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Yellow grease in sheep diets: intake and digestibility

[*Óleo residual de fritura em dietas para ovinos: consumo e digestibilidade*]

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ABSTRACT

This study aimed to assess the effects of yellow grease supplementation on the intake, digestibility, and nitrogen balance in sheep. Twenty Santa Inês lambs with a mean age of 95 ± 10 d and body weight of 19.29 ± 3.17kg were evaluated in a completely randomized design. The diets were supplemented with oil at concentrations of 0, 20, 40, 60, and 80 gkg^{-1} of dry matter (DM) of the concentrate. The diets were based on roughage and concentrate (50:50). The experimental period lasted 19 d and included 14 adaptation days and five collection days for the total supplied diet, orts, feces, and urine. Supplementation with yellow grease had no significant effect on the intake of DM, crude protein (CP), neutral detergent fiber (NDF), or non-fiber carbohydrates (NFC). However, the ether extract (EE) intake increased linearly with supplementation of yellow grease. Moreover, no effect was observed for DM, CP, NDF, and NFC digestibility and nitrogen balance. EE digestibility increased linearly with the yellow grease dietary supplementation. Thus, sheep dietary supplementation with yellow grease may be used at a level of up to 80 gkg^{-1} of DM of concentrate without impairing nutrient intake and digestibility.

Keywords: by-product, fat, lipid, ruminant, supplementation

RESUMO

Objetivou-se, com o estudo, avaliar os efeitos do óleo residual de fritura, em dietas para ovinos, sob o consumo, a digestibilidade e o balanço de nitrogênio. Foram utilizados 20 cordeiros Santa Inês, com idade de 95 ± 10 dias e peso corporal de 19,29 ± 3,17kg, em delineamento inteiramente ao acaso. As dietas continham óleo de fritura nas concentrações de 0; 20; 40; 60 e 80gkg^{-1} da matéria seca (MS) do concentrado. As dietas tinham relação volumoso:concentrado de 50:50. O período experimental foi de 19 dias, incluindo 14 dias em adaptação e cinco dias de coleta do fornecido, das sobras, das fezes e da urina. A suplementação com óleo de fritura não alterou o consumo de MS, proteína bruta (PB), matéria orgânica (MO), fibra em detergente neutro (FDN) e carboidratos não fibrosos (CNF). Entretanto, o consumo de extrato etéreo (EE) aumentou com a inclusão do óleo. Não foi observado efeito na digestibilidade da MS, da PB, da FDN, dos CNF e no balanço de nitrogênio. A digestibilidade do EE aumentou com a inclusão do óleo. Assim, a inclusão de óleo de fritura em dietas para ovinos pode ser utilizada em até 80gkg^{-1} da MS do concentrado, sem limitar ingestão e digestibilidade dos nutrientes.

Palavras-chave: gordura, lipídios, ruminante, subproduto, suplementação

INTRODUCTION

Lipid sources play an important role in diets for ruminants. These sources can help increase the energy density of diets and increase palatability and feed efficiency (Palmquist, 1991). Among the different lipid sources, vegetable oils are highlighted owing to the volume produced and availability in the market (OECD / FAO, 2015). However, the high added value of this product is still considered a barrier to inclusion in ruminant diets. One of the alternatives is the use of residual frying oil, which is still mostly discarded in the environment (ECÓLEO, 2020). This waste,

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widely used in the production of fried foods, can be recycled and returned to the production line, contributing to the preservation of the environment (Wildner and Hillig, 2012) and reducing the costs of animal production.

Yellow grease is highly polluting if improperly discarded, but as long as it is not used to fry foods of animal origin, it can be considered an alternative feed for lambs (Cleef *et al.*, 2016). Yellow grease can be used as a source of lipids in the diet of ruminants, and it produces less deleterious effects on the rumen because it contains saturated fatty acids (Murta, 2012). Ávila *et al.* (2000) found increased biohydrogenation levels and normal metabolism of ruminal microorganisms when tallow and yellow grease obtained from fried food restaurants were used as a source of fat for dairy cows.

Fatty supplements may affect ruminal fermentation and reduce the digestibility of other dietary nutrients, especially neutral detergent fiber. Nonetheless, negative effects depend on the amount and lipid source because unsaturated lipids and short-chain fatty acids have more deleterious effects on ruminal fermentation than saturated lipids (Palmquist, 1991). Nelson *et al.* (2008) also reported that yellow grease is a less expensive source of energy and has high linoleic acid content, which contributes to the increase in conjugated linoleic acid.

The effects of adding different concentrations of frying oil on fiber digestibility and animal consumption have not yet been fully elucidated and are divergent (Cleef *et al.*, 2016). Therefore, this study aimed to evaluate yellow grease as an alternative feed to increase the energy density of diets for lambs and assess the optimal oil concentration in concentrate supplements based on the intake and apparent digestibility of dietary dry matter and nutrients.

MATERIAL AND METHODS

The project was submitted to and approved by the Animal Ethics Committee (*Comissão de Ética no Uso de Animais*, CEUA), Protocol 23084.01916/2013-22, of the Federal Rural University of the Amazon (*Universidade Federal Rural da Amazônia*, UFRA). The experiment was conducted in Belém, Pará, Brazil at 01°28′S, 48°27′W and at an altitude of 12m. The climate is characterized by an average annual temperature of 26.4°C, relative air humidity of 84.0%, and average annual rainfall of 3,001.3mm. The experimental diets were formulated to be isonitrogenated, meet the nutritional demands of lambs, and provide an average daily weight gain of 200g according to guidelines from the National Research Council (Nutrient…, 2007), with a diet consisting of a 50:50 roughage/concentrate ratio. The roughage consisted of fresh elephant grass, *Pennisetum purpureum*, Schum 'roxo', chopped twice a day before feeding. The concentrate was based on ground corn, soybean meal, yellow grease (Table 1), mineral salt, and calcitic limestone in a variable composition depending on the treatment.

Table 1. Fatty acid profile of residual frying oil

	g 100g-1
C12:0 (lauric)	0.22
C14:0 (miristico)	0.60
C16:0 (palmitic)	30.78
C18:0 (stearic)	4.08
C18:1 (oleic)	42.60
C18:2 (linoleic)	19.62
C18:3 (linolenic)	0.34
C20:0 (arachidic)	1.31

Five concentrations of yellow grease obtained from microentrepreneurs, who worked exclusively in the sale of chips, were evaluated pursuant to regulation 8/2004 of the Brazilian Ministry of Agriculture, Livestock and Food Supply (*Ministério da Agricultura, Pecuária e Abastecimento*), thereby ensuring that contamination with animal products did not occur. The diets were formulated with oil at concentrations of 0, 20, 40, 60, and 80 gkg^{-1} of DM of concentrate (Table 2). The concentrate ingredients were ground to 2mm and homogenized in a vertical mixer to avoid possible selection of ingredients by the animals. The chopped elephant grass was mixed with the concentrate when the diets were supplied to the animals. The composition and chemical composition of the ingredients are outlined in Table 3. The diets with yellow grease were supplemented with 100g of antioxidant (Banox® E) per 100kg of feed to avoid possible oxidation of dietary lipids.

Table 2. Proportion and chemical composition of experimental diets

Ingredient	Yellow grease (gkg^{-1} of dry matter)				
	0	20	40	60	80
Proportion of ingredients (gkg^{-1} dry matter)					
Elephant grass	500.0	500.0	500.0	500.0	500.0
Corn meal	240.0	234.0	230.0	225.0	220.0
Soybean bran	240.0	235.0	230.0	225.0	220.0
Urea	6.4	7.4	8.4	9.4	10.4
Premix	4.5	4.5	4.5	4.5	4.5
Calcitic limestone	9.1	9.1	9.1	9.1	9.1
Yellow grease	0.0	10.0	20.0	30.0	40.0
Chemical composition					
Dry matter[1]	503.4	504.3	505.3	506.2	507.1
Organic matter[2]	948.7	947.4	945.9	944.5	943.2
Crude protein[2]	173.1	173.2	173.3	173.5	173.4
Ether extract[2]	25.1	33.8	42.5	51.3	60.2
Neutral detergent fiber[2]	380.9	379.6	378.3	377.0	375.8
Acid detergent fiber[2]	229.9	229.0	228.0	227.1	226.1
Lignin[2]	29.7	29.5	29.3	29.1	28.9
Neutral detergent insoluble nitrogen[3]	265.0	261.0	258.0	254.0	251.0
Acid detergent insoluble nitrogen[3]	80.0	78.0	77.0	75.0	73.0
Neutral detergent fiber corrected for ash and protein[2]	382.4	381.4	380.4	379.4	378.4
Total digestible nutrients[2]*	646.2	656.4	666.6	676.8	687.1

Total digestible nutrients* calculated based on the values reported by Valadares Filho *et al*. (2014).
[1]gkg^{-1} on a fresh basis
[2]gkg^{-1} dry matter
[3]gkg^{-1} total nitrogen

Table 3. Chemical composition of ingredients used in the experimental diets

	Elephant grass	Corn meal	Soybean bran	Yellow grease
Dry matter[1]	147.8	871.9	857.0	961.8
Organic matter[2]	937.5	999.9	999.9	1000
Crude protein[2]	55.9	78.6	463.3	-
Ether extract[2]	23.3	39.9	15.7	961.8
Neutral detergent fiber[2]	649.4	89.8	163.7	-
Acid detergent fiber[2]	370.2	59.8	127.1	-
Neutral detergent insoluble nitrogen[3]	241.0	82.0	603.0	-
Acid detergent insoluble nitrogen[3]	4.0	24.0	299.0	-
Lignin[2]	41.2	3.1	37.5	-

[1]gkg^{-1} on a fresh basis
[2]gkg^{-1} dry matter
[3]gkg^{-1} total nitrogen

Twenty lambs of the Santa Inês breed were used, males were uncastrated, with an average body weight (BW) of 19.29 ± 3.17kg and an average age of 95 ± 10 d. To avoid post-weaning stress, lambs were weaned early at 60 d of age and received a diet based on corn, soy, and grass during the pre-experimental phase. The animals were housed in metabolic cages with an area of 0.79m² (1.31m × 0.60m), slatted floors facilitated feces collection, and drinkers and feeders supplied water and feed. The animals were individually identified by collar and fed twice daily at 8 a.m. and 5 p.m. The total diets were supplied in sufficient quantities to provide approximately 100gkg^{-1} of orts adjusted based on the DM intake of the previous day. Deworming of endo- and

ecto-parasites was performed before the beginning of the experimental period. Ivermectin was administered subcutaneously at a dose of 0.5mL 25kg^{-1} live weight at the beginning of the experimental period as a prophylactic deworming measure.

The animals were weighed and allocated to their metabolic cages by a draw conducted at the beginning of the experimental period. The experimental period lasted 19 d, including 14 d for adaptation to the environment, diet, and intake adjustment, and 5 d for total collection of the provided diet, orts, feces, and urine. Samples of feed, orts, feces, and urine were collected and weighed for five consecutive days, placed in labeled plastic containers, and stored at -10°C. Additionally, 10% hydrochloric acid solution was added daily to the collectors to prevent the loss of urine nitrogen compounds by volatilization.

Samples of the feed, orts, and feces were thawed, homogenized, and pre-dried in a forced-air oven at 55°C for approximately 72 h, ground in a cutter type (Wiley) mill with a 1 mm screen, and placed in labeled plastic containers at the end of the collection period. Analyses were performed to assess the content of DM, organic matter (OM), mineral matter (MM), and CP, according to the method reported by the AOAC (Official…, 2005). The EE content was obtained by Randall method, replacing diethyl ether with petroleum ether (Thiex *et al.*, 2003). NDF was quantified with a heat-stable amylase and sodium sulfite (Mertens, 2002) using an Ankom 220 fiber analyzer (Ankom Technology, Fairport, NY, USA) and correcting for ash and protein. Acid detergent fiber (ADF) was measured using the sequential method.

The total carbohydrate (TCHO) content was assessed according to the guidelines of Sniffen *et al.* (1992) using the following equation: TCHO = 100 – (CP + EE + MM). NFC were calculated as follows: NFC = 100 – (CP + EE + NDFap + MM), where NDFap = NDF corrected for ash and protein contents. The coefficients of apparent digestibility of nutrients were assessed using the following equation: CD = [(Qi – Qe)/Qi] × 100, where CD = coefficient of digestibility, Qi = quantity of ingested nutrient, and Qe = quantity of nutrients excreted in feces.

For urine collection, the volume produced per animal was measured daily, and 10% of the total volume was collected. This material was identified and stored in a glass container with a total seal, and kept in a freezer at -20°C. To avoid volatilization and loss of nitrogenous compounds, 10 mL of hydrochloric acid was placed daily in the urine collection buckets. The nitrogen contents were assessed using these urine samples to calculate the apparent nitrogen balance (NB), which was expressed as g animal^{-1} day^{-1} and gkg$^{-0.75}$:

N assimilated = N ingested – (N feces + N urine);
N absorbed = N ingested – N feces;
N ingested = N supplied – N orts.

A completely randomized design with five treatments (concentrate oil concentrations) and four replicates (animals) was used. The assumptions of normality of error and homogeneity of variance were met according to Cramer-von Mises and Brown and Forsythe's tests, respectively. The data were subjected to polynomial regression analysis to assess the best fit according to concentrate supplementation with yellow grease. The GLM procedure of Statistical Analysis System (SAS, version 9.2) was used for all statistical analyses and assessed at 0.05 probability, according to the following model:

$$Y_{ij} = \mu + T_i + e_{ij},$$

where μ is the overall constant; T_i treatment is the effect of treatment i (i = 1 to 5), and e_{ij} is the random unobservable error.

RESULTS

Dietary supplementation with yellow grease had no effect (P>0.05) on the dry matter intake (DMI), organic matter intake (OMI), crude protein intake (CPI), neutral detergent fiber intake (NDFI), acid detergent fiber intake (ADFI), total digestible nutrient intake (TDNI), total carbohydrate intake (TCHOI) and non-fiber carbohydrate intake (NFCI) at all levels of supplementation (Table 4). However, the ether extract intake (EEI) showed a linear increase with oil concentrate supplementation (P<0.05), which was expressed as g day^{-1} and % BW. Supplementation with yellow grease did not have an effect (P>0.05) on the DM intake and CP intake, which followed the same trend.

Table 4 Nutrient intake of sheep fed diets with different quantities of yellow grease

Item	Yellow grease (gkg^{-1} of dry matter)							
	0	20	40	60	80	CV %	P	Regression
Nutrient intake ($g\ day^{-1}$)								
DM	890	867	1071	872	945	17.73	0.6956	Y = 929
OM	848	816	994	798	853	17.87	0.9773	Y = 862
CP	159	152	184	148	157	17.05	0.8854	Y = 160
EE	23	32	50	51	65	13.37	0.0001	Y = 0.024+0.005X*
NDF	296	288	355	276	306	20.11	0.8565	Y = 304
ADF	180	174	214	170	185	19.46	0.9374	Y = 185
TCHO	666	631	759	598	630	18.46	0.6290	Y = 657
NFC	369	343	403	322	324	17.29	0.3105	Y = 352
TDN	671	661	824	650	715	18.42	0.7455	Y = 704
Nutrient intake (% BW)								
DM	3.99	3.96	4.86	4.12	4.18	13.18	0.6020	Y = 4.22
OM	3.80	3.73	4.51	3.77	3.78	13.19	0.9970	Y = 3.92
CP	0.71	0.69	0.83	0.70	0.69	12.43	0.8825	Y = 0.72
EE	0.10	0.14	0.23	0.24	0.28	10.62	0.0001	Y = 0.112+0.023X**
NDF	1.33	1.31	1.61	1.30	1.35	1.57	0.9061	Y = 1.38
ADF	0.80	0.79	0.97	0.80	0.82	1.51	0.8884	Y = 0.84
TCHO	2.98	2.88	3.44	2.83	2.79	13.65	0.5747	Y = 2.98
NFC	1.65	1.57	1.83	1.52	1.43	12.10	0.2245	Y = 1.60
TDN	2.87	3.03	3.73	3.10	3.16	15.47	0.4742	Y = 3.18
Nutrient intake (MBW – $gkg^{-0.75}\ d^{-1}$)								
DM	86.35	85.55	105.24	88.14	91.22	13.99	0.5735	Y = 91.30
OM	82.29	80.50	97.65	80.66	82.39	14.02	0.9865	Y = 84.70
CP	15.41	15.05	18.13	15.00	15.18	13.20	0.8875	Y = 15.75
EE	2.30	3.20	4.97	5.19	6.31	10.69	0.0001	Y = 2.4021+0.49953X***
NDF	28.78	28.35	34.88	27.91	29.55	16.48	0.8930	Y = 29.89
ADF	17.50	17.16	21.07	17.15	17.88	15.91	0.8760	Y = 18.15
TCHO	64.57	62.24	74.54	60.46	60.89	14.53	0.5654	Y = 64.54
NFC	35.78	33.88	39.65	32.54	31.33	13.02	0.1989	Y = 34.64
TDN	64.98	65.40	80.89	66.05	68.96	15.31	0.6367	Y = 69.26

CV, coefficient of variation; DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber ADF, acid detergent fiber; TCHO, total carbohydrates; NFC, non-fiber carbohydrates; TDN, total digestible nutrients; BW, body weight; P, significance level (P<0.05). * P<0.001; r^2 = 82.38; ** P<0.001; r^2 = 85.53; r^2 = 88.35, *** P<0.0001.

The TDNI did not match (P>0.05) the dietary level of supplementation with yellow grease. The TCHOI followed the same trend as the NFCI. The coefficients of apparent digestibility of DM, OM, CP, NDF, ADF, NFC, and TDN were not affected (P>0.05) by dietary supplementation with yellow grease, as shown in Table 5. The digestibility of EE exhibited a linear increase (P<0.05) with dietary oil supplementation. NDF digestibility followed the same trend as DM digestibility. Dietary TDN contents (gkg^{-1} of DM) were not affected (P>0.05) by supplementation with yellow grease because the oil did not replace the dietary NFC. Table 6 shows that the NB was not affected (P>0.05) by dietary supplementation with yellow grease in sheep.

Table 5. Apparent digestibility of nutrients (%) and total digestible nutrient concentration assessed in sheep fed diets with different levels of yellow grease

	Yellow grease (gkg^{-1} of dry matter)							
	0	20	40	60	80	CV%	P	Regression
Digestibility								
DM	72.54	73.33	74.88	71.84	73.04	4.42	0.9089	Y = 73.13
OM	75.97	76.34	77.17	74.03	74.63	4.02	0.2695	Y = 75.63
CP	78.20	78.40	79.41	78.10	78.42	3.52	0.9707	Y = 78.51
EE	83.09	88.00	89.29	94.49	96.48	3.37	0.0001	Y =83.68+1.66x*
NDF	52.96	53.63	57.50	52.40	55.23	11.54	0.7381	Y = 54.34
ADF	33.40	34.93	39.74	35.33	37.85	23.61	0.4538	Y = 36.25
NFC	90.47	91.25	88.68	94.41	93.39	2.88	0.0624	Y = 91.64
TDN (%)	75.20	76.06	76.88	74.71	75.76	3.70	0.9525	Y = 75.72

CV, coefficient of variation; DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; NFC, non-fiber carbohydrates; TDN, total digestible nutrients. * ($P<0.01$); $r^2 = 76.30$

Table 6. Nitrogen balance in sheep fed diets with different levels of yellow grease in the concentrate

Parameters	Diets with yellow grease (gkg^{-1} of dry matter)						
	0	20	40	60	80	CV %	Regression
Ingested nitrogen, g day^{-1}	25.32	25.30	30.87	25.03	25.99	15.73	Y = 26.50
Absorbed nitrogen, g day^{-1}	19.80	20.10	24.89	19.79	20.54	15.88	Y = 21.02
Nitrogen balance, g day^{-1}	19.72	19.98	24.68	19.65	20.11	16.13	Y = 20.83
Nitrogen balance, gkg^{-1} $BW^{0.75}$	2.48	2.50	3.03	2.52	2.51	12.37	Y = 2.61

BW, body weight; CV, coefficient of variation

DISCUSSION

The linear increase in the EEI was expected and explained by the increasing increase in the concentration of EE in diets with greater oil supplementation. Supplementation with yellow grease did not influence the intake of other nutrients, which indicated that the quantity of supplemented oil may be used without impairing the ruminal fermentation patterns. In this case, especially for fiber digestibility, which is closely related to the voluntary intake of DM.

The effect of lipids on the DMI may be related to the fatty acid profile of frying oil, as according to Palmquist and Mattos (2006), the reduction in DM consumption can be explained by the toxicity caused by fatty acids to intestinal microorganisms responsible for biohydrogenation, due to the high proportion of medium-chain fatty acids (10 to 14 carbons) and polyunsaturated long-chain fatty acids. The results of DM corroborate the thesis of Maia *et al*. (2012), because only 21.55% of fatty acids are long-chain polyunsaturated or medium-chain, with 34.86% of fatty acids consisting of palmitic (C16: 0) and stearic (C18: 0) and 42.60 % oleic acid (18: 1), which is monounsaturated and less toxic to intestinal microorganisms. Maia *et al.* (2012) showed that canola, sunflower, and castor oil in nature were refined and obtained levels of palmitic acid of 4.4%, 6.5%, and 1.3%, respectively. However, divergent values caused by the heating of the oil were found in the frying process that modified the fatty acid profile of the oil originally with high proportions of polyunsaturated fatty acids in saturated and monounsaturated fatty acids, contributing to the trend in the DMI.

The quality of the dietary NDF showed adequate fiber content and may have accounted for the trend of the NDFI, which followed that of the DMI and contributed to an increased rate of digestion and passage through the rumen. The use of fat sources, especially vegetable oils, has not reduced the DMI in certain experiments, and this response is linked to the dietary NDF quality (Fiorentini *et al.*, 2015). Additionally, supplementation with different concentrations of frying oil did not affect the consumption of CP, OM, ADF, and NFC, which was expected because there was no difference in the consumption of DM. However, we have no explanation for the consumption of TDN because increasing the concentration of EE in the diet should increase the TDN content.

The increase in oil concentration in the diet increased the EE digestibility, presenting an optimal level of inclusion of 40 gkg^{-1} of DM. Atkinson *et al*. (2006) reported that supplementation with fatty acids up to 94 gkg^{-1} had no effect on the digestibility of dietary components. However, several other factors can affect the digestibility of fatty acids, including the DMI, the baseline characteristics of the diet, and the source of the fat. Supplementation with fat has been shown to decrease the digestibility of DM and the DMI (Allen, 2000) because it is linked to a low proportion of fiber in the diet and a high proportion of starch (Maia *et al.,* 2012; Morgado *et al.,* 2014). However, this result was not observed in the present study, which may be related to the amount of oil in the diet, the type of oil, or degree of unsaturation (Sanibal and Mancini Filho, 2004), and the proportion of roughage/concentrate in the diet.

The digestibility of NDF, ADF, CP, OM, and NFC followed the same trend as the digestibility of DM. This similarity in the trends may be related to the proportion of forage in the diet, which demonstrated that the addition of frying oil up to 40 gkg^{-1} DM, associated with the proportion of 500 gkg^{-1} of forage in the diet, does not alter the rumen environment. The fiber content may limit the effects of unsaturated lipids, because fatty acids bind to the hydrophobic surfaces of food and decrease the toxicity of fats, maintaining normal operations in the rumen (Bateman and Jenkins, 1998).

The findings of the present study were consistent with the results of Atkinson *et al.* (2006), who noted that NDF digestibility was not affected by increases in oil when assessing dietary supplementation with safflower oil in sheep (0, 30, 60, and 90 gkg^{-1}). Another factor that may have contributed to the lack of effect of yellow grease on the digestibility of NDF is related to the fatty acid profile of yellow grease. The frying process leads to a decrease in the concentration of unsaturated fatty acids and a proportional increase in saturated fatty acids (Lopes *et al.,* 2004).

An experiment conducted by Doreau *et al*. (1991) assessing supplementation with 50 and 100 gkg^{-1} of canola oil in ruminant diets concluded that no significant effect was observed on fiber digestibility, which was associated with 626 gkg^{-1} monounsaturated fatty acids found in canola oil (Canciam, 2010). These results corroborate those of the present study because the frying process of the soybean oil increased the monounsaturated fatty acids by 42.60 gkg^{-1}, indicating that yellow grease can be used without impairing fiber digestibility. Schafhauser Jr. (2005) reported a positive correlation between EE and the NFCI owing to the negative correlation between NFC and NDF in relation to the digestibility of NFC. However, the digestibility of NFCs followed the same trend as the other studied variables, which may have been caused by the yellow grease fatty acid profile and the decrease in unsaturated fatty acids with increased temperature during the frying process, thereby promoting the digestibility of NFCs without affecting fiber digestibility.

Morgado *et al*. (2014) evaluated the inclusion of 4.2% of sunflower oil, which was associated with different sources of carbohydrates soluble in neutral detergents (starch and fiber soluble in neutral detergent), and determined that the digestibility of DM, OM, NFC, and NDF was directly associated with the addition of oil to the carbohydrate source. Therefore, for a better understanding of the alteration of the fatty acid profile caused by the oil frying process, which is related to the intake and digestibility of the different dietary compounds, it would be important to study how the frying process alters the oil fatty acid profile and its association with the oil concentrations above the presentation in our study with different roughage/concentrate ratios in the diet.

These results indicated that supplementation with yellow grease had no effect on the absorption and ingested nitrogen usage, and the absence of effect may be related to the CPI and digestibility, which were also not affected by the dietary levels of supplementation. The neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) contents of the feed fiber fraction may also have affected the NB (Carvalho, 2006) because nitrogen compounds present in this form are unavailable to the animal. The forage the ADIN and NDIN contents in the present study were considered normal for tropical grasses at 4.0 and 241.0 gkg^{-1} of TN, respectively, which ensured adequate nitrogen use by the animals.

The nitrogen ingested by the animals in the present study surpassed the nutritional requirements of nitrogen intake for lambs with

weight gains of 200 g day^{-1}, which is 19.7 g according to NRC (Nutrient…, 2007). This result was caused by the lack of effect of the yellow grease on nitrogen intake. The results found in the present study corroborate the data reported by Morgado *et al.* (2014), who noted that the quantities of nitrogen assimilated, ingested, and absorbed did not differ following dietary supplementation with 70 and 42 gkg^{-1} of oil for sheep, respectively.

CONCLUSION

The amount of yellow grease used in the sheep diet had no negative effects on the consumption and digestibility of DM and dietary nutrients or on the NB, indicating that yellow grease can be used as an alternative source of lipid supplements in the diet of sheep at levels up to 80 gkg^{-1} of concentrate or 40 gkg^{-1} total DM of the diet.

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