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Research Article
Performance of Barki Lambs Fed on Rations Containing Olive Cake with or Without Polyethylene Glycol

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Abstract

Background and Objective: Olive by-products could be a suitable alternative feedstuffs ingredient in ruminants rations. This study was carried out to evaluate effects of replacing clover hay by olive cake with or without addition of poly ethylene glycol in growing lambs ration. **Methodology:** Thirty five Barki lambs averaged 34 kg body weight and 5 months old were divided into 5 groups (7 animals of each) according to live weight for 90 days feeding trial. Olive cake was treated mechanically by hummer mill, screened to produce screening olive cake (treated olive cake, TOC). **Results:** Data of dry matter and organic matter digestibility were decreased with ration containing 20% TOC from ration or 67% from clover hay comparing with others. No significant differences were observed among groups in crude protein digestibility. Total digestible nutrients (TDN) as an energy measurement for the experimental rations cleared that replacing process of clover hay by TOC up to 20% of DM intake or 67% of clover hay, given lower values (65.32 and 66.80%). The rumen pH values were not affected by the different experimental rations including control. The highest rumen NH_3 was recorded with lambs fed ration containing 33% TOC without PEG instead of clover hay, while the lowest values was recorded with that group fed ration containing 33% TOC with PEG. No significant differences were detected in total gain, ADG as well as feed efficiency among the experimental rations. Dry matter intake slightly increased with feeding growing lambs on TOC containing rations except R5 compared to the control group. **Conclusion:** Summing up partially de-stoned olive cake by screening could be used in replacing clover hay for growing lamb rations, at inclusion levels up to 33 and 67% with or without poly ethylene glycol, with no adverse on performance of growing lambs.

Key words: Olive cake, lambs, clover hay, feed growing lambs, digestibility, daily gain and rumen parameters

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In recent years the world human population has increased and the amount of crop and food by-product has increased, so by-products management programs become very important to eliminate and use it in ruminant feeding[1]. Researchers in animal nutrition field made many efforts to find different solutions to decrease cost of feeding. Depending on nature of metabolism in ruminants, diet could be based on locally available by-product feedstuffs are often a practical alternative, because the rumen microbial ecosystem can utilize by-product feedstuffs, which often contain high levels of structural fiber, to meet their nutrient requirements for maintenance and production[2].

Olive by-products consider important feed resources for ruminants, these by-products included olive leaves, olive cake. Olive cake could be preserved by different ways like ensiling or drying. Olive cake is the residue after the extraction of oil by pressure or centrifuging, which includes residue of pulp, stones, skins of olive and water[3]. Whereas, chemical composition of olive cakes differed according to the processing of oil extraction as well as de-stoned process method if it happened[4]. According to the previous studies chemical composition of olive cake ranged from 84-96% organic matter (OM), 5-13% crude protein (CP), 3-9% ether extract (EE),55-80% neutral detergent fiber (NDF) and 45-62% acid detergent fiber (ADF) as reported by Kotsampasi *et al.*[2], Molina-Alcaide and Yanez-Ruiz[4], Garcia *et al.*[5], Molina-Alcaide *et al.*[6] and Garcia *et al.*[7].

Tannins as a phenolic compounds considered the main anti-nutritional factor in olive by-products, so many studies advised to use polyethylene glycol (PEG) as in animal rations if it containing tannin because polyethylene glycol absorbs condensed tannins[8] and neutralize the negative effects of tannins on feed intake and digestibility in sheep, goats and cattle[9-13].

Many studies up till the recent years used olive cake as a part of diets especially to replace part from grains in animal diets[2,3]. This study had a different theory depending on fiber contents because there is a huge difference between olive cake and grains like corn and barley, by trying to replace part of high quality roughage by olive cake after mechanical treatment. Therefore, present study aimed to investigate the effects of replacing clover hay in diet by 33 and 67% treated olive cake with or without polyethylene glycol on digestibility, rumen parameters and growth performance of Barki lambs.

MATERIALS AND METHODS

Mechanical treatment of olive cake: Olive cake was obtained after extraction process of oil. Olive cake was sun dried and grinded by hummer mill and then screened by die have bores 1 mesh.

Experimental animals and rations: Thirty five Barki lambs averaged (34 kg) body weight and 5 months old were divided into 5 groups (7 animals of each) according to live weight for 90 days feeding trial. The experimental rations for the experimental animal groups were as follow: Animals in control rations, R1 fed clover hay plus concentrate feed mixture (CFM).The percentage between roughage and concentrate was 30:70 in all groups. while, R2 fed clover hay with replacing 33% from it by treated olive cake (TOC) plus CFM with adding poly-ethylene glycol (PEG), R3 fed clover hay with replacing 67% from it by TOC plus CFM with adding PEG, R4 fed clover hay with replacing 33% from it by TOC plus CFM and R5 fed clover hay with replacing 67% from it by TOC plus CFM to cover the total requirements of energy and protein needed for sheep maintenance and growth according to NRC[14]. Poly-ethylene glycol (PEG4000) addition level was 2 g/100 g olive cake, it purchased from El-Gomhouria company at Cairo. Formulations of experimental rations are presented in Table 1.

Feeding trial: rations were supplied to growing lambs (in groups) in the morning at 7:00 am and in the afternoon at 4:00 pm, in sufficient amount to result in at least 10% of the supplied as daily surplus. Orts were collected just before offering the next day's feed. Lambs were weighed every

Table 1: Formulation of experimental rations (g/100 g)

	Experimental rations		
Ingredients	Control ration	10% TOC rations	20% TOC rations
Yellow corn grains	31.50	31.50	31.50
Barley grains	14.00	14.00	14.00
Soybean meal	9.10	9.10	9.10
Wheat bran	14.00	14.00	14.00
Di-calcium phosphate	0.35	0.35	0.35
Clover hay	30.00	20.00	10.00
Treated olive cake (TOC)	-	10.00	20.00
Common salt	0.63	0.63	0.63
Ammonium chloride	0.21	0.21	0.21
*Mineral and vitamins mixture	0.21	0.21	0.21
Total	100	100	100

*Each 3 kg contained 7500000 IU vit. A,2000000 IU vit. D_3, 25000 mg vit. E, 40 g zinc, 40 g manganese, 50 g iron, 15 g copper, 8 g iodine, 4 g cobalt, 3 g selenium and carrier $CaCo_3$ up to 3 kg

15 days before morning feeding after 12 h of fasting. The dry matter (DM) was adjusted after weighing according to body weight changes.

Digestion trials: After growth trial ended, three animals from each group were used to evaluate digestibility and nutritive values of experimental rations. So, metabolic cages were used to determine total amount of feces from each animal during 7 consecutive days. Animals through this period were fed individually to cover maintenance allowance[14]. Feces were collected daily and samples were combined (on a wet basis) to form a composite sample. Samples were dried at 60°C in a forced-air oven for 3 days and ground in a knives mill to pass through a 1 mm screen (Wiley Mill, A. H. Thomas, Philadelphia, PA, USA).

Rumen liquor sampling: After growth trial ended ruminal fluid samples (200 mL) were collected before the morning feeding (0 h), then at 3 and 6 h after the morning feeding and straining rumen digesta (collected from all rumen sites) in four layers of cheese cloth[15]. Immediately after each sampling, ruminal fluid pH was determined using a Beckman pH meters. Ammonia was separated from rumen liquor acidified with 0.1 N hydrochloric acid and concentrated orthophosphoric acid by steam distillation, collected in boric acid solution and determined by titration with standard acid[16]. Total VFA was determined by steam distillation[17].

Chemical analysis: Samples of feeds, rations and feces were analyzed for DM (method 934.01)), ash (no. 942.05), crude protein (no. 968.06), crude fiber (No. 942.05) and ether extract (no. 942.05)[18]. The organic matter (OM) was calculated as the difference between DM and ash contents. Also, nitrogen free extract calculated by difference according to the following Equation:

$$NFE\ (\%) = 100-(Secondary\ moisture\ (\%)+ASH\ (\%)+CP\ (\%)+EE\ (\%)+CF(\%))$$

Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) excluding residual ash were determined according to the methods of Van Soest *et al.*[19].

Statistical analysis: All results were conducted using the SAS package (Statistical Analysis System, Inst. Inc[20]. The statistical model was:

$$Y_{ij} = \mu+R_i+e_{ij}$$

Where:

Y_{ij} = Observation of the effect of treatment R, the animal i
μ = Overall mean and
e_{ij} = Random error associated with each observation. The differences among means were separated according to Duncan's New Multiple Range Test[21] with significance level $p<0.05$

RESULTS AND DISCUSSION

Chemical composition of experimental feeds and rations: Proximate analysis and fiber fractions content of clover hay and treated olive cake (TOC) in Table 2 explained that TOC contained more ether extract (EE) 6.37% compared clover hay was 1.88%. Crude protein (CP) in olive cake was 10.90% as results of partially de-stoning by screening process. In the

Table 2: proximate analysis and fiber fractions content of the experimental feeds and rations (%)

	Experimental feeds			Experimental rations		
Items	Clover hay	TOC	CFM	Control ration	10% TOC ration	20% TOC ration
Proximate analysis						
DM	90.84	93.10	91.60	91.37	91.60	91.83
OM	86.63	89.72	94.91	92.42	92.73	93.05
Ash	13.37	10.28	5.09	7.58	7.27	6.95
CP	13.97	10.90	15.12	14.77	14.47	14.16
EE	1.88	6.37	2.20	2.10	2.55	3.01
CF	26.86	32.01	5.75	12.09	12.59	13.12
NFE	34.76	40.85	63.44	54.83	55.44	56.06
Fiber fractions						
NDF	42.95	66.55	31.46	34.91	37.24	39.65
ADF	31.71	52.42	7.50	14.76	16.81	18.92
ADL	5.24	22.48	2.21	3.12	4.83	6.59

TOC: Treated olive cake, CFM: Concentrate feed mixture, 33% TOC ration: Replacing of clover hay by olive cake 33 and 67% TOC ration: Replacing of clover hay by olive cake 67%, DM: Dry matter, OM: Organic matter, CP: Crude protein, EE: Ether extract, CF: Crude fiber, NFE: Nitrogen free extract, NDF: Neutral detergent fiber, ADF: Acid detergent fiber and ADL: Acid detergent lignin

Table 3: Effect of the experimental rations with or without PEG on digestion coefficients and nutritive values (%)

		Experimental rations					
		With PEG		Without PEG			
Items	Control R1	33% TOC R2	67% TOC R3	33% TOC R4	67% TOC R5	±SE	p-value
Digestibility							
DM	85.95[a]	83.82[b]	81.98[c]	83.51[b]	81.52[c]	0.45	0.000
OM	86.45[a]	84.74[b]	83.09[c]	84.47[b]	83.18[c]	0.37	0.002
CP	79.91	79.74	81.55	81.07	81.45	0.47	0.680
EE	81.46[b]	85.43[a]	83.35[ab]	83.18[ab]	84.43[a]	0.52	0.030
CF	77.86[a]	76.57[a]	70.84[b]	75.88[a]	65.41[c]	1.27	0.000
NFE	79.21[a]	78.49[ab]	75.19[b]	75.72[ab]	74.06[b]	0.95	0.001
NDF	75.60	73.83	72.11	73.22	76.01	0.907	0.690
ADF	68.07[a]	64.40[a]	59.41[b]	67.76[a]	56.99[b]	1.24	0.001
Nutritive values							
TDN	68.50[a]	69.60[a]	65.32[b]	67.48[ab]	66.80[b]	0.51	0.048
DCP	11.80	11.54	11.55	11.79	11.53	0.07	0.604

[a,b]Means in the same row with different superscript are significantly differ (p<0.05). TDN: Total digestible nutrients and DCP: Digestible crude protein

same way, carbohydrate contents expressed as crude fiber (CF) and nitrogen free extract (NFE) in TOC were numerically higher by 6% comparing clover hay. These differences reflected on fiber fractions content, so neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) of TOC were the highest by 23.9, 20.71 and 17.24% than clover hay. These results were matched with Sansoucy[22] and Kotsampasi *et al.*[2].

According to Yansari *et al.*[23] de-stoning process of olive cake significantly increased CP content and cell wall constituents. Concerning diverse sorts of olive cake, it was concluded that there are large variations in chemical composition and nutrients digestibility[22]. Results in the Table 3 also showed the tested experimental rations (control, 33% TOC from clover hay or 10% from ration and 67% TOC from clover hay or 20% from ration) were comparable in their proximate analysis except EE content being 2.10, 2.55 and 3.01, respectively. In the same context Obeidat[24] found that inclusion of olive cake by 15% of dry matter intake in lamb's diet increased the EE content compared to the control diet due to the greater content of EE in olive cake (oil remnants).

Digestion coefficients and nutritive values: Digestion coefficients and nutritive values of the experimental rations in Table 3 cleared that inclusion of olive cake up to 20% from diet decreased ($p \geq 0.05$) dry matter and organic matter digestibility comparing with control group. Similar results obtained by Al-Jassim *et al.*[25] and Obeidat[24] when Awassi lambs fed on olive cake at levels 10-30% of dry matter intake compared to olive cake free-diet. Ether extract digestibility was significantly higher of olive cake rations because its fat content compared the control one. Owaimer *et al.*[26] noticed that EE digestibility improved in the olive cake rations compared to the control ration when it used by 12 and 15% of DM intake.

As shown in Table 3, no significant differences were observed among groups in crude protein digestibility. This may be due to that crude protein (%) in diets was closed 14.77, 14.47 and 14.16% for control, 33 and 67% olive cake rations. Ration 5 (67% TOC without PEG) recorded the lower digestibility of crude fiber (65.41%), acid detergent fiber (54.41 and 56.99%) and nitrogen free extract (75.19 and 74.06%) compared with other diets. Many researchers found that, NDF, ADF and crude protein digestibilities were decreased possibly due to the effect of heat during the process of oil extraction. Heating makes CP less available (i.e., Maillard's reaction)[5], because most of the N is attached to carbohydrates[6] rendering it unavailable to rumen microbes. In the same time, there were positive effects of polyethylene glycol addition especially with 20% replacing of clover hay by TOC. This may be due to nature of PEG to decrease effect of tannin in olive cake[8]. Whereas, Rogosic *et al.*[13] confirmed that PEG neutralize the negative effects of tannins on feed intake and digestibility in sheep, goats and cattle.

Total digestible nutrients (TDN) as an energy measurement for the experimental rations cleared that replacing process of clover hay by TOC up to 20% of DM intake or 67% of clover hay, given lower values (65.32 and 66.80%). On contrast, no significant differences were observed among groups in crude protein digestibility. These results may be due to the effect of olive cake on carbohydrate digestibility. In the same trend, Abbeddou *et al.*[27] explained that reduction in digestibility of the fiber fractions (i.e., aNDF and ADF) could be attributed partly to the presence of higher levels of lignin that can be generated from the woody kernels in the olive cake.

Table 4: Effect of experimental rations on rumen parameters

		Experimental rations					
		With PEG		Without PEG			
Items	Control R1	33% TOC R2	67% TOC R3	33% TOC R4	67% TOC R5	±SE	p-value
Rumen PH							
Zero time before feeding	5.74^{a}	5.53^{ab}	5.69^{a}	5.46^{ab}	5.56^{ab}	0.043	0.020
3 h post feeding	5.36	5.20	5.08	5.19	5.15	0.038	0.294
6 h post feeding	5.68	5.59	5.61	5.52	5.55	0.027	0.477
Mean	5.59^{a}	5.44^{b}	5.45^{ab}	5.39^{b}	5.42^{b}	0.026	0.032
Rumen (NH_3, mg L^{-1})							
Zero time	4.34^{b}	3.40^{b}	4.55^{b}	5.80^{a}	3.61^{b}	0.27	0.011
3 h post feeding	7.23^{b}	6.72^{bc}	6.48^{c}	7.96^{a}	5.57^{d}	0.22	0.000
6 h post feeding	7.75	6.37	6.76	7.35	7.02	0.39	0.433
Mean	6.44^{b}	5.26^{d}	6.04^{bc}	7.48^{a}	5.18^{cd}	0.27	0.02
Rumen (TVFA's, meq L^{-1})							
Zero time	5.47	5.50	4.87	5.95	4.40	0.23	0.248
3 h post feeding	11.62^{a}	9.57^{ab}	9.25^{b}	8.52^{b}	8.87^{b}	0.38	0.054
6 h post feeding	8.90	8.17	8.02	8.70	10.07	0.39	0.563
Mean	8.66	7.75	7.38	7.72	7.78	0.27	0.712

^{a,b}Means in the same row with different superscript are significantly different ($p<0.05$). R1: Control ration, R2: 33% TOC ration with PEG, R3: 67% TOC ration with PEG, R4: 33% TOC ration without PEG and R5: 67% TOC ration without PEG. VFA: Volatile fatty acids

Rumen parameters: The effect of experimental rations on rumen parameters as pH, rumen ammonia NH_3 and total volatile fatty acids TVFA's is shown in Table 4. These parameters were determined at different times, before feeding (zero time), 3 and 6 h post feeding. It could be noticed that rumen pH values were not affected ($p<0.05$) by the different experimental rations including control. Generally, the values of pH mean were higher ($p<0.05$) of all treatments except 67% TOC ration with PEG in comparison to the control. The recorded values were 5.59, 5.44, 5.39 and 5.42, respectively.

Concerning the rumen NH_3, lambs fed ration containing 33% TOC without PEG instead of clover hay recorded the highest ($p<0.05$) rumen NH_3 at zero time compared the other experimental groups including the control. Besides, the same group of lambs was the highest ($p<0.05$) in rumen NH_3 at 3 h post feeding, while lambs fed ration containing 67% TOC without PEG instead of PEG was the lowest ($p<0.05$) in rumen NH_3 compared to the other tested groups including control. However, there were insignificant differences in rumen NH_3 at 6 h post feeding among the different experimental groups including the control. Generally, the highest ($p<0.05$) rumen NH_3 was recorded with lambs fed ration containing 33% TOC without PEG instead of clover hay, while the lowest ($p<0.05$) values was recorded with that group fed ration containing 33% TOC with PEG. These results meaning that polyethylene glycol has a significant effect on nitrogen utilization in rumen[28].

Regarding to TVFA's, the obtained results revealed insignificant differences in rumen TVFA's concentration among the different experimental groups whether at zero time or 6 h post feeding. Otherwise, the same observations were noticed with TVFA's mean. Conversely, the concentration of rumen TVFA's at 3 h post feeding were lower ($p<0.05$) with all lambs group fed TOC ration with PEG in comparison to the control group. These results may be due to the positive effect of PEG on carbohydrate fermentation with low level of olive cake replacement (33% TOC) and the negative effect of tannin content of rations containing 33% without PEG and 67% TOC rations with or without PEG. It could be concluded that 67% TOC ration with PEG contained does of tannin more than the ability of PEG action. These results agreed with Silanikove *et al.*[29] and Vargas-Bello-Perez *et al.*[30] when fed sheep and goats on shrubs containing tannin with or without PEG. This result may indicate that condensed tannins have an inhibitory effect on carbohydrate fermentation in the rumen.

Growth performance: Growth performance results were shown in Table 5. No significant ($p\geq0.05$) differences were detected in total gain, ADG as well as feed efficiency among the experimental rations. The obtained results showed that both averages dry matter intake was slightly increased with feeding growing lambs on TOC containing rations except R3 compared to the control group. Also, all results were comparable in the nutritive values of the experimental rations. These results agreed with Obeidat[24] when growing lambs fed on diets containing olive cake at 15% of DM with or without yeast. In the same context, Vargas-Bello-Perez *et al.*[30]

Table 5: Effect of the experimental rations on growth performance

	Experimental rations						
		With PEG		Without PEG			
Items	R1	33% TOC R2	67% TOC R3	33% TOC R4	67% TOC R5	±SE	p-value
Growth performance (kg)							
Initial weight	33.930	34.130	33.720	34.530	34.200	0.640	0.997
Final weight gain	50.760	50.690	50.100	51.180	50.670	0.930	0.998
Total body weight gain	16.830	16.560	16.380	16.650	16.470	0.640	0.985
Average daily gain	0.187	0.184	0.182	0.185	0.183	0.007	0.985
Feed intake							
Dry matter intake	1.503	1.527	1.439	1.538	1.520	-	---
CFM	1.052	1.069	1.007	1.077	1.064	-	---
Clover hay	0.451	0.307	0.142	0.309	0.151	-	---
Treated olive cake (TOC)	-	0.151	0.289	0.152	0.306	-	---
Feed efficiency							
FCR (kg DM intake/kg b.wt., gain)	8.030	8.300	7.900	8.450	8.300	-	-

Means in the same row with different superscript are significantly different (p<0.05). R1: Control ration, R2: 33% TOC ration with PEG, R3: 67% TOC ration with PEG, R4: 33% TOC ration without PEG and R5: 67% TOC ration without PEG. FCR: Feed conversion ratio

investigated that DM intake was similar among ewes fed diets containing olive cake at 9.8 and 24.4% of dietary DM or when growing lambs were fed diets containing 10 and 20% olive cake[31]. Also, the same results recorded with male lambs fed on concentrate that included 20% de-stoned olive cake. Abbeddou *et al.*[27] and Ragni *et al.*[32] noticed that DM intake decreased in Awassi sheep fed olive cake at 49% of DM intake compared to the control ration.

CONCLUSION

Partially de-stoned olive cake by screening could be used in replacing clover hay for growing lamb rations at inclusion levels up to 33% and 67% with or without poly ethylene glycol, with no adverse effects on their digestion coefficients, rumen parameters and growth performance. Therefore, this olive by-product can be considered as a valuable, but inexpensive, alternative feed ingredient, capable to decrease feeding cost, without disrupting lamb productivity for Mediterranean area, while reducing the environmental impact of waste disposal in the olive industry.

SIGNIFICANCE STATEMENT

This study confirmed that de-stoned olive cake by screening could be used in replacing clover hay for growing lamb rations, with or without poly ethylene glycol, with no adverse effects animal performance. Therefore, this olive by-product can be considered as a valuable, but inexpensive, alternative feed ingredient, capable to decrease feeding cost, without disrupting lamb productivity for Mediterranean area, while reducing the environmental impact of waste disposal in the olive industry.

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