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Soybean molasses replacing cracked corn grain improves intake stability in feedlot lambs

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ABSTRACT. In this study, we assessed the effects of replacing cracked corn grain with soybean molasses (SM) on the feed intake and ingestive behavior of 30 uncastrated lambs, Santa Inês × Dorper crossbreed, finished in feedlot. The treatments were 0 g kg^{-1} DM SM (CON), 150 g kg^{-1} DM SM (SM15), and 300 g kg^{-1} DM SM (SM30). Dry matter and nutrient intake were evaluated, in addition to ingestive behavior variables such as interactions with the feed bunker, stereotypes, chewing activities, and time spent in feed bunkers in a 24-h period at three different times during the feedlot period (beginning, middle, and end). The replacement of cracked corn grain with SM decreased the dry matter intake % BW ($p < 0.05$) and ether extract intake ($p < 0.05$) only at the final feedlot period. Additionally, it linearly decreased the cud chewing time $p = 0.01$) and increased the number of cuds ($p = 0.02$). The inclusion of SM allowed for a more stable feed intake during the feeding times ($p < 0.05$). Replacing cracked corn grain with SM in feedlot lamb diets offers a viable alternative without negatively affecting feed intake, even at levels of up to 300 g kg^{-1}. This substitution improves the stability of feed intake.

Keywords: alternative feedstuff; small ruminant; soluble carbohydrate; soybean by-product.

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Introduction

Soybean molasses (SM) is a by-product of soybean processing, from the production of soy protein concentrate, derived from defatted soybean meal subjected to dissolution in water and ethanol, separating protein from soluble carbohydrates (Silva et al., 2012). This by-product has a viscous appearance and dark brown color, rich in oligosaccharides such as stachyose, raffinose, and sucrose, which gives it potential nutritional value (Chajuss, 2004). Marketed in liquid form, it requires specific transportation and storage, with a recommended shelf life of 6 months according to manufacturers.

Incorporating liquid feeds, such as SM, into ruminant diets poses specific challenges, particularly for more selective species like sheep. As a liquid feed, SM alters the texture of the diet, which can influence its palatability and the feeding behavior of the animals. Previous studies have shown that including liquid feeds, such as crude glycerin and orange molasses, in diets for feedlot lambs can negatively influence DM intake and weight gain (Almeida et al., 2017; Santos et al., 2023). However, the literature still lacks a detailed evaluation of how the inclusion of liquid feeds affects the ingestive behavior of animals throughout the feedlot period.

Additionally, given the rapid fermentation of soluble carbohydrates present in SM, there is a risk of acidification of the ruminal environment, which can modify the animals' intake and rumination patterns, leading to potential changes in ingestive behavior (Silva et al., 2018; Klevenhusen & Zebeli, 2021). Therefore, better understanding the effect of these changes over time is essential to optimize the inclusion of SM in diets and ensure that the animals' ingestive behavior is not impaired.

Using SM in farms and commercial feedlots is common in Brazil, though it is typically included at low levels, primarily to enhance palatability and facilitate diet mixing. Studies on the use of SM as a nutritional source in ruminant diets have been recently reported in feedlot dairy cattle (Miletić et al., 2017), supplementation for beef cattle (Tschope et al., 2024), and feedlot lambs (Rodrigues et al., 2020; Pereira-Junior et al., 2024). Even so, none of these studies assessed the effects of SM on feeding patterns throughout the experimental period, nor elucidated its consequences over time.

Given the potential influence of SM on feeding patterns, feeding behavior analysis represents a valuable approach to evaluating diets and foods, aiding in the assessment of feeding-related issues, and allowing for the refinement of nutritional and feeding practices in animal production (Albright, 1993; Perazzo et al., 2017). Therefore, this study aimed to analyze the effect of SM on the feeding behavior and ingestive patterns of feedlot lambs. It is hypothesized that the partial or total replacement of cracked corn grain with SM does not negatively impact the evaluated parameters.

Material and methods

Experimental location and ethical approval

Experiments were conducted in Jaboticabal, state of São Paulo, Brazil (21°14’05’’ S latitude, 48°17’09’’ W longitude, and 615 m altitude). The Animal Welfare and Institutional Ethics Committee approved all the procedures involving animals (Protocol number: 6772/17).

Animals, housing, and feed supply

Thirty uncastrated male crossbred (Santa Inês × Dorper) lambs [approximately three months of age, and 16.8 kg ± 2.2 kg body weight (BW)] were kept in individual indoor feedlot pens with a suspended wooden slat floor (1.2 m^2). They had access to an individual feed bunk and a collective drinker, during all 70 days of the experimental period. The animals were distributed in five randomized blocks according to their initial body weight, and assigned to three treatments that consisted of inclusion level of SM: CON = control diet, without SM; SM15 = replacement 150 g kg^{-1} corn cracked grain with 150 g kg^{-1} SM in DM; and SM30 = replacement 300 g kg^{-1} corn cracked grain with 300 g kg^{-1} SM in DM. The composition of SM used in this study is listed in Table 1.

Table 1. Composition of soybean molasses.

Item	g kg^{-1} (1)
Dry matter	646.0
Mineral matter	122.5
Crude protein	69.3
Ether extract	17.7
Non-fiber carbohydrates	790.5
Minerals (g kg^{-1} Mineral matter)	
K	170.6
P	10.1
Mg	10.2
Na	1.6
Ca	0.5
Soluble carbohydrate profile (g kg^{-1} NFC)	
Glucose	35.8
Fructose	38.5
Galactose	18.8
Sucrose	290.4
Raffinose	99.8
Stachyose	307.2

(1) Caramuru Alimentos S/A, São Simão, Goias State, Brazil.

The feed was supplied twice daily, at 7 and 16h, using corn silage as roughage and concentrate based on soybean meal, wheat bran, and urea, offered as a total mixed ration (TMR – see Table 2). The experimental diets were formulated following the Nutrient Requirements of Small Ruminants (NRC, 2007) to be isoproteic and isoenergetic. The feed intake was determined daily by weighing the offered and orts and representative samples were collected for chemical analysis in the laboratory.

Feeding behavior

Feeding behavior was evaluated three times in the feedlot period, beginning (D18), middle (D39), and next to the end (D60). Animals were observed for 24-h by eight trained evaluators, considering the feeding, rumination, and time spent on other activities. The facility was equipped with artificial light to facilitate the observations during the night period. For this purpose, the animals were pre-adapted to constant light during the night five days before the evaluation day. Behavioral activities were evaluated between 7 and 6:55h (the next day), at 5-min. intervals.

Table 2. Ingredient proportions and chemical composition of experimental diets containing increasing levels of SM.

Item	Treatment [1]		
	CON	SM15	SM30
Ingredient (g kg^{-1} DM)			
Corn silage	400.0	400.0	400.0
Cracked corn grain	300.0	150.0	0.0
Wheat bran	121.0	110.5	98.5
Soybean meal	153.0	163.0	174.5
Urea	11.0	11.5	12.0
Soybean molasses	0.0	150.0	300.0
Mineral premix [2]	5.0	5.0	5.0
Limestone	10.0	10.0	10.0
Nutrient composition, g kg^{-1} DM			
Dry matter	448.3	423.0	352.6
Mineral matter	46.1	59.0	73.6
Organic matter	953.9	941.0	926.4
Crude protein	166.6	171.2	167.6
Ether extract	33.0	26.1	20.7
NDFap [3]	351.8	285.4	274.7
Acid detergent fiber	198.7	190.4	182.1
Total carbohydrates [4]	754.3	743.7	738.1
Non-fiber carbohydrates [4]	402.5	458.3	463.4
Metabolizable energy (KJ kg^{-1} DM) [5]	12.41	12.30	12.19

[1] CON: Control treatment without soybean molasses (SM); SM15: Replacement of cracked corn grain with 150 g kg^{-1} SM (DM basis); SM30: Replacement of cracked corn grain with 300 g kg^{-1} SM (DM basis). [2] Composition per kg: P (60 g), Ca (100 g), Na (195 g), Cl (300 g), Mg (10 g), S (25 g), Zn (4 g), Cu (0.6 g), Mn (0.6 g), Fe (1.2 g), Co (0.1 g), I (0.18 g), Fl (0.06 g). [3] NDFap: Mineral matter and protein-free neutral detergent fiber; [4] Total carbohydrates: 1000 – MM – CP – EE, Sniffen et al. [17], [4] Non-fiber carbohydrates: 1000 – ((CP – CPurea + urea g) + aNDFom + EE + MM), Hall [16]. [5] Metabolizable energy: Nutrient Requirements of Dairy Cattle (NRC, 2001).

Behavioral variables evaluated in this trial were the same as those assessed by Van Cleef et al. (2016), such as interaction with the feed bunker (head towards the feed bunk); interaction with the waterer (head towards the waterer); standing still (standing with four feet on the floor with no body movement); standing ruminating; laid (lateral recumbent position); laid ruminating; stereotypes (repetitive activity, such as chewing pen's parts, biting or licking), and other activities (activities not described previously). The total time for each activity (within a 24-h period) was obtained by summing the number of observations obtained for each behavioral variable and multiplying by 5, which was the interval between each observation.

The chewing activity was analyzed following the method proposed by Bürger et al. (2000). The average time spent chewing was measured using a digital stopwatch, recording ten observations for each animal on each behavior trial day. To ensure a representative sampling, the evaluations were equally distributed throughout the morning, afternoon, and night. In this assessment, the time (in seconds) spent chewing each cud (TCC, s cud^{-1}) and the number of chews per cud (NCC, cud number^{-1}) were recorded.

The DM and NDF intake, rumination rate, and chewing activity were calculated as follows:

Feeding time (FT, h day^{-1}): Interaction with the feed bunk 60 min.$^{-1}$
Rumination time (RT, h day^{-1}): Rumination (laid + standing) 60 min.$^{-1}$
Cud chewing time (CCT, h day^{-1}): FT + RT
Number of cuds (NC, n day^{-1}): RT / TCC
DM intake rate (DMIR, g DM h^{-1}): DM intake / FT
DM rumination rate (DMRR, g DM h^{-1}): DM intake / RT
NDF intake rate (NDFIR, g NDF h^{-1}): NDF intake / FT
NDF rumination rate (NDFRR g NDF min.$^{-1}$): NDF intake / RT (min.)

Laboratory analysis

Diet samples were collected on each day of the feeding behavior evaluation and stored at -20°C until analysis. Samples of the offered TMR and orts were dried in a forced-air oven (55°C, 72h) and ground in a Wiley mill equipped with a 1-mm mesh sieve. The DM was determined by oven drying samples at 105°C for 16h Association of Oficial Analytical Collaboration (AOAC, 2005); method 930.15], and the crude protein (CP) content was estimated using a micro-Kjeldahl apparatus and multiplying the total N value by 6.25 (AOAC, 2005); method 954.01]. The mineral matter (MM) was obtained by complete combustion in a muffle furnace at 600°C for 4h (AOAC, 2005); method 942.05]. The ether extract (EE) was evaluated using a Soxhlet apparatus with 4 h petroleum ether washing (AOAC, 2005); method 2003.05]. The acid detergent fiber (ADF) was analyzed as proposed by Van Soest and Wine (1967), and neutral detergent fiber using heat-stable amylase and corrected for MM and residual protein (NDFap), as recommended by Licitra et al. (1996). Non-fiber carbohydrates (NFC) were estimated using the equation proposed by Hall (2000), and the total carbohydrates, according to Sniffen et al. (1992).

Statistical analysis

The experimental design adopted was a randomized complete block, where the initial body weight was used as a criterion to assign lambs to five homogeneous blocks. Each animal was considered an experimental unit. Additionally, the intake and ingestive behavior variables were treated as repeated measures over time (evaluation day - D18, D39, and D60), and the covariance structure that best fit the data was selected based on the Akaike Information Criterion (AIC). The blocks were considered random effects while the treatments and the treatment × evaluation day interactions were treated as fixed effects.

The data were tested for homoscedasticity and normality of residuals before the analysis of variance. Variables with significant results in the analysis of variance ($p < 0.05$) were subjected to mean comparisons using orthogonal polynomial contrasts to test for linear and quadratic trends across the three levels of SM inclusion (0, 150, and 300 g kg^{-1}). The statistical model used was

$$Y = \mu + Bi + Dj + Sij + Tk + (DT)jk + Eijk \quad (1)$$

Where: Y is the dependent variable, μ is the overall mean, Bi is the block effect (i = 1 – 5), Dj is the treatment effect (j = CON, SM15, SM30), Sij is the residual error (block), Tk is the observation day effect (k = D18, D39, D60), (DT)jk is the interaction of treatment × evaluation day, and Eijk is the residual error.

To assess the distribution of time spent interacting with the feeder over 24 hours, the number of interactions during each hour was summed up and included as a repeated measure in the statistical model to observe patterns of diet intake over time. All data were analyzed using the PROC MIXED procedure of SAS version 9.4 (SAS Inst. Inc., Cary, NC).

Results

There was an interaction between observation days and treatment for DM in %BW, NDF, and EE intake ($p < 0.05$; Table 3). These interactions were broken down for further investigation (Figure 1), showing that replacing corn with SM influenced the intakes as the feedlot period progressed. The levels of stereotypes were linearly increased while both NCC and TCC were linearly decreased ($p < 0.05$). The intermediate level of SM increased the DMIR and NDFIR ($p < 0.05$; quadratic effect), on the other hand, SM increased linearly the NC and NDFRR variables ($p < 0.05$).

Table 3. Intake and feeding behavior of crossbreed lambs fed diets with increasing levels of SM.

Item	Treatment[1]			SEM	*P* - value			
	CON	SM15	SM30		Diet	L	Q	Diet × Day
n	9	7	9					
Intake								
Dry matter, g day^{-1}	953.6	1035.9	965.1	23.98	0.60	0.98	0.32	0.17
Dry matter, %BW	4.28	4.44	4.07	0.06	0.01	0.07	0.01	0.04
Neutral detergent fiber, g day^{-1}	336.4	326.5	275.1	8.97	<0.01	<0.01	0.47	0.04
Crude protein, g day^{-1}	179.4	196.5	171.9	4.87	0.07	0.34	0.04	0.06
Ether extract, g day^{-1}	35.7	34.5	25.5	0.96	<0.01	<0.01	0.03	0.02
Behavior (min day^{-1})								
Interaction with the feed bunk	260.6	237.0	240.2	7.43	0.35	0.35	0.27	0.26
Interaction with waterer	18.0	17.2	15.3	2.52	0.81	0.55	0.78	0.42
Standing ruminating	31.4	35.8	20.8	2.90	0.10	0.07	0.24	0.25
Laid ruminating	370.6	389.3	388.9	9.01	0.82	0.68	0.63	0.33
Standing still	163.3	174.5	176.9	4.68	0.56	0.30	0.78	0.61
Laid	503.5	503.6	486.1	11.89	0.55	0.29	0.82	0.51
Stereotypes	57.1	46.5	77.7	5.04	0.03	0.04	0.07	0.54
Other activities	26.9	28.9	21.4	2.97	0.22	0.15	0.32	0.24
Chewing activity [5]								
NCC, n cud^{-1}	76.6	78.9	69.2	1.54	0.02	0.03	0.07	0.89

TCC, s cud^{-1}	41.5	42.1	37.5	0.76	<0.01	0.01	0.06	0.70
DMIR, gDM h^{-1}	235.4	296.4	276.8	12.59	0.04	0.15	0.04	0.88
DMRR, gDM h^{-1}	144.9	151.3	143.6	4.01	0.84	0.94	0.56	0.67
CCT, h day^{-1}	11.02	11.03	10.82	0.17	0.87	0.71	0.70	0.37
NC, n day^{-1}	588.9	615.4	667.6	14.34	0.06	0.02	0.74	0.35
NDFIR, gNDF h^{-1}	83.1	93.8	79.0	3.96	0.03	0.08	0.05	0.68
NDFRR, min gNDF^{-1}	1.25	1.34	1.54	0.04	<0.01	<0.01	0.68	0.61

[1] NDF: Neutral detergent fiber. [2] CON: 0 g SM kg^{-1} DM; SM15: 150 g SM kg^{-1} DM; SM30: 300 g SM kg^{-1} DM. [3] SEM: Standard error of the mean. [4] Treatment effect; Linear effect; Quadratic effect; Diet × Day: Interaction between treatment and observation days; [5] NCC: Number of chews per cud; CCT: Cud chewing time by cud; DMIR: DM intake rate; DMRR: DM rumination rate; NC: Number of cud; NDFIR: NDF intake rate; NDFRR: NDF rumination rate.

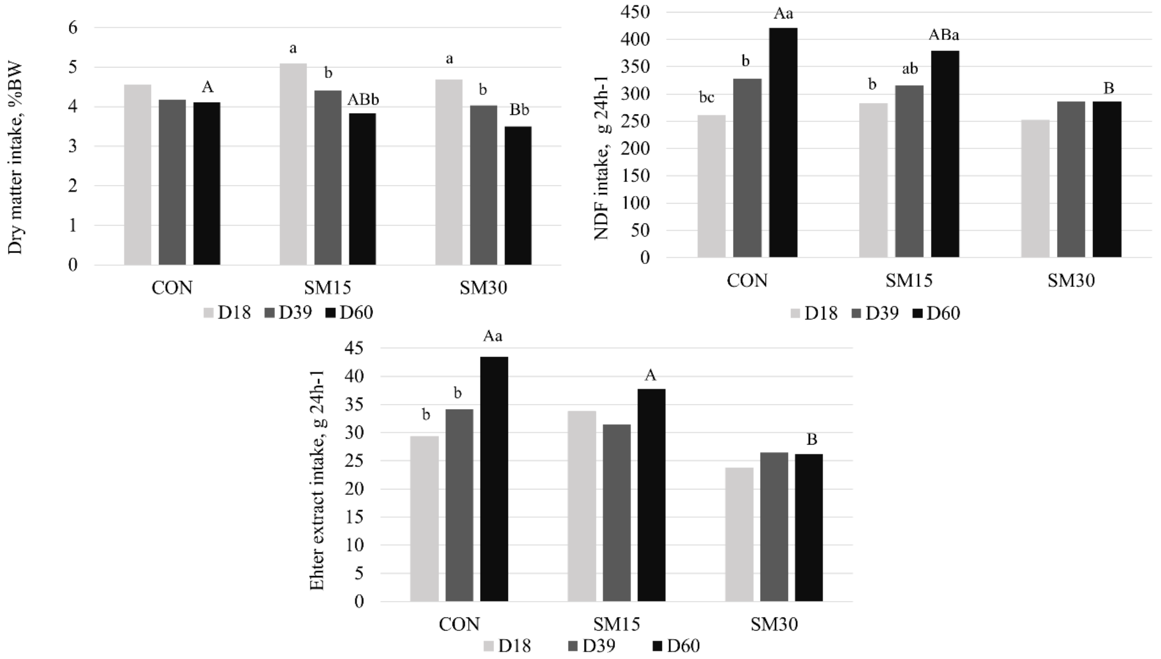

Figure 1. Breakdown of interactions for dry matter intake (%BW), neutral detergent fiber intake (g 24h^{-1}), and ether extract intake (g 24h^{-1}). CON: 0 g SMkg^{-1} DM; SM15: 150 g SM kg^{-1} DM; SM30: 300 g SM kg^{-1} DM. Different uppercase letters indicate significant differences between treatments (p ≤ 0.01). Different lowercase letters indicate significant differences between days (p < 0.05).

There were time and treatment interactions at times 7 and 16h for time spent interacting with the feed bunk (p < 0.05, Figure 2), which showed less time spent for animals assigned to treatments SM15 and SM30 at 7:00 h (p < 0.01) and lesser time for SM30 in 16:00 h (p = 0.01) compared to CON.

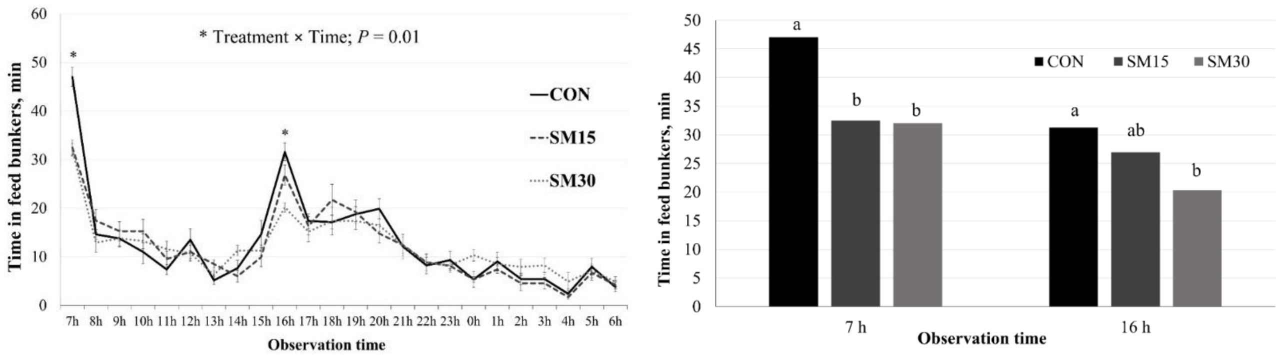

Figure 2. Time crossbred lambs spent in the feed bunk and interaction breakdown during 24-h observation (* p < 0.05), and feed delivery time 07:00 h (p < 0.01) and 16:00 h (p = 0.01) according to SM replacing corn in the diet. CON: 0 g SM kg^{-1} DM (n=9), SM15: 150 g SM kg^{-1} DM (n=7), and SM30: 300 g SM kg^{-1} DM (n=9).

Discussion

Feed intake

One of the aims of diet formulation was to make them nutritionally similar to explore the effects of replacing cracked corn grain with SM. Therefore, reductions in DM intake as % BW over the feedlot period, and in EE intake between treatments on D60, may indicate a change in the animal feeding pattern in response to the texture and flavor of the experimental diets, particularly in the SM15 and SM30 groups.

Sheep alter their food preference according to the flavor and nutrients of their diet, aiming to increase variability in intake (Provenza et al., 1996). They may even develop an aversion to recently ingested food based on the sensory response obtained, such as texture and flavor, high levels of rapidly digestible nutrients, or excess, leading to nausea and overfilling (Scott & Provenza, 1998).

In an analysis of the inclusion of up to 400 g kg^{-1} of orange molasses in the diet for lambs, Santos et al. (2023) observed a response pattern different from that found here. The reduction in intake occurred at the beginning of the feedlot period and stabilized from the middle to the end, indicating that after the adaptation of the ruminal microbiota, the intake pattern became similar to the control treatment (without the inclusion of orange molasses). In our study, the effects were registered at the end of the feedlot period, where the SM15 and SM30 animals reduced intake as %BW and did not increase EE intake compared to the CON treatment.

The animals possibly developed some degree of aversion or rejection of diets containing SM as the feedlot period progressed. The bittersweet flavor of SM may have contributed to this response, considering that lambs exhibited lower DM intake in diets with bitter and sweet flavors compared to umami-flavored and non-flavored diets (Villalba et al., 2011). A possible explanation is provided by Rolls (1986), where the preference for a certain flavor decreases during ingestion, a phenomenon known as specific sensory satiety. However, more appropriate and targeted studies have to be conducted for a better understanding of the sensory effects of adding SM to sheep diet.

On the other hand, NDF intake increased over the feedlot period. However, this behavior is more closely linked to the increase in the ruminal storage capacity of growing animals, which allows for greater fiber intake (Yang et al., 2018).

Feeding behavior

Animal behavior does not encompass two or more activities simultaneously; therefore, increasing the time spent on one activity will inevitably reduce the time spent on another (Araújo et al., 2020). In this way, the increase in the time spent on stereotypes is possibly related to the reduced time spent on chewing activities, such as the number of cuds and the time spent in each cud, due to the lower amount of dietary fiber, resulting in increased idle time for the SM30 animals.

The higher DM and NDF intake rate in the SM15 group can be explained by the higher *in vitro* digestibility of diets containing up to 200 g kg^{-1} of SM (van Cleef et al., 2018), which results in better digestive efficiency and increased feed utilization. In contrast, the SM30 diet lessened feeding time peaks throughout mealtimes, allowing for a more steady and uniform distribution of intake than the CON diet. The increased disappearance of DM in the first hours of *in vitro* incubation suggests that this is most likely caused by the amount of easily accessible nutrients, which allows early satiety (Arruda et al., 2019). Robles et al. (2007) reported that variations in intake can lead to an unstable rumen environment.

Arruda et al. (2021) fed lambs with similar SM concentrations but with a higher proportion of concentrate (75%). The authors observed longer time spent interacting with the feed bunk in animals fed SM, which is consistent with our study. Additionally, the lower dietary fiber content allows animals to have a higher rate of passage, permitting additional intakes and a greater number of cud, as observed here.

In general, the increase in the NDF rumination rate in SM30 lambs per unit of NDF effectively compensates for the lower dietary fiber content. It is noteworthy that all experimental diets were deemed safe concerning their NDF content. Therefore, the increase in the NDF rumination rate may be due to a mathematical effect stemming from the reduced fiber content, as the total rumination time remained unaffected by the treatments.

Conclusion

Based on our findings, soybean molasses proves to be a suitable energy source to replace cracked corn grain in feedlot sheep diets, with safe inclusion levels up to 300 g kg^{-1} of DM, which allows for better intake stability. However, in longer periods, as observed in the present study (70 days), SM may lead to reduced feed intake by the animals at the end of the feedlot period.

References

Albright, J. L. (1993). Feeding behavior of dairy cattle. *Journal of Dairy Science, 76*, 485-498. https://doi.org/10.3168/jds.S0022-0302(93)77369-5

Almeida, M. T. C., Ezequiel, J. M. B., Paschoaloto, J. R., Perez, H. L., de Carvalho, V. B., Castro Filho, E. S., & van Cleef, E. H. C. B. (2017). Effects of high concentrations of crude glycerin in diets for feedlot lambs: feeding behaviour, growth performance, carcass and non-carcass traits. *Animal Production Science*, *58*(7), 1271-1278. https://doi.org/10.1071/AN16628

Araújo, H. P. D. O., Paula, N. F. D., Martello, H. F., Teobaldo, R. W., Pereira, L. B., Mora, L. M., & Antunes, H. C. F. (2020). Urea and Tannin in multiple supplements: Ingestive behavior of grazing beef cattle. *Acta Scientiarum, 42*. https://doi.org/10.4025/actascianimsci.v42i1.47607

Arruda, M. C. G., Pereira-Junior, S. A., Almeida, M. T. C. (2019). PSXII-11 In vitro fermentative parameters of diets containing increasing inclusions of soybean molasses for sheep. *Journal of Animal Science*, *97*(3). https://doi.org/10.1093/jas/skz258.816

Arruda, M. C. G., Almeida, M. T. C., Bertoco, J. P. A., Pereira-Junior, S. A. G., Castro-Filho, E. S., Feliciano, A. L., Rodrigues, J. L., Torres, R. N. S., Costa, R. V., Grilo, L. M. S. F. S. S., & Ezequiel, J. M. B. (2021). Soybean molasses to replace corn for feedlot lambs on growth performance, carcass characteristics, and meat quality. *Translational Animal Science, 5*(1), txaa230. https://doi.org/10.1093/tas/txaa230

Association of Oficial Analytical Collaboration [AOAC]. (2005). *Official Methods of Analysis* (18th ed.). AOAC International.

Bürger, P. J., Pereira, J. C., Queiroz, A. C. D., Coelho da Silva, J. F., Valadares Filho, S. D. C., Cecon, P. R., & Casali, A. D. P. (2000). Comportamento ingestivo em bezerros holandeses alimentados com dietas contendo diferentes níveis de concentrado. *Revista Brasileira de Zootecnia, 29*, 236-242. https://doi.org/10.1590/S1516-35982000000100031

Chajuss, D. (2004). Soy molasses: Processing and utilization as a functional food. In K. Liu (Ed.), Soybeans as functional foods and ingredients (pp. 201-208). AOCS Press. https://doi.org/10.1201/9781003040286

Hall, M. B. (2000). *Neutral detergent-soluble carbohydrates nutritional relevance and analysis*. University of Florida.

Klevenhusen, F., & Zebeli, Q. (2021). A review on the potentials of using feeds rich in water-soluble carbohydrates to enhance rumen health and sustainability of dairy cattle production. *Journal of the Science of Food and Agriculture*, *101*(14), 5737-5746. https://doi.org/10.1002/jsfa.11358

Licitra, G., Hernandez, T. M., & Van Soest, P. J. (1996). Standardization of procedures for nitrogen fractionation of ruminant feeds. *Animal Feed Science and Technology, 57*(4), 347-358. https://doi.org/10.1016/0377-8401(95)00837-3

Miletić, A., Stojanović, B., Grubić, G., Stojić, P., Radivojević, M., Joksimović-Todorović, M., Popovac, M., & Obradović, S. (2017). The soybean molasses in diets for dairy cows. *Mljekarstvo*, *67*(3), 217-225. https://doi.org/10.15567/mljekarstvo.2017.0306

National Research Council [NRC]. (2007). *Nutrient requirements of small ruminants: Sheep, goats, cervids, and New World camelids* (7th ed.). The National Academies Press. https://doi.org/10.17226/11654

Perazzo, A. F., de Paula Homem Neto, S., Ribeiro, O. L., Santos, E. M., de Carvalho, G. G. P., de Oliveira, J. S. Bezerra, H. F. C., & de Freitas Junior, J. E. (2017). Intake and ingestive behavior of lambs fed diets containing ammoniated buffel grass hay. *Tropical Animal Health and Production, 49*(4), 717-724. https://doi.org/10.1007/s11250-017-1247-2

Pereira-Junior, S. A., Costa, R. V., Rodrigues, J. L., Torrecilhas, J. A., Chiaratti, M. R., Lanna, D. P., Chagas, J. C., Nociti, R. P., Meirelles, F. V., Ferraz, J. B. S., Fernandes, M. H. M. R., Almeida, M. T. C., & Ezequiel, J. M. (2024). Soybean molasses increases subcutaneous fat deposition while reducing lipid oxidation in the meat of castrated lambs. *Journal of Animal Science*, *102*, skae130. https://doi.org/10.1093/jas/skae130

Provenza, F. D., Scott, C. B., Phy, T. S., & Lynch, J. J. (1996). Preference of sheep for foods varying in flavors and nutrients. *Journal of Animal Science, 74*(10), 2355-2361. https://doi.org/10.2527/1996.74102355x

Robles, V., González, L. A., Ferret, A., Manteca, X., & Calsamiglia, S. (2007). Effects of feeding frequency on intake, ruminal fermentation, and feeding behavior in heifers fed high-concentrate diets. *Journal of Animal Science, 85*(10), 2538-2547. https://doi.org/10.2527/jas.2006-739

Rodrigues, J. L, Pereira-Junior, S. A. G., Castro Filho, E. S., Costa, R. V., Barducci, R. S., van Cleef, E. H. C. B., & Ezequiel, J. M. B. (2020). Effects of elevated concentrations of soybean molasses on feedlot performance and meat quality of lambs. *Livestock Science*, *240*, 104155. https://doi.org/10.1016/j.livsci.2020.104155

Rolls, B. J. (1986). Sensory-specific satiety. *Nutrition Reviews*, *44*(3), 93-101. https://doi.org/10.1111/j.1753-4887.1986.tb07593.x

Santos, I. J., Junior, P. C. G. D., Vicente, A. C. S., Alves, A. L., De Assis, R. G., Biava, J. S., Nogueira, M. V. V. A., Pires, A. V., & Ferreira, E. M. (2023). Orange molasses as a new energy ingredient for feedlot lambs in Brazil. *Tropical Animal Health and Production*, *55*(257), 257. https://doi.org/10.1007/s11250-023-03675-4

Scott, L. L., & Provenza, F. D. (1998). Variety of foods and flavors affects selection of foraging location by sheep. *Applied Animal Behaviour Science*, *61*(2), 113-122. https://doi.org/10.1016/S0168-1591(98)00093-8

Silva, P. A., de Carvalho, G. G. P., Pires, A. J. V., Santos, S. A., dos Santos Pina, D., Silva, R. R., Rodrigues, C. S., Matos, L. H. A., Eiras, C. E., Novais-Eiras, D., & Nunes, W. S. (2018). Feeding behavior of feedlot lambs fed diets containing levels of cassava wastewater. *Tropical Animal Health and Production*, *50*, 721-726. https://doi.org/10.1007/s11250-017-1487-1

Silva, F. B., Romão, B. B., Cardoso, V. L., Coutinho Filho, U., & Ribeiro, E. L. (2012). Production of etanol from enzymatically hydrolyzed soybean molasses. *Biochemical Engineering Journal, 69*, 61-68. https://doi.org/10.1016/j.bej.2012.08.009

Sniffen, C. J., O'Connor, J. D., Van Soest, P. J., Fox, D. G., & Russell, J. B. (1992). A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *Journal of Animal Science, 70*(11), 3562-3577. https://doi.org/10.2527/1992.70113562x

Tschope, G. L., de Moraes, K. A. K., de Oliveira, A. S., de Paula, N. F., Petrenko, N. B., Chaves, C. S., Socreppa, L. M., & de Moraes, E. H. B. K. (2024). Soybean molasses can be used as a substitute for corn in grazing beef cattle supplements during the rainy season. *Tropical Animal Health and Production*, *56*(219), 1-8. https://doi.org/10.1007/s11250-024-03994-0

van Cleef, F. D. O. S., Ezequiel, J. M. B., D'Aurea, A. P., Almeida, M. T. C., Perez, H. L., & van Cleef, E. H. C. B. (2016). Feeding behavior, nutrient digestibility, feedlot performance, carcass traits, and meat characteristics of crossbred lambs fed high levels of yellow grease or soybean oil. *Small Ruminant Research*, *137*, 151-156. https://doi.org/10.1016/j.smallrumres.2016.03.012

van Cleef, F., van Cleef, E., Almeida, M., Paschoaloto, J., Castro, E., Barducci, R., Soragni, G., Zampieri, E., & Ezequiel, J. (2018). PSI-13 In vitro digestibility and gas production of diets containing different levels of soybean molasses for feedlot sheep. *Journal of Animal Science*, *96*(Suppl 3), 63. https://doi.org/10.1093/jas/sky404.139

Van Soest, P. J., & Wine, R. H. (1967). Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. *Journal of the Association of Official Analytical Chemists*, *50*(1), 50-55. https://doi.org/10.1093/jaoac/50.1.50

Villalba, J. J., Bach, A., & Ipharraguerre, I. R. (2011). Feeding behavior and performance of lambs are influenced by flavor diversity. *Journal of Animal Science*, *89*(8), 2571-2581. https://doi.org/10.2527/jas.2010-3435

Yang, B., Le, J., Wu, P., Liu, J., Guan, L. L., & Wang, J. (2018). Alfalfa intervention alters rumen microbial community development in Hu lambs during early life. *Frontiers in Microbiology, 9*(574). https://doi.org/10.3389/fmicb.2018.00574