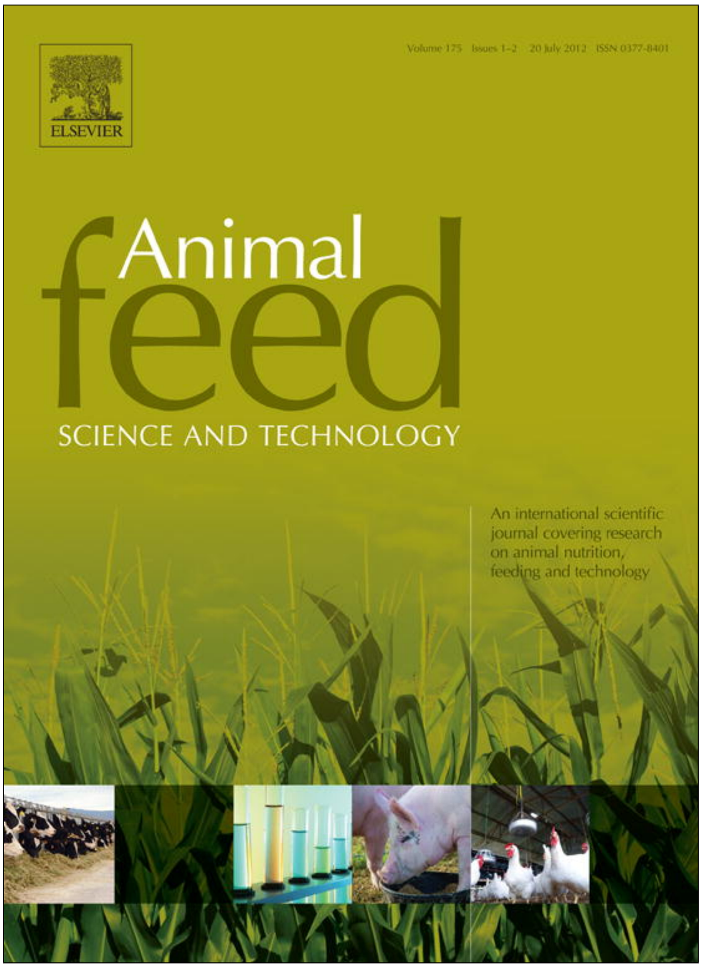
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Performance and carcass characteristics of finishing Black goat kids fed oil supplemented diets

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ABSTRACT

Effects of oil supplemented diets on growth performance and carcass proportions were studied using 27 male Black goat kids with a body weight (BW) of 19.4 ± 0.41 kg at the beginning of the experiment. Kids were randomly divided into 3 groups of 9, and those in each group were individually fed cereal grain-soybean meal (SBM) based total mixed rations (TMR) with a fixed amount (*i.e.*, 30 g/kg dry matter (DM)) of oil being either: sesame (SES), sunflower (SUN) or soybean (SOY). All TMR were isonitrogenous and iso-metabolizable energy (ME). At the termination of the 105 d feeding study, all kids were slaughtered. Kids fed SES or SOY supplemented diets consumed more (P<0.05) feed (*i.e.*, DM, organic matter, crude protein, neutral detergent fiber) and gained more BW (P<0.05) than those fed the SUN supplemented diet. However, kids fed the SES supplemented diets had a better (P<0.05) feed conversion ratio than kids fed the SUN or SOY diets. Oil type had no effect on carcass components (*i.e.*, loin, legs, shoulder, rack) weights. Liver and kidney fat were heaviest (P<0.05) in kids fed the SES supplemented diet. However, kids fed the SES supplemented diet had less (P<0.05) mesenteric fat and lower (P<0.05) total gastrointestinal tract weights compared to kids fed the SUN or SOY supplemented diets. Eye muscle width and depth and rib eye area were higher (P<0.05) in carcasses of kids fed the SES supplemented diet. Positive effects of SES as a supplemental oil on most responses is encouraging, but more investigation is needed to identify the optimal level of SES in various diets of goat kids.

1. Introduction

In Mediterranean countries it is common for cereal grains (*i.e.*, corn, barley, wheat) and wheat and barley straws to be used in ruminant feeding, but feeding costs are largely driven by the cost of the grains. Thus finding alternative high energy feeds would be of great advantage to local producers.

Oils and fats have often been used in ruminant rations to increase their metabolizable energy (ME) value (Clapperton and Steele, 1983). While, in recent years, dietary fat supplementation has become a common practice, fat supplemented diets have had variable effects on animal performance and carcass characteristics. Iso-ME diets have resulted in similar dry matter (DM) intake in lambs (Awawdeh et al., 2009; Jenkins and Fotouhi, 1990), but average daily gain (ADG) of lambs fed sunflower oil was lower than in lambs with no fat supplementation (52.6 *versus* 57.0 g/d, Marinova et al., 2001). Similar

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; CLA, conjugated linoleic acid; CP, crude protein; DM, dry matter; FCR, feed conversion ratio; ME, metabolizable energy; aNDF, neutral detergent fiber; OM, organic matter; SES, sesame; SOY, soybean; SUN, sunflower; TMR, total mixed ration.

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Table 1
Formulated ingredient and analyzed chemical composition of diets containing the different oil supplements.[a]

	Treatment[b]		
	SES	SUN	SOY
Ingredient composition (g/kg DM)			
n	9	9	9
Corn grain, yellow	130	130	130
Soybean meal, 440 g/kg CP solvent extracted	190	190	190
Wheat, bran	100	100	100
Wheat, straw	100	100	100
Ammonium chloride	3	3	3
Dicalcium phosphate	10	10	10
Limestone	21	21	21
Salt	3	3	3
Premix[c]	1	1	1
Fat[d]	30	30	30
Barley, grain (ground)	170	170	170
Wheat, grain (ground)	242	242	242
Nutrient composition (g/kg DM)			
n	3	3	3
Dry matter (g/kg)	907	903	897
Crude protein	180	184	178
Ether extract	43	41	40
Acid detergent fiber	104	100	102
aNeutral detergent fiber	305	310	300
Ash	61	69	65
ME (MJ/kg)[e]	8.3	8.7	8.5

[a] Composition values obtained from analysis of the final diets.
[b] SES, SUN, and SOY refer to dietary treatments containing 30 g/kg sesame oil, 30 g/kg sunflower oil and 30 g/kg soybean oil on DM basis, respectively.
[c] Composition/kg: vitamin A, 2,000,000 IU; vitamin D3, 40,000 IU; vitamin E, 400 IU; Mn, 12.8 mg; Zn, 9.0 mg; I, 1.56 mg; Fe, 6.42 mg; Co, 50 mg; Se, 32 mg plus an antioxidant (butylated hydroxyanisole, BHA).
[d] Ether extract for fat sources was estimated to be 999 g/kg (Table 2).
[e] Metabolizable energy; estimated based on NRC (1985) feed composition tables.

results were reported for other ruminants fed vegetable oil supplemented diets (Vermon, 1976; Zinn, 1989a; Boucque et al., 1990; Mir et al., 2000).

Fat supplemented diets did not change backfat thickness or the proportion of kidney, pelvic and heart fat in steers. In developing countries, availability of feed grade vegetable oils is often uncertain, as is the sale price of the animals. The main supplemental oils available in Palestine are sesame (SES), sunflower (SUN) and soybean (SOY) oils. The only oil produced locally is SES, a product of sesame seed crushing. However, this oil, obtained using a traditional pressing method with high levels of impurities, is not suitable for human consumption and is mainly used in poultry diets. However, SES supplemented diets are not fed to ruminants on a wide scale compared to diets supplemented with SUN or SOY oils. To our knowledge, inclusion of SES, SUN or SOY oil, especially SES, in diets for finishing Black goat kids has not been investigated.

Our objective was to determine effects of adding SES, a non conventional supplemental oil in ruminant feeding, as well as SUN or SOY oils to cereal grain based diets on performance and carcass characteristics of finishing Black goat kids.

2. Materials and methods

2.1. Study site

The study was conducted at Hebron University, Hebron city, Palestine, which is a semi-arid area, after approval of the Hebron University Animal Care and Use Committee.

2.2. Animals, design, dietary treatments and analytical methods

Twenty-seven male Black goat kids (initial body weight (BW) = 19.4 ± 0.41 kg) at 60 d of age (*i.e.*, soon after weaning) were used. Kids were individually housed in 1.5 m × 0.75 m shaded pens and treated with IVOMEC (Merial Limited, Luluth, GA, USA) and Cogla Vac (Cogla Laboratories, Libourne, France) against internal and external parasites, and enterotoxaemia, respectively, immediately prior to the start of the experiment.

Kids were assigned on the basis of BW to one of three dietary treatments (Table 1), being a sesame oil diet containing 30 g/kg DM sesame oil (SES; $n = 9$) and two additional diets containing similar levels of sunflower oil (SUN; $n = 9$) or soybean oil (SOY; $n = 9$). The experiment length was 105 d. The 30 g/kg fat addition level was chosen to avoid potential negative effects on animal performance associated with higher inclusion levels (Moore et al., 1986). Diets were composed of forage (*i.e.*, 100 g/kg DM wheat straw) and a concentrate (*i.e.*, 900 g/kg DM of a mixture of cereals, soybean meal, by product feeds

Table 2
Fatty acid profile of the oil supplements (g/kg fat).

	Oil supplements[a]		
	SES	SUN	SOY
C14:0	4	9	4
C16:0	90	60	90
C16:1	–	10	5
C18:0	45	55	40
C18:1	420	190	240
C18:2	420	650	540
C18:3	10	15	70
C20:0	10	10	10
Saturated	149	134	144
Unsaturated	850	865	855

Nzikou et al. (2009).
[a] SES, SUN, and SOY refer to sesame oil, sunflower oil, and soybean oil, respectively.

and a mineral premix) (Table 1). Oils were obtained from local commercial venders and mixed into the concentrate which was later mixed with the straw and fed as a total mixed ration (TMR). All diets were formulated to be isonitrogenous and iso-ME, and to meet all nutrient requirements for finishing kids (NRC, 1985).

2.3. Chemical analysis

The experimental rations were analyzed (three samples from each ration) according to procedures of AOAC (1990) for DM (105 °C in a forced air oven for 24 h), organic matter (ash; weight retained upon ashing at 550 °C for 8 h; #942.05), N (#976.06) and ether extract (EE; Soxhlet procedure, Soxtec System, TECATOR, Hoganas, Sweden; #920.29). Additionally, samples were analyzed for neutral detergent fiber (aNDF; with use of a heat stable amylase and sodium sulfite in the ND) and acid detergent fiber (ADF; ANKOM 2000 fiber analyzer, ANKOM Technology Corporation, Macedon, NY, USA) according to Van Soest et al. (1991, Table 1). Values for aNDF and ADF are expressed inclusive of residual ash. The ME values were calculated based on NRC (1985) feed composition tables.

Diets were fed as a TMR once daily at 08:00 h, and kids had free access to clean water at all times. The amounts of TMR offered and refused were recorded daily for each kid and adjusted to assure refusals of about 0.10 of intake for *ad libitum* consumption. For each kid, samples of refused TMR were collected daily, composited at the end of study, and saved (−20 °C) for later analysis of DM, ash, N, EE, aNDF and ADF to determine daily nutrient intakes.

2.4. Slaughtering procedure, carcass characteristics, and meat quality

At the end of the experiment, all kids were slaughtered after an 18 h fast according to routine procedures at local commercial slaughter facilities. Fasted-live and hot carcass weights were recorded before and immediately after slaughter. Directly after slaughter, non-carcass components (*i.e.*, head and feet, lungs and trachea, heart, liver, kidneys, kidney fat, mesenteric fat) were removed and weighed. Carcasses were chilled at 4 °C for 24 h and cold carcass weights were recorded. Dressing proportion was calculated as the hot carcass weight proportion of fasted BW. The day after slaughter, carcasses were cut into halves and further into four parts (*i.e.*, shoulders, racks, loins, legs) and dimensions (*i.e.*, eye muscle width, depth, area) were determined as described by Abdullah et al. (1998) and Abdullah and Musallam (2006).

2.5. Statistical analyses

Data (animal measures) were subjected to analysis of variance using the GLM procedure of SAS (2002). An LSD test was used to assess significance among treatment means. Each kid was considered as the statistical unit. The model was: $Y_{ij} = \mu + T_i + E_{ij}$, where Y_{ij} is the observation on the *j*th kid receiving *i*th treatment (oil source), μ is the overall mean, T_i is the effect of *i*th treatment (oil source), E_{ij} is the residual for the *j*th observation receiving *i*th treatment (oil source).

3. Results

All diets were homogeneous, dustless and isonitrogenous, iso-ME and met all nutrient requirements for finishing goat kids (NRC, 1985). All diets contained comparable levels of aNDF, ADF and EE (305, 102 and 41 g/kg DM, respectively, Table 1).

3.1. Kid performance

Kids fed the SUN supplemented TMR ate less ($P<0.05$) DM, OM, CP and aNDF than those fed the SES or SOY supplemented diets (Table 3), but kids fed the different oils ate similar amounts of EE. Kids fed the SES or SOY supplemented diets had more

Table 3
Performance and nutrient intakes of finishing male Black goat kids fed diets containing the different oil supplements.

	Treatment[a]			SEM
	SES	SUN	SOY	
n	9	9	9	
Initial weight (kg)	19.4	19.9	19.1	0.88
Final weight (kg)	41.4a	39.2b	40.1b	0.90
Total gain (kg)	22.0a	19.3b	21.0a	0.86
ADG (g)	210a	184b	200a	12.5
Nutrient intake				
Dry matter (g/d)	1004a	956b	1008a	52.1
Organic matter (g/d)	838a	798b	842a	38.9
Crude protein (g/d)	181.0a	172.0b	181.4a	8.00
Ether extract (g/d)	41.2	39.2	41.3	1.80
aNeutral detergent fiber (g/d)	306a	292b	307a	12.4
Acid detergent fiber (g/d)	102	98	103	32.7
FCR (g/g)[b]	4.78b	5.19a	5.04a	0.200

Within row, means with different letters differ at P<0.05.
[a] SES, SUN, and SOY refer to dietary treatments containing 30 g/kg sesame oil, 30 g/kg sunflower oil, and 30 g/kg soybean oil on DM basis, respectively.
[b] Feed conversion ratio = DM intake/ADG.

total gain (P<0.05) than kids fed the SUN supplemented diet. Kids fed the SES supplemented diet had the highest (P<0.05) feed conversion ratio (FCR).

3.2. *Carcass characteristics and meat quality*

Kids fed the SES or SOY supplemented diets had heavier (P<0.05) fasting BW than those fed the SUN supplemented diet (Table 4). However, hot and cold carcass weights were heavier (P<0.05) for kids fed the SES or SUN supplemented diets than for kids fed the SOY supplemented diet. Dressing proportion followed a similar trend, where it was higher (P<0.05) in kids fed the SES or SUN supplemented diets compared to kids fed the SOY diet. Carcass cut (*i.e.*, shoulder, rack, loin, legs) weights were not affected by dietary fat type, and non-carcass components (*i.e.*, head, lungs and trachea, heart, kidneys, kidney fat) weights were similar among treatments. Liver and kidney fats were heavier (P<0.05) in kids fed the SES supplemented TMR compared to those fed the SUN or SOY supplemented TMR. However, the SES supplemented diet resulted in less (P<0.05) mesenteric fat and total gastrointestinal tract total weights compared to that in kids fed the other oils.

Eye muscle width, depth and rib eye area were larger (P<0.05) in carcasses of kids fed the SES supplemented diet (Table 5).

Table 4
Carcass and non-carcass components, as well as carcass cut weights of finishing male Black goat kids fed diets containing the different oil supplements.

	Trt[a]			SEM
	SES	SUN	SOY	
n	9	9	9	
Fasting weight (kg)	40.4	39.2	40.1	0.96
Hot carcass weight (kg)	25.0a	23.9a	22.5b	1.34
Cold carcass weight (kg)	24.5a	22.0b	20.7b	1.20
Dressing proportion[b]	0.610a	0.600a	0.560b	0.0300
Carcass components (kg)				
Loin	3.92	3.71	3.82	0.020
Legs	8.01	8.21	8.54	0.030
Shoulder	10.19	10.57	9.83	0.032
Rack	3.53	3.84	3.70	0.010
Non-carcass components (kg)				
Head	2.60	2.70	2.60	0.110
Lungs	0.46	0.40	0.50	0.028
Heart	0.20	0.20	0.20	0.010
Liver	1.00a	0.90[b]	0.90b	0.034
Kidney	0.16	0.20	0.20	0.013
Kidney fat	0.05a	0.04b	0.04b	0.006
Mesenteric fat	0.20b	0.24a	0.24a	0.022
Total gut	6.50b	7.00a	7.10a	0.212

Within row, means with different letters differ at P<0.05.
[a] SES, SUN, and SOY refer to dietary treatments containing 30 g/kg sesame oil, 30 g/kg sunflower oil, and 30 g/kg soybean oil on a DM basis, respectively.
[b] Calculated as the hot-carcass weight as a proportion of fasted BW.

Table 5
Eye muscle dimensions of finishing male Black goat kids fed diets containing the different oil supplements.

	Treatment[a]			SEM
	SES	SUN	SOY	
n	9	9	9	
Eye muscle width (A) (mm)	63a	57b	58b	3.4
Eye muscle depth (B) (mm)	34a	32b	31b	1.4
Rib-eye area (cm^2)	16a	13b	12b	1.9

Within row, means with different letters differ at P<0.05.
[a] SES, SUN, and SOY refer to dietary treatments containing 30 g/kg sesame oil, 30 g/kg sunflower oil, and 30 g/kg soybean oil on a DM basis, respectively.

4. Discussion

Fat supplemented diets have had variable effects on ruminant performance (Ueda et al., 2003; Awawdeh et al., 2009), which may be related to conditions such as the composition of the basal diet, its ME density, level of fat inclusion, fat type (*e.g.*, level of saturated fatty acids), whether diets were formulated to be iso-ME as well as animal species (Awawdeh et al., 2009). Many studies have investigated effects of conjugated linoleic acid (CLA) on body composition and, although results vary by species, Whigham et al. (2007) found that CLA at levels 1–10 g/kg of diets affected nonruminant (*i.e.*, rats and pigs) performance.

In our study, intakes of DM, OM, CP and aNDF differed among diets even though they were iso-ME. In contrast, iso-ME diets resulted in similar DM intake in lambs (Awawdeh et al., 2009; Jenkins and Fotouhi, 1990). Kids fed sunflower or hydrogenated oils had similar DM intake, ADG and FCR (Marinova et al., 2001). However, DM was not affected when lambs were fed 100 g/kg DM soybean oil (Haddad and Younis, 2004; Bessa et al., 2005) compared to high concentrate control diets. Inclusion of palm oil improved lamb performance when fed for a period of 12 wks (Dutta et al., 2008).

Carcass characteristics were not affected by sunflower oil feeding in our study. Similar results were reported by Marinova et al. (2001) and Haddad and Younis (2004), where adding fats to diets for fattening lambs had no effect on performance or carcass characteristics. No differences in these parameters occurred when lambs received palm oil up to 60 g/kg diet DM (Castro et al., 2005). Likewise, Kott et al. (2003) did not observe differences in kidney knob and channel fat weights in lambs whose diet was supplemented with 60 g/kg DM sunflower oil.

In our experiment, adding SES or SOY to diets maximized growth and carcass weights of kids. The poorer performance of the SUN supplemented kids could be due to negative effects of SUN on digestion of other nutrients, such as aNDF, with negative consequences on intake and performance. Kim et al. (2007) reported a reduction in ruminal fiber digestion associated with linoleic acid supplementation of linseed, soybean and cottonseed oils. Oils high in C18 unsaturated fatty acids, such as SUN, in ruminant diets are generally associated with negative effects on ruminal digestion, particularly of structural carbohydrates. Indeed differences in level of unsaturation among our oils could have been enough to affect ruminal microbial composition, fermentation and/or nutrient digestion. SUN, with a high level of linoleic acid resulted in negative effects on ruminal fermentation, microbial protein flow to the duodenum and apparent nutrient digestibility in sheep (Jenkins, 1993). The magnitude of the antiprotozoal properties of feed oils, especially linoleic acid (Hristov et al., 2004) depends on the degree of unsaturation of their fatty acids. Williams and Coleman (1992) reported that these antiprotozoal properties are usually associated with a low ruminal ammonia concentration and depression nutrients digestibility. These inconsistencies could be partially due to the composition of the basal diets (*e.g.*, forage type), feeding strategies (*e.g.*, limit *versus ad libitum* fed) and/or fat type (Awawdeh et al., 2009), and/or the free fatty acid contents and degree of fat saturation (Zinn, 1989b).

The high level of linoleic acid in SUN may have altered fatty acid synthesis in adipose tissue and inhibited some of its lipogenic enzymes. The increase in rumen escape of the CLA trans-10,cis-12, as in SUN, when supplementing a high concentrate diet, as in our study, is capable of lowering fat syntheses (Park et al., 1999). Linoleic acid in a SUN supplemented diet decreased body fat deposition in lambs (Azain, 2004) The CLA content of SUN was lowered fat mass by decreasing cell size and abdominal fat deposition (Sanz et al., 2000).

The high ADG in kids fed the SES and SOY supplemented diets might be due to more efficient use of ME compared to that of SUN, as SES and SOY may have increased the rate of fat metabolism (Lough et al., 1993). It is clear that CLA effects on body composition are isomer specific. For example, the *t*10, *c*12 isomer has been identified as being responsible for decreasing body fat synthesis. Mechanisms by which this isomer has this affect include reduction of lipid accumulation by adipocytes mediated through effects on lipoprotein lipase and stearoyl-coenzyme A (CoA) desaturase (Hristov et al., 2004).

Growing Suffolk × Hampshire rams and ewe lambs fed high forage diets containing palm oil had higher kidney and pelvic fats than lambs fed similar diets with no oil, with no effects on slaughter weight, dressing proportion and longissimus muscle area (Solomon et al., 1992; Lough et al., 1993). Inconsistent effects of dietary oil supplements on fat depots could be because, during fat deposition, the rate of fat synthesis and lipogenic enzyme activity varies among body tissues (*i.e.*, intramuscular, subcutaneous, mesenteric, kidney fat).

The dressing proportion was higher in kids fed SES or SUN supplemented diets compared to that of kids fed the SOY diets. Engle et al. (2000) reported similar results when soybean oil was fed to steers at levels of 40 g/kg. Dutta et al. (2008) found that palm oil up to 100 g/kg diet DM had no effect on kidney, omental, mesenteric, subcutaneous and intermuscular and intramuscular fats in local Indian-breed lambs. The overall improvement in rib eye muscle width, depth and area associated with kids fed the SES supplemented diet compared to that in kids fed other sources of oil might be due to more efficient use of ME from SES (Awawdeh et al., 2009).

5. Conclusions

Studies with goats, especially Black goats are limited. Our results, the first in our region, show advantages of feeding SES supplemented diets to kids in comparison to diets supplemented with SOY or SUN. However more research is needed to investigate effects of SES feeding level and duration of feeding on fat deposition, intra and intermuscular, subcutaneous fats and nutrient digestibility in goat kids.

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