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Comparative energy value of cooked grease recovered from rinse-trap water lines used as dietary fat source for feedlot lambs

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Abstract

The objective of this experiment was to compare the effects of dietary supplementation with cooking grease recovered from rinse-trap water lines (rinse-trap grease; RTG) versus conventional supplemental fats (tallow; TL, and yellow grease; YG) on 84-d growth performance, dietary energy, and carcass traits of feedlot lambs. Forty-eight Pelibuey × Katahdin lambs (27.7 ± 3.4 kg) were assigned in a randomized complete block design to evaluate: 1) basal diet without supplemental fat (Control); 2) 4% TL; 3) 4% YG, and 4) 4% RTG. Supplemental fats replaced maize in the control diet. Rinse-trap grease contained greater moisture (16.5 vs 0.92%) and impurities (3.6 vs 0.56%), and less total fatty acid (64.90 vs 89.60%) than that of conventional fats (TL and YG). Daily weight gain and gain efficiency were similar for control and RTG supplemental lambs, whereas ADG and gain efficiency were greater for lambs fed conventional fats than control or RTG-supplemented lambs. Both dietary net energy (NE) as well as ratio of observed-to-expected dietary NE were 4% greater for lambs supplemented with conventional fats vs RTG. Supplemental fat increased fat deposition but did not affect any other carcass measures or non-fat visceral mass. Estimated NE value for RTG was 57% of the average NE value (6.11 Mcal/kg) of tested conventional fats. Supplementation with RTG does not affect diet acceptability, and accordingly, is a suitable energy source for feedlot lambs. However, due to its lower total fatty acid content, its energy value is much lower than conventional supplemental fats.

Key words: carcass, conventional feeding fats, dietary energy, feedlot, growth performance, recycled fat
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Introduction

Environmental regulations regarding disposal of fat and oil residues are increasingly rigorous (Sheinbaum *et al.*, 2015), prompting a more widespread recycling of fatty waste for use as feed supplements (Abdel-Shafy & Mansour, 2018). Presently, the more common recycled fats fed to livestock are tallow (TL) and yellow grease (YG). When priced competitively with dry rolled corn (energy value= 2.23 Mcal NE_m/kg; NRC, 2007), the main source of energy for ruminants diets in Mexico and USA, tallow and yellow grease (energy value = 6.30 and 5.80 Mcal NE_m/kg for YG and TL, respectively;

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NRC, 2007) are suitable and generally less expensive energy sources. Currently, a large number of restaurants and cafeterias place traps in the rinse water lines to collect grease, and reduce pollution of waste-water (Sheinbaun-Pardo *et al*., 2013; Wang & Wang, 2013). When recycled separately for use in animal feed, this rinse-trap grease (RTG) is also referred to as “griddle grease”. Due to the collection and handling process, RTG has a characteristically greater content of impurities and moisture, and a markedly lower total fatty acid content than conventional dietary fats (Hums *et al*., 2018; Ramos-Méndez *et al*., 2021). It is well known that fat quality (moisture, impurities and total fatty acid content) affects its energy value (Zinn & Jorquera, 2007). Previously, Ramos-Mendez *et al*. (2021), evaluated the energy value of RTG included at different levels of supplementation (0, 2, 4, and 6% of dietary DM) in high-energy, cracked-corn-based diets for feedlot lambs. Applying the replacement equation (using observed NE value of non-supplemented diet and dry corn grain as reference), researchers estimated that the NE value of RTG at levels of up to 4% of dietary DM was 0.93 when compared to the assigned net energy for supplemental fats published by the NRC (2007). When RTG was included at 6% of dietary DM, the NE of RTG was 0.79 of expected. The lower NE for RTG at 4% supplementation was attributed to its lower FA content. The greater depression in NE of RTG at 6% supplementation was attributed to potential negative associative effects on characteristics of digestion. Therefore, Ramos-Méndez *et al*. (2021) recommended that the level of RTG supplementation should not exceed 4% of dietary DM. When RTG was compared with conventional fats supplemented at 4% of dietary DM fed to feedlot cattle, the comparative NE value of RTG was 0.70 that of TL and YG (Ramirez & Zinn, 2000). In Mexico and USA, RTG is less expensive than tallow and yellow grease. However, RTG has much greater variation in moisture and total fatty acid content than conventional fats (Hums *et al*., 2018). Variation in composition of RTG is attributable to differences in fatty acid recovery in processing (Henriksson, 2016). To our knowledge, no information is available on how the energy value of RTG is assessed by direct comparison with conventional supplemental fats (yellow grease and tallow) in the long-term fattening of lambs receiving a high-energy diet. For this reason, the objective of this experiment was to evaluate the comparative feeding value of cooking grease recovered from rinse-trap water lines (rinse-trap grease) versus tallow and yellow grease (positive control), and no supplemental fat (negative control), on growth performance, dietary net energy, carcass characteristics, tissue composition, and visceral mass of finishing lambs.

Material and methods

All animal management procedures were conducted within the guidelines of locally-approved techniques for animal use and care (NOM, 1995, 1999) and approved by the Ethics Committee of Faculty of Veterinary Medicine and Zootechnics from the Autonomous University of Sinaloa (Protocol #7042019).

This experiment was conducted at the Universidad Autónoma de Sinaloa Feedlot Lamb Research Unit, located in the Culiacán, México (24°46'13'' N and 107°21'4'' W). Culiacán is ~55 m above sea level and has a tropical climate. The average ambient temperature and relative humidity during the course of the experiment were 29.5 °C, and 46.7%, respectively.

Forty-eight Pelibuey × Katahdin crossbred intact male lambs (27.7 ± 3.4 kg initial average shrunk body weight) were used in an 84-d growth performance experiment to evaluate cooked grease recovered from rinse-trap water lines (also referred to as “griddle grease”) used as a supplemental fat included in a corn-based, high-energy diet for finishing lambs. Four weeks before initiation of the experiment, the lambs were treated against parasites (Closantel oral; 7 mg/kg LW, CLOSANTIL® 5%, Laboratorio Chinoin, Mexico, City, Mexico), injected with 2 mL vitamin A (500,000 IU, Synt-ADE®, Zoetis México, México City), and vaccinated against *Mannheimia haemolityca* (One Shot Ultra Zoetis México, México City). Upon initiation of the experiment, lambs were weighed before the morning meal (electronic scale; TORREY TIL/S: 107 2691, TOR REY Electronics Inc., Houston TX, USA). Lambs were blocked by initial weight (six blocks) and assigned to 24 pens, two lambs/pen (six pens/treatment). Pens were 6 m^2 with overhead shade, automatic waterers, and 1-m fence-line feed bunks. The maximal total fat (from basal ingredients plus added fat) content recommended for feedlot diets is 8.0% (Vasconcelos & Galyean, 2007; Zinn & Jorquera, 2007). We chose to evaluate RTG at 4% of dietary DM, as Ramos-Méndez *et al*. (2021) observed that the NE value of supplemental RTG markedly declined at levels of supplementation greater than 4% of dietary DM. Dietary treatments consisted of a dry, rolled corn-based finishing diet supplemented with: 1) 0% fat (Control); 2) 4% tallow (TL); 3) 4% supplemental yellow grease (YG), and 4) 4% grease trap waste (RTG). The composition of experimental diets is shown in Table 1, in which supplemental fats replaced corn in a total mixed ration.

Table 1. Composition of dietary treatments offered to lambs

Item	Treatments [a]			
	Control	**Tallow**	**Yellow grease**	**Griddle grease**
Ingredient composition (% on DM basis)				
Dry-rolled corn	67.00	63.00	63.00	63.00
Sudan grass hay	8.00	8.00	8.00	8.00
Soybean meal	10.50	10.50	10.50	10.50
Tallow	----	4.00	----	----
Yellow grease	----	----	4.00	----
Griddle grease	----	----	----	4.00
Molasses cane	9.00	8.85	8.85	8.85
Urea	0.40	0.55	0.55	0.55
Zeolite	3.00	3.00	3.00	3.00
Trace mineral salt [b]	2.50	2.50	2.50	2.50
Dry matter	87.76	87.50	87.55	87.80
Chemical composition [c], (DM basis)				
Total crude protein (%)	13.85	13.88	13.90	13.86
Ether extract (%)	3.10	6.94	6.83	5.61
NDF (%)	14.65	13.65	13.77	13.55
Calculated net energy [d] (Mcal/kg)				
Maintenance	1.97	2.13	2.13	2.13
Gain	1.33	1.46	1.46	1.46

[a] Chemical composition of fat sources: 1) Tallow (animal fat): moisture, 0.28%; impurities, 0.32%; total fatty acids, 90.70%; 2) yellow grease (restaurant grease): moisture, 1.56%; impurities, 0.80%; total fatty acids, 88.50%; 3) griddle grease (trap-grease): moisture, 16.48%; impurities, 3.60%; and total fatty acids 64.90%. Samples of fats were analysed by Laboratorios de Análisis Industriales, Culiacán Sinaloa, México

[b] Mineral premix contained: Calcium, 28%; Phosphorous, 0.55%; Magnesium, 0.58%; Potassium, 0.65%; NaCl, 15%; vitamin A, 1,100 IU/kg; vitamin E, 11 UI/kg

[c] Dietary composition was determined by analysing subsamples collected and composited throughout the experiment. Accuracy was ensured by adequate replication with acceptance of mean values that were within 5% of each other

[d] Based on tabular net energy (NE) values for individual feed ingredients (NRC, 2007) and assuming that all fats sources (TL, YG, and RTG) contained similar energy value of 6.30 and 5.11 Mcal of NE_m and NE_g, respectively (NRC 2007)

Supplemental fats were obtained from a single recycling company (Acidulados la Tapatía, S.A. de C.V., Guadalajara, México). Supplemental fats were added to the mixer prior to adding molasses (last added ingredient) in diet preparation. Once all the ingredients were included in the mixer, the diets were mixed for 5 to 7 min. Chemical characteristics of fat sources used are described as a footnote in Table 1. Dietary treatments were randomly assigned to pens with blocks. Initial live weights were obtained just prior to the morning meal. Live weights (LW) on day 1 were converted to shrunk body weight (SBW) by multiplying LW by 0.96 to adjust for the gastrointestinal fill (Cannas *et al*., 2004). All lambs were fasted (drinking water was not withdrawn) for 18 h before recording the final LW (day 84). Lambs were provided fresh feed twice daily at 0800 and 1400 in 30:70 proportion, allowing for a daily feed residual of refusal of ~50 g per lamb. Residual feed was collected between 0740 and 0750 each morning and weighed. Adjustments to either increase or decrease daily feed delivery were provided in the afternoon feeding. Feed samples were collected from each batch. Daily feed refusal was composited weekly for dry matter analysis (DM; oven drying at 105 °C until no further weight loss; method 930.15, AOAC, 2000). Feed samples were subjected to the following analyses: DM (oven drying at 105 °C until no further weight loss; method 930.15, AOAC, 2000); CP (N × 6.25; method 984.13, AOAC, 2000), ether extract (method 920.39; AOAC, 2000), and NDF [Van Soest *et al*., 1991, corrected for NDF-ash, incorporating heat stable α-amylase (Ankom Technology, Macedon, NY)]. Chemical composition (moisture, impurities and total fatty acids) of supplemental fat sources were assayed by an external laboratory (Industrial Analyses Laboratory, Culiacán, Sinaloa, México).

Average daily gain (ADG) was computed by subtracting the final shrunk body weight (SBW) from the initial SBW and dividing by the number of days on feed. The gain efficiency was computed by dividing ADG by the daily dry matter intake (DMI; gain-to-feed ratio, GF).

One approach for evaluation of the efficiency of dietary energy utilization in growth–performance trials is the ratio of observed-to-expected DMI and observed-to-expected dietary net energy (NE). Based on dietary NE concentration and measures of growth performance, there is an expected energy intake. This estimation of expected DMI is performed based on observed ADG, average SBW, and NE values of the diet (Table 1) as follows:

Expected DMI, kg/d = $(EM/NE_m) + (EG/NE_g)$,

where EM (energy required for maintenance, Mcal/d) = $0.056 \times SBW^{0.75}$,

EG (energy required for gain, Mcal/d) = $0.276 \times ADG \times SBW^{0.75}$,

and NE_m (diet net energy for maintenance) and NE_g (diet net energy for gain) are corresponding NE values based on the ingredient composition (NRC, 2007) of the experimental diet (Table 1).

The coefficient (0.276) was taken from NRC (1985) assuming a mature weight of 113 kg for Pelibuey × Katahdin male lambs (Canton *et al*., 2009). The observed dietary net energy was calculated using EM and EG values, and DMI observed during experiment by means of the quadratic formula:

$x = (-b - \sqrt{b^2-4ac})/2c$,

where: $x = NE_m$, Mcal/kg, $a = -0.41EM$, $b = 0.877\ EM + 0.41\ DMI + EG$, and $c = -0.877\ DMI$ (Zinn *et al*., 2008).

Given that the NE_m value of dry rolled corn is 2.23 Mcal/kg (NRC, 2007), the comparative NE_m value for the supplemental fats at 4% level of substitution was determined as follows:

NE_m (Mcal/kg) of tested fat = [(NE_m observed for each diet containing supplemental fat – NE_m observed for the Control diet)/0.04] + 2.23.

The divisor (0.04) represents the amount of supplemental fat in diet, and the 2.23 represent the NE_m value of dry rolled corn (NRC, 2007) replaced by the supplemental fat. The NE_g value of tested fats was derived from their estimated NE_m values as follows:

NE_g, Mcal/kg = $0.877\ NE_m - 0.41$ (Zinn *et al*., 2008).

All lambs were harvested on the same day. Lambs were stunned (captive bolt), exsanguinated, and skinned. Gastrointestinal organs were separated and weighed, the omental and mesenteric fat were weighed, and hot carcass weight (HCW) was recorded. After carcasses chilled in a cooler at -2 to 1 °C for 24 h, the following measurements were obtained: 1) cold carcass weight (CCW); 2) subcutaneous fat (fat thickness) taken over the 12th to 13th thoracic vertebrae; 3) Longissimus muscle (LM) surface area, measured using a grid reading of the cross-sectional area of the longissimus muscle between the 12th and 13th rib, and 4) kidney, pelvic, and heart fat (KPH) was removed manually and afterward weighed and reported as a percentage of the cold carcass weight (USDA, 1992). The tissue composition of shoulder was assessed using physical dissection by the procedure described by Luaces *et al*. (2008).

Components of the digestive tract (GIT), including tongue, oesophagus, stomach (rumen, reticulum, omasum, and abomasum), pancreas, liver, gall bladder, small intestine (duodenum, jejunum, and ileum), and large intestine (caecum, colon, and rectum) were removed and weighed. The GIT was then washed, drained, and weighed to get empty weights. The difference between full and washed digesta-free GIT was subtracted from the SBW to determine empty body weight (EBW). All tissue weights are reported on a fresh tissue basis. Organ mass is expressed as grams of fresh tissue per kilogram of final EBW, where final EBW represents the final live weight minus the total digesta weight. Full visceral mass was calculated by the summation of all visceral components (stomach complex + small intestine + large intestine + liver + lungs + heart+ kidney), including digesta. The stomach complex was calculated as the digesta-free sum of the weights of the rumen, reticulum, omasum and abomasum.

Growth performance (ADG, DMI, and gain efficiency), estimated dietary NE and expected DMI, carcass data (characteristics, tissue composition) and visceral mass were analysed as a randomized complete block design, using pen as the experimental unit according to the following statistical model:

$$Y_{ij} = \mu + B_i + T_j + \varepsilon_{ij}$$

where: μ is the common experimental effect, B_i represents initial weight block effect, T_j represents dietary treatment effect, and ε_{ij} represents the residual error (SAS, 2004). All the data were tested for normality using the Shapiro–Wilk test. Hot carcass weight (HCW) was used as a covariate in evaluation of treatment effects on carcass measures. Treatments effects were tested by means of orthogonal contrasts (SAS, Inst., Inc., Cary, NC; Version 9) as follows: 1) no fat vs conventional supplemental fats (TL and YG fat); 2) no fat vs RTG fat, and 3) RTG fat vs conventional supplemental fats (TL and YG fat). In all cases, least squares means and standard errors are reported and contrasts were considered significant when the P value was ≤0.05.

Results and Discussion

Yellow grease had a slightly more moisture and impurities than tallow, but very similar total fatty acid content (Table 1). The profiles of TL and YG are consistent with the standards set by American Fats and Oils Association (AFOA 2020). In contrast, RTG had 17.9-fold greater moisture, 6.4-fold greater impurities, and 27.6% lower total fatty acid content than the corresponding average for tallow and yellow grease (Table 1). Official industry standards for RTG have yet to be established. As delivered prior to further processing, RTG has ~40% and ~38% FA (Tran *et al*., 2017). Due to variation in methods and degrees of processing, the impurities, moisture and hence, total fatty acid composition of RTG is highly variable (Henriksson, 2016; Hums *et al*., 2018). The moisture and impurity content of RTG used in two studies conducted in the United States with feedlot cattle (Plascencia *et al*., 1999; Ramirez & Zinn, 2000) was low, averaging ~0.70% for moisture and a concentration ≤1% for impurities. Plascencia *et al*. (1999) reported that the RTG used in their study contained 84% total FA. The RTG produced in Mexico and reported in a previous experiment with feedlot lambs (Ramos-Méndez *et al*., 2021) had a moisture and total FA content of 6.5 and 80%, respectively. Fat composition, particularly total fatty acid content, is closely associated with its NE value (Zinn & Jorquera, 2007). As mentioned previously, there are no official standards for chemical composition of RTG. Considerations regarding feeding value should be discounted against its total FA content.

Treatment effects on growth performance and estimated dietary NE are shown in Table 2. Dry matter intake was not affected (P >0.05) by treatment, averaging 1.12 ± 0.16 kg/d. The feeding value of any new ingredient under evaluation for livestock depends on several factors, including it how might influence diet acceptability. The effect of conventional fats on DMI in lambs is variable. In some experiments, supplemental fats reduce DMI (Haddad & Younis, 2004; Mossad & Sayed, 2010), whereas in other studies, supplemental fat increased DMI (Manso *et al*., 2009). It has been argued that the effects of supplemental fat on cattle DMI are affected by type of fat, level of supplementation, and dietary composition and energy density (Hess *et al*., 2008; Joy *et al*., 2021).

Table 2. Effect of source of dietary supplemental fat on 84-d feedlot growth performance and dietary energy of lambs

	Treatments [a]					***P*-value**		
Item	Control	**TL**	**YG**	**RTG**	**SEM**	**Control vs TL and YG**	**Control vs RTG**	**TL and YG vs RTG**
Replicates	6	6	6	6				
Live weight (kg) [b]								
Initial	27.69	27.79	27.52	27.64	0.132	0.82	0.79	0.94
Final	47.60	47.03	48.35	46.71	0.805	0.93	0.43	0.34
Average daily gain (kg)	0.237	0.229	0.248	0.227	0.009	0.94	0.46	0.35
Dry matter intake (kg/d)	1.177	1.052	1.111	1.104	0.039	0.07	0.23	0.61
ADG/DMI	0.201	0.219	0.224	0.206	0.003	<0.01	0.17	<0.01
Dietary NE (Mcal/kg)								
Maintenance	1.98	2.13	2.14	2.03	0.014	<0.01	0.04	<0.01
Gain	1.33	1.46	1.47	1.37	0.012	<0.01	0.04	<0.01
Observed-to-expected dietary NE ratio								
Maintenance	1.01	1.00	1.01	0.96	0.007	0.42	<0.01	<0.01
Gain	1.00	0.99	1.00	0.93	0.009	0.68	<0.01	<0.01
Observed to expected DMI	1.00	1.01	1.00	1.05	0.008	0.70	<0.01	<0.01
Fat net energy value (Mcal/kg)								
Maintenance	---	5.98	6.23	3.48				
Gain	---	4.83	5.05	2.64				

SEM = standard error of the mean; NE= net energy; DMI=dry matter intake; ADG=average daily gain

[a] Control=without supplemental fat; TL = 4% tallow; YG = 4% supplemental yellow grease, and RTG = 4% grease trap waste.

[b] Live weights (LW) on day 1 was converted to shrunk body weight (SBW) by multiplying LW by 0.96 to adjust for the gastrointestinal fill (Cannas *et al*., 2004). All lambs were fasted (drinking water was not withdrawn) for 18 h before recording the final LW (day 84)

Even at moderate levels of supplementation (2–4%), type of fat is a relevant consideration with respect to DMI. Manso *et al*. (2009) observed that supplemental hydrogenated palm oil tended to increase DMI, while sunflower oil tended to depress lamb DMI (fats were supplemented at 4% of dietary DM). Compared with a non-supplemented diet, supplementation with 4% soybean oil depressed DMI, whereas supplementation with 4% fish oil did not affect lamb DMI (Ferreira *et al*., 2014). Most reports point out, similar to our results, that supplemental fat up to 4% of the diet (palm oil, Manso *et al*., 2006; yellow grease, Nelson *et al*., 2008; Jatropha oil, Félix-Bernal *et al*., 2016) does not affect DMI. Effects of RTG supplementation on lambs and cattle DMI have been variable. In some reports (Plascencia *et al*., 1999; Ramos *et al*., 2021) inclusion of RTG in diets did not affect DMI. Ramirez & Zinn (2000) observed a 7% decrease in DMI when RTG replaced flaked corn in finishing diets for feedlot cattle. However, they observed that DMI also decreased with supplemental tallow and yellow grease.

Daily weight gain (P =0.46) and gain efficiency (P =0.17) were similar for non-supplemented and RTG-supplemented lambs. In contrast, lambs fed conventional fats had greater (8.1%, P <0.01) gain efficiency than control and RTG lambs. Due to the difference in energy concentration between the supplemental fat and the corn replaced, a greater gain efficiency was expected. The similar gain efficiency observed between the control and RTG indicates that RTG has a lower energy value than that of TL and YG. However, even though gain efficiency is a widely used tool in the assessment of feeding value, is important to note that this estimation can be misleading due to factors including energy density and rate of weight gain (Kenny *et al*., 2018).

Another approach for the evaluation of the efficiency of dietary energy utilization in growth-performance trials is the ratio of observed-to-expected DMI and observed-to-expected dietary net energy (NE). This estimation of dietary energy intake and the ratio of observed-to-expected DMI reveals differences in efficiency of energy utilization independently of ADG. Applying this estimation to growth performance data, RTG lambs had greater estimated dietary NE (2.5%, P =0.04) than controls, but lower dietary NE (4.9%, P <0.01) than conventional fats (TL and YG). In healthy animals grown under non-stressful ambient conditions, the expected ratio of observed-to-expected dietary NE would be 1.0. That is, lamb ADG is consistent with DMI and energy density of the diet. If ratio is greater than 1, the observed dietary NE is greater than anticipated based on dietary composition NRC (2007), and efficiency of energy utilization is enhanced. In contrast, if the ratio is less than 1, energetic efficiency is less than expected. In this sense, lambs that were fed with Control, TL, and YG treatments had an observed-to-expected dietary net energy ratio closely to 1.00. In contrast, lambs that were fed RTG had a 4% lower observed-to-expected diet NE value (0.96). Stated differently, based on ADG and tabular dietary NE, observed DMI was 5% greater than expected for RTG. Using the replacement equation described in the Methods section, the estimated net energy values for TL, YG, and RTG were 5.98 and 4.83, 6.23 and 5.05, and 3.48 and 2.64 Mcal/kg for maintenance and gain, respectively. These values correspond to 0.95, 0.99, and 0.55 of the assigned tabular values for conventional feed fats (6.30 and 5.1 Mcal/kg NE_m and NE_g, respectively; NRC, 2007). The NE value of RTG was 57% that of the average observed for conventional fats tested. This value is considerably lower (57 vs 88 to 93%) than the comparative values obtained in prior studies (Plascencia *et al*., 1999; Ramos-Méndez *et al*., 2021), reflecting the low total fatty acid content of the RTG evaluated in the present study. When RTG is processed so that the total moisture, impurities, and unsaponifiable material are similar to those of conventional fat (i.e., <3%) the comparative NE values for RTG are similar (Ramirez & Zinn, 2000).

According to its gross energy value, fatty acids represent ~95% of the total energy of fat. Thus, the feeding value of feed fats should be discounted based on total FA content. An alternative approach to estimating the energy value of supplemental fats is using the relationship of the FA intake (g/kg BW), intestinal digestibility, and the partial efficiency in the use digestible energy for BW gain (Plascencia *et al*., 2003). Accordingly, the NE_m value for TG is 5.8 Mcal/kg. As the supplemental RTG used in the present study only contained 64.9% FA, then its estimated NE_m value is 3.7 Mcal/kg (5.8 × 0.649), or 0.60 of the energy value estimated for conventional fats. This value is in close agreement to the comparative energy value estimated based on growth performance using the replacement technique (0.57).

There were no treatment effects on carcass weight, dressing percentage, LM area, and tissue composition (Table 3). Absence of effects of supplemental fats on dressing percentage, LM area, and tissue composition of lambs is consistent with prior studies (Bath *et al*., 2011; Pinto *et al*., 2011; Ferreira *et al*., 2014). Increased LM area have been reported when cattle were supplemented with fat (Zinn, 1989; Brandt & Anderson, 1991). However, this effect was expected due to enhancements in ADG and carcass weight (Zinn & Plascencia, 2004; Urías-Estrada *et al*., 2021).

Table 3. Effect of source of dietary supplemental fat on carcass characteristics and shoulder tissue composition in lambs

Item	Treatments [a]				SEM	*P*-value		
	Control	TL	YG	RTG		Control vs TL and YG	Control vs RTG	TG vs TL and YG
Hot carcass weight (kg)	27.52	26.92	28.05	26.69	0.404	0.95	0.17	0.13
Dressing percentage	57.70	57.24	58.05	57.16	0.534	0.86	0.44	0.47
Longissimus area (cm²)	18.88	18.42	18.60	18.82	0.568	0.60	0.95	0.66
Fat thickness (mm)	1.47	1.88	1.92	1.83	0.067	<0.01	<0.01	0.43
Kidney-pelvic-heart fat (%)	1.94	2.28	2.36	2.47	0.114	0.02	<0.01	0.31
Shoulder composition (%)								
Muscle	62.04	62.22	61.98	61.76	0.385	0.90	0.62	0.49
Fat	19.13	19.47	19.37	19.82	0.541	0.67	0.39	0.56
Muscle to fat ratio	3.25	3.20	3.22	3.17	0.104	0.77	0.57	0.71

[a] Control = without supplemental fat; TL = 4% tallow; YG = 4% supplemental yellow grease, and RTG = 4% grease trap waste

Fat supplementation increased (*P* <0.01) FT (21%) and KPH (18%) but did not affect the proportion of fat in shoulder tissue. Dureau & Chilliard (1997) observed that fat supplementation leads to increased proportion of carcass fat, but not the proportion of fat in muscle tissue. The increase in FT and KPH pelvic fat is consistent studies evaluating fat supplementation in finishing diets for feedlot cattle (Zinn & Jorquera, 2007; Donicht *et al*., 2011). However, this response has been less consistent in feedlot lambs (Félix-Bernal *et al*., 2014; Estrada-Angulo *et al*., 2017). These inconsistencies may be due in part to degree of finish (shorter finishing period in which fats were supplemented). Ramos-Menéndez *et al*. (2021) observed that supplemental RTG (2, 4, and 6% of dietary DM) linearly increased KPH, but did not affect FT of finishing lambs during a 61-d feeding period. Similarly, RTG increased KPH but not FT in cattle fattening over 144 d (Plascencia *et al*., 1999).

All fat sources tested did not affect non-fat visceral organs mass (expressed as organ weight, g/kg EBW), but increased (*P* ≤0.03) visceral fat (Table 4). In non-restricted feeding regimes, the main factors influencing non-fat visceral organ mass seems to be dietary fibre (Sainz & Bentley, 1997) and protein intake (Fluharty & McClure, 1997).

Table 4. Effect of source of dietary supplemental fat on visceral organ mass

Item	Treatments [a]				SEM	*P*-value		
	Control	**TL**	**YG**	**RTG**		Control vs TL and YG	Control vs RTG	TG vs TL and YG
EBW (% of full weight)	93.09	92.52	93.08	92.71	0.311	0.46	0.40	0.82
Organs weight, g/kg of EBW								
Stomach complex [b]	27.14	27.08	26.64	26.78	0.854	0.79	0.77	0.93
Intestines [c]	42.61	43.46	43.78	43.65	1.396	0.58	0.60	0.95
Heart plus lungs	20.94	19.21	19.60	21.23	0.883	0.18	0.82	0.12
Liver plus spleen	18.64	18.29	17.55	18.32	0.740	0.44	0.77	0.67
Kidney	2.37	2.38	2.30	2.49	0.098	0.82	0.64	0.45
Omental fat	26.29	32.89	32.56	30.03	1.141	<0.01	0.04	0.08
Mesenteric fat	4.31	5.49	5.20	4.60	0.337	0.03	0.55	0.09
Visceral fat	30.59	38.38	37.75	34.62	1.177	<0.01	0.03	0.04

[a] Control = without supplemental fat; TL = 4% tallow; YG = 4% supplemental yellow grease, and RTG = 4% grease trap waste; EBW, empty body weight
[b] Stomach complex = (rumen + reticulum + omasum + abomasum), without digesta
[c] Small and large intestines without digesta

In this experiment, dietary treatments contained very similar protein and NDF concentrations (Table 1) and were consumed at similar levels. Thus, no treatment effects were anticipated. Increases in visceral fat are a reflection of increased energy intake (Soares *et al*., 2012; Estrada *et al*., 2017). Accordingly, the increases in visceral fat were more evident for conventional fats than for RTG (38.05 vs 34.62%, P =0.04).

Conclusions

Supplementation with RTG does not affect diet acceptability, and accordingly, is a suitable energy source for feedlot lambs. However, due to its lower total fatty acid content, the net energy value of RTG is much lower than that of conventional fat. When considering RTG as a supplemental fat source is important to verify its total fatty acid content.

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AP and AEA: Conceptualization, methodology, supervision, visualization, writing—review and editing: RAZ: Writing—review and editing final version of the manuscript: IGMA and XPPD: Writing—original draft preparation; AB: Data curation, statistical analyses; JLRM, BICP, LCG; Executed the experiment, carcass evaluation, analysed the samples

Conflict of interest
The authors declare that there are no conflicts of interest associated with this experiment.

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