OILSEEDS IN DIETS OF FATTENING LAMBS[1]

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ABSTRACT: An experiment was conducted to compare different oilseeds in replacement of ground corn in diets of fattening lambs, evaluating performance, apparent diet digestibility, ingestive behavior, and carcass traits. Twenty-four crossbred lambs, three months old and with initial body weight 25.97 ± 0.75 kg, were kept in individual pens. The animals received one of the following diets: 'control' (no oilseeds, 3.11% Ether Extract - EE), 'cottonseed' (6.14% EE), 'sunflower' (6.33% EE), and 'soybean' (6.30% EE). All diets contained 23.63% of *coast cross* hay and 76.37% of concentrate. After 84 days in feedlot, the animals were slaughtered and the carcasses were evaluated. The dry matter intake (DMI) and daily weight gain (DWG) of animals fed with the control diet was higher than sunflower (P≤0.05). Final body weight and carcass weight were higher (P≤0.05) in the control (42.42 kg and 19.27 kg, respectively) than for sunflower diet (34.85 kg and 16.05 kg, respectively). Neutral detergent fiber (NDF) digestibility was reduced (P≤0.05) when ~~the~~ animals received cottonseed diet (50.34%) in comparison to soybean (71.07%), sunflower (67.07%) and control (66.50%). NDF digestibility for soybean, sunflower and control diets did not differ from each other. Lower (P≤0.05) EE digestibility was observed for the control diet (73.67%). There were no differences (P≥0.05) in the ingestive behavior, however, the addition of cottonseed or sunflower negatively affected (P≤0.05) rumination efficiency of NDF. Sunflower should not be included in high concentrate diets for fattening lambs.

Keywords: Cottonseed, Sheep, Soybean, Sunflower

OLEAGINOSAS EM DIETAS PARA CORDEIROS EM ENGORDA

RESUMO: Um experimento foi conduzido para comparar diferentes oleaginosas em substituição ao milho moído na dieta de cordeiros em engorda, avaliando o desempenho, a digestibilidade aparente da dieta, o comportamento ingestivo e as características de carcaça. Vinte e quatro cordeiros cruzados, com 3 meses de idade e peso corporal inicial de 25,97 ± 0,75 kg, foram mantidos em baias individuais. Eles receberam uma das seguintes dietas ou tratamentos: 'controle' (sem grãos de oleaginosas, 3,11% de Extrato Etéreo - EE), 'caroço de algodão' (6,14% EE), 'girassol' (6,33% EE) e 'soja' (6,30% EE). Todas as dietas continham 23,63% de feno de *coast cross* e 76,37% de concentrado. Após 84 dias de confinamento, os animais foram abatidos e as carcaças avaliadas. O consumo de matéria seca e ganho de peso diário dos animais alimentados com a dieta controle foi maior daqueles alimentados com girassol (P≤0,05). O peso corporal final e o peso da carcaça foram maiores (P≤0,05) para aqueles alimentados com a dieta controle (42,42 kg e 19,27 kg, respectivamente) que aqueles da dieta com girassol (34,85 kg e 16,05 kg, respectivamente). A digestibilidade da Fibra em Detergente Neutro (FDN) foi reduzida (P≤0,05) quando os animais receberam caroço de algodão (50,34%) comparado à soja (71,07%); para as dietas com girassol (67,07%) e controle (66,50%) não houve diferenças das demais. Menor (P≤0,05) digestibilidade do extrato etéreo foi observada para a dieta controle (73,67%). Não houve diferenças (P≥0,05) no comportamento ingestivo, no entanto, a inclusão de caroço de algodão ou girassol afetou negativamente (P≤0,05) a eficiência de ruminação da FDN. Grãos de girassol não devem ser incluídos em dietas de alto concentrado para cordeiros em engorda.

Palavras-chave: Caroço de algodão, Girassol, Ovino, Soja

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INTRODUCTION

Several animal feeds compete in the human food chain, especially corn. Therefore, alternative feeds to corn in diets for ruminants are important to replace traditional feeds and reduce costs (CORTE et al., 2015; ALMEIDA et al., 2016). Oilseed grains, lipid sources, are used in animal diets to replace rapidly fermentable carbohydrates for fattening and milked animals in many countries, without competing with human diets (HENDERSON et al., 2017).

In intensive animal systems production, oilseeds can increase the energy density of diets (PEREIRA et al., 2016; HUMER et al., 2018). They have enough energy to supply the highest nutritional requirement of fattening animals, reduce time to achieve the slaughter weight, and enhance the nutritional quality of lamb meat (OLIVEIRA et al., 2017; GALLO et al., 2019; VAN LE et al., 2019).

The addition of whole grains to the concentrate composition to ruminants may reduce the total cost of the diet, as it does not require grain processing. Particularly, whole oilseed grains may increase nutrient digestion efficiency (NUR ATIKAH et al., 2018), decrease daily CH4 emissions (TOPRAK, 2015; BECK et al., 2019), and modify rumen fermentation to improve its microbial efficiency (PEREIRA et al., 2016).

Rumen metabolism modifies the fatty acid profile of the diet available for intestinal absorption (MILTKO et al., 2019), besides influencing digestibility of EE (PALMQUIST and JENKINS, 2017) and fibrous fractions of the diet (PEREIRA et al., 2016). Several oleaginous grains have been used in concentrate formulations to enrich ruminant diets, as they have a favorable cost-energy ratio and good protein content, reducing diet costs. Besides, oilseeds have lower caloric increment and better feed conversion (MEDEIROS et al., 2015) compared to starch.

Major oilseeds grown worldwide are soybean, cottonseed, and sunflower (USDA, 2015). Soybeans can be considered a partially protected oil source, since lipid droplets in oilseeds are inserted into the protein matrix of the beans, providing natural protection (SILVA et al., 2007; GALLO et al., 2019). In addition, lipid sources, such as cottonseed and sunflower, supplied to finishing lambs increased availability for absorption and deposition of polyunsaturated fatty acids in the muscles (HOMEM JÚNIOR et al., 2015; CORTE et al., 2015).

Sheep present dietary limitations inherent to ruminants due to the presence of unsaturated fatty acids in the rumen (FERLAY et al., 2017; FREITAS JR et al., 2019). Oilseed sources are expected to show a different fatty acid profile, inducing different impacts on rumen microbes (JIAN et al., 2016) and animal performance (VAN LE et al., 2019). When whole grains are offered to ruminants, rumen microbes are less affected because fatty acids are released more slowly and depends of rumination (PALMQUIST and MATTOS, 2006), compared to oils.

This study assessed the efficiency of partial replacement of energy of ground corn for oilseeds, cottonseed, sunflower, and soybeans, in diet of fattening lambs, evaluating performance, diet digestibility, ingestive behavior, and carcass traits.

MATERIAL AND METHODS

Study site

The study was carried out at São Paulo Agency for Agribusiness Technology, located in the municipality of Assis, São Paulo, Brazil. The procedures were approved by the Research Ethics Committee; under protocol No. 361/2010 of University of Campinas, Brazil.

Data collection

The experiment comprised twenty-four crossbred lambs with three months old, intact males, weaned, ~~and~~ with an initial body weight 25.97± 0.75 kg. The animals were kept under feedlot conditions for 84 days in individual pens and received diets with 23.63% of coast cross hay and one of the following concentrates: 1. Control (no additional lipid source), 2. Cottonseed, 3. Sunflower, and 4. Soybean (Table 1). The treatments were formulated to contain about 6% of EE in DM. The soybean diet the addition of oil to obtain 6% of EE and reach iso-protein diets, because addition of fat sources should not exceed 6% of ether extract (EE) in the dry matter basis (CABIDDU et al., 2017; NGUYEN et al., 2018).

The adaptation period to increase the concentrate level up to each treatment lasted

Table 1 – Composition (% of dry matter) and chemical composition of experimental diets

Characteristic	Diet			
	Control	Cottonseed	Sunflower	Soybean
Ingredient				
Coast cross hay	23.63	23.63	23.63	23.63
Soybean hull	15.00	15.00	15.00	15.00
Ground corn	50.92	33.59	42.24	40.79
Soybean meal	7.48	7.48	7.48	7.48
Limestone	1.00	1.00	1.00	1.00
Minerals	0.60	0.60	0.60	0.60
Urea	1.37	0.70	1.05	0.50
Cottonseed	--	18.00	--	--
Soybean	--	--	--	9.00
Soybean oil	--	--	--	2.00
Sunflower seed	--	--	9.00	--
Nutrient (g/100g)				
Total digestive nutrients[1]	76.75	77.88	77.21	78.01
Crude protein	14.61	14.65	14.66	14.79
Rumen degradable protein	9.59	9.28	9.48	9.40
Neutral detergent fiber	37.20	38.62	44.63	47.56
Ether extract	3.11	6.14	6.33	6.30

[1] Weiss et al. (1992)

14 days and all animals received the control diet. The quantity offered corresponded to 3% of body weight (DM basis) plus 100 g, daily, until achieving maximum voluntary intake. Another 14 d were used to adapt to the treatments. After that, during 64 d of the experimental period, the animals received one of each experimental diet, offered twice a day and it was allowed 10% of leftovers, weighted daily.

Diet apparent digestibility was estimated using the method of total feces collection, with 10 d to adaptation (day 15 to 24) and 5 d of collection (day 25 to 29 of feedlot), using collecting bags (PEARSON et al., 2001). The lambs were weighed at the beginning and end of the sampling period, after 16 h of water and feed withdrawal.

Feces were collected at intervals of 24 h, before meal, and samples of 10% of total daily by each animal were frozen individually. The composite samples (5 subsamples) per animal for diets, orts, and feces were sent to the bromatological analysis. Dry matter (DM), minerals, crude protein (CP) and ether extract (EE) were analyzed according to the AOAC (1995). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin were determined as described by Van Soest et al. (1991). To estimate total digestible nutrients in the diet, the percentage of non-fibrous carbohydrates were ~~as~~ calculated by Weiss et al. (1992).

Animal performance was evaluated during 55 d, from day 30 to 84 of feedlot, after the digestibility test. The lambs were weighted at intervals of 14 d before the morning feed, without fasting. Sample of diets and orts per treatment were dried individually, each 14 d, to obtain the best value of DM feed intake.

At day 64 day of feedlot, the ingestive behavior of the animals was observed for 24 h. The ingestive behavior was evaluated by visual inspection of each animal performed by four trained examiners divided into pairs, who took turns at each 3-hour shift. All animals were evaluated every 10 min and their behavior was recorded to determine the time spent on intake, rumination, and idleness (JOHNSON and COMBS, 1991). Intake and rumination efficiency was calculated, as well as the total chewing time (FONTENELLE et al., 2011).

After 84 d of feedlot, the lambs were slaughtered at the experimental plant of USP – Universidade de São Paulo - *Campus* Pirassununga, in compliance with the Humanitarian Slaughter Guidelines, as required by Brazilian laws. After separating non-carcass components, the carcass was weighted before and after 24 h of cooling at 4°C.

Statistical analysis

The experimental design was a completely randomized block (separated by initial body weight) with four treatments and six repetitions. Results of performance, digestibility, and carcass were analyzed using the Mixed procedure of the SAS® program (SAS Institute Inc., Cary, NC). Treatment means were compared by the Tukey test, adopting a 5% level of significance. The activities of intake, idleness, and rumination were analyzed as repeated measures over time and interaction between time and treatment was tested.

RESULTS

Performance and diet digestibility

Animals fed the control diet had a higher final body weight (P=0.03) than those under sunflower diet (Table 2). The final body weight of lambs fed cottonseed and soybean did not differ from the control and cottonseed treatments. The DWG of animals fed the control diet was higher (P<0.01) than of animals in the cottonseed, sunflower, and soybean diets, which in turn did not differ from each other (Table 2).

The DMI, expressed as absolute value (g/day), was higher (P=0.02) for animals fed the control diet in comparison to ~~compared to~~ those in the sunflower diet (Table 2). The DMI in treatments cottonseed, sunflower, and soybean was not different. When the DMI was expressed as percentage of body weight, the control and cottonseed diets were higher than sunflower and soybean diets.

The sunflower diet promoted the best (P=0.04) feed efficiency than the control

Table 2 – Performance and nutrient digestibility of fattening lambs with and without addition of oilseeds

Characteristic	Diet				Probability	SE[2]
	Control	Cottonseed	Sunflower	Soybean		
Body weight, kg						
Initial	15.68	15.67	15.67	15.70	1.00	1.06
Final	42.42[a]	37.25[ab]	34.85[b]	36.32[ab]	0.03	1.75
Daily weight gain, kg	0.334[a]	0.270[b]	0.240[b]	0.258[b]	<0.01	0.01
Dry matter intake						
g/day	1,325[a]	1,198[ab]	1,046[b]	1,094[ab]	0.02	0.06
% of body weight	4.57[a]	4.54[a]	4.12[b]	4.22[b]	0.04	0.12
Feed efficiency[1]	0.267[b]	0.271[b]	0.297[a]	0.290[ab]	0.04	0.007
Digestibility, %						
Dry matter	74.16	72.83	73.90	74.85	0.80	1.56
Neutral detergent fiber	66.50[ab]	50.34[b]	67.07[ab]	71.07[a]	0.01	4.51
Acid detergent fiber	64.07	64.68	71.39	67.45	0.17	2.48
Crude protein	74.71	71.38	75.94	74.40	0.23	1.68
Ether extract	73.67[b]	93.04[a]	92.41[a]	86.44[a]	<0.01	1.91

[a,b] Average in the same row followed by different superscript letters differ by the Tukey test (P≤0.05).
[1] g daily weight gain/g dry matter intake. [2] SE: Standard error.

Table 3 – Ingestive behavior, ingestion and rumination efficiency, and total chewing time of fattening lambs with and without the addition of oilseeds

Characteristic	Diet				Probability	SE[4]
	Control	Cottonseed	Sunflower	Soybean		
Idleness, hours per day	13.61	11.92	13.03	13.25	0.43	0.76
Rumination, hours per day	7.17	8.35	7.83	7.47	0.49	0.58
Intake of DM[1], hours per day	3.22	3.73	3.14	3.28	0.75	0.43
Efficiency[2]						
Intake of DM, g/h	347	289	326	349	0.86	57
Rumination of DM, g/h	157[a]	124[ab]	114[b]	137[ab]	0.04	11
Intake of NDF[3], g/h	155	107	126	166	0.30	25
Rumination of NDF, g/h	69.93[a]	46.23[b]	43.99[b]	65.31[a]	<0.01	4.84
Total chewing time, hours	10.39	12.08	10.97	10.75	0.43	0.76

[a,b] Average in the same row followed by different superscript letters differ by the Tukey test ($P \leq 0.05$).
[1] DM: dry matter; [2] Efficiency: nutrient ingestion (g)/time in activity (h) (Mendes et al., 2008); [3] NDF: neutral detergent fiber; [4] SE: Standard error.

and cottonseed diets. Soybean diet showed no differences than control, sunflower and cottonseed.

The apparent DM digestibility (P=0.80), ADF (P=0.17) or CP (P=0.23) did not differ between the diets (Table 2). The NDF digestibility (P=0.01) was higher in the soybean diet when compared to the cottonseed diet. The EE digestibility was lower (P<0.01) for the control diet compared to the diets containing oilseeds.

Ingestive behavior

No differences (P>0.05) in the time spent on idleness, rumination, and DMI of lambs were observed between treatments (Table 3).

The inclusion of different oilseeds to diet did not alter efficiency of DMI (P=0.86) or NDF (P=0.30), and total chewing time (P=0.43) (Table 3). Animals fed the sunflower diet showed lower (P=0.04) efficiency of DM rumination than those in the control diet (Table 3). The NDF rumination showed higher efficiency (P<0.01) for the control and soybean diets compared to the cottonseed and sunflower diets (Table 3).

Carcass traits

Lambs fed the control diet showed higher weight of hot (P=0.03) and cold (P=0.03) carcass than those fed the sunflower diet (Table 2). Hot and cold carcass weight of animals treated with cottonseed or soybean diets showed intermediate values for the control and sunflower diet, without statistical differences.

Different oilseeds in diet did not alter hot (P=0.56) or cold (P=0.57) carcass yield as well as carcass dripping losses (P=0.55) (Table 4).

DISCUSSION

Sunflower grains in the diet reduced DMI (g/d) and consequently animal performance (Tables 2 and 4), compared to control diet. Probably, this effect was not only due to increase of EE in diet, since the diets with soybean and cottonseed had DMI (g/d) similar to control diet (Table 2), but EE similar to the sunflower diet (Table 1). Thus, it seems that sunflower grain have some incompatibility with sheep (MAJEWSKA et al., 2016; CABIDDU et al., 2017) and the ruminal balance (PASHAEI et al., 2016), especially in high concentrate diets.

The lower DMI in BW percentage of animals fed soybean or sunflower seeds (Table 2) may have been due to the higher NDF concentration in these diets (Table 1), since the DMI is inversely related to dietary NDF concentration (ANDUEZA et al., 2012).

According to Nur Atikah et al. (2018), diet supplementation with oils containing different fatty acid profiles improved rumen fermentation by reducing ammonia concentration and increasing total VFA concentration (BECK et al., 2019), partially due to decreases of CH4 emissions (HENDERSON et al., 2017). However, high concentration of unsaturated fatty acid is toxic for rumen microorganisms,

Table 4 – Carcass weight and yield of fattening lambs with and without the addition of oilseeds

Trait	Diet				Probability	SE[1]
	Control	Cottonseed	Sunflower	Soybean		
Hot carcass						
Weight, kg	19.27[a]	16.58[ab]	16.05[b]	16.30[ab]	0.03	0.78
Yield, %	45.41	44.64	46.06	44.89	0.56	0.75
Cold carcass						
Weight, kg	19.03[a]	16.34[ab]	15.83[b]	16.12[ab]	0.03	0.78
Yield, %	44.86	44.00	45.42	44.39	0.57	0.74
Cooling loss, %	1.20	1.44	1.40	1.12	0.55	0.18

[a,b] Averege in the same row followed by different superscript letters differ by the Tukey test (P≤0.05).
[1] SE: Standard error.

because it limits ruminal microorganisms to lipolysis and bio hydrogenate unsaturated fatty acid to saturated fatty acid (JIAN et al., 2016; FEARLAY et al., 2017; MILTKO et al., 2019).

The DMI (Table 2) was possibly more influenced by the NDF (Table 1) content than by the EE amount in the diet. The differences between energy supply by lipid and carbohydrate was possibly influenced by fiber concentration in diet.

Animals fed the cottonseed diets produced similar results than those fed the control diet for DMI in percentage of BW, probability due NDF and ADF digestibility interference (BECK et al., 2019). The difference for DMI (%BW) between the cottonseed diet and the sunflower and soybean diets seems to be related to cotton linters, resulting in lower NDF digestibility in the cottonseed diet (PIONA et al., 2012), or to their effect in rumen metabolism (PEREIRA et al., 2016; HUMER et al., 2018).

The low EE digestibility for the control diet is probably because this fraction is more linked to the waxy portions of foods than to the soluble fats of the oilseeds used (YAMAMOTO et al., 2005b), as reported in the literature (ALMEIDA et al., 2016; NUR ATIKAH et al., 2018; FREITAS JR. et al., 2019). The differences of feed intake caused significant changes in feed efficiency of animals fed different diets. The animals that had the higher intake and were fed the control and cottonseed diets showed lower feed efficiency, but not the same BWG.

The time spent on intake was expected for diets containing 50% roughage (CARDOSO et al., 2006b; MENDES et al., 2008); however, rumination time for all diets was shorter, consistent with the lower amount of roughage of all diets. The time spent on idleness was high for all treatments because the diets are rich in energy, including the control diet (CARDOSO et al., 2006).

Similar rumination NDF efficiency was observed for animals fed the control and soybean diets and this is related to the greater digestibility of the NDF fraction of soybeans, accelerating the passage of feed through the rumen (MORAIS et al., 2006). Rumination NDF efficiency was similar for the cottonseed and sunflower diets, possibly related to the NDF component in whole grain hull (Table 1).

The control and cottonseed diets had a lower NDF content (37.2 and 38.6%, respectively) and different efficiencies. The cottonseed and sunflower diets contained 38.6 and 44.6% NDF, respectively, but provided similar rumination efficiency. According to Cardoso et al. (2006), NDF content lower than 44% in feedlot diets of lambs does not influence the time spent on ingestion, rumination, or idleness. However, the authors observed a linear decrease in rumination efficiency, expressed as g of DM/hour, with increasing concentration of NDF in the diet. Differently from this study, the NDF source used by the authors was always the same, indicating the structural difference of NDF in the foods studied (ANDUEZA et al., 2012).

Carcass weight is a yield indicator in feedlot lambs (SOUZA et al., 2013). The diets affected carcass weight, indicating inferiority of diets with additional lipid sources. Urano et al. (2006) reported similar carcass yields of animals fed diets without an additional fat source or with inclusion of oilseeds for feedlot animals fed soybean (FURUSHO-GARCIA et al., 2010), cottonseed by-products (PAIM et al., 2014), and sunflower seeds (HOMEM JR et al., 2010).

In intensive production systems of fattening lambs, sunflower is not suitable to replace ground corn in feedlot diets that contain a high concentrate proportions.

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