Tropical Animal Health and Production (2023) 55:257
https://doi.org/10.1007/s11250-023-03675-4

SHORT COMMUNICATIONS

Orange molasses as a new energy ingredient for feedlot lambs in Brazil

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Received: 24 January 2023 / Accepted: 27 June 2023

Abstract

The objectives of this experiment were to evaluate the effects of increasing levels of orange molasses in replacement of flint corn grain in high-concentrate diets on dry matter intake (DMI), average daily gain (ADG), and feed efficiency (FE) of feedlot lambs. Thirty male lambs without defined racial pattern (30.3 ± 5.3 kg of initial BW; mean ± SD) were used in a randomized complete block design with 10 blocks and 3 treatments. The treatments were defined by partial replacement of flint corn by orange molasses in the diet with 90% of concentrate and 10% of *Cynodon* spp. hay, as follows: *0OM*—control diet without orange molasses; *20OM*—20% of orange molasses replacing flint corn; and *40OM*—40% of orange molasses replacing flint corn (DM basis). The experiment lasted 72 days divided into 3 subperiods, with 1 subperiod of 16 days and 2 subperiods of 28 days. Animals were weighed after a 16-h fast on days 1, 16, 44, and 72 of the experimental periods to determine the ADG and FE. The DMI, ADG, and FE showed an interaction between treatments and experimental periods. The DMI in the first period decreased linearly ($P < 0.01$); in the third period, there was no effect of treatments ($P > 0.05$) on DMI. The ADG decreased linearly ($P < 0.01$) in the first period as the orange molasses increased. Otherwise, in the third period, ADG increased linearly ($P = 0.05$) as flint corn was replacement by orange molasses. The FE showed an interaction between treatment and period ($P = 0.09$). The first period had a decreased linear effect; in the third period, there was a trend ($P = 0.07$) of increased linear effect. There was no difference between the diets regarding the final BW of the lambs. In conclusion, the orange molasses can replace up to 40% of flint corn in diets for feedlot lambs without affecting final BW. However, it is important to consider the adaptation time proved to be very important for better use of orange molasses as a source of energy in diets for lambs.

Keywords Sheep · Performance · By-product · Replacement · Flint corn · Feed efficiency

Introduction

Finish lambs on feedlot receiving a high-concentrate diets are a technique that increases the ADG and reduces the slaughter time. However, these diets are expensive. Corn grain is the main source of energy used in ruminant diets in Brazil, and 97% of feedlot nutritionists use corn as source of energy (Silvestre and Millen 2021). Corn is the main agricultural commodity that impacts the cost of farm animal diets. According to USDA (United States Department of Agriculture n.d.), corn consumption in the 2019/2020 harvest reached 1.127 billion tons higher than total production, resulting in a reduction in world stock. An alternative to reduce the cost of animal feed and dependence on corn is the use of agro-industry by-products (De Evan et al. 2020; Vastolo et al. 2022). The orange molasses is a by-product of the citrus processing industry, which produces many by-products that are already used in animal feed, having citrus pulp as the most commonly used by-product for ruminants (Fegeros et al. 1995; Arthington et al. 2002).

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Published online: 03 July 2023

Brazil is the world's largest orange juice producer, accounting for more than one quarter of the world production (Pires et al. 2021). In this context, it produces a large number of co-products, including orange molasses. The orange molasses is made by concentrating the press liquor from the citrus peel residue. It is an ingredient with high moisture content, which has about 100–170 g/kg solubles of which 500–700 g/kg consists of sugar (Ensminger et al. 1990). The orange molasses is a safe food with high nutritional potential and can be a source of energy in the ruminant diet, but it is not yet explored for animal production. It is mainly destined for the food industry as an emulsifying agent for pellets and for fertigation (Tuttobene et al. 2009). There are studies in the literature that evaluated the effects of orange molasses in the diet of cows, steers, and lambs (Becker et al. 1944; Chen et al. 1982; Wing et al. 1988). However, there is a lack of information on the effects of orange molasses in high-concentrate diets for lambs.

Orange molasses has a competitive advantage in relation to corn, due to its lower price per unit of TDN compared to orange molasses. It is important to emphasize that the comparison must be made in relation to TDN because the moisture content of corn and orange molasses is very different (10% vs 83%, respectively). In addition, orange molasses has a high concentration of pentoses and simple sugars (Bampidis et al. 2006). These compounds are more extensively digested in the rumen when compared to the starch present in flint corn, which makes orange molasses even more competitive since it makes better use of nutrients.

The use of orange molasses in diets for ruminants can reduce dependence on corn, the main ingredient in finishing diets and whose price is currently high. Furthermore, this article has an environmental appeal, as the use of by-products from the industry in animal feed contributes to the lowest disposal in the environment, reducing the inappropriate disposal of potential pollutants to the environment. Thus, this study evaluated the partial replacement of flint corn by orange molasses on the performance of feedlot lambs.

Material and methods

This study was carried out at the at the sheep confinement facility of the Sheep and Goat Intensive Production System of Animal Science Department "Luiz de Queiroz" College of Agriculture, University of São Paulo (ESALQ-USP), located in Piracicaba, SP, Brazil, at altitude of 540 m and average annual temperature of 24.40 °C. The research protocol was approved by the Animal Care and Use Committee (number 7366010422).

Thirty male lambs with no defined racial pattern and BW 30.3 ± 3.07 kg (mean ± SD) were used in a randomized completely block design (10 blocks and 3 treatments). The control diet contained 70.6% flint corn and 0% orange molasses (*0OM*). In the remaining diets, orange molasses replaced flint corn at the rate of 20 (*20OM*) or 40% (*40OM*) of the original corn concentration, resulting in 0, 14.1, or 28.2% of orange molasses in the dietary DM (Table 1). The experimental diets were formulated to be isonitrogenous (Table 1), and the Small Ruminant Nutrition System was used (Cannas et al. 2004). Before beginning the experimental period, the lambs were fed a pattern diet with 90% of concentrate and 10% of *Cynodon* spp. hay.

The chemical composition of orange molasses is shown in Table 2. Experimental diets were provided daily ad libitum as total mixed ration (TMR) to allow 10% of orts, and the average daily intake of diet was determined by daily quantify of the amount of TMR offered and of the orts throughout the experimental period. Manually, the orange molasses was added to a pre-mix with the other ingredients; it was homogenized and immediately fed to the animals. The experimental period lasted 72 days, with 1 subperiod of 16 days and 2 subperiods of 28 days.

Table 1 Proportion of ingredients and chemical composition of experimental diets (g/kg of DM)

	Treatments[1]		
	0OM	20OM	40OM
Ingredients (g/kg of DM)			
Hay of coastcross (*Cynodon* sp.)	100	100	100
Ground flint corn	707	565	424
Orange molasses	–	141	282
Soybean meal	143	143	142
Urea	–	1	2
Ammonium chloride	5	5	5
Limestone	14	14	14
Mineral mix[2]	15	15	15
Monensin[3], mg/kg of MS	16	16	16
Chemical composition (g/kg of DM)			
Dry matter (g/kg as-fed basis)	912	525	415
Crude protein	166	164	164
Neutral detergent fiber	199	173	158
Ether extract	41	37	32
Non-fibrous carbohydrate	540	570	592
ME (Mcal/kg of DM)[4]	2.9	2.7	2.8

[1]0OM: 0% inclusion of orange molasses in dry matter; 20OM: 20% inclusion of orange molasses replacing corn; 40OM: 40% inclusion of orange molasses replacing corn

[2]Composition (dry matter basis): 75 g/kg P; 134 g/kg Ca; 10 g/kg Mg; 70 g/kg S; 145 g/kg Na; 500 ppm Fe; 300 ppm Cu; 4600 ppm Zn;15 ppm Se

[3]Rumensin 100 (Sodium monensin, Elanco of Brazil, São Paulo, Brazil)

[4]ME: Metabolizable energy according to *Small Ruminant Nutrition System* (Cannas et al. 2004)

Table 2 Chemical composition of orange molasses

Chemical composition (g/kg of DM)	Orange molasses
Dry matter (g/kg as-fed basis)	171
Crude protein	84
Neutral detergent fiber	24
Ether extract	12
Non-fibrous carbohydrate	842

Lambs were weighed after a 16-h fast at the beginning of the experiment and on days 16, 44, and 72 of the experimental periods to determine the ADG and FE (FE; kg of BW gain/kg of DMI). At each experimental period, diet samples and ort samples were collected and frozen at −20 °C for later analysis. After the end of the trial, feed and ort samples were dried in a forced-air oven at 55 °C for 72 h (AOAC 1990; #930.15). Then all samples were ground with a Wiley mill (Marconi, Piracicaba, São Paulo, Brazil) to pass a 1-mm screen. The DM was determined by oven-drying at 65 °C for 72 h and then at 105 °C for 24 h according to the method of the Association of Official Analytical Chemists (AOAC, 1990; #930.15). Ash was determined by incinerating the sample in a muffle furnace at 550 °C for 4 h (AOAC, 1990; #942.05). The total nitrogen concentration in the samples of feed and orts was determined using the Dumas combustion method using a LecoTruMac N (Leco Corporation, St. Joseph, MI USA) (AOAC 1997; #990.03). The ether extract (EE) was determined using an Ankom XT15 extractor (Ankom Tech Corp., Macedon, NY, USA) (AOAC 1990; #920.39). The neutral detergent fiber (NDF) concentration was determined with an Ankom A2000 Fiber Analyzer (Ankom Tech. Corp., Macedon, NY, USA) (AOAC, 1990; #968.06) according to Van Soest et al. (1991). Non-fiber carbohydrates (NFCs) were calculated according to equation: NFC (g/kg) = 1000 − ((NDF (g/kg) + CP (g/kg) + EE (g/kg) + Ash (g/kg)).

The data were analyzed using the MIXED procedure (SAS Inst. Inc. Cary, NC) and the command LSMEANS was used to generate individual means. The effects of orange molasses levels in the diets were determined by linear and quadratic polynomials. The difference was considered significant when $P < 0.05$ and trend when $P > 0.05$ and < 0.10.

Results and discussion

There was interaction between treatments and experimental periods for DMI (Table 3). In the first period, the DMI decreased linearly ($P < 0.01$) and in the second period there was a trend for DMI decreased linearly ($P = 0.06$) according to the increase in orange molasses content in the diets. On the other hand, in the third period, DMI was not affected by treatments. It was clear that the lambs were not adapted to the diets in the first period. However, in the third period, the similarity in DMI shows that the lambs were already completely adapted to the diets (Table 3). Probably, a factor associated with the negative effect on DMI in the initial period was the high moisture content of orange molasses (Table 2) and adaptation of ruminal microorganisms, since normally in 21 days the animals adapt to a new diet (Pitta et al. 2018; Parra et al. 2019).

Orange molasses is rich in sucrose from the remaining juice (Bampidis et al. 2006). Sucrose is composed of glucose and fructose, which represent important substrates for microbial fermentation (Palmonari et al. 2020; Ravelo et al. 2022). These compounds are more rapidly fermented in the rumen when compared to the starch present in corn (Dong et al. 2021) and can result in reduced rumen pH and lead to reduced digestibility of fibrous carbohydrates (Monteiro et al. 2020). It may have occurred in the first period, resulting in lower DMI (Table 3). However, the process of adaptation of the ruminal papillae (Xu et al. 2018) makes the ruminal environment more efficient to absorb short chain fatty acids, which favors the reestablishment of ruminal pH and DMI.

There was interaction between treatments and experimental periods for ADG ($P = 0.05$). In the first period, the ADG decreased linearly ($P = 0.01$) as the orange molasses increased and in the second period they were not affected by the treatments. Otherwise, in the third period, the ADG ($P = 0.05$) increased linearly as flint corn replaced orange molasses. The rate of decline in DMI when corn replaced orange molasses up to 40% was higher in the first period than in the second period (Table 3); this explains the linear decrease in ADG in the first period and similarity in ADG in the second period. It is very well documented the positive correlation between DMI and ADG (AFRC 1998; Cannas et al. 2004; INRA 2007). Furthermore, increasing orange molasses in the diets probably increased the content of assimilable nutrients; when animals consumed similarly, there was an increasing linear effect on ADG. It is clear from the results obtained in the third period (Table 3) that there was a linear increase in ADG as orange molasses was added in the diet; on the other hand, the DMI was similar between treatments.

In the present study, the overall mean ADG was similar between treatments, resulting in similar BW throughout the experiment (Table 3).

There was a trend of interaction between treatment and period for FE ($P = 0.09$) (Table 3). The first period had a decreased linear effect on FE when corn replaced orange molasses. In the second period, orange molasses inclusion promotes higher FE when compared to the 0OM diet (0.19, 021, and 0.21 to 0OM, 20OM, and 40OM, respectively).

Table 3 Effects of increasing levels of orange molasses in replacement corn on performance of feedlot lambs

Item[2]	Treatments[1]			SEM[3]	*P*-value[4]				
	0OM	20OM	40OM		L	Q	T	P	T × P
Body weigth (kg)									
Initial, day 0	29.84	30.70	31.00	0.89	0.74	0.21			
1st period, day 16	32.62	32.46	31.73	1.26	0.47	0.81			
2nd period, day 44	39.13	39.13	37.64	1.28	0.39	0.95			
3rd period, day 72	44.38	44.24	44.29	1.49	0.99	0.84			
Mean	38.67	38.46	37.88	0.83	0.41	0.83	0.69	< 0.01	0.97
Dry matter intake (kg/day)									
1st period, day 16	0.98	0.80	0.60	0.04	< 0.01	0.94			
2nd period, day 44	1.15	1.03	0.96	0.07	0.06	0.81			
3rd period, day 72	1.10	1.17	1.18	0.06	0.17	0.90			
Mean	1.09	1.00	0.90	0.03	< 0.01	0.98	0.01	< 0.01	< 0.01
ADG (kg/day)									
1st period, day 16	0.19	0.12	0.03	0.04	< 0.01	0.80			
2nd period, day 44	0.23	0.24	0.21	0.06	0.82	0.22			
3rd period, day 72	0.18	0.19	0.24	0.02	0.05	0.78			
Mean	0.20	0.19	0.17	0.02	0.25	0.80	0.5	< 0.01	0.05
Feed efficiency									
1st period, day 16	0.19	0.14	0.05	0.04	0.08	0.41			
2nd period, day 44	0.19	0.21	0.21	0.02	0.69	0.80			
3rd period, day 72	0.16	0.16	0.20	0.02	0.07	0.10			
Mean	0.18	0.18	0.19	0.01	0.64	0.15	0.64	0.02	0.09

[1]0OM: 0% inclusion of orange molasses; 20OM: 20% inclusion of orange molasses replacing corn; 40OM: 40% inclusion of orange molasses replacing corn

[2]*ADG*: average daily gain

[3]*Sem*: standard error of the mean.

[4]*L*: linear effect; *Q*: quadratic effect; *T*: treatment effect; *P*: period effect; *P* × *T*: period and treatment interaction effect

Although there was a trend ($P = 0.06$) of linear decrease in DMI in the second period, there was no effect on ADG, demonstrating the potential of orange molasses to increase FE. In turn, in the third period, the linear increase in ADG was consistent with the increase in FE as the content of orange molasses in the diet increased.

The linear increase in FE in the third period indicates that orange molasses is an ingredient with high nutritional value for lambs. Orange molasses has a high content of NFC, mainly pentoses, sucrose, simple sugars such as fructose, and soluble fiber, mainly pectin and beta-glucans (Wagner et al. 1983; Bampidis et al. 2006). These compounds are more extensively digested in the rumen when compared to the starch present in flint corn (Ariza et al. 2001; Tables INRA 2007), which made it possible to increase FE.

The increase in FE with the inclusion of orange molasses makes this byproduct attractive, especially because FE summarizes the zootechnical results of animal performance (Terry et al. 2020; Ettoumia et al. 2022). From an environmental standpoint, the use of orange molasses makes agroindustry and livestock more sustainable, reduces industrial disposal in the environment, and improves the efficiency of nutrient use.

Conclusion

In conclusion, the orange molasses can replace up to 40% of flint corn in diets for feedlot lambs without affecting final BW, demonstrating potential to increase feed efficiency after adaptation of the animals to diet. Therefore, orange molasses proved to be a potential source of energy in feedlot lamb diets.

Acknowledgements The authors would like to thank the USP (University of São Paulo), SIPOC (Sheep and Goats Intensive Production System), for providing the facilities and financial support and CP Kelco Brazil Company financial support of this study.

Author contribution Isabela J. dos Santos: conceptualization, methodology, investigation, validation, formal analysis, data curation, writing original draft; Paulo César G. Dias Junior, Rhaissa G. de Assis, Adrielly Lais Alves, Ana Carolina S. Vicente, Mateus Vigo Vercesi Almada Nogueira: investigation, writing—review and editing; Janaina S. Biava and Alexandre V. Pires: methodology; writing—review and editing; visualization; Evandro M. Ferreira: conceptualization; methodology; validation; formal analysis; writing—review and editing; supervision; funding acquisition.

Funding This study was funded by the FEALQ (Luiz de Queiroz Foundation), USP-ESALQ (University of São Paulo, "Luiz de Queiroz" College of Agriculture), and CP Kelco Brazil Company.

Data availability The datasets analyzed in the current study are available from the corresponding author on a reasonable request.

Declarations

Ethics approval All the procedures have been conducted in accordance with Animal Care and Use Committee (research protocol number 7366010422).

Consent to participate All authors consented to participation.

Consent to publish All authors consented to submit the manuscript to the journal.

Competing interests The authors declare no competing interests.

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