aJava

Asian Journal of Animal and Veterinary Advances

Academic
Journals Inc.

www.academicjournals.com

Asian Journal of Animal and Veterinary Advances 8 (6): 775-785, 2013
ISSN 1683-9919 / DOI: 10.3923/ajava.2013.775.785

Effects of Dietary N-3 Fatty Acids on Growth Performance, Apparent Digestibility and Carcass Characteristics of Crossbred Boer Goat under Tropical Conditions

[1,4]K. Abuelfatah, [1,2]A.B.Z. Zuki, [1]Y.M. Goh and [3]A.Q. Sazili

[1]Faculty of Veterinary Medicine, [2]Institute of Biosciences, [3]Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
[4]Faculty of Animal Production, Khartoum University, Sudan

Corresponding Author: A.B.Z. Zuki, Faculty of Veterinary Medicine, Institute of Biosciences, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

ABSTRACT

Recently, feeding animals with dietary essential fatty acids have become of interest in animal nutrition. This is mainly to enrich their content in animal products in order to improve consumer health. Most of these studies have been focused in sheep and cattle while goats received a little attention. This study was conducted to assess effects of feeding different levels of linseed as a source of n-3 fatty acid on goat's growth performance, apparent digestibility and carcass characteristics. Twenty-four 5-month old crossbred Boer bucks were divided into three groups (n = 8) and assigned into three treatment diets differed in level of linseed for 110 days. The diets were L0, L10 or L20 contained 0% (control), 10 and 20% (w/w) linseed, respectively. In the last 14 days of the trial, four animals from each group were placed in metabolic crates for collection of feces. At the end of the trial all goats were slaughtered. The results showed that the final weight, total weight gain and apparent digestibility were not affected by the treatments ($p>0.05$). Goats fed L20 diet had lower ($p<0.05$) feed intake (669.30 g day^{-1}) compared to L0 (705.21 g day^{-1}) or L10 (698.51 g day^{-1}). The gain: Feed ratio was higher ($p<0.05$) in L20 compared to other treatments. The internal fat weight was heavier ($p<0.05$) in L20 (550.57 g) compared to L10 (373.00 g), while in L0 was (469.40 g) without significant difference from both. The percentage of lean was better ($p<0.05$) in L10 (67.82) compared to L0 (65.25) or L20 (64.78). It is concluded that linseed can be included to goat diets up to 20% (w/w), without adverse effects on growth and carcass quality of goat. Feeding goat 20% linseed can increase feed efficiency while 10% can improve goat carcass traits.

Key words: Goat, linseed, growth, digestibility, carcass characteristics

INTRODUCTION

Feeding animals with sources of Essential Fatty Acids (EFA) have not historically been an issue in animal nutrition. It is only because of growing interests in EFA for human well-being and the possibility to enrich their content in animal products have become of interest in animal nutrition (Palmquist, 2009). Enhancing the level of n-3 fatty acids in meats contributes toward improving consumer health and would help to combat the negative image of ruminant meat attributed to its high saturated nature (Cabiddu *et al*., 2010). Dietary n-3 fatty acids are not only necessary nutrients, but could positively influence coronary artery diseases, inflammatory disease, behavioral

disorders (Connor, 2000), diabetes and some cancers (Deckelbaum *et al*., 2006). Manipulation of meat fatty acids composition toward recommended ratios is mainly based on increasing the level of n-3 fatty acids (Hocquette *et al*., 2010). The PUFA is considered highly toxic to the rumen fibrisolvens bacteria (Maia *et al*., 2010), which may affect rumen fermentation and consequently, the digestibility and growth performance when added to ruminant feeds. Linseed (*Linum usitatissimum*) contains about 40% oil, with a high level of alpha-linolenic acid (C18: 3 n-3), which making up 50-60% of total fatty acids (Legrand *et al*., 2010). Furthermore, it has a lower content of linolenic acid (C18: 2 n-6) and saturated fatty acid compared to other oilseeds, such as soybeans, cottonseed, corn and sunflowers (Maddock *et al*., 2005). All these make it a leading source of plant based n-3 fatty acid (Legrand *et al*., 2010). In addition, linseed lignan has antioxidant properties, which may increase shelf life of produced meat (Prasad, 2000).

Goat meat is mainly produced and consumed in developing countries. However, during the last 20 years consumption of goat meat has increased all over the world due to nutritional aspects, since it contains low levels of fat and cholesterol (Madruga and Bressan, 2011). The goat population around the world was estimated at 867, 968, 573 heads in 2009. The majority of the goats in are found in Asia 60% (FAO, 2011), reflecting the significance of goat meat to feed millions of people in this region. A considerable research has been conducted to study the effects of feeding n-3 dietary in ruminant. Unfortunately, most of this research has been directed towards sheep and cattle while goat received a little attention in spite of the potential to increase PUFA in goat meat, since naturally has higher PUFA than that noted in mutton and beef (Banskalieva *et al*., 2000). The growth performance and carcass characteristics are among the important factors, which determine the feasibility in meat production. So, this research in current stage was conducted to study the effects of moderate and high inclusion levels of whole linseed, as a source of n-3 fatty acids on growth performance, apparent digestibility and carcass characteristics of goat under tropical condition.

MATERIALS AND METHODS

Experimental animals and housing: The trials were conducted at the Experimental Ruminant Unite, Department of Animal Science, Faculty of Agriculture, University of Putra Malaysia (UPM), under a tropical climate. Twenty four 5-month old Boer bucks with initial body weight (mean and SE) of 14.23±0.33 kg, were identified with uniquely numbered, dewormed and housed in individual wooden pens built inside a shed with a slatted wooden-floor, 0.8 m above the ground. According to their body weight, they were divided randomly into three equal groups (8 animals each) and assigned to one of three treatments diets after three weeks of an adaptation period.

Feeds and feeding: Three isonitrogenous and isocaloric diets: L0, L10 and L20, containing 0, 10, or 20% of whole linseed, respectively were formulated to meet the nutrient requirements (NRC, 2007). The experimental diets and their chemical composition are given in Table 1. Throughout the feeding trial, daily feed allowances were served to each group (3% body weight DM intake). The trial period lasted for 110 days (excluding three weeks for the adaptation period) during which various parameters were recorded. These included Dry Matter Intake (DMI), weight gain, Feed Conversion Ratio (FCR), Gain: Feed ratio (G: F) and final live weight.

Digestibility trial: During the last two weeks of study, four goats from each treatment group were randomly selected and placed in individual metabolism crates. The animals were allowed to adapt

Table 1: Formulation, proximate analyses and fatty acid of the experimental diets containing different levels of whole linseed

	Experimental diets		
Parameters	L0	L10	L20
Ingredient, dry matter (%)			
Whole linseed	-	10	20
PKC	40	30	20
Soybean meal	11	9	6
Corn	20	20	20
Rice straw	20	20	20
Molasses	4	9	5
Palm oil	3	-	-
$CaCO_3$	1	1	1
Salt	0.5	0.5	0.5
Mineral and vitamin mix	0.5	0.5	0.5
Chemical composition (% of DM)			
Dry matter	89.79±0.06	89.22±0.03	90.17±0.03
Crude protein	14.25±0.78	14.45±0.35	14.69±0.26
Ether extract	4.86±0.35	05.09±0.10	07.38±0.70
NDF	48.58±1.02	46.63±1.44	48.30±0.72
ADF	30.10±0.34	27.34±0.56	27.09±0.20
Ash	10.19±0.12	09.32±0.16	09.14±0.06
Metabolizable energy (MJ kg^{-1})	11.30	11	11
Fatty acids composition (mg 100 g^{-1} feed)			
Total saturated fatty acids	1315.5±118.9[a]	0723.8±95.4[b]	0771.9±63.7[b]
Total unsaturated fatty acids	1739.2±352.2[b]	3440.4±489.4[a]	4214.8± 345.3[a]
Total monoenes	1034.9±308.1	1160.6±160.7	1357.0±105.1
Total PUFA n-3	56.1±6.0[c]	1389.8±188.6[b]	1960.3±168.0[a]
Total PUFA n-6	648.2±60.1	0889.9±142.12	0897.5±73.0

L0 diet: Control diet contains 0% whole linseed, L10 diet: Contains 10% whole linseed, L20 diet: Contains 20% whole linseed, [1]Calculated, [abc] Values with different superscripts within row differ significantly at $p<0.05$ NS: No significant difference

to metabolism carte for 7 days followed by a total feces collection for the 7 day period. Feed samples were taken daily before feeding, the amount of feed offered and refused was weight daily and recorded through the collection period to determine dry matter intake. Fecal output of each animal was collected in a plastic tray, weighted and recorded daily. About 10% of total fecal out but for each animal was taken and kept in -20°C until used. At the end of the collection period, the sample of fecal belongs to each animal were pooled, thoroughly mixed and sub sample for further analyses.

Slaughtering and pH determination: At the end of the experiment, the weight of each animal was taken just before slaughter, after an overnight lairage. Animals were humanely slaughtered at the slaughter house, Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia. The entire slaughtering and processing procedures were carried out following DSM (2004). The pH of each carcass was measured using a portable pH meter (HANNA Hi8314 with an INGOLD type electrode Metrohm, Herisau, Switzerland.) consistently on the left *Longissimus* muscle caudal to the 12th rib within 30 min, 24 h and 7 days postmortem.

Carcass composition: All carcasses were conditioned (at 4°C) for 24 h before being split into two halves from the pelvis to the neck along the vertebral column using carcass splitting saw

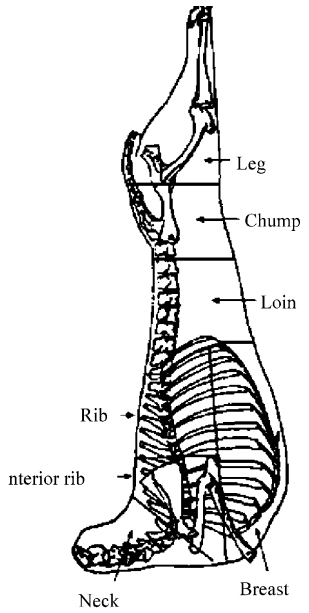

Fig. 1: Illustration of carcass prime cuts of goats (Calheiros and Neves, 1968)

(Jarvis, USA). The Kidney Knob and Pelvic Fat (KKPF) were removed, weighed and recorded accordingly. The left side of the chilled carcass was cut between the 12 and 13th ribs for the determination of the rib-eye area. On the other hand, the similar half was further subjected to fabrication for prime cuts (Calheiros and Neves, 1968) which are neck, anterior ribs, ribs, breast, loin, chump and leg (Fig. 1). Each resulted prime cut was then dissected into lean, bone, fat and trimmable tissues (major blood vessels, tendons, thick connective tissue sheets and glands).

Chemical analysis: Samples of feed and feces were subjected to proximate analysis according to the standard methods of AOAC (1990). For determination of Dry Matter (DM) content, samples of feeds, feces and refusal were dried at 105°C for 24 h in a forced-air oven. Ash content was determined by combusting the samples in a muffle furnace at 550°C for 6 h and Organic Matter (OM) content was calculated by difference (OM = 100-ash content). The N content of samples was determined using a Kjeltec Auto Analyzer (Tecator, Hoganas, Sweden) and Crude protein (CF) was calculated as N×6.25. Ether Extract (EE) was determined in petroleum ether using a Soxtec Auto Analyzer (Tecator). Neutral Detergent Fiber (NDF) and acid detergent fiber were determined using the procedures of Van Soest *et al.* (1991). The total Fatty Acids (FA) were extracted from experimental diets using chloroform-methanol 2:1 (v/v) based on the method of Folch *et al.* (1957) and transmethylated to their fatty acid methyl esters using 14% methanolic Boron Trifluoride (BF_3). The fatty acids were quantified by gas liquid chromatography (Agilent, Palo Alto, CA, USA) using a 100 m×0.25 mm ID (0.20 μm film thickness) Supelco SP-2560 capillary.

Statistical analysis: Data of the growth performance digestibility and the carcass characteristics were subjected to one-way analysis of variance using the GLM procedure of SAS (2003). Least-square means were computed and tested for differences by Duncan multiple range test. Differences between least squared means were considered to be significant at $p<0.05$. Data were presented as least-square Means±Standard errors.

RESULTS

Chemical composition of diets: Table 1 showed the ingredient and chemical and fatty acid composition of the three experimental diets. Their chemical compositions were almost similar except for EE, which was highest (7.38%) in L20. The total saturated fatty acids were significantly higher in L0 (1315.5 mg 100 g^{-1} feed) compared to L10 (723.8 mg 100 g^{-1} feed) and L20 (771.9 mg 100 g^{-1} feed). As expected, inclusion of linseed contributed to variation in n-3 FA. The highest amount of n-3 FA was in L20 (1960.3 mg 100 g^{-1} feed), followed by L10 (1389.8 mg 100 g^{-1} feed) and the lowest in L10 (56.1 mg 100 g^{-1} feed). There were no significant differences among the experimental diets in total monoenes and n-6 FAs.

Growth performance: The initial and final weight, total weight, weight gain, feed intake, FCR and G: F ratio are presented in Table 2. There were no differences ($p<0.05$) among treatments in initial weight, final weight, total weight gain, average daily gain and FCR. However, the highest final weight, daily gain and total gain were scored by the L20 group. The daily feed intake was significantly lower in the L20 (669.30 g day^{-1}) compared to the L10 (698.51 g day^{-1}) and L0 (705.21 g day^{-1}), which demonstrated the highest feed intake. The G: F ratio in this study was significantly improved with increasing of inclusion levels of linseed in the diets. The highest ratio was demonstrated by L20 (168.17 g of gain kg^{-1} of feed) compared to L10 (151.10 g of gain kg^{-1} of feed) and L0 (148.9 g of gain kg^{-1} of feed).

Apparent digestibility: The nutrient intake and digestibility of experimental diets are summarized in Table 3. There was no significant difference in nutrients intake except for ether extract and neutral detergent fiber. The highest intake of ether extracts was in L20 (52.5±1.3 g day^{-1}). The control group (L0) showed the highest intake of ADF (231.0±5.9 g day^{-1}). There were no significant ($p>0.05$) difference in the apparent digestibility coefficient between the three dietary treatments for DM, 0M, CP, EE, CF, NFE, NDF and ADF.

Slaughter data and carcass characteristics: Table 4 shows the slaughter data of goats fed diets contained different levels of linseed. No significant differences were found in hot carcass weight, cold carcass weight and dressing percentage among the treatment groups. The rib-eye area was significantly bigger in L10 (13.54 cm^2) compared to L0 (11.00 cm^2), while L20 (11.99 cm^2) was in between, without significant different from both. Internal fat was significantly heavier in L20 (550.57 g) compared to L10 (373.00 g), which revealed the least amount while in L0 was in

Table 2: Growth performance of crossbred Boer bucks fed diets containing different levels of whole linseed

	Experimental diets		
Parameters	L0 (n = 8)	L10 (n = 8)	L20 (n = 8)
Initial weight (kg)	14.00±0.60	14.50±0.353	14.00±0.453
Final weight (kg)	25.89±0.32	26.20±0.49	26.21±0.50
Total weight gain (kg)	11.89±0.36	11.82±0.45	12.21±0.63
Daily intake (g)	705.21±9.98^a	698.51±6.33^a	669.30±11.60^b
Average daily gain (g day^{-1})	104.85±3.03	105.42±4.05	111.93±5.03
FCR	6.76±0.20	6.70±0.27	6.0389±0.23
G: F, g of gain kg^{-1} of feed	148.9±4.75^a	151.10±6.27^a	168.17±6.67^b

^{abc}values with different superscripts within row differ significantly at $p<0.05$, NS: No significant difference

Table 3: Intake and apparent digestibility (Mean±SE) of crossbred boer bucks fed diets containing different levels of whole linseed

	Experimental diets			
Parameters	L0	L10	L20	p-value
Intake g day^{-1}				
Dry matter	712.1±18.1	705.1±15.6	700.7±11.6	0.10
Organic matter	634.3±16.1	649.4±28.4	660.6±16.3	0.69
Crude protein	101.5±2.6	101.1±4.4	104.5±2.6	0.74
Ether extract	34.6±0.9^{b}	035.6±1.6^{b}	052.5±1.3^{a}	>0.001
Acid detergent fibre	231.0±5.9^{a}	204.3±8.9^{b}	200.7±4.9^{b}	0.03
Neutral detergent fibre	388.8±9.9	383.1±16.8	349.5±8.6	0.13
Digestibility (%)				
Dry matter	62.0±0.7	059.2±1.8	058.6±2.0	0.34
Organic matter	65.5 ±0.7	064.2±2.0	063.6±1.4	0.68
Crude protein	66.9±0.4	064.0±1.2	062.7±2.7	0.27
Ether extract	92. 0±0 .2	090.2±0.8	092.9±1.2	0.13
Acid detergent fibre	31.8±1.6	025.6±3.0	024.9±3.5	0.16
Neutral detergent fibre	53.7±1.1	048.9±1.6	047.4±3.3	0.12

^{abc}Values with different superscripts within row differ significantly at p<0.05, NS: No significant difference

Table 4: Slaughter weight and carcass measurements of crossbred boer bucks fed diets containing different levels of whole linseed

	Experimental diets		
Parameters	L0	L10	L20
Slaughter wt. (kg)	25.89±0.32	26.20±0.49	26.21±0.50
Hot carcass wt. (kg)	12.03±0.22	12.78±0.66	12.00±0.48
Cold carcass wt. (kg)	11.73±0.24	12.44±0.59	11.67±0.44
Dressing percentage (hot)	46.48±0.91	46.29±1.78	45.88±1.15
Rib-eye area (cm^{2})	11.00±0.14^{a}	13.54±0.67^{b}	11.99±0.40^{ab}
Chiller shrinkage (%)	2.51±0.57	2.79±0.47	2.68±0.34
Internal fat (g)	469.40±52.96^{ab}	373.00±44.51^{a}	550.57± 43.50^{b}
Carcass pH at 1 h	6.39±0.076	6.23±0.07	6.47±0.092
Carcass pH at 24 h	5.81±0.10	5.92±0.12	5.74±0.08
Carcass pH at 7 days	5.71±0.07950	5.92±0.315	5.74±0.08

^{abc}Values with different superscripts within row differ significantly at p<0.05, NS: No significant difference

Table 5: Carcass composition as a percentage of half cold carcass weight of crossbred boer bucks fed diets containing different levels of whole linseed

	Experimental diets		
Parameters	L0	L10	L20
Total lean (%)	65.25±0.23^{ab}	67.82±1.41^{a}	64.78±0.75^{b}
Total bone (%)	21.65±1.07	20.71±0.32	22.28±1.02
Total carcass fat (%)	11.96±1.03	10.38±1.42	12.01±0.99
Total trims (%)	1.15±0.04	1.09±0.15	0.93±0.12
Lean to bone ratio	3.04±0.16	3.28±0.10	2.94±0.16
Lean to fat ratio	5.57±0.45	6.96±1.05	5.54±0.45

^{abc}values with different superscripts within row differ significantly at p<0.05, NS: No significant difference

between (469.40 g) without significant different from both. Carcass composition of treatment groups is shown in Table 5. The highest percentage of lean (67.82) was indicated by the carcasses produced by the animals of L10 group, compared with the L20 group which revealed the lowest parentage

Table 6: Primal cuts expressed as a percentage of half cold carcass weight of crossbred boer bucks fed diets containing different levels of whole linseed

	Experimental diets		
Prime cuts (%)	L0	L10	L20
Neck (%)	10.01±0.10	8.58±0.68	9.01±0.95
Breast (%)	11.57±0.69	12.17±0.95	12.29±0.59
Interior rib (%)	31.40±0.34	32.49±1.46	31.16±1.28
Rib (%)	8.13±0.87	9.15±0.41	8.72±0.38
Loin (%)	12.92±0.24	12.08±0.41	12.01±0.24
Chump (%)	12.73±0.13	10.93±0.39	10.91± 0.79
Leg (%)	25.95±0.94	25.53±1.16	26.81± 0.37

of lean (64.78). The L0 group was in between (65.25), but not different from both L10 and L20. Unlike lean, the percentages of fat, bone and trims were not significantly different between treatment groups. However, L20 group showed the highest fat percentage. The lean to bone ratio and lean to fat ratio were not significantly different, although the Ll0 group scored the highest percentage for both ratios (3.28 and 6.96, respectively). No difference among treatment groups in pH for both warm and carcass cold carcass (1 or 7 days postmortem). The result of prime cuts expressed as a percentage of half cold carcasses of experimental groups is as shown in Table 6, while their physical compositions are as presented in Table 7. The results revealed no significant difference in the prime cuts between the experimental groups. The percentages of lean in the anterior rib and chump cuts were significantly higher in L10 (68.37 and 66.67) and L20 (65.83 and 67.03) than those of L0 (63.21 and 61.49). The percentage of fat was significantly lower in L10 (10.84) and L20 (15.77) compared to those in L0 (25.19) in the rib cut, but it was significantly higher in L20 (7.45) compared to those in L0 (5.56) and L10 (5.10) in the leg cut.

DISCUSSION

The objective of this study was to investigate the effects of moderate (10%) and high (20%) inclusion levels of whole linseed, as a source of n-3 fatty acids, on growth performance, apparent digestibility and carcass characteristics of goat under tropical condition.

The high percentage of EE (7.38 %) in L20 diet is reasonable since linseed contains about 40% oil (Legrand *et al*., 2010). This also explains the high EE intake in this group, which revealed the highest intake (52.5±1.3 g day^{-1}).The high amounts of n-3 fatty acids (mainly C18:3 n-3) in L10 (1389.8±188.6 mg 100 g^{-1} feed) and L20 (1960.3±168.0 mg 100 g^{-1} feed) diets, came as had been planned, as a result of the high amount of n-3 LNA in linseed oil (50-60%).

The control group (L0) showed the highest intake of ADF (231.0±5.9 g day^{-1}) and this resulted from the high proportion of PKC (40%) in their diets, which contributed to increase ADF in diets (Abubakr *et al*., 2013). Fat added to the ruminants diet often have adverse effect on rumen fermentation and fiber digestion (Palmquist, 1984). Moreover, the PUFA is considered highly toxic to the rumen fibrisolvens bacteria (Maia *et al*., 2010), which may affect rumen fermentation thus the fiber digestibility. However, in this study, the two different inclusion levels of linseed had no significant effect on nutrient digestibility. This possible because feeding oilseeds might be have lesser adverse effects on rumen fermentation than feeding free oils (Palmquist, 1995). Since either the seed coat prevents the access of rumen microorganisms to the unsaturated FA (Aldrich *et al*., 1997) or masticated seeds release oil slowly. Unsaturated fat is not inhibitory if provided slowly or in low concentrations (Palmquist, 2009).

Table 7: Composition (%) of physically dissected primal cuts from crossbred boer bucks fed diets containing different levels of whole linseed

	Diet		
Tissues composition (%)	L0	L10	L20
Neck			
Lean	70.55±3.14	70.26±5.00	65.13±2.20
Bone	19.61±2.98	15.99±2.21	21.77±1.55
Fat	8.33±0.14	11.61±4.25	10.87±1.75
Trim	1.52±0.17	2.15±0.38	2.23±0.45
Breast			
Lean	54.47±1.75	56.92±3.38	50.34±2.78
Bone	21.47±2.39	19.34±3.05	23.95±23.95
Fat	21.75±0.31	21.84±0.98	24.16±2.45
Trim	2.33±0.52	1.91±.47241	1.55±0.22
Interior rib			
Lean	63.21±0.30^{b}	68.37±1.51^{a}	65.831±1.93^{ab}
Bone	24.63±0.13	22.25±1.40	24.58±1.44
Fat	11.06±0.15	8.76±1.30	8.72±1.38
Trim	1.10±0.12	0.62±0.06	0.86±0.15
Rib			
Lean	56.13±3.26	59.17±1.20	55.33±2.03
Bone	16.23±3.44^{b}	28.44±2.84^{a}	27.19±2.04^{a}
Fat	25.19±6.45^{a}	10.84±2.16^{b}	15.77±2.63^{b}
Trim	2.45±0.39	1.55±0.20	1.71±0.20
Loin			
Lean	71.77±2.41	73.24±2.84	68.50±1.48
Bone	19.40±2.20	15.33±2.57	19.42±1.65
Fat	8.83±0.35	10.41±1.73	11.87±1.37
Trim	-	-	
Chump			
Lean	61.49±0.68^{a}	66.67±1.23^{b}	67.03±2.12^{b}
Bone	23.83±1.10	18.09±0.94	16.32±1.80
Fat	14.51±0.58	14.95±1.44	16.65±0.76
Trim	0.16±0.16	0.30±0.30	0.10±0.10
Leg			
Lean	72.48±0.604	73.08±0.66	71.97±0.53
Bone	20.76±0.77	20.68±0.84	20.86±0.44
Fat	5.56±0.17^{b}	5.10±0.92^{b}	7.45±0.92^{a}
Trim	1.21±0.17	1.14±0.24	1.12±0.18

^{abc}Values with different superscripts within row differ significantly at $p<0.05$, NS: No significant difference

In this study, neither moderate (10%) nor high (20%) inclusion levels of linseed showed adverse effects on growth performance of goats. This finding is consistent with some studies conducted in beef by Litton (2011) fed 10% linseed, Corazzin *et al.* (2012) fed 5 or 10% linseed and LaBrune *et al.* (2008). Also a similar finding reported in lamb fed 17% whole linseed (Noci *et al.*, 2010). They all concluded that there were no significant effects in daily or total gain. However, Maddock *et al.* (2006) reported that whole linseed inclusion significantly increased the average daily gain and G: F ratio in beef cattle fed 8% whole linseed.

The decline in the feed intake in the L20 group is attributable to the high proportion of lipid in its diet (7.38% dry matter). This finding in agreement with Good (2004), who also observed a linear decreased in feed intake as the levels of linseed increased in beef diets. This also is consenting with a number of studies reported that increasing of lipid proportion in general reflected in decreasing in the feed intake (Felton and Kerley, 2004; Ramirez and Zinn, 2000).

However, Noci *et al.* (2010) found that the dry matter intake was significantly higher in linseed-based rations (17% whole linseed or 6% linseed oil) compared with Megalac or Camelina-based rations contained the same level of fat (6% dry matter) in lamb. This may indicate that the linseed-based diets have less negative effects on feed intake compared to other fat sources. The G: F ratio in this study was increased with increasing of inclusion levels of linseed in the diets. The highest ratio was demonstrated by L20 and this due to their lowest dry matter intake among the experimental groups. However, Maddock *et al.* (2006) also found that the G: F ratio was significantly higher in beef fed linseed despite no difference in dry matter intake and they attributed that to increase of energy density of the flax diets.

Carcass dressing percentages (hot and cold) were similar across the treatment groups and within the reported range of 37-55% (Ensminger, 2002). In general, the effects of feeding linseed on carcass quality are rather inconsistent and variable among the earlier related studies. Litton (2011) and Noci *et al.* (2010) reported no effect on carcass weight in beef cattle and lambs, respectively, while Maddock *et al.* (2006) documented significant increase in hot carcass weight of beef cattle fed 8% linseed. The higher amount of internal fat L20 in can be related to higher lipid intake in this group and may explain the lower value of dressing percentage (45.88) of this group. This result is in agreement with Maddock *et al.* (2006) and Zinn (1989) who reported that Kidney, Pelvic and Heart fat (KPH) increased linearly with the inclusion levels of lipid in the diet, which in turn has negatively affected the carcass yield. In this study, pH of the hot and cold carcass was not influenced by experimental diets. Therefore, we can suggest that the inclusion of linseed had no effects on glycogen content since the other factors that affecting carcass pH such as sex, weight, age and stress (McGeehin *et al.*, 2001), were similar to all animals.

CONCLUSION

It is concluded that linseed can be included to goat diets up to 20% (w/w), without adverse effects on growth and carcass quality of goat. Feeding goat 20% linseed might increase feed efficiency, while feeding 10% can improve goat carcass characteristics due to increment in the proportion of lean and decrease in the amount of internal fat.

REFERENCES

AOAC, 1990. Official Methods of Analysis of the Association of Official Analytical Chemists. 13th Edn., Association of Official Analytical Chemist, Washington, DC., USA.

Abubakr, A.R., A.R. Alimon, H. Yaakub, N. Abdullah and M. Ivan, 2013. Growth, nitrogen metabolism and carcass composition of goats fed palm oil by-products. Small Ruminant Res., 112: 91-96.

Aldrich, C.G., N.R. Merchen, J.K. Drackley, S.S. Gonzalez, G.C. Fahey and L.L. Berger, 1997. The effects of chemical treatment of whole canola seed on lipid and protein digestion by steers. J. Anim. Sci., 75: 502-511.

Banskalieva, V.V., T. Sahlu and A.L. Goetsch, 2000. Fatty acid composition of goat muscles and fat depots: A review. Amall Ruminant Res., 37: 255-268.

Cabiddu, A., L. Salis, J.K. Tweed, G. Molle, M. Decandia and M.R. Lee, 2010. The influence of plant polyphenols on lipolysis and biohydrogenation in dried forages at different phenological stages: *In vitro* study. J. Sci. Food Agric., 90: 829-835.

Calheiros, F. and A. Neves, 1968. Rendimentos ponderais no borrego merino precoce Carcacae 5° quarto. Separata Bol. Pecuario, 26: 117-126.

Connor, W.E., 2000. Importance of n-3 fatty acids in health and disease. Am. J. Clin. Nutr., 71: 171S-175S.

Corazzin, M., S. Bovolenta, A. Sepulcri and E. Piasentier, 2012. Effect of whole linseed addition on meat production and quality of Italian Simmental and Holstein young bulls. Meat Sci., 90: 99-105.

DSM, 2004. Malaysian standards MS 1500: 2004, Halal food-production, preparation, handling and storage-general guidelines (First revision). SIRIM Berhad, Malaysia.

Deckelbaum, R.J., T.S. Worgall and T. Seo, 2006. N-3 fatty acids and gene expression. Am. J. Clin. Nutr., 83: S1520-1525S.

Ensminger, M.E., 2002. Sheep and Goat Science. 6th Edn., Interstate Printers and Publishers, Danville, IL., USA., ISBN: 9780813431161, Pages: 693.

FAO, 2011. FAOSTAT database. Food and Agriculture Organization of the United Nations. http://faostat.fao.org

Felton, E.E.D. and M.S. Kerley, 2004. Performance and carcass quality of steers fed different sources of dietary fat. J. Anim. Sci., 82: 1794-1805.

Folch, J., M. Lees and G.H.S. Stanley, 1957. A simple method for the isolation and purification of total lipides from animal tissues. J. Biol. Chem., 226: 497-509.

Good, E.J., 2004. The Effects of Ground Flaxseed Supplementation on Performance, Carcass Composition and Sensory Attributes of Finishing Cattle. Kansas State University, USA., Pages: 194.

Hocquette, J.F., R.I. Richardson, S. Prache, F. Medale, G. Duffy and N.D. Scollan, 2010. The future trends for research on quality and safety of animal products. Ital. J. Anim. Sci., 4: 49-72.

LaBrune, H.J., C.D. Reinhardt, M.E. Dikeman and J.S. Drouillard, 2008. Effects of grain processing and dietary lipid source on performance, carcass characteristics, plasma fatty acids and sensory properties of steaks from finishing cattle. J. Anim. Sci., 86: 167-172.

Legrand, P., B. Schmitt, J. Mourot, D. Catheline and G. Chesneau *et al.*, 2010. The consumption of food products from linseed-fed animals maintains erythrocyte omega-3 fatty acids in obese humans. Lipids, 45: 11-19.

Litton, L.K., 2011. Effects of flaxseed supplementation and exogenous hormones on finishing performance, carcass characteristics and plasma and longissimus muscle fatty acid profiles in finishing cattle. Ph.D. Thesis, Kansas State University.

Maddock, T.D., V.L. Anderson, G.P. Lardy and N.E. Service, 2005. Using flax in livestock diets. NDSU Extension Service. http://www.agmrc.org/media/cms/as1283_E9EE897D14437.pdf

Maddock, T.D., M.L. Bauer, K.B. Koch, V.L. Anderson and R.J. Maddock *et al.*, 2006. Effect of processing flax in beef feedlot diets on performance carcass traits and trained sensory panel ratings. J. Anim. Sci., 84: 1544-1551.

Madruga, M.S. and M.C. Bressan, 2011. Goat meats: Description, rational use, certification, processing and technological developments. Small Rumin. Res., 98: 39-45.

Maia, M.R.G., L.C. Chaudhary, C.S. Bestwick, A.J. Richardson and N. McKain *et al.*, 2010. Toxicity of unsaturated fatty acids to the biohydrogenating ruminal bacterium, Butyrivibrio fibrisolvens. BMC Microbiol., Vol. 10. 10.1186/1471-2180-10-52

McGeehin, B., J.J. Sheridan and F. Butler, 2001. Factors affecting the pH decline in lamb after slaughter. Meat Sci., 58: 79-84.

NRC, 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids and New World Camelids. National Research Council of the National Academies, Washington DC.

Noci, F., F.J. Monahan and A.P. Moloney, 2010. The fatty acid profile of muscle and adipose tissue of lambs fed camelina or linseed as oil or seeds. Anim.: Int. J. Anim. Biosci., 5: 134-147.

Palmquist, D.L., 1984. Use of Fats in Diets for Lactating Dairy Cows. In: Fats in Animal Nutrition, Wiseman, J. (Ed.). Butterworths, London, UK., pp: 357-381.

Palmquist, D.L., 1995. Digestibility of cotton lint fiber and whole oilseeds by ruminal microorganisms. Anim. Feed Sci. Technol., 56: 231-242.

Palmquist, D.L., 2009. Omega-3 fatty acids in metabolism, health and nutrition and for modified animal product foods. Prof. Anim. Sci., 25: 207-249.

Prasad, K., 2000. Antioxidant activity of secoisolariciresinol diglucoside-derived metabolites, secoisolariciresinol, enterodiol and enterolactone. Int. J. Angiol., 9: 220-225.

Ramirez, J.E. and R.A. Zinn, 2000. Interaction of dietary magnesium level on the feeding value of supplemental fat in finishing diets for feedlot steers. J. Anim. Sci., 78: 2072-2080.

SAS, 2003. Statistical Analytical System. SAS Institute Inc., Cary, NC., USA.

Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583-3597.

Zinn, R.A., 1989. Influence of level and source of dietary fat on its comparitive feeding value in finishing diet for steers. Metabolism. J. Anim. Sci., 67: 1032-1037.