A]
With chemical treatment	6.19	6.33	4.19	5.61	5.58[A]
Means	5.96[a]	4.86[a]	5.01[a]	5.58[a]	

Note: Means followed by different letters uppercase and lowercase letters columns in the lines differ by SNK test at 5% probability.

Table 7. Food efficiency and nictemeral pattern of sheep receiving different levels of inclusion of the byproduct of cashew with or without chemical treatment

Chemical treatment	**Levels of inclusion of the byproduct of cashew (%)**				**Means**
	6	11	16	21	
Feeding efficiency (CV=21.50%)					
Without chemical treatment	213.14[Ab]	245.18[Ab]	366.40[Aa]	201.23[Ab]	256.49
With chemical treatment	197.56[Aa]	307.64[Aa]	230.57[Ba]	202.50[Aa]	234.57
Means	205.35	276.41	298.49	201.86	
Rumination efficiency (DM) (CV=20.03%					
Without chemical treatment	152.04	154.79	168.01	194.62	167.37[A]
With chemical treatment	177.62	185.01	156.61	141.01	165.06[A]
Means	164.83[a]	169.90[a]	162.31[a]	167.81[a]	
Ruminantio efficiency (NDF) (CV=20.21%)					
Without chemical treatment	78.98	79.84	87.39	97.53	85.93[A]
With chemical treatment	99.17	107.23	95.81	93.52	98.93[A]
Means	89.08[a]	93.53[a]	91.60[a]	95.53[a]	
Chews total time (CV=12.98%)					
Without chemical treatment	10.64	10.83	10.75	9.53	10.58[A]

With chemical treatment	10.83	10.61	11.83	11.94	11.31[A]
Means	10.74[a]	10.68[a]	10.68[a]	11.67[a]	
Number of boli daily ruminantion (CV=26.49%)					
Without chemical treatment	554.77	579.62	590.06	393.22	529.42[A]
With chemical treatment	560.57	580.11	614.05	210.59	491.33[A]
Means	557.67[a]	579.87[a]	602.05[a]	301.90[b]	
Number of chews daily (CV=26.79%)					
Without chemical treatment	21.884	24.093	23.465	11.364	20.201[B]
With chemical treatment	20.298	22.975	26.561	13.956	20.947[A]
Means	21.091[c]	23.534[b]	25.013[a]	12.660[d]	
Number of chews boli (CV=17.84%)					
Without chemical treatment	57.93	62.59	58.96	57.78	59.32[A]
With chemical treatment	61.37	64.48	61.74	66.03	63.41[A]
Means	59.65[a]	63.54[a]	60.35[a]	61.91[a]	
Chewings time for boli (CV=14.08%)					
Without chemical treatment	41.78	42.63	40.37	41.15	41.48[A]
With chemical treatment	42.48	42.44	40.04	41.44	41.60[A]
Means	42.13[a]	42.54[a]	40.23[a]	41.30[a]	

Note: Means followed by different letters uppercase and lowercase letters columns in the lines differ by SNK test at 5% probability.

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