Effect of dietary energy level and docking on carcass characteristics of fat-tailed Kurdi sheep

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Abstract Effects of partial docking on feedlot performance and body fat characteristics were studied in a fat-tailed sheep breed. Thirty-eight male lambs with an average weight of 4.44 ± 0.48 were randomly divided into two groups. The lambs in one group were partially docked at 3-4 h after birth, using rubber rings, and the lambs in another group remained intact (control). After weaning, 20 male lambs from each group were divided into two subgroups; one subgroup was fed with a normal dietary energy level (2.45 Mcal/kg ME) and the other subgroup received a high-energy diet (2.73 Mcal/kg ME) for 84 days. The lambs were fed individually. At the end of the fattening period, the lambs were slaughtered for determination of carcass characteristics. Warm carcass weight (WCW) and fat depth at the12th rib was recorded. At 24 h postmortem, samples of omental fat (for chemical analysis), and caudal fat were taken from chilled (4°C) carcasses for the determination of fatty acid (FA) composition. No significant difference was observed for the weight gain between docked and control lambs during the suckling period. During the fattening period, docked lambs as well as lambs on high level of energy diet showed better weight gain ($P < 0.05$). No significant difference ($P > 0.05$) was observed for WCW and fat depth at the 12th rib between docked and control lambs, but WCW was significantly affected by the diet energy density ($P < 0.05$). Docked lambs produced leaner carcasses than did the intact lambs ($P < 0.01$). Docking did not influence feed consumption, but improved meat quality and amounts (by weight and percentage) of high price carcass cuts, and reduced total fat content as a percentage of the live weight. Dietary energy level affected the average daily gain and daily feed intake ($P < 0.05$). The most abundant FA in caudal and omental fat depots was oleic acid. Significant difference was observed in the percentage of all fatty acids between omental and caudal fat depots ($P < 0.05$). A negative correlation (-0.8465) was recorded between oleic and stearic acid concentrations ($P < 0.001$). In conclusion, docking of Kurdi lambs improved most feedlot characteristics (such as daily gain and feed efficiency) and may be recommended under industrial sheep production.

Keywords: Kurdi sheep, docking, carcass characteristics, fatty acid composition

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Introduction

Kurdi sheep are fat-tailed. The lambs in this breed are usually born during winter, with a small reserve of fat around the tail nut, and during the lush (spring) season which they graze on pasture, fat accumulates around this organ, so that by the end of the lush season, fat-tail contributes to 25% of the carcass weight. In ruminants, adipose tissue is the principal site of the *de novo* synthesis of long-chain fatty acids, and a major site for the production of the monounsaturated fatty acyl-CoA esters (Enoch et al., 1976).

Energy and protein supplements fed to improve growth rate of pasture-based lambs affect energy intake and partitioning of energy retained (Beauchemin et al., 1995; Margan, 1994). Supplements used can vary markedly in the chemical nature of absorbed substrates in the metabolizable energy fraction. Such differences may affect not only the nature but also the anatomical distribution of the lipids deposited (Rule et al., 1995; Smith, 1995). Any

effects, where they occur, may be significant in relation to eating quality (Wood, 1990). Measurement of the amount of external fat is an important factor for grading of carcasses. The level of feed intake affects the body composition in sheep (Burton and Reid, 1969) and cattle (Prior et al., 1977). On the other hand docking of fat-tail can help reduce fat in carcasses of lambs (Epstein, 1961; Joubert, and Uckermann, 1971; Sefidbakht and Ghorban, 1972; Marai et al., 1987).

The main objectives of this study were to examine the effects of partial docking and two dietary energy levels on the performance of Kurdi sheep, and determine major fatty acids and their correlations in fat depots.

Materials and methods

Animals and care

Male lambs were randomly divided into two groups, soon after parturition. In one group, two-thirds of fat-tail was docked 3-4 h after birth, using rubber rings; and the tails of other group left intact (control). The lambs were weighed at weaning, and 20 lambs from each group were divided into two subgroups, being fed with normal energy diet (2.45 MJ/kg ME) and high-energy diet, respectively (2.73 MJ/kg ME for 84 days. The ration ingredients and chemical composition are presented in Table 1. Lambs were housed in individual pens and had free access to water. At the end of feeding trial, 28 lambs (7 from each sub-group) were slaughtered for determination of carcass characteristics. The day before slaughter, the lambs were fasted and weighed.

Feed and carcass analysis

Feed samples were analyzed for crude protein (copper catalyst Kjeldahl method ID 984.13; AOAC, 1991), and neutral detergent fiber (NDF), and acid detergent fiber (ADF) according to Van Soest et al. (1991).

Determination of carcass characteristics

Carcasses were chilled at 4°C for 24 h and split into retail cuts. Fat-depth and the cross-sectional area of the *Longissimus dorsi* muscle at 12th and 13th ribs were measured using calipers. One half of each carcass was mechanically deboned and minced thoroughly. Sub-samples were analyzed for moisture (air oven method ID 925.10), protein (copper catalyst Kjeldahl method ID 984.13), fat (solvent extraction method ID 991.36) and ash (ID 923.03) contents (AOAC, 1991). Samples of meat, omental fat and caudal fat were stored at –80ºC for fatty acid analysis.

Determination of melting-point and refractive index

For measurement of melting point, each fat sample was placed in a capillary, which was then heated at a controlled rate. A special instrument (Electrothermal IA9100) was used to control the heating rate (1–2°C/min). The refractive index of the samples was measured with a refractometer (Thermo Fisher Scientific, Madison, WI, USA) using a monochromatic light source, after successful retest of the laboratory control standards at 40ºC.

Table 1: Ingredients and nutrient composition of the experimental diets

	Rations	
	Normal energy	High energy
Dietary components (%)		
Alfalfa hay	27	16
Barley straw	17	11
Barley grain	20	32
Corn grain	7	11
Beet pulp	11.6	10
Cotton-seed meal	9.4	8
Wheat bran	6	10
Limestone	0.5	1
Salt	0.9	0.6
Vitamin and mineral mixture	0.6	0.4
Nutrient composition (% DM)		
Dry matter[2]	89	89
ME (MJ/kg)[1]	2.45	2.73
CP[2]	14.5	14.5
NDF[2]	41.6	35.3
ADF[2]	26.6	20.2
Ca[1]	0.76	0.76
P[1]	0.39	0.46

DM = dry matter ; ME = metabolizable energy ; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; Ca = calcium ; P = phosphorus.
[1]Calculated according to NRC (2007).
[2] Laboratory analysis.

Determination of fatty acid composition

Fat samples were extracted (Folch et al., 1957), using a chloroform/methanol mixture (v:v/2:1). Fatty acids were converted to methyl esters by base-catalyzed trans-esterification, and any free acids in the fat were esterified by subsequent reaction with BF3/CH_3OH.

Methyl esters were analyzed by gas chromatography on an Omegawax 320 capillary column; 30 m × 0.32 ID fused silica (Supelco, Bellefonte, PA). Injector and detector temperatures were 300°C and 310°C, respectively. The column was programmed as follows: 160°C for 2 minutes, which was raised to 210°C at 3°C/min; the column was held at this temperature for 10 minutes. Peaks were identified by the use of standards, and concentration of each fatty acid was expressed as a percentage of total extracted fat.

Statistical analysis

A completely randomized model, arranged as a 2 × 2 factorial (partial docking vs. intact, and two dietary energy levels), was used to analyze the data for weight gain, feed intake and feed conversion ratio (n = 10 lambs per sub-group), and for carcass characteristics (n = 7 lambs per sub-group). The data were analyzed using the general linear model procedure of SAS (2003). Depending on the parameter being analyzed, the initial weight, warm carcass weight or cold carcass weight were used as the covariate in the model. The covariate was omitted from the model when its effect was not significant ($P > 0.05$). Data are reported as least squares means and the standard errors. Correlations among fatty acids were determined, with their significance being determined using the t-test (SAS, 2003).

Table 2. Performance of docked and intact lambs as affected by the dietary energy level

Item	Tail		Dietary energy		SE	Probability		
	Intact	Docked	Normal	High		O	D	O×D
Lamb daily weight gain before weaning (g)	179	180	-	-		0.9898		
Feedlot performance								
Daily gain (g)	177	196	175	198	8.870	0.0373	0.0169	0.8119
Daily feed intake (kg)	1.727	1.750	1.636	1.841	0.482	0.6831	0.0013	0.9835
Feed conversion ratio	9.93	9.02	9.47	9.48	0.521	0.0950	0.9951	0.7775

O = tailed vs. docked; D = diet; O × D = interaction.

Results

Animal performance

Lamb performance as affected by tail docking and dietary energy level is presented in Table 2. Average daily weight gain of lambs during the suckling periods was not affected by tail docking; however, during the fattening period tail docking resulted in an increase in daily weight gain ($P = 0.0373$) compared with the intact lambs. Feeding of the high-energy diet resulted in about 13 percent increase in daily gain ($P = 0.0169$).

There was no effect of tail docking on daily feed intake. Feed intake in lambs on high-energy diet was 12.5 percent higher than in lambs on normal-energy diet ($P = 0.0013$). No significant effect of tail docking, dietary energy, or their interaction was recorded on the feed conversion ratio.

Carcass cuts and meat chemical analysis

There was no effect of treatments on live weight, and warm and cold carcass weights (Table 3). Docked lambs showed superiority for high price cuts percentage (leg and *Longissimus dorsi* muscle), and had less caudal fat compared to intact lambs ($P < 0.05$). Caudal fat content was not affected by dietary energy concentration. Warm carcass weight was the only parameter affected by the level of energy in the diet ($P < 0.05$). Chemical analysis of meat and total carcass fat are presented in Table 4. Meat ether extract was higher but meat ash content was lower in docked lambs ($P < 0.05$). An interaction effect on meat moisture content was found between dietary energy level and tail condition ($P = 0.0566$). Carcass fat content, both absolute and relative, was lower in docked lambs (Table 4, $P < 0.05$), but was not affected by dietary energy level.

Table 3. Slaughter weight and carcass characteristics in docked and intact lambs as affected by the dietary energy level[1]

Item	Tail		Dietary energy		SE	Probability		
	Intact	Docked	Normal	High		O	D	O×D
Live weight (kg)	48.43	47.57	46.53	49.59	2.001	0.7643	0.2860	0.7161
Warm carcass weight (kg)	25.25	24.85	24.43	25.68	0.343	0.2580	0.0017	0.9339
Cold carcass weight (kg)	24.50	24.13	24.17	24.47	0.336	0.2798	0.4244	0.3152
Omental fat (g)	891	1255	912	1234	138.2	0.0328	0.0746	0.1840
Leg (g)	5896	6520	6206	6210	144.32	0.0002	0.9801	0.1013
Foreshank (g)	4052	4418	4204	4265	130.65	0.0097	0.6678	0.2617
LD muscle[2] (g)	3400	3862	3705	3557	113.20	0.0004	0.2312	0.1033
LD area[3] (cm^2)	36.23	39.23	39.25	36.20	1.445	0.0492	0.0583	0.6438
Back fat depth[4] (mm)	5.03	5.46	5.41	5.09	0.504	0.4593	0.6129	0.4438
Caudal fat (g)	5602	3689	4376	4916	138.2	0.0000	0.1073	0.4801
Total fat (%)	37.79	34.23	35.66	36.36	1.173	0.0048	0.5809	0.4371
Total fat (g)	9420	8580	8840	9150	623.1	0.0075	0.3418	0.3856

O = tailed vs. docked; D = diet; O×D = interaction.

[1] Warm carcass weight adjusted for live weight; cold carcass and omental fat adjusted for warm carcass weight; other parameters adjuste for cold carcass weight.

[2] *Longissimus dorsi* muscle including the vertebrae.

[3] Area of the cross section of the *Longissimus dorsi* muscle at 12th and 13th ribs.

[4] Fat depth over *Longissimus dorsi* muscle at 12th and 13th ribs.

Fatty acid composition

No significant effects of tail docking and level of dietary energy were recorded on the melting point, refractive index and fatty acid composition in caudal and omental fat depots (data not shown for individual fat depot); pooled data are reported in Table 5. Omental fat was higher in saturated fatty acid (SFA) but lower in unsaturated fatty acid (UFA) content. The percentage of linoleic and linolenic acids was similar in these depots. The percentage of stearic acid content in caudal fat was lower compared with the omental fat ($P = 0.0001$). Lower percentage of oleic acid ($P < 0.05$) in the omental fat was the reason for lower percentage of unsaturated fatty acids in this depot.

Table 4. Chemical analysis of meat samples excluding caudal fat (as-is basis) in docked and intact lambs as affected by the dietary energy level

Item	Tail		Dietary energy		SE	Probability		
	Intact	Docked	Normal	High		O	D	O×D
Moisture (%)	53.97	51.62	53.94	51.65	0.884	0.2045	0.1912	0.0566
Protein (%)	23.85	23.29	23.15	24.00	0.926	0.5515	0.3678	0.4236
Ether extract (%)	21.38	24.34	22.11	23.60	1.253	0.0248	0.2434	0.8472
Ash (%)	0.77	0.70	0.76	0.71	2.081	0.0058	0.0314	0.9710

O = tailed vs. docked; D = diet; O×D = interaction.

Correlation between fatty acid contents

Correlation coefficients between fatty acid contents were computed using the pooled data (Table 6). High negative correlation was found between oleic acid content and that of stearic and palmitic acids ($P < 0.0001$). A positive correlation was observed between linolenic and oleic acids ($r = 0.3127$; $P < 0.0089$). Despite the common use of the correlation coefficient, it has been reported that in the case of pooled data the coefficient of determination (R^2) may better explain the degree of association between variables (Moharrery, 2007); therefore R^2 values were computed for pooled data. Calculated coefficient of determination of oleic acid with stearic (0.7165) and palmitic (0.2992) acids indicated that 71.7% and 29.9% of total variation in oleic acid could be explained by its relationship with stearic and palmitic acids, respectively. The coefficient of determination between palmitic and stearic acids was 0.09.

Discussion

Fat-tailed sheep are believed to be more tolerant to feed shortages prevalent in most parts of Asia, compared to European breeds. This is probably due to the amount of stored fat in the tail during lush season, which can be catabolized during long periods

of plant growth dormancy, or in drought conditions (Sefidbakht and Ghorban, 1972). Average daily gain was higher in docked than in intact lambs. In contrast, O'Donovan *et al*. (1973) reported a non-significantly higher final body weight in docked than in undocked Kallakui lambs. Results of the present study were in accord with those in Badghisian (Moharrery, 2007) and Balouchi sheep (Moharrery, 2009). Daily weight gain was generally higher in lambs fed on the high-energy diet. This is in agreement with data reported by Fluharty and McClure (1997). The higher daily weight gain was as a result of higher daily dry matter intake in lambs feeding on the high-energy diet. O'Donovan et al. (1973), El-Karim (1980) and Marai et al. (1987) reported similar findings in docked and undocked Kallakui lambs, Dubasi (Sudan desert) sheep and Ossimi sheep.

However, carcass data did not agree with those reported by Epstein (1961), Asker et al. (1964) and Joubert and Uckermann (1971) who showed that docking decreased carcass weight. The trend to heavier primal cuts in docked than in intact animals (Table 3) were similar to the results of Qureshi (1968) and Juma et al. (1974). Hypertrophy of adipose cells in these depots might be an important factor in increasing the weight of leg and loin area as primal cuts. The heavier primal cuts might be an indicative of a change in body fat metabolism, but no conclusion could be drawn from the present data.

Table 5: Fatty acid content (%) of the caudal and omental fat in Kurdi lambs

	Caudal	Omental	SE	Probability
Fatty acid				
Myristic acid	7.01	6.06	0.376	0.0220
Palmitic acid	28.05	31.32	0.977	0.0125
Stearic acid	7.13	51.65	0.452	0.0001
Oleic acid	51.65	37.66	0.536	0.0001
Linoleic acid	4.28	4.49	0.266	0.3160
Linolenic acid	1.88	0.14	0.507	0.0981
SFA	46.67	57.69	1.044	0.0001
UFA	53.33	42.31	1.044	0.0001
SFA/UFA	0.99	1.37	0.036	0.0001

Meat in docked lambs, excluding of the caudal fat, had higher ether extract content compared to intact lambs being fed the same diet. It might be postulated that due to space limitations in the tail of docked lambs, part of the fat that was supposed to be deposited in the tail was redirected to other fat depots such as omental fat tissue and intermuscular or intramuscular fat. The meat samples of lambs on high energy-diet showed the same chemical composition compared to lambs on normal energy-diet. In agreement with this proposition, Hausman et al. (2001) reported that higher extracellular concentrations of fatty acids promote the proliferation and maturation of adipocytes, and hence adipose tissue hypertrophy. A 3.56% reduction in total body fat in the docked lambs may be due to limitation of other fat depots to accommodate all lipids usually deposited in the tail of intact individuals. Sefidbakht and Ghorban (1972) reported that docked lambs produced about 11.25% less physically separated fat compared to intact lambs. The degree of reduction in carcass fat content in docked lambs in the present study was less than that reported by Sefidbakht and Ghorban (1972), but was in agreement with data in Badghisian (Moharrery, 2007)) and Balouchi sheep (Moharrery, 2009).

The ratio of SFA to UFA in the caudal fat was less than 1, as also reported in Badghisian (Moharrery, 2007) and Balouchi sheep (Moharrery, 2009). However, it did not confirm the view that ruminants in general, and sheep in particular, have a high ratio of saturated to monounsaturated fatty acids in their adipose tissue (Christie, 1981). This may be due a variety of factors. Dietary fatty acids are usually polyunsaturated, although they are hydrogenated by ruminal microorganisms. Additionally, because ruminant diets have a relatively low fat content, there is a high rate of *de novo* fatty acid synthesis in the adipose tissue (Vernon, 1980). Therefore, phenotypic variation in monounsaturated fatty acid composition in adipose tissue depots is primarily due to site-specific differences in fatty acid metabolism. Depot-specific differences in adipocyte cell volume can arise through a variety of mechanisms, including the differences in synthetic capacity, lipolysis, and nutrient supply through blood flow (Barber et al., 2000). In contrast to the carcass and epicardial adipose tissues, stearoyl-CoA desaturase (SCD) gene expression did not vary significantly with adipocyte cell volume in the abdominal depots (Barber et al., 2000). This is likely to be a major factor responsible for the low ratio of oleic acid to stearic acid in abdominal depot compared with caudal fat in fat-tailed sheep. The reason why SCD in abdominal fat does not increase with increases in adipocyte size is not clear. The pattern of fatty acids composition of caudal and omental fat in the present study confirmed the previous reports in Badghisi (Moharrery, 2007) and Balouchi sheep (Moharrery, 2009). However, in

abdominal adipocytes, variation in the monounsaturated fat content of ovine adipose tissue depots is accounted for by site-specific expression of the stearoyl-CoA desaturase gene. The mechanisms for this depot-specific expression are not clear (Barber et al., 2000).

Table 6: Correlation coefficients between fatty acid contents of pooled meat, omental and caudal fats in Koprdian lambs

Item	Fat (g)	Fatty acids (%)					
		Myristic acid	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid
Fat (g)	1.0000 [a] (.0000 [b])	0.1471 (0.2793)	-0.2446 (0.0692)	-0.7439 (0.0001)	0.6359 (0.0001)	-0.2221 (0.8713)	0.3502 (0.0082)
Myristic acid		1.0000 (.0000)	-0.0786 (0.5212)	-0.2234 (0.0650)	0.0052 (0.9664)	-0.0472 (0.7003)	0.1878 (0.1224)
Palmitic acid			1.0000 (.0000)	0.3018 (0.0117)	-0.5470 (0.0001)	-0.1016 (0.4064)	-0.4022 (0.0006)
Stearic acid				1.0000 (.0000)	-0.8465 (0.0001)	0.1625 (0.1822)	-0.4465 (0.0001)
Oleic acid					1.0000 (.0000)	-0.4187 (0.0003)	0.3127 (0.0089)
Linoleic acid						1.0000 (.0000)	-0.1070 (.3817)

[a] Coefficient of correlation.
[b] Significant level.

Three main fatty acids (palmitic, stearic and oleic acids) represented the major portion (on average 90%) of the total fatty acids in the omental and caudal fats (Tables 5). This was in agreement with the reported data in the literature (Sanudo et al., 1998; Bas and Morand-Fehr, 2000; Moharrery, 2007; 2009). The meat and omental fat in lambs, ewes and rams did not contain measurable quantities of C20 and C22 polyunsaturated fatty acids (Enser et al., 1996). This is probably due to the low proportion of phospholipid in the adipose fraction and the failure of ruminant adipose tissue to incorporate these fatty acids into triacylglycerols, despite the fact that they are not hydrogenated by in rumen (Ashes et al., 1992; Enser et al., 1996).

A study on suckling six-week-old lambs showed breed differences in the melting point and fatty acid composition of tail and perinephric fat (Zygoyiannis et al., 1985). L' Estrange et al. (1980) reported breed differences in melting point in subcutaneous rib fat that was explained by a difference in stearic and oleic acids; stearic acid and melting point decreased with increased carcass weight. No significant effect of tail docking and level of dietary energy was recorded for the percentage of fatty acids in caudal and omental fat depots. Crouse et al. (1972) also did not find any differences in the fatty acid content in relation to carcass weight, which was associated with increasing quantities of fat. A study in Wyoming, USA, showed that no significant difference was detected in the melting point of fat in wethers (Vimini et al., 1984).

The ratios of oleic to stearic acid in the omental and caudal fats were 1.82 and 6.83, respectively. It might be due to lower oleic acid concentration in the omental fat compared with the caudal fat, along with a higher percentage of stearic acid in corresponding fractions. In accordance with an earlier study of Buller and Enser (1986), the ratio of oleic to stearic acid suggested that the activity of the SCD is tissue-specific, being higher in the back fat outer (BFO) (4.00 to 2.76) and lower in the omental fat (OF) (2.36 to 1.56). As they have mentioned, the concentration of linoleic acid was not sufficient for blocking the enzyme activity.

In sheep, SCS influences the desaturation of fatty acids, independently of total fat synthesis, and this strongly suggests that there may be potential for specifically increasing the level of oleic acid in ruminant tissues (Daniel et al., 2004).

Desaturation of stearic acid to oleic acid is catalyzed by SCD (Enoch et al., 1976), and, because the rate of elongation is greater than the rate of desaturation (Chang et al., 1992), it is believed that the step catalyzed by SCD is a rate-limiting factor in the production of oleic acid. Oleic acid content of adipose tissue correlates well with depot-specific expression of ovine SCD (Barber et al., 2000). Thus, increasing the activity of SCD in ovine adipose tissue

may significantly improve the nutritional quality of lamb by decreasing the saturated fatty acid content and increasing the oleic acid content.

Caudal adipose tissue contained less stearic acid and more oleic acid than the omental fat. This finding was in agreement with that of Barber et al. (2000) who reported that subcutaneous adipose tissue contained less stearic acid and more oleic acid than did internal adipose tissue depots.

According to Daniel et al. 2004, although each adipose tissue depot responded to hormones, the proportion of monounsaturated fatty acids was always greater in the subcutaneous depot, suggesting that in addition to hormones, depot factors may also play a role in regulating its synthesis.

Since the elongation of palmitic acid produces stearic acid and the precursor for synthesis of oleic acid is stearic acid, a high negative correlation was detected between stearic acid and oleic acid contents, and simultaneously a positive correlation was recorded between palmitic with stearic acids, and a negative correlation between palmitic and oleic acids. This is because the preferred substrate of SCD is stearic rather than palmitic acid (Enoch et al., 1976). Strong, positive correlation between SCD mRNA and oleic acid content in sheep tissues were reported by Daniel et al. (2004).

The strong significant correlations between stearic acid and total body fat weight ($r = -0.7439$; $P < 0.0001$), and between oleic acid and total fat percentage ($r = 0.6359$; $P < 0.0001$), and also the relationship between stearic and oleic acids, may explain the significant overlapping of metabolic pathways in synthesis of fatty acids with 18 carbon atoms and desaturase activity in these processes.

The significant correlation of total fat with stearic and oleic acids in the present study is in contrast to the findings of Daniel et al. (2004). In fat-tailed sheep, the main site of fat deposition is the area around the tail nuts. Results showed that the percentage of oleic acids in caudal fat was higher than other fatty acids in this site. As a result, increased body fat synthesis resulted in greater fat deposition in the caudal adipose tissue, containing a high percentage of oleic acid. Barber et al. (2000) reported a site-specific expression in the desaturase gene, which is a factor in synthesis of oleic acid from stearic acid.

Conclusions

Docking Kurdi fat-tailed lambs at birth did not influence their feed consumption, but improved daily weight gain, meat quality and the weight of high priced carcass cuts, and at the same time reduced the percentage of fat in the body. Increasing the energy concentration in the diet increased the average daily gain and feed intake. There was no interaction between docking and dietary energy level. Docking of Kurdi lambs did not influence the fatty acid profile in the adipose tissue, but improved most feedlot parameters, and may be recommended under certain husbandry conditions.

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References

AOAC. 1991. Official Methods of the Association of Official Analytical Chemists. 16th Ed. Washington DC., USA.

Ashes, J.R., Sibert, B.D., Gulati, S.K., Cuthbertson, A.Z., Scott. T.W., 1992. Incorporation of n-3 fatty acids of fish oil into tissue and serum lipids of ruminants. *Lipids* 27, 629-631.

Asker, A.A., El-Khalsy, I.G., Juma, K.H., 1964. Effect of docking on growth and development of Awassi lambs. U.A.R. *Animal Production* 4, 11-26.

Barber, M.C., Ward, R.J., Richards, S.E., Salter, A.M., Buttery, P.J., Vernon, R.G., Travers, M.T., 2000. Ovine adipose tissue monounsaturated fat content is correlated to depot-specific expression of the stearoyl-CoA desaturase gene. *Journal of Animal Science* 78, 62–68.

Bas, P., Morand-Fehr, P., 2000. Effect of nutritional factors on fatty acid composition of lamb fat deposits. *Livestock Production Science* 64, 61-79.

Beauchemin, K.A., McClelland, L.A., Jones, S.D.M., Kozub, G.C., 1995. Effects of crude protein content, protein degradability and energy concentration of the diet on growth and carcass characteristics of market lambs fed high concentrate diets. *Canadian Journal of Animal Science* 75, 387–395.

Buller, K.J., Enser, M., 1986. The effect of food intake and dietary fatty acids on the activity of stearoyl-CoA Δ^9

desaturase in pig adipose tissue. *Journal of Agricultural Science, Cambridge* 106, 601–609.

Burton, J.H. Reid, J.T., 1969. Interrelationships among energy input body size age and body composition of sheep. *Journal of Nutrition* 97, 517-523.

Chang, J.H.P., Lunt, D.K., Smith, S.B., 1992. Fatty acid composition and fatty acid elongase and stearoyl CoA desaturase activities in tissues of steers fed high oleate sunflower seed. *Journal of Nutrition* 122, 2074–2080.

Christie, W.W., 1981. The composition, structure and function of lipids in the tissues of ruminant animals. In: Christie, W.W. (Ed.), Lipid Metabolism in Ruminant Animals. Pergamon Press, Oxford, U.K. pp. 95–191.

Crouse, J.D., Kemp, J.D., Fox, J.D., Ely, D.G., Moody, W.G., 1972. Effect of castration, testosterone and slaughter weight on fatty acid content of ovine adipose tissue. *Journal of Animal Science* 34, 384-387.

Daniel, Z.C.T.R., Richards, S.E., Salter, A.M., Buttery, P.J., 2004. Insulin and dexamethasone regulate stearoyl-CoA desaturase mRNA levels and fatty acid synthesis in ovine adipose tissue explants. *Journal of Animal Science* 82, 231–237.

El-Karim, A.I.A., 1980. Effect of docking on growth and carcass characteristics of Dubasi desert sheep. *Tropical Animal Production* 5,5-17.

Enoch, H.G., Catala, A., Strittmater, P., 1976. Mechanism of rat liver microsomal stearoyl-CoA desaturase. *Journal of Biological Chemistry* 251, 5095–5103.

Enser, M., Hallett, K., Hewitt, B., Fursey, G.A., Wood, J.D., 1996. Fatty acid content and consumption of English beef, lamb and pork at retail. *Meat Science* 42, 443–456.

Enser, M., Nute, G., Wood, J., Sanudo, C., Berge, P., Zygoyiannis, D., Thorkelsson, G., Piasantier, E.E., Fisher, A., 2000. Effects of production systems on the fatty acids and flavour from six European countries. Proceedings of the 46th ICoMST, Buenos Aires. pp. 186-187.

Epstein, H. 1961. The development and composition of docked and undocked fat-tailed Awassi lambs. *Empirical Journal of Experimantal Agriculture* 29,110-118.

Fluharty, F.L. McClure, K.E., 1997. Effects of dietary energy intake and protein concentration on performance and visceral organ mass in lambs. *Journal of Animal Science* 75, 604-610.

Folch, J., Less, M., Sloane Stanley, G.H., 1957. A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry* 226, 497-509.

Hausman D.B., DiGirolamo, M., Bartness, T.J., Hausman, G.J., Martin, R.J., 2001. The biology of white adipocyte proliferation. *Obesity Review* 2, 239–254.

Joubert, D.M., Uckermann, L., 1971. A note on the effects of docking on fat deposition in fat-tailed sheep. *Animal Production* 13,191-192.

Juma, K.H., Karam, H.A., Al-Maali, H.NA., Al-Barazanji, J., 1974. Effect of docking in Awassi sheep. *Indian Journal of Animal Science* 43, 931-935.

L'Estrange, J.L., Hanrahan, J.P., 1980. Some breed effects on the melting point and fatty acid composition of carcass fat in lambs. *Journal of Agricultural Science, Cambridge* 95, 73-76.

Marai, I.F.M., Nowar, M.S., Bahgat, L. ., 1987. Effect of docking and shearing on growth and carcass traits of fat-tailed Ossimi sheep. *Journal of Agricultural Science, Cambridge* 109, 513-518.

Margan, D.E., 1994. Energy and protein value of lupin seed as a production ration or as a supplement for sheep fed chaffed wheaten hay. *Australian Journal of Experimental Agriculture* 34, 331–337.

Moharrery, A., 2007. Effect of docking and energy of diet on carcass fat characteristics in fat-tailed Badghisian sheep. *Small Ruminant Research* 69, 208-216.

Moharrery, A., 2009. Effect of docking and energy of diet on carcass fat characteristics in fat-tailed Baluchian sheep. *Turkish Journal of Veterinary and Animal Science* 33, 95-103.

NRC, 2007. Nutrient Requirements of Small Ruminants: sheep, goats, cervids, and New World camelids. The National Academy Press, Washington, D.C., USA.

O'Donovan, P.B., Ghadaki, M.B., Behesti, R.D., Saleh, B. A., Rollinson, D.H.L., 1973. Performance and carcass composition of docked and control fat-tailed Kellakui lambs. *Animal Production* 16, 67-76.

Prior, R.L., Kohlmeier, R.H., Cundiff, L.V. , Dikeman, M. E., Cruse, J.D., 1977. Influence of dietary energy and protein on growth and carcass composition in different biological types of cattle. *Journal of Animal Science* 45, 32-146.

Qureshi, M.J., 1968. Influence of docking fat-tailed lambs on fat deposition. *Agriculture of Pakistan* 19, 97-100.

Rule, D.C., Smith, S.B., Romans, J.R., 1995. Fatty acid composition of muscle and adipose tissue of meat animals. In: S.B. Smith and D.R. Smith (Eds.), The Biology of Fat in Meat Animals: Current Advances. American Society of Animal Science, Champaign, IL., pp. 144-147.

Sanudo, C., Sierra, I., Olleta, J.L., Martin, L., Campo, M.M., Santolaria, P., Wood, J.D., Nute, G.R., 1998.

Influence of weaning on carcass quality, fatty acid composition and meat quality in intensive lamb production systems. *Journal of Animal Science* 66,75-187.

SAS, 2003. User's Guide: Statistics, Version 9.1 Edition. SAS Inst., Inc., Cary, NC, USA.

Sefidbakht, N., Ghorban, K., 1972. Change arising from docking of fat-tailed sheep in feedlot performance. *Iranian Journal of Agricultural Research* 1, 72-77.

Smith, S.B., 1995. Substrate utilization in ruminant adipose tissues. In: S.B. Smith and D.R. Smith (Eds.) The Biology of Fat in Meat Animals: Current Advances. American Society of Animal Science, Champaign, IL., pp.166-169.

Van Soect, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* 74, 3583-3597.

Vernon, R.G., 1980. Lipid metabolism in the adipose tissue of ruminant animals. *Progressive Lipid Research* 19, 23–106.

Vimini, R.J., Field, R.A., Crouse, J.D., Miller, G.J., 1984. Factors affecting melting point of subcutaneous fat from heavy ram and wether lambs. *International Goat and Sheep Research* 2, 105-113.

Wood, J.D., 1990. Consequences for meat quality of reducing carcass fatness. In: J.D. Wood and A.V. Fisher (Eds.) Reducing Fat in Meat Animals. Elsevier, Barking, U.K. pp. 344-389.

Zygoyiannis, D., Stamataris, C., Catsaounis, N., 1985. The melting point, iodine value, fatty acid composition and softness index of carcass fat in three different breeds of suckled lambs in Greece. *Journal of Agricultural Science, Cambridge* 104, 361-365.