Original Article

Production performance, carcass traits and meat quality of growing Naemi lambs fed a diet containing palm kernel meal

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Abstract

Palm kernel meal (PKM) is a byproduct produced after oil extraction from palm kernels. It is a valuable source of fiber, energy and protein which can reduce the cost of total mixed ration (TMR). This study was conducted to assess the growth performance, carcass characteristics and meat quality of lambs fed TMR pellet with PKM. A total of 32, three-month-old male lambs were randomly distributed into two diets (PTMR1= 0; PTMR2= 200 kg PKM/ton TMR). Results of the study showed that the production performance and the characteristics, composition and fat content of carcasses, as well as meat quality traits were not affected by PTMR2. The relative weight of the loin and tail and cohesiveness were lower while the index of myofibril fragmentation was higher when compared to PTMR1. The pH and color of the carcass and meat components were not significantly different except for hindquarter color (Lightness) and the ultimate meat pH in PTMR2. The pH value and tissue color (Redness) of rumen were higher when the lambs were fed with PTMR2 compared to PTMR1. The study indicates that 20% PKM addition to TMR may be a safe strategy for lamb feeding with no negative impact on growth performance, carcass characteristics and meat quality of lambs.

Keywords: Lambs, meat quality, malm kernal meal, total mixed ration

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Introduction

As a result of the increasing demand for sheep meat consumption in the Middle East, there are consistent efforts to improve the growth and production of local breeds (Alhidary *et al*., 2016ab). Total mixed rations (TMR) mainly consists of concentrates, forages, roughage and mineral-vitamins complex that meet animals requirements for optimum performance (Alhidary et al. 2016c; Abdelrahman et al., 2017a; Zhong *et al*., 2018). Therefore, there is a growing interest in the use of TMR in modern sheep production systems as a result of reduced feed costs and the consequent rise in the cost of traditional grasses, wheat straw, barley and alfalfa (Islam *et al*., 2017; Trabi *et al*., 2019). Naemi lamb is a local hairy breed of Saudi Arabia and is well adapted to the local environmental conditions. Being a dual purpose breed, it is used both for milk and meat production. The meat is known for its health benefits and taste. The weight of an adult Naemi lamb is about 43-48kg for a female and 51-55 kg for amale (Alhidary et al., 2016a).

Several food by-products such as palm kernel meal (PKM) have been reported to enhance animal production in comparison with TMR (Menezes *et al*., 2016; Ribeiro *et al*., 2018), however, the results reported are inconsistent. Based on the chemical composition of PKM (15% crude protein, 61% neutral detergent fiber and 11% ether extract), it can be used to feed ruminants to improve rumen health and performance (Neto *et al*., 2015). The inclusion of PKM in the lamb's diet consisting of TMR has no effect on dry matter intake (Oliveira *et al*., 2017). The PKM inclusion in a TMR diet has no effect on growth performance, nutrient digestibility and meat quality traits in growing Nili-ravi buffalo calves (Tipu *et al*., 2014) and crossbred Holstein x Zebu cattle (Ferreira *et al*., 2012). The objective of the present study was to evaluate the effect of 20% PKM in pelleted TMR on growth performance, carcass characteristics and meat quality of growing Naemi lambs.

Materials and Methods

This experiment was conducted at the research station of the College of Food and Agricultural Sciences, which was approved by the Committee on Research Ethics at King Saud University (Approval No. KSUSE2027).

Animals and feeding: In this study, 32 non-castrated Naemi male lambs about three-months-old (14.12±0.45 kg) were obtained from a local farm, weighed individually and randomly divided into two dietary treatments :pelleted total mixed ration (PTMR1) consisting of TMR with no inclusion of PKM and PTMR2 (TMR + 20% PKM). The TMR ingredients and their nutrient composition used in the experiment appear in Table 1 to meet the requirement of growing male lambs. Before conducting the experiment, all lambs for each treatment were acclimated to the feed used (PTMR; pelleted total mixed ration). Feed and water were freely available during the trial period from 1 to 70 days. All lambs were placed in open trial units (pens). Vaccination against enterotoxaemia, septicemia and Peste des petits ruminants was performed for all lambs subcutaneously according to the recommendations of the Directorate of Animal Resources of the Ministry of Environment, Water and Agriculture (MEWA), Saudi Arabia.

Table 1 TMR Ingredients and their nutrient composition used in the experiment.

Ingredients, kg/ton	Diets[1]	
	PTMR1	PTMR2
Barley grain	270	170
Wheat	299.5	299.2
Wheat Bran	50	50
Sunflower Meal	173.5	100.5
Soya Hulls	135.5	110.3
Palm Kernel Meal[2]	0	200
Salt	5.4	4.7
Limestone	25.1	25.8
Molasses	30	30
Acid buffer	9.5	8.0
Vit. & Min. premix[3]	1.5	1.5
Total	1000	1000
Calculated analysis		
ME, Kcal/kg	2,800	2,790
Crude protein, %	13.24	13.79
Crude fiber, %	10.72	11.98
EE, %	3.40	2.61
Ash, %	10.30	9.09
Chemical analysis		
NDF %	29.09	27.88
ADL %	1.44	2.05
ADF %	11.57	12.07
Hemicelluloses %	17.53	15.81
Cellulose %	10.12	10.01
Lignin %	0.63	1.94

[1]PTMR1: (0% PKM); PTMR2 = 20% PKM. [2]Palm kernel meal containing DM= 92 %, crude protein= 11 %, crude fiber=16.58%, ME= 2.66 Mcal / kg. [4]Premix contained vit. A, D, and E (1000, 1000 and 20 IU / kg; respectively) and Minerals such as Mg, Cu, Co, I, Mn, Se and Zn (300, 24, 0.6,1.2, 60,0.3, 60 mg / kg; respectively).

Growth performance: All lambs were weighed individually to determine initial body weight (1 day) and final body weight (70 days of the experiment), as well as feed intake (feed submitted, kg - feed the remaining, kg), were taken to calculate weight gain of total, daily [(final body weight, kg - Initial body weight, kg) or / day] and average feed conversion ratio (feed intake, kg /weight gain, kg) according to Pereira *et al*., (2020).

Carcass characteristics: At 70 days of age, all lambs (n=16) in both groups were slaughtered. Slaughter weight and empty body weight were taken. Hot and cold carcasses after removing all internal organs were weighed to calculate the dressing percentage (dressing A= dressing% of slaughter weight; dressing B= dressing% of empty body weight) (Santos *et al*., 2017). The chill shrinks, head, heart, lungs, liver, spleen, kidneys, genitals, tail, gut fill, stomach empty, intestine empty were separated and weighed to calculate as a percentage of slaughter weight according to Sen *et al*., (2011). Carcasses were stored and cooled for 24 hours (3–4°C) and then divided into two identical halves, one of the two halves was divided into six cuts (shoulder, rack, loin, leg and fore shank with breast) to be recorded as a percentage of half carcass weight. The thickness of the carcass fat on the back and body wall was measured with measuring tape. The relative weight of pericardial fat, kidney knob and channel fat, mesentery fat and omental fat was calculated on the basis of slaughter weight (Andrés *et al*., 2019; Pereira *et al*., 2020) .

Meat quality characteristics: The color of the carcass and meat components (rack, forequarters and hindquarters) were measured twice in initial (at the slaughter directly) and ultimate (after cooling for 24 hours) according to Blanco *et al*., (2014) using a Chroma meter (CR-400, Minolta, Tokyo, Japan) set on the L* (lightness), a* (redness), b* (yellowness) system. Meanwhile, the pH value was assessed using a meat pH meter (Padova, Italy) at 1 and 24 h after slaughter according to Sen *et al*., (2011). Rack muscle per carcass was cut into five slices, then kept frozen at -20 °C until conducting the analysis. Measurements of meat quality such as cooking loss, water holding capacity via cooking losses, texture profile analysis of cooking samples, shear force and myofibril fragmentation index were determined according to Andrés *et al*., (2014, 2019).

Rumen characteristics: At 45 days of the experimental period, pH values of the rumen fluid were determined from four lambs per treatment two times (pre-feeding 0 h;post-feeding 3h) using an esophageal tube and pump from the rumen. The pH value was assessed using a pH meter (Padova, Italy) whereas the rumen color was measured using a Chroma meter (Tokyo, Japan) according to Abdelrahman *et al*., (2019).

Statistical analysis: The animals were distributed to the treatments with their replicates in the experimental units using a completely randomized design. During the trial period, data was collected for all variables per treatment. The data was tested by normality distribution and then analyzed using the GLM procedure of SAS 9.2 (SAS, 2008) with the following model: V (observation value) = μ (the overall mean) + Di (the fixed effect of diet) + eij (the random error). For the significance between the means of value, Duncan's multiple range tests ($P \leq 0.05$) with a standard error of the mean (SEM) was used.

Results

The effect of PTMR with or without PKM on growth performance of Naemi lambs appears in Table 2. The results obtained through the current study show that the indicators of productive performance represented by body weight, weight gain, feed consumption and feed conversion ratio during the experimental period did not have any significant differences ($P > 0.05$) among the lambs.

The effect of PTMR with or without PKM on the carcass characteristics of Naemi lambs appears in Table 3. All variables of carcass characteristics such as weight of slaughter and carcass, dressing percentage, the parts of the internal organs of the carcass were not influenced ($P > 0.05$) among PTMR1 and PTMR2 except, the percentage of the tail was lower (P= 0.013) in PTMR with PKM (PTMR2) compared to PTMR1 (10.84% and 14.09% respectively).

The effect of PTMR with or without PKM on the carcass composition of Naemi lambs appears in Table 4. The relative weight of half carcass weight, shoulder, rack, leg, and fore shank with breast were not influenced ($P > 0.05$) among PTMR1 and PTMR2, although, the relative weight of the loin cut was lower (P= 0.042) in PTMR2 (12.78%) compared to PTMR1 (13.75%).

The effect of PTMR with or without PKM on carcass fat content appears in Table 5. All variations of carcass fat content such as the thickness of back fat and body wall fat as well as the relative weight of pericardial fat, Kidney knob and channel fat, mesentery fat and omental fat were not influenced ($P > 0.05$) between PTMR1 and PTMR2.

The effect of PTMR with and without PKM on meat quality appears in Table 6. All variables of meat quality such as cooking loss, water holding capacity and shear force as well as the texture profile analysis except cohesiveness index were not influenced ($P > 0.05$) among PTMR1 and PTMR2. The index of myofibril fragmentation was higher (P= 0.001) in lambs fed on PTMR2 (20 % PKM) while the cohesiveness index was lower (P= 0.011) when compared to PTMR1.

The effects of PTMR with or without PKM on rumen pH, carcass color and meat components are shown in Table 7. The color of carcass, rack meat (initial and ultimate) and ultimate forequarter were not influenced ($P > 0.05$) among PTMR1 and PTMR2. The color of ultimate hindquarter (L*; Lightness) and value of ultimate meat pH were lower (p = 0.019 and p = 0.013 respectively) in lambs fed on PTMR2 (20% PKM) while another variable was not influenced ($P > 0.05$) when compared PTMR1 with PTMR2.

The effects of PTMR with and without PKM on rumen characteristics are given in Table 8. The value of pH at 0 hours and 3 hours was higher (P= 0.031; P= 0.030; respectively) when the lambs were fed on

PTMR2 compared to PTMR1 (7.22 and 6.50 vs 6.41and 5.44; respectively). Rumen tissue color (a*, Redness) after removing the rumen during the slaughter directly was higher (P= 0.022) in lambs fed on PTMR2 (20% PKM) when compared to PTMR1 (3.77 and 4.89; respectively). Whereas, lightness (L*) and yellowness (b*) were not significantly affected ($P > 0.05$) between the groups.

Table 2 The effect of PTMR without or with palm kernel meal on general performance of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
Initial body weight, kg	29.56	29.28	1.537	0.902
Final body weight, kg	50.08	47.56	2.047	0.427
Average feed intake, Kg	1.64	1.35	0.092	0.086
Total weight gain, kg	20.51	18.28	1.061	0.189
Average daily gain, Kg	0.293	0.260	0.015	0.180
Average FCR, Kg : Kg	5.64	5.21	0.292	0.354

[1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean.

Table 3 The effect of PTMR with or without palm kernel meal on carcass traits of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
Slaughter weight (kg)	49.78	47.10	1.8	0.31
Empty weight (kg)	45.82	43.35	1.7	0.34
Hot carcass (kg)	25.18	24.20	1.1	0.54
Cold carcass (kg)	24.67	23.76	1.1	0.56
Dressing A% [3]	50.56	51.28	0.6	0.45
Dressing B % [3]	54.91	55.76	0.5	0.27
Chill Shrink%	2.01	1.83	0.2	0.44
Head%	6.29	6.86	0.2	0.11
Heart%	0.67	0.69	0.02	0.45
Lungs %	1.87	2.06	0.1	0.26
Liver%	2.88	2.96	0.1	0.66
Spleen%	0.27	0.28	0.01	0.87
Kidneys%	0.55	0.50	0.03	0.24
Genitals%	1.46	1.34	0.1	0.44
Tail%	14.09[a]	10.84[b]	0.8	0.01
Gut fill%	15.71	15.78	1.3	0.97
Stomach empty%	4.90	4.79	0.3	0.82
Intestine empty%	4.63	3.83	0.5	0.32

[1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean. [3]Dressing A= Dressing% on slaughter weight; Dressing B= Dressing% on empty body weight.

Table 4 The effect of PTMR with or without palm kernel meal on carcass composition of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
Half carcass weight (kg)	10.61	10.18	0.37	0.44
Shoulder%	25.64	24.86	0.36	0.16
Rack%	9.63	9.67	0.35	0.94
Loin%	13.75[a]	12.78[b]	0.29	0.04
Leg%	30.26	31.07	0.47	0.26
Fore shank + Breast%	20.71	21.61	0.65	0.35

[a-b] Different superscripts are significant ($P < 0.05$) between the values of the means within the row. [1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean.

Table 5 The effect of PTMR with or without palm kernel meal on carcass fat content of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
Back fat thickness (mm)	4.32	4.75	0.73	0.68
Body wall fat thickness (mm)	5.05	5.91	0.63	0.35
Pericardial fat%	0.41	0.36	0.04	0.32
Kidney knob and channel fat %	2.34	1.80	0.33	0.27
Mesentery fat%	1.92	2.08	0.21	0.60
Omental fat%	2.96	3.07	0.35	0.83

[1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean.

Table 6 The effect of PTMR with or without palm kernel meal on meat quality traits of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
CL %	41.80	45.66	1.35	0.07
WHC %	34.06	33.12	1.82	0.72
SF (N)	36.76	39.96	3.19	0.49
MFI	63.92[b]	110.70[a]	7.68	0.01
Texture Profile Analysis				
Hardness (N)	4.48	5.39	0.47	0.20
Springiness	0.78	0.75	0.02	0.37
Cohesiveness	0.46[a]	0.42[b]	0.01	0.01
Chewiness	1.63	1.84	0.17	0.40

[a-b] Different superscripts are significant ($P < 0.05$) between the values of the means within the row. [1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean. CL= Cooking loss; WHC= Water holding capacity; FS= Shear force; MFI= Myofibril fragmentation index.

Table 7 The effect of PTMR with or without palm kernel meal on pH and color of carcass and meat components of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
Carcass color				
Lightness (L*)	56.20	58.47	2.14	0.47
Redness (a*)	10.31	8.95	1.14	0.41
Yellowness (b*)	11.31	11.76	0.63	0.62
Initial rack meat color				
Lightness (L*)	30.67	29.96	0.70	0.49
Redness (a*)	16.04	16.64	0.69	0.56
Yellowness (b*)	3.70	4.39	0.51	0.36
Ultimate rack meat color				
Lightness (L*)	40.81	36.35	1.61	0.08
Redness (a*)	20.12	18.93	0.85	0.34
Yellowness (b*)	8.94	8.19	0.65	0.44
Ultimate Forequarter Color				
Lightness (L*)	43.01	41.75	1.92	0.65
Redness (a*)	18.23	17.53	1.16	0.68
Yellowness (b*)	7.25	6.24	0.70	0.33
Ultimate Hindquarter Color				
Lightness (L*)	42.32[a]	37.38[b]	1.25	0.02
Redness (a*)	15.59	16.13	0.69	0.59
Yellowness (b*)	5.46	5.98	0.54	0.51
Initial meat pH value	6.28	6.10	0.06	0.07
Ultimate meat pH value	5.98[a]	5.83[b]	0.03	0.01

[a-b] Different superscripts are significant ($P < 0.05$) between the values of the means within the row. [1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean.

Table 8 The effect of PTMR with or without palm kernel meal on rumen traits of lambs

Variable	Diets[1]		SEM[2]	*P. value*
	PTMR1	PTMR2		
pH value				
0 (h)	6.41[b]	7.22[a]	0.18	0.03
3 (h)	5.44[b]	6.50[a]	0.23	0.03
Color				
Lightness (L*)	33.27	31.18	1.82	0.44
Redness (a*)	3.77[b]	4.89[a]	0.29	0.02
Yellowness (b*)	9.65	10.80	0.43	0.09

[a-b] Different superscripts are significant ($P < 0.05$) between the values of the means within the row.
[1]Diets: PTMR1: RD without PKM; PTMR2: RD with 20% PKM. [2]SEM: standard error of the mean.

Discussion

In the current study, the inclusion of 20% PKM in the PTMR had no effect on feed consumption and growth performance. These results are in agreement with Tipu *et al*., (2014) and Ferreira *et al*., (2012), who reported that the lambs fed diets with PKM had no effect on performance parameters. Santos *et al*., (2016) found that the inclusion of high levels of PKM (>16%) led to a decrease in final weight gain due to the decrease of total dry matter intake and nutrient digestibility of cows. Alhidary *et al*., (2016) reported that 20% PKM mixed within a traditional feed resulted in a lower growth performance of lambs. The difference in results could be due to the species of

animal, composition and level of feed ingredients and other experimental conditions.

Carcass characteristics and meat quality in ruminants are influenced by the diet composition (Lee *et al*., 2008; Jacques *et al*., 2011). Most of the carcass characteristics and fat content were not influenced in ,the treatment groupsprobably because the body weight did not differ between the groups .The relative weight of the loin cut decreased significantly in PTMR2 compared to PTMR1. This may probably due to higher dressing weight of the lab.

The meat cooking loss, water holding capacity and shear force as well as the texture profile analysis were not affected by the inclusion of 20% PKM in feeding systems. This is consistent with Ribeiro *et al*., (2018), who mentioned that the use of PKM in TMR ingredients does not have any effect on meat quality traits in goats. Similar to our findings, another study reported that shear force, hardness and springiness were significantly higher with no effect on other meat quality traits when lambs fed on 20% PKM in TMR fed the diet to Naemi lambs (Alhidary *et al*., 2016).

The results obtained in the current study show that the inclusion of the PKM at a rate of 20 % in the ingredients of the TMR diet has no effect on the number of green carotenoids stored in the meat. The color of carcass and meat components (rack, Forequarters and Hindquarters) are considered as the important factors of interest to many consumers of lamb meat (Martínez-Cerezo *et al*., 2005). The meat pH value and meat color were not affected by PKM plus TMR diet in goats (Ribeiro *et al*., 2018). Alhidary *et al*., (2016) found that lambs fed on alfalfa had better meat color with no change in the meat pH compared with 20% PKM fed lambs. Carrasco *et al*., (2009) also reported that the meat color variations might be due to the stored carotenoids.

The ultimate lower meat pH in lambs fed on PTMR2 could possibly be due to PKM since all the lambs were subjected to the same procedures prior to and post-slaughter. These parameters are among the most important characteristics of meat considered as primary attributes at the time of purchase (Muela *et al*., 2016). Abdelrahman *et al*., (2017a) reported that rumen characteristics and general performance resulted in a significant change in lambs fed TMR with PKM compared to the traditional diet. On the other hand, reduced value pH in lambs fed TMR plus 20% PKM compared to the control was reported (Abdelrahman *et al*., 2019).

In conclusion, based on the results obtained from this study, we conclude that PKM can be included at a rate of 20% within the TMR ingredients due to its lack of negative impact on general performance parameters and the characteristics of the carcass, meat and rumen in growing lambs and thus may be a safe strategy to maintain performance and carcass characteristics of lambs.

Conflicts of Interest: The authors have no conflicts of interest to declare.

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References

Abdelrahman MM, Alhidary I, Albaadani HH, Alobre M, Khan RU and Aljumaah RS 2019. Effect of palm kernel meal and malic acid on rumen characteristics of growing Naemi lambs fed total mixed ration. Animals 9(7): 408-416.

Abdelrahman M.M., I. Alhidary, A.H. Alyemni, R.U. Khan, A.R.S. Bello, M.Y. Al- Saiady and R.A. Amran. 2017a. Effect of alfalfa hay on rumen fermentation patterns and serum biochemical profile of growing Naemi lambs with ad libitum access to total mixed rations. Pakistan Journal of Zoology 49: 1519-1522.

Abdelrahman MM, Aljumaah RS and Khan RU 2017b. Effects of prepartum sustained-release trace elements ruminal bolus on performance, colustrum composition and blood metabolites in Najdi ewes. Environ Sci Poll Res. 24(10): 9675-9680.

Alhidary IA, Abdelrahman MM, Alyemni AH, Khan RU, Al-Saiady MY, Amran RA and Alshamiry FA 2016a. Effect of alfalfa hay on growth performance, carcass characteristics, and meat quality of growing lambs with ad libitum access to total mixed rations. Rev Bras Zootec. 45(6): 302-308.

Alhidary, I., M.M. Abdelrahman, A.H. Alyemni, R.U. Khan, A.H. Al-Mubarak and H.H. Albaadani, 2016b. Characteristics of rumen in Naemi lamb: Morphological characteristics in response to altered feeding regimen. Acta Histochemica, 118(4): 331-337.

Alhidary, IA, M.M. Abdelrahman and R.U. Khan. 2016c. Comparative effects of direct-fed microbial alone or with a traces mineral supplement on the productive performance, blood metabolites and antioxidant status of grazing Awassi lambs. Environmental Science and Pollution Research 23: 25218-25223.

Andrés S, Huerga L, Mateo J, Tejido ML, Bodas R, Morán L, Prieto N, Rotolo LU and Giráldez FJ. 2014. The effect of quercetin dietary supplementation on meat oxidation processes and texture of fattening lambs. Meat Sci. 96(2):806-11.

Andrés S, Jaramillo E, Mateo J, Caro I, Carballo DE, López S and Giráldez FJ 2019. Grain grinding size of cereals in complete pelleted diets for growing lambs: Effects on animal performance, carcass and meat quality traits. Meat science, 157, 107874.

Blanco C, Bodas R, Prieto N, Andrés S, López S and Giráldez FJ 2014. Concentrate plus ground barley straw pellets can replace conventional feeding systems for light fattening lambs. Small Rumin Res. 116:137–143.

Carrasco S, Panea B, Ripoll G, Sanz A and Joy M 2009. Influence of feeding systems on cortisol levels, fat colour and instrumental meat quality in light lambs. Meat Sci 83(1): 50-56.

Fereira AC, Lopes O R, Regina B A, Pinto de C GG, Nunes Vaz S R and Andrade O P 2012. Intake,

digestibility and intake behaviour in cattle fed different levels of palm kernel cake. Revista MVZ Córdoba 17: 3105-3112.

Neto SG, Oliveira RL, de Lima FH, de Medeiros AN, Bezerra LR, Viégas J, do Nascimento NG and de Freitas Neto MD 2015. Milk production, intake, digestion, blood parameters, and ingestive behavior of cows supplemented with by-products from the biodiesel industry. Trop Anim Health Prod. 47: 191–200.

Islam R, Redoy MR, Shuvo AA, Sarker MA, Akbar MA and Al-Mamun M 2017. Effect of pellet from total mixed ration on growth performance, blood metabolomics, carcass and meat characteristics of Bangladeshi garole sheep. Progress Agric. 28(3): 222-229.

Jacques J, Berthiaume R and Cinq-Mars D 2011. Growth performance and carcass characteristics of Dorset lambs fed different concentrates: Forage ratios or fresh grass. Small Rumin Res. 95:113-11.

Lee JH, Kouakou B and Kannan G 2008. Chemical composition and quality characteristics of chevon from goats fed three different post-weaning diets. Small Rumin Res. 75:177-184.

Muela E, Monge P, Sañudo C, Campo MM and Beltrán JA 2016. Sensory quality of lamb following long-term frozen storage. Meat Sci. 114:32-7.

Menezes DR, Costa RG, de Araújo GG, Pereira LG, de Medeiros GR, Oliveira JS, Nascimento TV, de Souza Rodrigues RT, Pereira Filho JM and Busato KC 2016. Detoxified castor meal in substitution of soybean meal in sheep diet: growth performance, carcass characteristics and meat yield. Trop Anim Health Prod. 48: 297–302.

de Oliveira RL, de Carvalho GG, Oliveira RL, Tosto MS, Santos EM, Ribeiro RD, Silva TM, Correia BR and de Rufino LM 2017. Palm kernel cake obtained from biodiesel production in diets for goats: feeding behavior and physiological parameters. Trop Anim Health Prod. 49(7): 1401-1407.

Pereira TL, Fernandes AR, Oliveira ER, Cônsolo NR, Marques OF, Maciel TP, Pordeus NM, Barbosa LC, Buarque VL, Padilla AR, Colnago LA 2020. Serum metabolomic fingerprints of lambs fed chitosan and its association with performance and meat quality traits. Animal 15:1-2.

Ribeiro RD, Medeiros AN, Oliveira RL, de Araújo GG, Queiroga RD, Ribeiro MD, Silva TM, Bezerra LR, Oliveira RL 2018. Palm kernel cake from the biodiesel industry in goat kid diets. Part 2: Physicochemical composition, fatty acid profile and sensory attributes of meat. Small Rumin Res. 165: 1-7.

Santos RD, Alves KS, Mezzomo R, Oliveira LR, Cutrim DO, Gomes DI, Leite GP and de Souza Araújo MY 2016. Performance of feedlot lambs fed palm kernel cake-based diets. Trop Anim Health Prod. 48:367-372.

dos Santos RD, Gomes DI, Alves KS, Mezzomo R, Oliveira LR, Cutrim DO, Sacramento SB, de Moura Lima E, de Carvalho FF. 2017. Carcass characteristics and meat quality of lambs that are fed diets with palm kernel cake. Asian-Aust J Anim Sci. 30:865-871.

SAS, 2008. Statistical Analysis Systems Users Guide: Statistics. SAS Institute Inc., Cary, NC., USA. F

Sen U, Sirin E, Ulutas Z and Kuran M 2011. Fattening performance, slaughter, carcass and meat quality traits of Karayaka lambs. Trop Anim Health Prod. 43(2): 409-416.

Tipu M, Ahmad F, Khalique A, Haque M, Mirza R and Tayyab U 2014. Replacement of cotton seed cake with palm kernel cake in growing Nili-ravi buffalo male calves. J Anim Plant Sci. 24:24-7.

Trabi EB, Seddik HE, Xie F, Lin L and Mao S 2019. Comparison of the rumen bacterial community, rumen fermentation and growth performance of fattening lambs fed low-grain, pelleted or non-pelleted high grain total mixed ration. Anim Feed Sci Technol. 253:1-2.

Zhong RZ, Fang Y, Zhou DW, Sun XZ, Zhou CS and He YQ 2018. Pelleted total mixed ration improves growth performance of fattening lambs. Anim Feed Sci Technol. 242: 127-134.