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EFFECT OF DIETARY PROTECTED FAT AND ROUGHAGE LEVEL ON DIGESTION, RUMEN METABOLISM AND PLASMA LIPIDS OF GROWING-FINISHING LAMBS

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SUMMARY

Sixty male Barki lambs, 8 month old and 27.5 kg average body weight , were randomly divided into six similar groups. Lambs were fed ration at level of 3.5% of body weight for 70 days. Rations were iso nitrogenous containing 10 % or 30 % berseem hay each with 0, 4 or 8% Ca –Soap.

At the end of growth trail, twenty-four metabolism trials were conducted to evaluate nutrient digestibilities, nutritive value of the experimental rations, nitrogen balance and water intakes. Ruminal fluid samples were collected at 0 and 4 hrs post feeding to determine pH, ammonia-nitrogen, total VFA'S concentrations and molar proportions of fatty acids, total nitrogen and non- protein nitrogen. Blood plasma total lipids, triglycerides and cholesterol were also determined.

Results indicated feeding 4% calcium soap rations (P<0.05) improved nutrient digestibilities but this effect was not evident by feeding with 8% calcium soap supplement. Increasing roughage from 10% to 30% had no significant effect on nutrient digestibility. Cell wall constituents digestibilities were higher for 30% roughage rations and positively affected by fat supplement. Higher energetic values (DE and TDN) was associated with fat supplement and low roughage levels. The DCP values were not affect by the dietary treatments.

Calcium soap supplement significantly improved DE and TDN intakes specially with high roughage level but had no significant effect on DCP intake. Water intake (P<0.05) increased by increasing fat supplement to 8% and roughage level to 30%. Nitrogen balance was not affected by the dietary treatments.

Fat Supplement had no significant effect on ruminal parameters. However, increasing roughage level increased (P<0.05) ruminal pH, acetate concentration and acetate: propionate ratio but decreased propionate, iso butyrate and valerate. Ruminal total VFA's concentrations, butyrate and iso valerate were not affected by dietary roughage level. Lower pH and higher total VFA's concentrations, acetate, butyrate, iso butyrate, valerate and iso valerate were found at 4 hrs post-feeding, but propionate and acetate: propionate ratio were not affected by sampling time. Increasing calcium soap level in sheep diet had no significant effect on rumen nitrogen metabolism. However, increasing roughage level (P<0.05) decreased ruminal total nitrogen, non protein nitrogen ammonia nitrogen and true protein nitrogen. All forms of ruminal nitrogen were (P<0.05) lower at 4 hrs post feeding than those before feeding

Increasing protected fat level to 4% or 8% of ration dry matter significantly increased plasma total lipids and (P<0.05) triglycerides. Total cholesterol was

(P<0.05) higher for 8% fat group than the control and 4% fat group but increasing roughage level (P<0.05) increased total plasma lipids and total cholesterol but had no significant effect on triglycerides. Total cholesterol (P<0.05), total lipids and triglycerides (P>0.05) were higher at 4 hrs post feeding than those before feeding.

Inclusion of 4% calcium soap improved the nutrient utilization of high (30%) roughage diet to be comparable to that of low (10%) roughage one with no adverse effect on rumen metabolism or blood plasma metabolites.

Keywords: sheep, calcium soaps, digestion, rumen metabolism, plasma lipids

INTRODUCTION

Fat can be used to increase the energy density of high-forage diets fed to ruminants. However, it is believed that lipid supplementation to ruminant diets often has a negative effect on feed intake and fiber digestibility (Corine *et al*., 1993). This effect is more marked with polyunsaturated fatty acids (Palmquist and Jenkins, 1980; Sutton et al., 1983). Lower digestibility of fiber may reduce the ratio of acetic to propionic acids in the rumen and also may decrease digestible energy (Chalupa *et al*., 1984; Broudiscou *et al*., 1988).

Because only 3 to 5% of fat added to common feeds seems to be tolerated by ruminal microorganisms (Palmquist and Jenkins, 1980), research has been conducted to develop high- fat feeds that do not impair fermentative digestion *i.e.* encapsulated fat, prilled fat, and calcium salt of fatty acids (Grummer, 1988). The use of these fats suggests the potential to employ lipids up to 8 to 9% of the diet DM (Ostergaard *et al*., 1981).

Protected fats are widely used in dairy rations, less for growing-finishing steer and not often in growing sheep diets. The objective of this work is to study the effects of supplemental protected fat on lamb performance, nutrient digestibility, feed intake, rumen function and blood lipid metabolites of lambs fed low or high roughage diets.

MATERIALS AND METHODS

Sixty male Barki lambs aged 8 months with 27.5 kg average body weight were randomly divided into six similar groups, each of ten lambs and adapted to the experimental rations for one week before data collection.

Lambs were fed at DM Level of 3.5% body weight for 70 days. Six diets containing 10 % or 30 % berseem hay as roughage source and Ca -Soaps with three levels 0 (low), 4 (medium) and 8 % (high) of dietary DM. Ingredient and chemical composition of the experimental rations are presented in Table 1.

Metabolism trial

Six metabolism trial were conducted to determine the nutrient digestibilities and nutritive value of the experimental rations. Nitrogen balance and water intakes were also determined. Four lambs from each group were housed in metabolic cages for 8 days as a preliminary period followed by 7 days for total collection. The experimental rations were offered once a day at 09:30 hrs. Feces and urine were collected before feeding at 08:30. Actual feed intake, fresh weight of feces, urine volume and water intake were daily recorded. Chemical composition of rations, feces and urine was carried out according to the standard methods of A.O.A.C. (1984). Cell wall constituents were determined in feeds and feces according to Goering and Van Soest (1970).

Table 1. Feed and chemical composition of the experimental rations

Item	10 % roughage Calcium soap, %			30 % roughage Calcium soap, %		
	0	4	8	0	4	8
Feed composition, %						
Concentrate mix. [1]	89.7	85.2	81.7	73.5	70.2	66.9
Berseem hay	10.3	10.6	10.3	26.5	25.6	25.1
Protected fat [2]	0	4.2	8.0	0	4.2	8.0
Chemical composition, %						
DM	89.32	89.52	89.48	90.68	91.06	91.45
DM composition%						
OM	94.18	93.62	93.04	93.20	92.66	92.14
CP	19.38	19.07	18.81	19.09	18.75	17.35
EE	2.90	6.37	9.84	2.65	6.12	9.59
CF	5.22	5.27	5.16	9.65	9.61	9.91
NFE	66.68	62.91	59.23	61.81	58.18	55.29
Ash	5.82	6.38	6.96	6.80	7.34	7.86
Cell wall constituents, %						
NDF	19.41	18.99	18.78	31.64	31.21	30.56
ADF	5.97	6.35	5.80	11.80	12.19	12.56
Hemicellulose [3]	13.44	12.64	12.98	19.84	19.02	18.00
ADL	1.42	1.42	1.40	3.94	3.83	3.53
Cellulose [4]	4.55	4.93	4.40	7.86	8.36	9.03

1 Concentrate mixture was composed of 60% yellow corn, 20%, soy bean meal, 17 % wheat bran, 0.8% sodium chloride 1.2% limestone and 1 % common salt.
2 Fat source, Magnapac® is a commercial product of calcium salts of long chain fatty acids of palm oil. 3 Hemicellulose = NDF – ADF 4 Cellulose = ADF – ADL

Rumen fluid parameters

Rumen fluid samples were collected at the end of the metabolism trials from four lambs from each group, by using stomach tube. Samples were collected for two consecutive days before and 4 hrs post feeding. Rumen fluid samples were filtered through four layers of cheese cloth. Ruminal pH was immediately determined using Orion Research digital pH meter, model (201). Ammonia-nitrogen (Conway, 1962), total VFA's concentrations (Kromann *et al*., 1967) and molar proportions of fatty acids (Erwin *et al.* 1961), total nitrogen and non- protein nitrogen (A.O.A.C., 1984) were determined. True protein nitrogen was calculated by the difference between total nitrogen and non- protein nitrogen.

Blood plasma constituents

Blood samples were collected from the same lambs at the end of metabolism trials from the left jugular vein in heparinized test tubes before and 4 hrs post feeding. Blood plasma was spent by centrifugation of blood samples at 5.000 rpm for

15 minutes. Plasma were kept frozen at –20 °C for total lipids, triglycerides and cholesterol analyses (Roche Diagnostics GmbH kits, D-68298, Mannheim).

Data collected were subjected to statistical analysis as two factor factorial analysis of variance (Mstat C., 1989). Duncan's Multiple Range Test (Duncan, 1955) was used to separate means when the dietary treatment effect was significant according to the following model 1.

$Y_{ijk} = M + F_i + R_j + (FR)_{ij} + e_{ijk}$ (model 1)

Ruminal and blood plasma data according to model:

$Y_{ijkl} = M + F_i + R_j + T_k + FR_{ij} + FT_{jk} + RT_{jk} + FRT_{ijk} + e_{ijkl}$ (model 2)

Where:

Y_{ijk} = Observation
ц = Overall mean.
F_i = Effect of dietary fat level for i = 1- 3
1 = No fat, 2 =4% fat and 3 = 8% fat
R_j = Effect of roughage levels for j =1-2,
1=10% hay and 2= 30% hay.
$(FR)_{ij}$ = interaction of fat level x roughage level
e_{ijk} = Experimental error. (model 1)
T_k = Effect of sampling time for k = 1-2,
1 = before feeding and 2= 4 hrs post feeding.
FT_{jk} = the interaction of fat level x sampling time.
RT_{jk} = the interaction of roughage level and sampling time.
FRT_{ijk} = the interaction of fat level x roughage level x sampling time.
e_{ijkl} = the experimental error. (model 2)

RESULTS AND DISCUSSION

Feed and chemical composition of the experimental rations are shown in Table 1. Protected fat was used to replace 4.2 % of concentrate dry matter in 0 % or 8 % in high fat diets. Rations were almost iso-nitrogenous containing 19.38, 19.07 and 18.81% for low roughage diets and 19.09, 18.75 and 17.35% for high roughage one. The corresponding ether extract contents were 2.90, 6.37 and 9.84% for low roughage diet and 2.65, 6.12 and 9.59% for high roughage one. The NDF was about 19 % for low roughage rations and 30% for high roughage level. The experimental rations differed in EE and CF content due to fat supplemented and roughage level (Table 1).

Inclusion of 4% protected fat did not affect DM digestibility but increasing fat level to 8% decreased (P<0.05) DM digestibility by about 4 digestion units (Table 2). Canale *et al*. (1990) found that adding of 0.5 kg calcium soaps to dairy cow’s ration increased the apparent digestibility of DM when diets contained 25% NDF. Hill and West (1991) found that DM digestibility was higher when 4.5% calcium soaps was added to the diet compared to the control with no added fat. However, El-Bedawy *et al*. (2004b) found that protected fat supplement to growing-finishing bulls insignificantly (P>0.05) decreased the DM digestibility.

Digestibility of OM improved by incorporation of 4% dietary fat. This was not evident with 8% fat level. The same trend was observed for CP digestibility. El-Bedawy *et al*. (2003) noticed that OM digestibility was significantly increased when calcium soaps was added at 4% and 8% levels to the rations. While El-Bedawy *et al*.

(2004b) found that protected fat containing ration decreased OM digestibility and Zinn (1992) found no significant effect on total tract digestion of OM for beef cattle that fed 5% fat level.

The digestibility of CP was improved by incorporation of 4% dietary fat but this was not evident with the 8% fat level. Feeding 4% fat containing ration increased CP digestibility by 2.4% while, feeding 8% fat level decreased CP digestibility by 1.2% compared to control (no added fat). Palmquist and Conard (1978) and El- Bedawy *et al*. (2003) reported that addition of fat to the diet had no significant effect on digestibility of nitrogen. Jenkins and Palmquist (1984) found that added fatty acid in forms of Ca- Soap slightly increased nitrogen digestibility. However, El-Bedawy *et al*. (2004b) observed that protected fat supplemented diet at 5% insignificantly (P>0.05) decreased CP digestibility.

Increasing dietary fat increased EE digestibility. No significant differences between 4% and 8% fat level in EE digestibility. The higher digestibility of EE associated with fat supplement in ration might be related to the higher digestibility of supplementary fat (Palmquist and Conrad, 1978). El-Bedawy (1995) found that supplemented fat either from oil or Ca- Soap significantly increased EE digestibility from 70% to 90%, which could be due to the high digestibility of fatty acid in supplementary fat. Also, El-Bedawy *et al*. (2004a) found that EE digestibility increased by 19% when calcium soaps was added to the Frisian bull rations. However, El-Bedawy *et al*. (2004b) found that EE digestibility insignificantly (P>0.05) decreased by feeding protected fat containing diets to fattening bulls.

Crude fiber digestibility was not significantly influenced by increasing dietary fat level. However, NFE digestibility was decreased with 8 % fat level. These results were in agreement with the findings of El- Bedawy (1995) in a study on sheep and El-Bedawy *et al*. (2004a) and El-Bedawy *et al*. (2004b) in a study on finishing bulls that calcium soap supplement had no significant effect on CF digestibility.

Roughage level had no significant effect on nutrient digestibility. However, slight decrease was observed for all nutrients by feeding high roughage level except for DM and CF, which showed slight increase.

Table 2. Main effects of dietary treatments on nutrient digestibilities of the experimental rations

Item	Calcium soap, %			SEM	Roughage, %		SEM
	0	4	8		10	30	
DM	84.37^{a}	85.58^{a}	80.05^{b}	1.09	82.63	84.04	1.10
OM	74.69^{b}	77.25^{a}	73.80^{b}	0.83	76.54	73.95	0.69
CP	70.66^{b}	72.33^{a}	69.78^{b}	0.97	72.41	69.78	0.72
EE	45.77^{b}	82.78^{a}	84.86^{a}	1.61	74.06	68.22	5.47
CF	40.28	43.97	43.97	1.88	40.81	44.67	1.48
NFE	81.06^{a}	82.26^{a}	76.82^{b}	0.69	80.36	79.73	0.87

^{a,b} Means within each treatment having different superscripts (P<0.05) differ

Data in Table 3 showed the fat x roughage level interaction on nutrient digestibility. Feeding high fat level 8% with low roughage diet decreased DM digestibility (77.26). However this effect was not evident with high roughage diet (82.85%). Addition of 4% fat containing diet slightly increased DM, OM, EE, CF, CP and NFE digestibilities. Zinn and Plascencia (1996) found that forage level did not affect (P>0.10) total tract digestion of fiber, starch and nitrogen. However, as excepted, increasing forage level decreased (P<0.01) total tract digestion of OM. The same authors found no interaction (P>0.10) between forage level and supplemental fat on total tract digestibility of OM, lipid and starch.

Table 3. Effects of dietary fat and roughage level on nutrient digestibilities of the experimental rations

Item	10% roughage diets			30% roughage diets			SEM
	Calcium soap, %			Calcium soap, %			
	0	4	8	0	4	8	
DM	83.79[a]	86.84[a]	77.26[b]	84.96[a]	84.32[a]	82.85[a]	1.35
OM	76.68[ab]	78.50[a]	74.44[bcd]	72.71[d]	76.00[abc]	73.15[cd]	0.90
CP	72.80[a]	72.77[a]	71.66[ab]	68.52[b]	71.90[ab]	68.93[ab]	1.15
EE	53.81[b]	83.83[a]	84.55[a]	37.73[c]	81.74[a]	85.18[a]	1.29
CF	39.09	42.48	40.87	41.47	45.47	47.08	2.43
NFE	81.74[a]	82.76[a]	76.58[b]	80.38[a]	81.77[a]	77.06[b]	0.91

[a,b,c, d] Means in the same row having different superscripts (P<0.05) differ.

Feeding 4% fat containing diet improved (P<0.05) NDF, ADF, hemicellulose and cellulose digestibilities. However, feeding 8% fat level insignificant decreased (P>0.05) cellulose digestibility. High roughage level (30% hay) increased the digestibilities of cell wall constituents by 8% for NDF; 15% for ADF; 9% for hemicellulose and 11% for cellulose, respectively (Table 4).

The interactions between fat level and roughage level (F x R) was significant (P<0.01) for NDF, ADF, hemicellulose and cellulose digestibilities (Table 5). These results were in agreement with those obtained by Jenkins and Palmquist (1984), that the digestibility of ADF was found to be higher with added 4.5% calcium soap than the control. While Schauff and Clark (1989); Zinn (1992); Brinkmann and Abel (1992) and El-Bedawy *et al*. (2004a) found that apparent digestibilities of NDF and ADF were not affected by feeding fat containing rations.

Table 4. Main effects of dietary treatments on digestibility of cell wall constituents of the experimental ratios

Item	Calcium soap, %			SEM	Roughage, %		SEM
	0	4	8		10	30	
NDF	60.13[b]	69.23[a]	68.90[a]	1.06	63.58[b]	68.60[a]	1.33
ADF	50.30[b]	58.78[a]	51.13[b]	1.56	49.72[b]	57.07[a]	1.35
Hemicellulose	65.26[c]	75.22[b]	78.55[a]	1.30	69.95[b]	76.07[a]	1.76
Cellulose	55.58[b]	62.96[a]	54.63[b]	1.48	54.77[b]	60.68[a]	1.31

[a,b] Means within each treatment having different superscripts (P<0.05) differ.

Increasing fat level to 8% increased digestible energy (DE) and TDN but decreased the DCP content (Table 6). Andrew *et al*. (1991); Hill and West (1991) and El-Bedawy *et al*. (2004a) reported that inclusion of calcium soaps in rations increased digestible energy by 10 to 12%. Zinn and Plascencia (1996) found that supplementary fat increased (P<0.01) the DE and ME values of the diet. However, El-Bedawy *et al*. (2004b) found that TDN values decreased for bulls fed fat containing rations. The DCP content of fat containing rations was lower than the control group. However, Bendary *et al*. (1994) found that DCP significantly increased by fat supplementation. High roughage rations were characterized by low digestible energy, TDN, CP and DCP values. Zinn and Plascencia (1996) found that increasing forage level decreased (P<0.01) dietary DE and ME.

Table 5. Effects of dietary fat and roughage level on the digestibility of cell wall constituents of the experimental ratios

	10% roughage diets			30% roughage diets			
Item	0	4	8	0	4	8	SEM
NDF	56.16[d]	68.21[b]	66.36[b]	64.10[c]	70.26[a]	71.44[a]	0.64
ADF	46.65[c]	58.04[a]	44.48[c]	53.96[b]	59.53[a]	57.78[a]	0.87
Hemicellulose	60.39[e]	73.33[c]	76.14[b]	70.14[d]	77.12[b]	80.96[a]	0.75
Cellulose	51.49[c]	63.24[a]	49.58[c]	59.67[b]	62.68[ab]	59.68[b]	1.10

[a,b,c, d] Means in the same row having different superscripts (P<0.05) differ.

Table 6. Main effects of dietary treatments on nutritive value of the experimental rations

Item	Calcium soap, %			SEM	Roughage, %		SEM
	0	4	8		10	30	
DE Mcal / kg DM	3.176[b]	3.460[a]	3.554[a]	0.05	3.487[a]	3.306[b]	0.06
TDN %	71.59[b]	78.44[a]	78.63[a]	0.95	78.00[a]	74.44[b]	1.14
DCP %	13.60[a]	13.68[a]	12.72[b]	0.25	13.82[a]	12.84[b]	0.19

[a,b] Means within each treatment having different superscripts (P<0.05) differ.

There were no interactions between fat level and roughage level (FxR) on TDN and DCP content (Table 7). These results are in agreement with those found by Zinn and Plascencia (1996).

Table 7. Effects of dietary fat and roughage level on nutritive value of the experimental rations

Item	10% roughage diets			30% roughage diets			SEM
	0	4	8	0	4	8	
DE Mcal/ kg DM	3.291[c]	3.531[ab]	3.638[a]	3.061[d]	3.338[bc]	3.470[ab]	0.05
TDN %	74.16[c]	80.19[a]	79.64[ab]	69.01[d]	76.68[bc]	77.62[ab]	0.88
DCP %	14.11[a]	13.88[a]	13.48[ab]	13.08[b]	13.48[ab]	11.96[c]	0.22

[a,b,c,d] Means in the same row having different superscripts differ (P<0.05).

Daily dry matter and nutrient intakes during the 70-day experimental period are shown in Table 8. The mean values of concentrate intake by lambs fed high roughage level ranged from 754 to 762 g /day, while, it ranged from 874 to 912 g/day for lambs fed low roughage diets. On the other hand, roughage intake ranged from 275 to 285 g /h /day for high roughage level but it ranged from 105 to 111 g /h /day for lambs fed low roughage level.

Total dry matter intake (DMI) as g/day, g /kg $W^{0.75}$ or kg /100 kg BW were not significantly (P>0.05) different among the dietary treatments. These results might indicate that protected fat had no adverse effect on palatability. Comparable results were recorded for sheep by El-Bedawy (1989) and Ammann (1991). However, El-Hag *et al*. (1985) and Ilian *et al* (1988) reported lower intake for fat supplemented sheep. On the other hand, Pantoja *et al*. (1996) and Elliott *et al*. (1996) reported higher intake when fat was added to the rations.

Digestible energy (DE) and TDN intakes were higher ($P<0.01$) for protected fat supplemented group than the control (no added fat). The interaction between fat supplementation and roughage level (F x R) on DE and TDN intakes was not significant. These results are in agreement with those found by El-Bedawy (1995) that TDN intake increased by fat addition in sheep diets.

No significant differences ($P>0.05$) in digestible crude protein (DCP) intake among the experimental groups were detected. Bendary *et al*. (1994); El-Bedawy *et al*. (1996) and El-Bedawy *et al*. (2004a) reported that fat addition had no significant effect on DCP intake.

Table 8. Dry matter, energy and nutrient intakes by the experimental groups

Item	10% roughage diets			30% roughage diets			SEM
	0	4	8	0	4	8	
Av. body weight	34.6	34.8	35.9	34.5	34.8	35.2	1.0
Concentrate mix.	912	874	882	762	754	758	33
Berseem hay	105	109	111	275	275	285	10
Protected fat	0	43	87	0	45	90	2
Dry matter							
g /day	1017	1026	1080	1037	1074	1133	44.0
g / kg $W^{0.75}$	71.30	71.61	73.67	72.80	74.90	78.48	3.06
Kg/100 kg BW	2.94	2.95	3.01	3.00	3.08	3.22	0.13
DE (Mcal)							
Mcal/ day	2.93^{b}	2.99^{b}	3.52^{ab}	2.71^{b}	3.26^{ab}	3.90^{a}	0.21
Mcal/100 kg BW	8.5^{b}	8.6^{b}	9.8^{ab}	7.9^{b}	9.4^{ab}	11.1^{a}	0.6
Kcal/$W^{0.75}$	205^{b}	209^{b}	240^{ab}	190^{b}	227^{ab}	270^{a}	15
TDN							
g/day	755^{bc}	823^{ab}	860^{a}	716^{c}	823^{ab}	879^{a}	33.5
g / kg $W^{0.75}$	52.9^{bc}	57.4^{abc}	58.7^{ab}	50.3^{c}	57.4^{abc}	60.9^{a}	2.30
Kg/100 kg BW	2.18^{bc}	2.37^{ab}	2.40^{ab}	2.07^{c}	2.36^{ab}	2.50^{a}	0.09
DCP							
g /day	143	142	146	136	145	136	6
g / kg $W^{0.75}$	10.0	9.9	10.0	9.6	10.1	9.4	0.4
g/100 kg BW	413	408	407	394	416	387	2

^{a,b,c} Means in the same row having different superscripts ($P<0.05$) differ.

Addition of fat at 8% level increased ($p<0.05$) water intake. However, no significant differences were found in water intake between the control and 4% fat group. Feeding high roughage diet increased ($p<0.05$) water intake by about 19% than low roughage level did (Table 9). However, El-Bedawy *et al*. (1996) reported lowest water intake by calves fed fat containing rations.

The increasing effect of roughage level on water intake was much pronounced with the high fat level (Table 10). Bartle *et al*. (1994) and Zinn and Plascencia (1996) found that increasing roughage level from 10% up to 30% in fat containing rations fed to steers ($P<0.05$) increased water consumption. The effect of dietary treatment on water intake was not related to change in dry matter intake which was almost constant but it was specific effect of roughage and fat levels.

Table 9. Main effects of dietary treatment on water intake by the experimental groups

Item	Calcium soap, %			SEM	Roughage, %		SEM
	0	4	8		10	30	
ml/day	2099[b]	1873[b]	2673[a]	142	2033[b]	2397[a]	89
ml / kg $W^{0.75}$	147 [b]	131[b]	184[a]	10	141[b]	167[a]	10
ml / 100 kg BW	6.1[b]	5.4[b]	7.5[a]	0.4	5.8[b]	6.9[a]	0.4
L / kg DM intake	2.04[b]	1.78[b]	2.41[a]	0.13	1.95	2.21	0.12

[a,b] Means within each treatment having different superscripts ($P<0.05$) differ.

Table 10. Effects of dietary fat and roughage level on water intake by the experimental groups

Item	10% roughage diets			30% roughage diets			SEM
	0	4	8	0	4	8	
ml / h day	1956 [bc]	1761[c]	2381[b]	2241[bc]	1985[bc]	2965[a]	179
ml / kg $W^{0.75}$	137[b]	123[b]	162[b]	157[b]	138[b]	205 [a]	13
ml / 100 kg BW	5.66[b]	5.06[b]	6.64[b]	6.49[b]	5.70[b]	8.44[a]	0.51
ml / g DM intake	1.9[b]	1.7[b]	2.2[ab]	2.2[ab]	1.9[b]	2.6[a]	0.2

[a,b,c] Means in the same row having different superscripts ($P<0.05$) differ.

Dietary treatments had no significant effect on nitrogen balance of the experimental groups (Table 11). Increasing fat to 8% insignificantly increased ($P>0.05$) nitrogen intake, fecal and urinary nitrogen loss as well as total nitrogen excretion. However, feeding 4% fat containing rations ($P>0.05$) improved nitrogen retention by 15% in comparison with control or 8% fat rations. Sklan (1989) found that inclusion of calcium soap to diet slightly improved nitrogen retention. Roughage level had no significant effect on nitrogen balance. Feeding high roughage ration ($P>0.05$) has no significant effect on nitrogen intake and output. Similar results were found by Zinn and Plascenica (1996) for steers.

Table 11. Main effects of dietary treatments on nitrogen balance (g/day) of the experimental groups

Item	Calcium soap, %			SEM	Roughage, %		SEM
	0	4	8		10	30	
Nitrogen intake	27.35	27.57	30.69	1.38	27.85	29.06	1.24
Fecal nitrogen	8.03	7.62	9.10	0.50	7.72	8.78	0.38
Digested nitrogen	19.32	19.95	21.59	1.02	20.13	20.28	0.89
Urinary nitrogen excretion	8.63	7.66	10.98	0.86	9.48	8.70	0.81
Total nitrogen excretion	16.65	15.28	20.08	1.15	17.20	17.49	1.12
Nitrogen retention	10.70	12.25	10.61	0.90	10.65	11.58	0.74

Data in Table (12) showed no significant differences (P>0.05) among the dietary treatments. High roughage - medium fat diet showed the highest nitrogen retention but high roughage - low fat showed the lowest one. Bayourthe *et al*. (1993) found that nitrogen retention was improved due to decrease in both fecal and urinary nitrogen excretion of fat fed sheep. In contrary, El-Hag *et al*. (1985) found that feeding fat containing diet tended to (P<0.05) decrease nitrogen intake and retention for sheep and goats.

Table 12. Nitrogen intake, excretion and retention (g/day) of the experimental groups

Item	10% roughage diets			30% roughage diets			SEM
	0	4	8	0	4	8	
Nitrogen intake	27.67	25.78	30.10	27.04	28.86	31.28	1.94
Fecal nitrogen	7.55	7.10	8.51	8.51	8.14	9.70	0.67
Digested nitrogen	20.12	18.68	21.59	18.53	20.72	21.58	1.38
Urinary nitrogen excretion	8.47	8.15	11.83	8.80	7.18	10.13	1.18
Total nitrogen excretion	16.02	15.25	20.34	17.31	15.32	19.83	1.61
Nitrogen retention	11.65	10.53	9.76	9.73	13.54	11.45	1.09

Feeding fat had no significant effect on ruminal parameters (Table 13). Chalupa *et al*. (1986) found that calcium soaps did not alter the fermentation in the rumen because of its low insolubility in rumen. Increasing roughage level (P<0.05) increased ruminal pH, molar proportions of acetate and actate: propionate ratio but decreased molar proportions of propionate, iso butyrate and valerate. Ruminal VFA's concentrations, butyrate and iso butyrate, were not affected by roughage level. Lower pH and higher total VFA's concentrations, acetate, butyrate, iso butyrate, valerate and iso valerate were determined at 4 hrs post-feeding, but propionate and acetate: propionate ratio were not affected by sampling time (Table 13). El-Bedawy *et al*. (2004a) found that molar proportions of acetate; propionate; butyrate; iso- butyrate; valerate and iso-valerate were higher after feeding than those before feeding

There was no significant roughage x fat interaction on molar proportions of acetate and A: P ratio. However, the interactions on molar proportions of propionate; butyrate; iso- butyrate; valerate and iso- valerate were significant (Table 14). Zinn and Plascencia (1996) found that the interactions between forage and fat (F x R) on molar proportions of volatile fatty acids were not significant (P<0.10).

The mechanism of how lipids interfere ruminal fermentation is a complex model involving partitioning of lipid into microbial cell membrane, potency of the lipid to disrupt membrane and cellular function, physical attachment of microbial cells to plant surfaces expression and activity of microbial hydrolytic enzymes (Jenkins, 1993).

Increasing calcium soap level in sheep diet had no significant effect on nitrogen metabolism in the rumen (Table 15). These results are in agreement with those obtained by Doreau *et al*. (1993); Elliott *et al*. (1996); Belknap and Trenkle (1999) that calcium salts of fatty acids are inert in the rumen and does not alter rumen fermentation. Jenkins (1993) suggested that protein metabolism in the rumen is altered only when fat supplements interfere with fermentation. The decrease in ruminal ammonia nitrogen associated with feeding calcium soap containing rations could be related to the probable increase in ammonia nitrogen absorption by rumen epithelium as the ruminal pH was increased (Tamminga and Doreau, 1991).

Table 13. Main effects of dietary treatments on rumen fluid parameters of the experimental groups

Item	Calcium soaps, %			SEM	Roughage, %		SEM	Sampling time, hrs		SEM
	0	4	8		10	30		0	4	
pH	5.95	5.95	6.03	0.11	5.72^{b}	6.23^{a}	0.06	6.25^{a}	5.70^{b}	0.06
VFA's %	4.74	5.91	5.54	0.37	5.38	5.41	0.32	4.82^{b}	5.98^{a}	0.33
Acetate %	59.08	58.84	59.82	1.81	53.72^{b}	64.78^{a}	0.90	56.73^{b}	61.76^{a}	1.37
Propionate %	24.03	25.18	27.12	1.59	31.30^{a}	19.59^{b}	0.48	24.07	26.81	1.29
Butyrate %	11.67	11.35	10.67	0.41	11.12	11.34	0.34	9.99^{b}	12.47^{a}	0.23
Iso butyrate %	1.22	1.02	1.08	0.07	1.27^{a}	0.95^{b}	0.05	0.96^{b}	1.26^{a}	0.05
Valerate %	1.98	2.26	2.37	0.16	2.61^{a}	1.79^{b}	0.09	1.94^{b}	2.47^{a}	0.12
Iso valerate %	1.52	1.51	1.50	0.08	1.55	1.47	0.05	1.29^{b}	1.72^{a}	0.05
A:P ratio	2.45	2.33	2.20	0.21	1.73^{b}	3.32^{a}	0.05	2.35	2.47	1.17

^{a,b} Means within each treatment having different superscripts (P<0.05) differ

Table 14. Effect of feeding experimental rations on rumen fluid parameters of the experimental groups

Item		10% roughage diets			30% roughage diets			SEM
		0	4	8	0	4	8	
pH	0	6.06^{b}	6.08^{b}	6.17^{b}	6.35^{a}	6.36^{a}	6.45^{a}	0.05
	4hrs	5.32^{c}	5.31^{c}	5.36^{c}	6.05^{b}	6.07^{b}	6.12^{b}	
VFA's.%	0	4.38^{b}	5.45^{b}	4.73^{b}	4.48^{b}	5.45^{b}	4.43^{b}	0.58
	4hrs	4.50^{b}	7.65^{a}	5.60^{b}	5.60^{b}	5.08^{b}	7.43^{a}	
Acetate %	0	51.60^{e}	50.30^{e}	51.26^{e}	61.79^{abc}	62.77^{ab}	62.66^{ab}	1.91
	4hrs	56.36^{cde}	54.84^{de}	57.93^{bcd}	66.57^{a}	67.46^{a}	67.42^{a}	
Propionate%	0	27.96^{c}	29.34^{c}	32.27^{b}	17.75^{g}	18.35^{fg}	18.77^{efg}	0.66
	4hrs	30.13^{bc}	32.14^{b}	53.97^{a}	20.27^{def}	20.89^{de}	21.49^{d}	
Butyrate %	0	10.68^{c}	9.97^{c}	9.32^{c}	9.70^{c}	10.07^{c}	10.21^{c}	0.47
	4hrs	13.40^{a}	12.51^{a}	10.85^{bc}	12.92^{a}	12.87^{a}	12.30^{ab}	
IsoButyrate%	0	1.02^{c}	0.99^{cd}	0.95^{cde}	0.94^{cde}	0.84^{e}	1.03^{c}	0.04
	4hrs	1.98^{a}	1.40^{b}	1.28^{b}	0.96^{cde}	0.86^{de}	1.05^{c}	
Valerate %	0	1.96^{cd}	2.10^{bcd}	2.26^{bcd}	1.69^{d}	1.73^{d}	1.93^{cd}	0.11
	4hrs	2.48^{b}	3.44^{a}	3.46^{a}	1.82^{cd}	1.76^{d}	1.85^{cd}	
Isovalerate %		1.14^{d}	1.21^{d}	1.06^{d}	1.41^{c}	1.43^{c}	1.51^{c}	004
	4hrs	2.09^{a}	1.96^{ab}	1.68^{b}	1.44^{c}	1.46^{c}	1.56^{c}	
A:P ratio	0	1.85^{c}	1.71^{c}	1.59^{c}	3.48^{a}	3.42^{ab}	3.34^{ab}	0.09
	4hrs	1.87^{c}	1.71^{c}	1.61^{c}	3.28^{ab}	3.23^{ab}	3.14^{b}	

$^{a, b, c,d,e,f.g}$ Means in the same row having different superscripts (P<0.05) differ.

Increasing roughage level (P<0.05) decreased ruminal total nitrogen, non protein nitrogen, ammonia nitrogen and true protein nitrogen. Elliott *et al*. (1995); Bateman *et al*. (1996) and Zinn and Plascencia (1996) found that feeding high roughage rations insignificantly decreased (P>0.05) ruminal total nitrogen, ammonia nitrogen and true protein nitrogen. All forms of ruminal nitrogen were (P<0.05) lower at 4 hrs post feeding than those before feeding

Data of Table 16 showed that there were no interactions (p>0.05) between roughage level and supplemental fat (F x R) on ruminal total nitrogen; non-protein nitrogen; ammonia nitrogen and true protein nitrogen. These results are in agreement with those found by Zinn and Plascencia (1996) that there were no interactions (P>0.10) between forage level and supplemental fat (F x R) on ruminal nitrogen.

Table 15. Mean effects of dietary treatments on ruminal nitrogen fraction (mg/100ml) of the experimental groups

Item	Calcium soaps, %			SEM	Roughage, %		SEM	Sampling time, hrs		SEM
	0	4	8		10	30		0	4	
Total nitrogen	111	127	113	15	130^{a}	104^{b}	15	142^{a}	93^{b}	15
NPN	59	66	67	6	67	60	6	69^{a}	58^{b}	6
NH_3-N	30.8	35.0	34.4	2.5	36.7^{a}	30.1^{b}	1.9	39.6^{a}	27.2^{b}	1.6
True protein-N	53	62	46	11	63^{a}	44^{b}	11	73^{a}	35^{b}	11

[a,b] Means within each treatment having different superscripts (P<0.05) differ

Table 16. Ruminal nitrogen fraction (mg/100 ml) before and 4 hrs post feeding for different experimental groups

Item		10% roughage			30% roughage			SEM
		0	4	8	0	4	8	
Total nitrogen	0 hrs	136^{abc}	154^{ab}	162^{a}	129^{abc}	149^{ab}	121^{abc}	15
	4 hrs	97^{bcd}	127^{abcd}	110^{abcd}	86^{cde}	79de	60^{e}	
NPN	0 hrs	61.3^{abc}	71.3^{abc}	75.5^{ab}	62.3^{abc}	65.5^{abc}	80.0^{a}	6.4
	4 hrs	50.0^{c}	70.5^{abc}	76.0^{ab}	61.3^{abc}	54.8^{bc}	37.1^{c}	
NH_3-N	0 hrs	39.4^{a}	43.1^{a}	44.4^{a}	33.9^{abc}	37.9^{a}	38.7^{a}	2.9
	4 hrs	23.9^{cd}	36.2^{ab}	33.1^{abc}	26.0^{bcd}	22.9^{d}	21.4^{d}	
True protein –N	0 hrs	74.3^{abc}	82.5^{ab}	86.9^{a}	66.5^{abc}	83.5^{ab}	41.1^{abc}	11.0
	4 hrs	47^{bcd}	56.2^{abcd}	33.8^{abcd}	25.1^{cde}	23.7^{de}	22.9^{e}	

[a,b,c,d,e] Means in the same row having different superscripts (P<0.05) differ.

Increasing protected fat level to 4% or 8% of dietary ration dry matter (P<0.05) increased total lipids and (P>0.05) triglycerides in blood plasma. Total cholesterol was (P<0.05) higher for 8% fat group than the control and 4% fat group (Table 17). On the other hand, increasing roughage level (P<0.05) increased total plasma lipids and total cholesterol but had no significant effect on triglycerides. Total cholesterol (P<0.05), total lipids and triglycerides (P>0.05) were higher at 4 hrs post feeding than those before feeding (Table 17). The increase in plasma total lipids of fat supplemented groups may be attributed to greater quantity of fatty acids absorbed from fat supplemented diets through the gut (Jenkins *et al*., 1989) and/or the fact that feeding fat is associated with depression in lipogenic enzyme activities by liver and adipose tissues (Steele, 1980 and Storry, 1981). Moreover, feeding long - chain fatty acids induced shifting in the balance from active polymeric to inactive polymeric forms of acetyl Co- A carboxyl's in bovine adipose tissues (Bauman and Davis, 1975).

Table 17. Main effect of dietary treatments on blood plasma lipids (mg/100 ml) of the experimental groups

Item	Calcium soaps, %			SEM	Roughage, %		SEM	Sampling time, hrs		SEM
	0	4	8		10	30		0	4	
Total lipids	6.44^{b}	6.67^{a}	6.77^{a}	0.06	6.54^{b}	6.71^{a}	0.05	6.60	6.65	0.05
Triglycerides	89	94	100	5	94	95	4	89	99	4
Total cholesterol	110^{b}	114^{b}	141^{a}	8	110^{b}	133^{a}	7	107^{b}	137^{a}	7

^{a,b} Means within each treatment having different superscripts (P<0.05) differ.

No significant interaction was found between supplemental fat level and roughage level (F x R) on total lipids and triglycerides. However, there were significant interactions (F x R) on total cholesterol. Lambs fed high roughage- high fat diet showed the highest value of total lipids (6.88g /100 ml) and total cholesterol (205.2 mg/100 ml). Hill and West (1991) suggested many factors may influence plasma fatty acids concentrations including metabolism of other nutrients, level or composition of dietary fat, and production stage and type of production (meat or milk).

Table 18. Blood plasma lipids (mg/100ml) of the experimental groups

Item		10% roughage diets			30% roughage diets			SEM
		0	4	8	0	4	8	
Total lipids	0 hrs	6.35^{d}	6.55^{abcd}	6.64^{abcd}	6.46^{bcd}	6.73^{abc}	6.86^{a}	0.1
	4 hrs	6.40^{cd}	6.60^{abcd}	6.69^{abcd}	6.56^{abcd}	6.79^{ab}	6.88^{a}	
Triglycerides	0 hrs	105.4^{ab}	88.8^{abc}	90.7^{abc}	73.4^{c}	86.8^{abc}	89.0^{abc}	7.6
	4 hrs	78.4^{bc}	86.3^{abc}	112.3^{a}	97.0^{abc}	114.2^{a}	108.2^{ab}	
Total cholesterol	0 hrs	115.7^{bcd}	90.9^{d}	102.3^{cd}	84.2^{d}	107.9^{bcd}	137.9^{bc}	11.2
	4 hrs	119.9^{bcd}	111.3^{bcd}	118.2^{bcd}	118.9^{bcd}	145.3^{b}	205.2^{a}	

^{a,b,c,d,e} Means in the same row having different superscripts (P<0.05) differ.

Implications:

The effect of adding protected fat to fattening diets of lambs was limited, however, incorporation of 4% calcium soap improved feed utilization of the 30% roughage diet to be comparable to that containing 90% concentrate without adverse effects on rumen metabolism and blood plasma metabolites.

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تأثير مستوى الدهن المحمى و المادة الخشنة على الهضم و التمثيل الغذائى فى الكرش وليبيدات بلازما الدم فى الحملان النامية

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١قسم الإنتاج الحيوانى، كلية الزراعة، جامعة القاهرة، الجيزة، مصر، ٢قسم الإنتاج الحيوانى، المركز القومى للبحوث، الدقى، مصر

قسم ستون حملا من سلالة البرقى عمرها ٨ شهور و متوسط أوزانها ٢٧.٥ كجم عشوائيا إلى ست مجموعات متشابهة. غذيت الحملان بمعدل ٣.٥% من وزنها لمدة ٧٠ يوما على علائق متساوية البروتين و تحتوى على ١٠% أو ٣٠% دريس برسيم ومضاف إليها إما صفر% أو ٤% أو ٨% دهن محمى.

فى نهاية التجربة نفذت ٢٤ تجربة تمثيل غذائى لتقييم معاملات الهضم، و القيمة الغذائية للعلائق التجريبية و ميزان النتروجين وكمية ماء الشرب، كما أخذت عينات من سائل الكرش قبل و بعد أربع ساعات من التغذية، قدر فيها درجة الحموضة و الامونيا و تركيز الأحماض الدهنية الطيارة و نسبها و النتروجين الكلى و النتروجين غير البروتيني. وقدرت نسبة الليبيدات الكلية و الجلسريدات الثلاثية و الكوليسترول فى البلازما.

أوضحت النتائج أن إضافة الدهن المحمى بمستوى ٤% حسن معاملات الهضم معنويا و لم يؤد المستوى العالي من الدهن إلى مثل هذا التحسن. ولم تؤثر نسبة المادة الخشنة فى العليقة معنويا على معاملات الهضم فيما عدا مكونات الجدار الخلوي التى زاد معامل هضمها فى العلائق العالية فى المادة الخشنة.

زادت طاقة العليقة سواء طاقة مهضومة أو مجموع المركبات المهضومة بإضافة الدهن المحمى، بينما لم تتأثر نسبة البروتين الخام المهضوم بالمعاملات الغذائية.

حسنت إضافة صابون الكالسيوم من المأكول من الطاقة المهضومة أو مجموع المركبات المهضومة خاصة فى العلائق مرتفعة المادة الخشنة. كما زاد استهلاك الحيوانات من الماء عند تغذيتها على العلائق عالية الدهن و المادة الخشنة، بينما لم يتأثر ميزان النتروجين بالمعاملات الغذائية.

لم تؤثر اضافة الدهن على مقاييس التخمر فى الكرش بينما أدت زيادة المادة الخشنة إلى زيادة معنوية فى درجة الحموضة و نسبة الخلات و النسبة بين الخلات إلى البروبيونات و قللت من نسبة البروبيونات و الايزوبيوترات و الفاليرات و لم يتأثر التركيز الكلى للأحماض الطيارة و نسبة البيوترات و الأيزوفاليرات بالمعاملات الغذائية. وكانت درجة حموضة الكرش أقل و التركيز الكلى للأحماض الطيارة و نسبة الآسيات و البيوترات و الأيزوبيوترات والفاليرات والأيزوفاليرات أقل عند ٤ ساعات بعد التغذية عن قبل التغذية و لم تتأثر نسبة البروبيونات و النسبة بين الخلات إلى البروبيونات بوقت أخذ العينة.

لم تؤثر إضافة الدهن على تمثيل النتروجين فى الكرش بينما أدت زيادة نسبة المادة الخشنة الى انخفاض معنوى فى نسبة النتروجين الكلى ونسبة النتروجين غير البروتينى و نتروجين الامونيا و البروتين الحقيقى و لم تؤثر على نسبة النتروجين غير البروتينى فى الكرش.

أدت إضافة الدهن إلي زيادة معنوية فى الليبيدات الكلية و الجلسريدات الثلاثية فى بلازما الدم، بينما زاد الكوليسترول معنويا فقط عند تغذية العلائق المحتوية على ٨ % دهن. و أدت زيادة نسبة المادة الخشنة إلي زيادة معنوية فى الليبيدات الكلية و الكوليسترول بينما لم تتأثر نسبة الجلسريدات الثلاثية.

وكانت قيم الكوليسترول بعد ٤ ساعات من بدء التغذية أعلى بدرجة معنوية و الليبيدات الكلية الجلسريدات الثلاثية بدرجة غير معنوية عن نفس القيم قبل التغذية.

إضافة ٤% دهن محمى حسن الاستفادة الغذائية للعلائق المحتوية على نسبة عالية من المادة الخشنة (٣٠% دريس) و قربها من العلائق عالية المركزات (١٠% دريس) دون تأثير مغاير على التمثيل الغذائى فى الكرش أو نواتج التمثيل الغذائى لليبدات فى بلازما الدم، و المستوى العالى من الدهن المحمى (٨%) لم يعط نتائج أفضل من هذا المستوى.