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Scientific Article

Intake and digestibility in sheep fed diets that include waste frying oil

Consumo e digestibilidade em ovinos submetidos a dietas contendo óleo residual de fritura

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ABSTRACT - Waste frying oil may serve as a viable alternative to fresh vegetable oils, potentially reducing environmental impacts and animal feed costs. This study aimed to assess the effects of incorporating waste frying oil into sheep diets and to determine the optimal dietary oil concentration. We evaluated intake and apparent digestibility using 25 uncastrated Santa Inês male sheep (average, 90 d of age; 20 ± 3.56 kg) in a randomized block design over a 21-d experimental period. The sheep were housed in individual metabolic cages and fed diets with a 50:50 roughage-to-concentrate ratio twice daily. Diets included waste frying oil at concentrations of 0, 2, 4, 6, and 8% of the total dry matter. Animals receiving higher concentrations of waste frying oil exhibited lower nutrient intake ($p < 0.05$) compared to those with up to 4% inclusion. Nutrient digestibility decreased linearly ($p < 0.05$) with increasing oil content, except for ether extract digestibility ($p = 0.02$), which improved. Although the addition of oil increased the concentration of total digestible nutrients, the intake of total digestible nutrients was not maintained or enhanced at 6% and 8% oil ($p = 0.82$). Including up to 4% waste frying oil in sheep diets is feasible without compromising nutrient intake and digestibility.

Keywords: Feed. Animal. Environmental impacts. Residue.

RESUMO - O óleo de residual de fritura pode ser uma opção viável para diminuir os impactos ambientais e os gastos com alimentação animal substituindo óleos vegetais in natura. Com isso, o presente trabalho objetivou avaliar o efeito da inclusão de óleo residual de fritura em dietas para ovinos e determinar a concentração ideal de óleo na dieta. Para o ensaio de consumo e digestibilidade aparente foram utilizados 25 cordeiros machos, inteiros, da raça Santa Inês com idade média de 90 dias e 20 kg (± 3,56), distribuídos em delineamento em blocos casualizados. O experimento teve duração de 21 dias. Os animais foram alojados em gaiolas metabólicas e alimentados duas vezes ao dia com dietas formuladas na proporção volumoso/concentrado de 50:50. O óleo residual de fritura integrou as dietas nas concentrações 0, 2, 4, 6 e 8% da matéria seca total. Os animais que receberam dietas com maiores concentrações de óleo residual de fritura apresentaram menor consumo dos nutrientes em contraste às dietas que continham até 4% de inclusão. A digestibilidade dos nutrientes diminuiu linearmente com a adição do óleo, com exceção a digestibilidade do extrato etéreo que foi maior. Apesar da maior concentração de Nutrientes Digestíveis Totais com a adição de óleo, esta não foi suficiente para manter ou aumentar o consumo de NDT nas dietas com 6 e 8% de óleo. A inclusão de até 4% de óleo residual de fritura, na dieta de ovinos, pode ser utilizada sem comprometer o consumo e a digestibilidade dos nutrientes.

Palavras-chave: Alimentação. Animal. Impactos ambientais. Resíduo.

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INTRODUCTION

Sheep meat production in Brazil faces challenges in supplying the domestic market efficiently and with high quality. The limited availability of sheep meat and the lack of appropriate cuts have been identified as barriers to increasing consumption among Brazilians. However, despite these obstacles, the market is promising if the demands and needs of consumers are met (SANTOS; BORGES, 2019).

Feed constitutes a substantial portion of the production costs of these animals. Thus, enhancing techniques that utilize alternative, less expensive feeds is crucial for system sustainability. Incorporating lipids into the ruminant diet increases energy density and fosters a more suitable balance between non-structural and structural carbohydrates in the feed (JOY et al., 2021). However, when lipid use surpasses the capacity of ruminal metabolism of these compounds, adverse effects such as reduced voluntary intake and carbohydrate digestibility have been observed (MEDEIROS; ALBERTIN; MARINO, 2015).

The use of vegetable oils in ruminant feed is limited in Brazil due to their high costs (RÊGO et al., 2021). Consequently, waste frying oil may serve as a cost-effective alternative to fresh vegetable oils. Waste frying oil is categorized as a material posing major environmental risks due to its high pollution potential. Recycling represents the most appropriate method to minimize the environmental impacts associated with this waste. Moreover, this reverse cycle facilitates reuse and proper disposal, yielding new by-products (FOO et al., 2021). Furthermore, studying the characteristics of waste frying oil for use in animal feed is crucial, as the oil undergoes chemical and physical changes during the frying process, such as hydrolysis and oxidation reactions, which can alter its nutritional properties (FREIRE; MANCINI-FILHO; FERREIRA, 2013). However, to date, there have been no reports of adverse effects on animal health when it is included in their diet.

Therefore, incorporating frying oil into sheep feed presents an intriguing alternative that may minimize environmental impacts, enhance the energy density of diets, and decrease production costs. The objective of this study was to assess the impact of diets containing varying levels of waste frying oil on nutrient intake and apparent digestibility in sheep, as well as to ascertain the optimal concentration of oil in the diet.

MATERIAL AND METHODS

The project was provisionally submitted to and approved by the Ethics Committee on the Use of Animals (ECUA) under Protocol 2308401916/2013-22 (UFRA).

The research took place in Belém, Pará, Brazil, situated at 01° 28' S latitude and 48° 27' W longitude, with an altitude of 12 m. We formulated the experimental diets to be isoproteinic, adhering to the NRC (2007) recommendations for the crude protein (CP) requirements necessary to achieve an average daily weight gain of 0.2 kg in sheep. We used a roughage to concentrate ratio of 50:50, based on dry matter, utilizing sugarcane silage *(Saccharum officinarum L.)* as the roughage source.

Five concentrations of waste frying oil, obtained from a microentrepreneur specializing in the sale of French fries and adhering to Regulation No. 8 of March 25, 2004, of the Ministry of Agriculture, Livestock, and Supply (BRASIL, 2004), were evaluated to ensure no contamination with animal -origin products. The oil was incorporated into the diets at 0, 2%, 4%, 6%, and 8% of the total dry matter.

The diet provided to the animals consisted of sugarcane silage mixed with concentrate. Tables 1 and 2 present the chemical compositions of the ingredients in the experimental feeds and the proportions of these ingredients, respectively.

Twenty-five crossbred Santa Inês sheep were used, consisting of uncastrated, weaned males with an average age of 90 d and an initial average body weight of 20 ± 3.56 kg. The animals were accommodated in wooden metabolic cages, each measuring 0.79 m² (1.31 m × 0.60 m) and equipped with a drinker and feeder. These cages were located in a covered shed, offering protection against rain and direct solar radiation.

Levamisole sulfate was administered subcutaneously as a prophylactic measure against worm infestation at a dosage of 0.5 ml per 25 kg of body weight at the start of the adaptation period. Each animal was individually identified with a collar and fed twice daily at 8 am and 5 pm. Diets were provided in quantities that ensured approximately 10% remained as leftovers, with adjustments made according to the previous day’s dry matter intake.

Table 1. Chemical composition of the ingredients used in the formulation of the experimental diets for sheep.

Composition (%)	Foods				
	Sugarcane silage	Ground corn	Soybean meal	Wheat bran	Frying oil
DM	17.2	86.50	82.60	87.90	100
OM	95.5	98.50	92.60	93.00	100
CP	2.8	7.80	44.50	20.03	-
EE	1.2	1.11	1.30	1.70	100
NDF	55.16	24.09	25.93	42.14	-
ADF	35.46	2.96	12.16	15.14	-
$NIND_{NDF}$	0.12	0.70	7.90	1.73	-
$NIAD_{ADF}$	0.14	1.15	2.99	0.85	-
Fatty acid profile (g $100g^{-1}$) of waste frying oil					
C12:0 (lauric)	0.22				
C14:0 (myristic)	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				

DM = dry matter; OM = organic matter; CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; NIAD = nitrogen insoluble in acid detergent; NIND = nitrogen insoluble in neutral detergent.

Table 2. Composition of experimental diets (based on dry matter, DM) fed to sheep.

Ingredients	Dietary oil concentration (%)				
	0	2	4	6	8
	Proportion of ingredients (%)				
Sugarcane silage	50	50	50	50	50
Ground corn	14.5	12.1	9.7	7.3	5.0
Soybean meal	26.5	26.9	27.3	27.7	2.8
Wheat bran	7.5	7.5	7.5	7.5	7.5
Urea	1.0	1.0	1.0	1.0	1.0
Calcitic Limestone	0.50	0.5	0.5	0.5	0.5
Waste frying oil	0	2	4	6	8
Total	100	100	100	100	100
	Chemical composition (%)				
DM	51.12	51.37	51.63	51.88	52.14
OM	93.55	94.55	94.56	94.57	94.58
CP	18.67	18.66	18.65	18.65	18.60
EE	1.21	3.18	5.16	7.13	9.10
NDFcp	41.11	40.63	40.16	39.68	39.21
ADF	22.52	22.50	22.47	22.45	22.42
NIND	2.38	2.39	2.41	2.42	2.43
NIAD	1.14	1.13	1.12	1.12	1.11
TDN	65.08	67.51	69.93	72.35	74.77

DM = dry matter; OM = organic matter; CP = crude protein; EE = ether extract; NDF = neutral detergent fiber; ADF = acid detergent fiber; NIAD = nitrogen insoluble in acid detergent; NIND = nitrogen insoluble in neutral detergent; NDF_{CP} = neutral detergent fiber corrected for ash and protein; TDN = total digestible nutrients.

The experiment lasted 21 d, with 14 d for adaptation to the environment and diet, as well as intake adjustment, followed by 7 d dedicated to the total collection of provided diets, leftovers, and feces. To estimate the animals' consumption, the food provided, and leftovers were weighed throughout the data collection period.

The composite samples of the feed provided, leftovers, and feces were stored in a freezer for subsequent processing and chemical analysis. Analyses were conducted to determine the contents of dry matter (DM; method 950.15, AOAC, 2000), mineral matter (MM; method 942.05, AOAC, 2000), and crude protein (CP; method 984.13, AOAC, 2000), following the methodologies described by AOAC (AOAC, 2005). The ether extract (EE) content was determined using the Randall method by substituting diethyl ether with petroleum ether (THIEX; ANDERSON; GILDEMEISTER, 2003). Neutral detergent (NDF) analysis was performed according to the method described by Mertens (2002), with adjustments for ash and protein content. The acid detergent fiber (ADF) analysis utilized the sequential NDF method (DETMANN et al., 2012; method F-003/1).

A fatty acid profile was determined for the waste frying oil used to formulate the diets. This involved converting fatty acids into methyl esters following the method proposed by Hartman and Lago (1973); these were detected using gas chromatography (Varian model CP 3380 – Varian Chromatography/ USA) equipped with an ionization detector and a CP capillary column (Sil 88) (Table 1).

Total carbohydrate values (CHOT) were obtained according to the recommendations of Sniffen, Connor and Van Soest (1992), using the Equation 1:

$$CHOT = 100 - (CP + EE + MM) \quad (1)$$

Non-fibrous carbohydrates (NFC) were calculated using Equation 2:

$$NFC = 100 - (+CP + NDF_{CP} + MM) \quad (2)$$

where NDFcp = neutral detergent fiber corrected for ash and protein content.

The apparent digestibility coefficients of nutrients were obtained using Equation (3):

$$DC(\%) = \left[\frac{Qi - Qe}{Qi}\right] * 100 \quad (3)$$

where DC represents the digestibility coefficient, Q_i denotes the amount of nutrient ingested, and Q_e indicates the amount of nutrient excreted in the feces.

The experiment was conducted using a randomized block design, with five treatments (oil concentrations) and five replications per treatment (animals from two weight categories: > 20 kg and < 20 kg). The results were analyzed using polynomial regression with the REG procedure from SAS (2008). Data lacking regression fit were compared using contrasts: control *versus* oil diets (0 vs 2; 4; 6; 8); control *versus diets containing 2 and 4% waste frying oil* (0 vs 2, 4); and diets with 2 and 4% versus *those with* 6 and 8% waste frying oil (2, 4 vs 6, 8), at a 5% significance level.

RESULTS AND DISCUSSION

No regression effect was observed on the intake of dry matter (DMI), organic matter (OMI), crude protein (CPI), and ether extract (EEI). However, contrast analyses revealed that the inclusion of waste frying oil in the diet influenced ($p < 0.05$) the intake of dry matter (DMI), organic matter (OMI), and crude protein (CPI) in kg.day $^{-1}$, percentage of body weight (%BW), and metabolic size unit (UMS) in sheep (Table 3).

Table 3. Intake of dry matter (DM), organic matter (OM), crude protein (CP) and ether extract (EE) (kgday^{-1}, % of body weight (%BW), and metabolic size unit (UMS) in sheep fed diets containing different amounts of waste frying oil.

Item	Dietary oil concentration (%)					Contrasts (p-value)		
	0	2	4	6	8	0vs 2468	0vs 24	24 vs 68
	Intake (kg/day)							
DM	0.706	0.755	0.790	0.558	0.652	0.84	0.50	0.05
OM	0.668	0.720	0.758	0.534	0.623	0.91	0.45	0.04
CP	0.147	0.155	0.163	0.111	0.135	0.74	0.57	0.04
EE [1]	0.008	0.026	0.045	0.044	0.067	<0.01	<0.01	<0.01
	Intake (% body weight)							
DM	3.13	3.21	3.40	2.70	2.93	0.77	0.49	0.03
OM	2.96	3.07	3.26	2.59	2.76	0.85	0.40	0.02
CP	0.65	0.66	0.70	0.53	0.59	0.49	0.62	0.01
EE [2]	0.04	0.11	0.19	0.21	0.30	<0.01	<0.01	<0.01
	Intake (UMS – g kg $^{-0.75}$)							
DM	68.02	70.40	74.59	57.43	62.71	0.75	0.47	0.02
OM	64.41	67.41	71.39	55.06	60.11	0.86	0.40	0.02
CP	14.20	14.53	15.39	11.32	12.96	0.58	0.56	0.02
EE [3]	0.80	2.41	4.25	4.58	6.45	<0.01	<0.01	<0.01

[1] $\hat{Y} = 0.01067 + 0.00687x$; R = 0.73. coefficient of variation (CV%) = 32.13. $p < 0.001$; [2] $\hat{Y} = 0.04586 + 0.03122x$; R = 0.89. CV = 18.61. $p < 0.001$; [3] $\hat{Y} = 0.99818 + 0.67453x$; R = 0.87. CV = 20.99. $p < 0.001$.

Sheep fed diets with higher concentrations of waste frying oil (6% and 8%) exhibited lower nutrient intake compared to those fed diets with up to 4% inclusion. There are several factors that regulate intake in ruminants, which may depend on the characteristics of the food (fiber content, energy density), the intrinsic aspects of the animal (physiological state, health, thermal comfort of the animal) and feed management (diet provided, schedule, access to water) (FREITAS; SIQUEIRA; SIQUEIRA, 2014). The reduced intake observed in sheep subjected to treatments with 6% and 8% waste frying oil inclusion, compared to those with 0%, 2%, and 4%, may be attributable to the fatty acid profile of the waste frying oil used in the diets (Table 1). These oils are predominantly composed of long-chain unsaturated fatty acids, such as linoleic and oleic acids. Such long-chain, unsaturated fatty acids can be toxic to rumen microorganisms due to their amphiphilic nature, which can damage the microbial population, disrupt fermentation, and consequently slow the rate of food passage. This results in decreased intake and nutrient digestibility (HE et al., 2018). Additionally, the high concentration of oil may trigger chemostatic control of intake regulation by the central nervous system, as the increased levels of fatty acids in the bloodstream can reduce the desire for ingestion (MEDEIROS; ALBERTIN; MARINO, 2015).

The lower intake of diets with higher concentrations of waste frying oil observed in this study supports the findings of Peixoto et al. (2017). In examining diets containing identical levels of waste frying oil, Peixoto also noted a reduction in the consumption of DM, OM, CP, TDN, CHOT, and NFC by sheep as the oil content increased. The quantities of oil used in these studies—6% and 8%, added to the ether extract of the raw materials in the diets—surpassed the maximum level of EE recommended by Palmquist and Mattos (2011), which is 5% of the total diet. The highest intakes of DM and nutrients, obtained from diets with no added oil, 2%, and 4% waste frying oil, align with the findings of Rêgo et al. (2021). Their study on the inclusion of up to 4% waste frying oil in sheep diets revealed no differences in nutrient intake.

The inclusion of lipids in the diet is a strategy that can be employed in regions with a hot climate, where DM intake may be lower than expected. Since the caloric density of lipids is higher than that of carbohydrates and proteins, increasing the intake of this macronutrient can enhance energy consumption (SARTORI; SPIES; WILTBANK, 2016; FOURNEL; OUELLET; CHARBONNEAU, 2017). The intake of crude ether extract (CEE) in kg.day $^{-1}$, % of BW, and UMS increased linearly ($p < 0.05$) with the inclusion of waste frying oil in the animals' diet (Table 3).

No regression effect was observed for the intake of neutral detergent fiber (NDFI) and acid detergent fiber (ADFI). However, when evaluated using contrasts, these intakes followed the trend of dry matter intake (DMI), with diets containing 6 and 8% residual oil showing lower intake ($p < 0.05$) compared to diets with lesser amounts of this residue (0, 2, and 4%) (Table 4).

Reduced intake of NDF and ADF in diets containing higher residual oil levels (6% and 8%) may be attributed to oil adhering to fibrous particles in the rumen. This adherence alters the membrane permeability of gram-positive bacteria, predominantly cellulolytic species such as *Ruminococcus sp.* and *Butyrivibrio sp.* (NAGARAJA et al., 1997). Other metabolic effects (ALLEN, 2000) contribute to decreased digestibility and intake of these nutrients.

Peixoto et al. (2017) evaluated the inclusion of waste frying oil (0, 2, 4, 6, and 8%) in sheep feed and found a reduction in nutrient intake with higher oil contents. However, the authors noted that nutrient intake decreased as the level of inclusion increased. Contrary to the findings of the current study, diets containing 6% and 8% oil had lower nutrient intakes, whereas those with 2% and 4% had nutrient intakes comparable to the control treatment.

Table 4. Intake of neutral detergent fiber (NDF), acid detergent fiber (ADF), total carbohydrates (CHOT), non-fibrous carbohydrates (NFC), and total digestible nutrients (TDN) (kg/day, % of body weight (BW), and metabolic size unit (UMS) by sheep fed diets containing different amounts of waste frying oil.

Item (%)	Dietary oil concentration (%)					Contrasts (p-value)		
	0	2	4	6	8	0vs 2468	0vs 24	24 vs 68
	Intake (kg/day)							
NDF	0.260	0.282	0.290	0.206	0.234	0.83	0.47	0.03
ADF	0.132	0.145	0.156	0.108	0.122	0.97	0.37	0.04
CHOT	0.513	0.539	0.549	0.379	0.422	0.50	0.64	0.02
NFC [1]	0.251	0.258	0.259	0.174	0.189	0.26	0.81	0.01
	Intake (% body weight)							
NDF	1.16	1.20	1.25	1.00	1.03	0.66	0.52	0.02
ADF	0.58	0.62	0.66	0.52	0.55	0.93	0.32	0.03
CHOT [4]	2.27	2.30	2.36	1.84	1.87	0.28	0.74	<0.01
NFC [2]	1.11	1.10	1.11	0.84	0.84	0.06	0.94	<0.01
	Intake (UMS – g $kg^{-0.75}$)							
NDF	25.20	26.29	27.37	21.20	22.43	0.68	0.49	0.02
ADF	12.70	12.69	14.57	10.98	11.95	0.93	0.30	0.03
CHOT [5]	49.41	50.48	51.75	39.16	40.70	0.31	0.69	<0.01
NFC [3]	24.21	24.19	24.38	17.95	18.27	0.09	0.97	<0.01
	TDN intake							
TDN (kg/day)	0.54	0.60	0.63	0.447	0.55	0.82	0.36	0.09
TDN (%BW)	2.38	2.54	2.70	2.15	2.42	0.69	0.24	0.05
TDN (UMS)	51.80	55.86	59.04	45.75	52.58	0.73	0.26	0.05
TDN (%) [6]	76.10	77.49	79.11	79.73	84.18	0.07	0.36	0.07

[1] $\hat{Y} = 0.26690 - 0.01031x$; R = 0.24. CV = 24.50. p = 0.02; [2] $\hat{Y} = 1.16133 - 0.03986x$; R = 0.40. CV = 14.56. $p < 0.01$; [3] $\hat{Y} = 25.37574 - 0.90018x$; R = 0.37. CV = 16.16. $p < 0.01$; [4] $\hat{Y} = 2.3754 - 0.06198x$; R = 0.25. CV = 15.30. p = 0.01; [5] $\hat{Y} = 51.93577 - 1.42305x$; R = 0.23. CV = 16.91. p = 0.02 ; [6] $\hat{Y} = 75.64320 + 0.91970x$; R = 0.30. CV = 5.21. p = 0.004.

Total carbohydrate (CHOT) and non-fibrous carbohydrate (NFC) intakes decreased linearly ($p < 0.05$) with increasing concentrations of residual oil in the diets (Table 4). This reduction in CHOT and NFC intake was anticipated, as the addition of oil resulted in a decreased proportion of these nutrients in the diet, owing to the diminished inclusion of corn (Table 3). Corn can contain between 70 and 80% starch in its composition, and this starch is a readily available and quickly digestible source of energy in the rumen (SILVA et al., 2023).

A linear increase in TDN concentration was observed with the rising inclusion of oil in the diets ($p < 0.05$). No regression effect was noted for TDN intake (% of BW and UMS) in the animals. However, contrast evaluations revealed that TDN intake followed the same trend as DMI, with animals receiving diets containing 6% and 8% oil exhibiting lower TDN intake (Table 4). The inclusion of waste frying oil directly influenced TDN concentration in the diets, as lipids possess a higher energy concentration than carbohydrates and proteins. Nevertheless, the elevated TDN concentration in high-oil diets did not suffice to sustain or enhance TDN intake. The diminished TDN intake in animals fed 6% and 8% oil diets resulted from reduced dry matter intake coupled with decreased digestibility.

Regarding nutrient digestibility, a linear regression effect was observed where the inclusion of waste frying oil in the diet resulted in a decrease ($p < 0.05$) in the digestibility coefficients of DM, OM, NDF, and ADF (Table 5).

Table 5. Apparent digestibility of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and non-fibrous carbohydrates (NFC) obtained from sheep fed diets containing different levels of waste frying oil.

Item (%)	Dietary oil concentration (%)					Contrasts (p-value)		
	0	2	4	6	8	0vs 2468	0vs 24	24 vs 68
	Apparent digestibility (%DM)							
DM [1]	71.96	69.13	64.22	65.03	62.75	0.02	0.08	0.25
OM [2]	75.66	74.71	70.87	71.01	71.11	0.11	0.25	0.40
CP	84.22	82.55	82.93	80.92	84.24	0.40	0.47	0.92
EE	79.55	91.13	86.73	84.73	87.03	0.02	0.01	0.30
NDF [3]	65.76	65.35	57.26	57.71	58.53	0.10	0.26	0.33
ADF [4]	57.78	56.90	54.23	49.67	47.08	0.16	0.62	0.06
NFC	82.52	79.89	77.45	81.51	74.85	0.13	0.20	0.84

[1] $\hat{Y} = 75.09982 - 1.12353x$; R = 0.31. CV = 7.46. $p < 0.001$; [2] $\hat{Y} = 83.33728 - 0.63234x$; R = 0.17. CV = 5.8. p = 0.05; [3] $\hat{Y} = 65.15622 - 1.08173x$; R = 0.19. CV = 11.17. p = 0.04; [4] $\hat{Y} = 65.15622 - 1.08173x$; R = 0.25. CV = 13.97. p = 0.01.

The observed linear decrease in DM and nutrient digestibility with increasing waste frying oil inclusion in the diets, as reported in this work, aligns with the findings of Van Cleef et al. (2016). In their study involving Santa Inês sheep fed diets with no added oil, 6% waste frying oil, and 6% commercial soybean oil, Van Cleef et al. (2016) reported reduced digestibility of DM, NDF, and ADF in the treatments containing 6% oil compared to the oil-free diet. They also reported no significant difference in digestibility between the two oil sources.

The waste frying oil included in the diets contained a higher proportion of unsaturated fatty acids, specifically oleic and linoleic acids, (Table 1). The degree of fatty acid unsaturation is a factor affecting digestibility; an increase in unsaturated acids can inhibit microorganisms and disrupt the fermentation of fibrous carbohydrates in the rumen (JENKINS et al., 2008).

Conversely, incorporating waste frying oil at the concentrations employed in this study did not affect NFC digestibility ($p > 0.05$).

According to Adejoro, Hassen and Akanmu (2019), the addition of lipid sources to feed has been associated with a decrease in fiber digestibility. This effect is not solely attributable to the quantity of lipids in the diet but also to the fatty acid profile of the supplement. Lipids high in unsaturated fatty acids typically result in a more pronounced decrease in digestibility. In the current study, there was a linear decrease in NDF digestibility corresponding to the rising content of waste frying oil, a lipid source rich in unsaturated fatty acids.

Conversely, the digestibility of the ether extract was positively affected, as evidenced by the higher digestibility in diets containing waste frying oil ($p < 0.05$) compared to the control diet. The control diet exhibited a digestibility of 79.55%, whereas the other diets had an average digestibility of 87.40%. The enhanced digestibility of the ether extract in diets with added oil may be attributed to the animals' increased consumption of EE in oil form, which is more readily hydrolyzable than when provided through whole oilseeds (BASSI et al., 2012) or cereal grains. Rêgo et al. (2021) also reported increased EE digestibility with higher waste frying oil levels in the diet.

CONCLUSIONS

Waste frying oil, when included at up to 4% in the sheep diet, does not compromise the intake and digestibility of dry matter and nutrients, provided the total diet's maximum ether extract content is maintained. Thus, waste frying oil represents a viable alternative source for lipid supplementation in sheep.

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