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Effects of different forms of olive cake on the performance and carcass quality of Awassi lambs

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ABSTRACT

Effects of form of olive cake (OC) on growth performances and carcass quality were studied on forty-eight Awassi lambs. All lambs were male with an average body weight of 29.5 kg (S.D. = 2.3 kg) at the beginning of the experiment. Animals were randomly divided into four groups of 12 lambs each. Lambs in each group received individually corn–soybean meal (SBM) total mixed rations (TMRs). Rations were incorporated with a fixed amount (149 g/kg DM) of OC of different forms: crude OC, a product of the three centrifugation extraction procedure (control group), alkali treated, ensiled and pelleted. All rations were isonitrogenous and isocaloric. The growth experiment lasted 10 weeks. In the following week, all lambs were slaughtered. At termination of the experiment, lambs fed crude, alkali treated or ensiled OC rations consumed more feed and gained more weight ($P<0.05$) than those fed the pelleted OC. This same trend was found for the feed conversion (FC), carcass and empty body weights (EBWs). However, external (hide, head and feet, HHF) and thoracic organs (heart and lungs, HL), gut and liver weights proportional to EBW (g/kg) were not affected by the form of OC. The form of OC had no effects on muscle ($P=0.4$) and bone ($P=0.21$) tissues. Carcass, pelvic, kidney fats and total carcass fats weights when expressed as g/kg EBW and the percent of carcass fat of total body fat (TBF) were lower in lambs fed the pelleted OC compared to those offered the other forms of OC. However, the subcutaneous, inter muscular and TBF fats weights (g/kg) were comparable among lambs in different OC form rations. Results from this work suggest that the treated OC had no advantages compared to crude in regard to parameters investigated in this research.

1. Introduction

There are two centrifugation extraction procedures used in olive processing, the two and the three stage procedures (Molina Alcaide and Yáñez Ruiz, 2008). The chemical composition of OC differs between these two procedures. The main difference is the higher moisture and the lower oil content of OC obtained from the two stage procedure. The crude protein (CP) content is low and variable (Martín García et al., 2003) and with high structural carbohydrate content (Martín García et al., 2003; Molina Alcaide and Yáñez Ruiz, 2008).

OC treatment has variable effects on nutrient composition (Nefzaoui and Vanbelle, 1986; Aguilera et al., 1992; Hadjipanayiotou, 1999; Ben Salem et al., 2000; Chiofalo et al., 2004; Christodoulou et al., 2008). The main constraints to

Abbreviations: CP, crude protein; CR, conversion ratio; DM, dry matter; EBW, empty body weight; HHF, hide–head–legs; HL, heart–lungs; OC, olive cakes; SBM, soybean meal; TBF, total body fat; TMR, total mixed ration.

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Table 1
The ingredients and chemical composition of experimental feeds incorporated with olive cake (OC) fed to Awassi fattening lambs, g/kg DM.

Ingredient	Crude	Alkali treated	Ensiled	Pelleted
Yellow corn	400	400	400	400
Soybean meal	257	257	257	257
Wheat bran	79	79	79	79
OC	149	149	149	149
Ammonium chloride	3	3	3	3
DCP	6	6	6	6
Limestone	17	17	17	17
NaCl	3	3	3	3
Premix[a]	1	1	1	1
Soapstock	1	1	1	1
Wheat straw	84	84	84	84
Chemical analysis:(DM basis)				
DM	900	890	890	890
CP	180	180	180	180
ADF	185	145	186	175
aNDF	550	480	519	538
Ash	65	64	71	67
Ca	9.1	9.2	9.2	9.3
P	6.2	6.4	6.2	6.4
ME[b], MJ/kg DM	6.65	6.72	6.7	6.67

[a] Composition per 1 kg contained, 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.
[b] Metabolizable energy; based on tabular values (NRC, 1985).

preserve crude OC are its high water and oil contents. However, silage has been reported to be a simple, cheap, and efficient procedure to preserve OC, either alone (Hadjipanayiotou, 1999) or with the addition of poultry manure (Nefzaoui, 1991), conventional feedstuffs (Hadjipanayiotou, 1999), urea (Al Jassim et al., 1997) or an alkali (Nefzaoui and Vanbelle, 1986). Different ways to include OC in animal diets have been described, feeding it fresh (Giozelgiannis et al., 1978), ensiled (Hadjipanayiotou, 1999; Hadjipanayiotou and Koumas, 1996; Christodoulou et al., 2008), dried (Abo Omar and Gavoret, 1995), as a component of concentrate pellets and multi-nutrient feed blocks (Priolo et al., 2002) or urea treated (Al Jassim et al., 1997).

Several papers have examined the effect of including olive by-products on animal performance; however, very few studies have addressed the effects of different forms of OC on carcass quality and visceral organs. The objectives of this research were to investigate the form of OC (crude, a product of the three centrifugation extraction procedures, alkali treated, ensiled or pelleted) on the performance and carcass quality and visceral organs of Awassi lambs.

2. Materials and methods

2.1. Preparation of diets

The fresh OC needed for the whole experiment was obtained from a traditional olive press factory near the experimental site. A portion of the fresh OC was spread on a plastic sheet for sun drying. The air-dried crude OC was temporally stored to be fed as crude OC and considered as the control group. Another portion of the crude OC was treated with NaOH as described by Nefzaoui (1985). The fresh OC was ensiled as described by Hadjipanayiotou (1999). To produce the pellet, the sun dried OC was wetted with water to elevate moisture content to about 65% then it was immediately pelleted at about 80 °C and cooled down to a temperature below 20 °C, suitable for stable preserving.

2.2. Animals and experimental design

Forty-eight weaned male Awassi lambs with an initial mean weight of 29.5 kg (SD = 2.3 kg) were used in the experiment. The experiment was conducted at Zief farm of Hebron University, Hebron city, Palestine after the approval of the Animal Care and Use Committee. Lambs were treated with IVOMEC (Merial Limited, Luluth, GA, USA) and Cogla Vac (Cogla Laboratories, Libourne, France) against internal and external parasites and the enterotoxaemia, respectively. Both treatments were applied subcutaneously at 1 cm^3 dose. Lambs were then assigned randomly to four experimental fattening diets (12 lambs/treatment). Lambs in each treatment were fed individually with TMR (Table 1), and each lamb was considered as an experimental unit. Animals in treatment groups were fed corn–SBM based rations. OC was incorporated at a fixed level to all rations. Crude OC was fed to lambs in group 1 (control group), however, alkali treated, ensiled and pelleted OC was fed to lambs in groups 2–4, respectively, in a completely randomized design, for 68 days (Table 1). Rations fed were formulated to meet NRC (1985) standards.

Table 2
Chemical composition of crude, alkali treated and ensiled olive cake (OC) fed to Awassi lambs, g/kg DM.

Nutrient	Crude	Alkali treated	Ensiled
DM, g/kg	900	880	410
CP, g/kg DM	52	58	60
C fat, g/kg DM	50	45	47
ADF, g/kg DM	500	400	550
NDF, g/kg DM	601	470	630
Ash, g/kg DM	123	140	130
Ca, g/kg DM	20.0	21	15.0
P, g/kg DM	3.0	4.0	2.1
Cu, mg/kg DM	13.9	14.5	15.8

Lambs were housed in individual pens (1.5 m × 1.00 m) with constant illumination and fed the experimental diets twice daily at 0900 and 1700 h. Feed offered and refused was recorded daily. Clean drinking water was available in plastic buckets. Animal pens were cleaned weekly. Lambs weights were recorded weekly before the 0900 h feeding. Ingredient composition of the experimental diets is shown in Table 1.

2.3. Chemical analysis

Following AOAC (1990) procedures, samples were analyzed for DM (100 °C in air-forced oven for 24 h; method 967.03), ash (550 °C in ashing furnace for 6 h; method 942), CP (Kjeldahl procedure), EE (Soxtec procedure, Soxtec Systems HT 1043 Extraction Unit, TECATOR, Box 70, Hoganas, Sweden).

Additionally, samples were analyzed for neutral detergent fiber (aNDF; with heat stable-amylase and sodium sulfite) and acid detergent fiber (ADF; ANKOM2000 fiber analyzer, ANKOM Technology Corporation, Fairport, NY, USA) according to Van Soest et al. (1991). Values for aNDF and ADF are expressed inclusive of residual ash.

2.4. Measurements at slaughter

At the end of the 70 days feeding period, lambs had a 12 h fasting period after which all lambs were slaughtered. The bodies were skinned; the head and feet were removed. The carcass was eviscerated and the hot carcass weight was determined.

The internal organs (liver, kidneys, heart, and skin) were weighed. Cold carcass weight (CCW) was determined after chilling for 24 h at 4 °C. The CCW, wet carcass weight (WCW) and live body weight (BW) were used for the determination of the real and commercial dressing percentage (RDP and CDP). These dressing percentages were determined as the following:

$$\text{CDP} \quad (\%) = 100 \times \frac{\text{WCW}}{\text{BW}}$$

$$\text{RDP} \quad (\%) = 100 \times \frac{\text{CCW}}{\text{EBW}}$$

2.5. Statistical analysis

Data were subjected to ANOVA for a completely randomized design using the general linear procedure of SAS (1989). Differences among treatment means for significant dietary effect were detected using the LSD procedure of SAS. Unless otherwise stated, significance was declared at $P<0.05$.

3. Results

3.1. Chemical composition of OC

The chemical analysis of the crude, alkali treated and ensiled OC is presented in Table 2. The alkali treatment resulted in about 20% reduction in both the ADF and NDF fractions.

3.2. Diet intake and lambs growth

Dry matter intake (DMI) was affected ($P<0.05$) by the form of OC. Feed intake was higher ($P<0.05$) by lambs fed the crude, alkali treated or ensiled OC compared to lambs fed the pelleted OC diets (Table 3).

The body weight gain and feed CR were lower ($P<0.05$) in lambs fed pelleted OC diets than for those receiving other forms of OC diets (Table 3).

Table 3
Effect of olive cake (OC) form on feed intake, body gain, slaughter body weight (BW), empty body weight (EBW) and dressing percentages (DP) of Awassi fattening lambs.

Group	Crude	Alkali treated	Ensiled	Pelleted	OC form effect
DMI	1968a	2025a	1760a	1687b	0.05
Initial body weight, kg	29.5	28.9	29.8	29.3	
Final body weight, kg	53.0a	52.2a	52.6a	45.2b	0.05
Average daily gain, g	335a	332a	325a	227b	0.05
CR	5.38b	5.55b	5.40b	6.5a	0.05
EBW, kg	45.1a	43.8a	44.7a	38.8a	0.05
Carcass weight, kg	24.4a	24.5a	24.2a	21.2a	0.05
Commercial[a] DP, %	46.0	46.9	46.0	46.9	0.34
Real DP[b], %	54.1	55.9	54.1	54.6	0.40

Means in the same line with different alphabets (a, b) are significantly different (P<0.05). CR, conversion rate.

[a] Commercial dressing percent, CDP (%) = 100 × (WCW/BW).

[b] Real dressing percent, RDP (%) = 100 × (CCW/EBW).

3.3. Empty body weight, dressing percentage and offal weights

The OC form had significant effects on EBW and carcass weight. These parameters were (P<0.05) higher in lambs fed the crude, alkali treated and ensiled OC diet compared to pelleted OC. However, OC form had no effects on DP (Table 3). External (HHF) and thoracic (HL) organs when expressed as g/kg EBW were not affected by form of OC (Table 4).

3.4. Carcass tissue composition and fat repartition

The form of OC had no effects on muscle and bone tissues proportional to EBW (Table 5). Heavier (P<0.05) carcass fat was observed in animals fed the crude (60.2 g/kg EBW), alkali treated (60.0 g/kg EBW) or ensiled (59.6 g/kg EBW) OC compared to lambs fed the pelleted OC (55.3 g/kg EBW). Animals of crude, alkali treated or ensiled OC diets had lower pelvic, kidneys and OMN (P<0.05) than those receiving the pelleted OC diet (Table 5). The deposition of TBF was the same in all experimental lambs, however, the percent of carcass fat to TBF was lower (P<0.05) in lambs fed the pelleted OC (60.7%). The fraction of TBF from lambs EBW was the same among animals in different OC forms groups (0.09, 0.091, 0.09 and 0.091) in lambs fed crude, alkali treated, ensiled and pelleted OC, respectively).

Table 4
Offal weights g/kg empty body weight (EBW) in Awassi fattening lambs fed different forms of olive cake (OC).

Group	Crude	Alkali treated	Ensiled	Pelleted	OC form effect
HHF, g/kg EBW	211.5a	212.1	211.8	221.3	0.27
Gut, g/kg EBW	91.8	98.4	94.6	94.6	0.32
Liver, g/kg EBW	25.3	26.3	26.6	26.8	0.36
HL, g/kg EBW	24.4	27.3	25.9	24.1	0.40
Sum of organs, g/kg EBW	358.0	363.0	358.9	366.8	0.45

Means in the same line with different alphabets (a, b) are significantly different (P<0.05).
HHF, hide–head–feet; HL, heart and lungs.

Table 5
Carcass tissues and body fat weights g/kg empty body weight (EBW) in Awassi fattening lambs fed different forms of olive cake (OC).

Group	Crude	Alkali treated	Ensiled	Pelleted	OC form effect
Muscle, g/kg EBW	322.0	330.0	325.0	327.8	0.45
Bone, g/kg EBW	94.6	98.0	94.0	96.8	0.21
Fat, g/kg EBW	60.2a	60.0a	59.6a	55.3b	0.05
Subcutaneous fat,g/kg EBW	16.4	16.7	16.1	14.2	0.10
Inter muscular fat, g/kg EBW	32.3	32.4	32.6	30.5	0.12
Pelvic fat, g/kg EBW	3.5a	3.0b	3.0b	2.4c	0.05
Kidney fat, g/kg EBW	8.0a	7.8a	7.9a	7.2b	0.05
[a]OMF, g/kg EBW g/kg EBW	29.0b	31.5b	30.5b	35.8a	0.05
Total body fat, g/kg EBW	89.2	91.40	90.2	91.1	0.34
Carcass fat/TBF	0.67a	0.65a	0.66a	0.61b	0.05
[b]TBF/EBW	0.09	0.091	0.09	0.091	0.65

Means in the same line with different alphabets (a, b) are significantly different (P<0.05).

[a] OMF, mesenteric fat.

[b] TBF, total body fat.

4. Discussion

Laboratory analyses of OC showed comparable values to those associated with the OC resulted from the traditional olive presses (the three phase centrifugation extraction procedure, Molina Alcaide and Yáñez Ruiz, 2008). CP content was reported to be low and variable (from 48 to 106 g/kg DM) (Molina Alcaide and Yáñez Ruiz, 2008). Fibrous components vary depending largely on the proportion of stones in OC (Molina Alcaide and Yáñez Ruiz, 2008). This study showed that alkali treatment decreased NDF and ADF by 0.22 and 0.20, respectively. Similar finding was reported by Nefzaoui and Vanbelle (1986) where a decrease (0.18 and 0.08, respectively) in NDF and ADF after NaOH treatment.

Most of the information available on intake of OC concerns crude OC (Aguilera and Molina, 1986; Molina and Aguilera, 1988; Abo Omar and Gavoret, 1995; Chiofalo et al., 2004). This study showed that the lowest intake was observed in lambs fed the pelleted OC. In contrast, (Nefzaoui and Vanbelle, 1986) observed higher intakes of extracted OC in sheep when fed as pellets (116 g/BW$^{0.75}$/day) than as silage (99 g/BW$^{0.75}$/day). The results of this research showed that the lambs consumption of the crude, alkali treated or ensiled OC was higher compared to pelleted OC. Aguilera et al. (1992) reported intakes of 750 g DM/day of concentrates including 100–300 g/kg of OC by lactating ewes. However, higher intakes in lactating ewes compared to lactating goats and cows were reported by Hadjipanayiotou (1999) when conventional roughages were replaced with ensiled OC (6, 5 and 4.9 g DM/kg BW$^{0.75}$, respectively). Low intakes (150 g DM/day in growing lambs and 100 g DM/day in rams) were observed when animals fed feed blocks including 400 g/kg DM as OC. Chiofalo et al. (2004) reported intakes of 700 g/day of a pellet including crude OC (200 g/kg DM). However, intake was not affected by lambs fed crude OC at levels from 0.15 to 0.25 (Giozelgiannis et al., 1978).

The form of OC had significant ($P<0.05$) effect on lambs weight gain. Lambs fed the crude, alkali treated or ensiled OC had more ($P<0.05$) gain compared to lambs fed the pelleted OC rations. The form of OC had no advantage regarding body gain compared to the gain in crude OC lambs. The depressed gain in lambs fed the pelleted OC rations can be explained by the low organic matter digestibility (OMD) associated with pelleting due to the reduction in particle size resulting in a decrease retention time in rumen (Molina Alcaide and Yáñez Ruiz, 2008). These results agree with previous research (Hadjipanayiotou and Koumas, 1996) in which young ewe lambs had faster gain as utilized OC silage effectively. The shorter ruminating time in lambs fed pelleted OC than those fed the ensiled (417 and 529 min/day, respectively) may explain the reduced gain observed in lambs fed the pelleted OC. The use of high-fat OC might be constrained by its effect on the rumen microbial population, especially on cellulolytic activity (Uceda and Hermoso, 1997; Chiofalo et al., 2002). The degradability of OM (0.51) and ADF (0.37) in sheep increased by 0.35 and 0.40, respectively as a result of alkaline treatment (Nefzaoui and Vanbelle, 1986).

The apparent digestibility of cell wall components was improved by the alkali treatment which also improved the ME content (from 4.22 to 6.46 MJ/kg DM) (Aguilera and Molina, 1986; Molina and Aguilera, 1988). The alkali treated OC resulted in comparable performance values which means that there is no soap formation as described by Hadjipanayiotou (1999). With oil-rich OC, treatment with alkali may lead to soap formation and, therefore, ensiling may be the best option for improving its nutritive value (Hadjipanayiotou, 1999).

Lambs were slaughtered at different weights. Then lambs had different EBW, and carcass weights. These parameters depend on slaughtering BW (Fehr et al., 1976; Marinova et al., 2001; Mourad et al., 2001; Naser, 2009). Weights of visceral organs when expressed as g/kg EBW were not affected by the form of OC. Volatile fatty acids (VFAs) and other nutrients produced by fermentation in the case of feeding OC diets were probably the reason behind the visceral organs development. Similar visceral organs mass in this experiment was in contrast to previous research where heavier mass of some tissues as liver, kidney and gut is expected due to the high metabolic activity of these tissues (Fluharty and McClure, 1997). Similarly, the weight of offal components rich in bone and/or with a low metabolic activity (head, feet and lungs) was also not affected with OC diet. This result is in agreement with previous research where early maturing parts (Wallace, 1948; Prud'hon, 1976) are less affected by feeding in growing animals (Kamalzadeh et al., 1998).

Muscle and bone tissue weights (g/kg EBW) were not affected by form of OC (322.0, 330.0, 325.0 and 327.8 g/kg EBW in lambs fed crude, alkali treated, ensiled and pelleted OC, respectively). Bone is a tissue with early development in all animal species and does not depend on regimen at older ages. On the other hand, fat depots depend on nutrient utilization.

Carcass fat was heavier in lambs fed crude (60.2 g/kg EBW), alkali treated (60.0 g/kg EBW), ensiled (59.6 g/kg EBW) compared to that fed the pelleted OC (55.3 g/kg EBW). However, intramuscular, kidney fat and OMN were the same in lambs among different feeding groups.

The indicated improvement in performance associated with alkali treatment might be explained by the increase in OM and ADF degradability. Nefzaoui and Vanbelle (1986) reported that alkali treatment caused about 0.35 and 0.40, improvement in OM and ADF degradability in sheep. The ruminal values of NH_3-N concentration (3.79 mg/100 ml) in sheep offered extracted OC *ad libitum* were below the suggested values for good microbial activity in animals fed high fiber materials (Balcells et al., 1993), however, the form in which it is offered may influence rumen function.

5. Conclusions

It can be concluded that alkali treated or ensiled OC had no advantages compared to crude OC when fed to the growing Awassi lambs. Olive cake can be incorporated into concentrate mixtures as crude OC, ensiled or alkali treated at inclusion levels of 149 kg/t, with no adverse effects on performance or carcass characteristics. Adoption this option provides the fattening industry with an inexpensive nonconventional feed ingredient and reducing the environmental pollution caused by wastes disposal in the olive industry.

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