The Utilization of Rumen Content-Barley Meal in Diets of Growing Lambs[a]

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ABSTRACT : The nutritive value of rumen contents and barley mixture (4:1 w/w; RCB) was evaluated and the effect of their feeding on growth performances in Najdi lambs was studied. A metabolism trial was conducted with 16 rams divided into four dietary groups. The diets were: a whole-mixed control diet and three diets where RCB was incorporated at the rates of 25, 50 and 100%, replacing an equal amount of control diet. The results showed that there was a depression ($p<0.05$) in DM digestibility for the 100% RCB diet in comparison with other diets. The digestibility of CP was higher ($p<0.05$) for the 25% RCB diet as compared to the control diet; there was a trend for a small ($p>0.05$) decrease in digestibility as level of RCB increased. Lambs in all studied diets were in positive nitrogen balance; the differences between diets were not significant. A total of 45 lambs were allotted into three groups and used to evaluate the effect of dietary inclusion of RCB (0, 25 and 50%) on growth performance and carcass traits. Daily DM intake, final body weight, carcass weight and dressing percentage were not different among treatments. Average weight gain and ether extract (EE) in 9-11th rib joint were higher ($p<0.05$) in lambs fed control diet than those fed RCB diets. The substitution of RCB for 50% of control diet exhibited 11.8% reduction in feeding cost for each kg of body weight gain. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 8 : 1234-1240*)

Key Words : Lambs, Rumen Contents, Digestibility, Growth Performance

INTRODUCTION

Rumen contents are abundantly available as slaughterhouse by-product and mainly considered as a waste material creating environmental pollution. With appropriate processing and proper use, rumen contents could provide a valuable source of nutrients when included in diets for various classes of livestock. Previous studies have generally indicated that dry rumen contents contained substantial amounts of CP and utilizable energy for ruminants (Messersmith et al., 1974; Prokop et al., 1974; Reddy and Reddy, 1980; Ghosh and Dey, 1993). In practice, the high moisture of the total rumen contents as collected at the slaughterhouse is still regarded as one of the obstacles that require an appropriate solution. Goodrich and Meiske (1969) used a forced air oven to dry rumen contents and found that beside its high economical costs, drying temperature had adversely affected the feeding value of the crude protein component. Sun drying is an excellent approach for tackling this problem (Abdelmawla, 1990; Khattab et al., 1996). Jovanovic and Cuperlovic (1977) mixed total rumen contents with maize meal as an organic carrier before sun drying, and found that the water content of the mixture was reduced and drying time considerably shortened. Such practice, if successful, could increase the nutritive value of rumen contents and improve its palatability.

This work was designed to determine the feasibility of mixing barley grain with total rumen contents before sun drying as a method of preparing rumen content-barley meal (RCB) for feeding to lambs. Nutritional effects of diets containing various proportions of RCB were determined in Najdi ram lambs.

MATERIALS AND METHODS

Preparation of rumen content-barley meal

Total rumen contents comprising a mixture of solid and liquid were collected over 90 consecutive days from 50 each of freshly slaughtered camels, cattle and sheep from the Riyadh slaughterhouses, weighed and sterilized with commercial formaldehyde solution at the rate of 0.3 ml/kg rumen contents. A representative sample from each rumen content of about 0.5 kg was taken, dried in a current of air at 60℃ to moisture content of about 8 to 10%, and ground for chemical analysis. When prepared for composting RCB, crushed barley grain as an organic carrier was added to ovine rumen contents in the proportion of 1:4 (w/w), mixed thoroughly for 30 min in plastic drums and sun dried in a 5 cm layer depth. The moisture content of the resulting mixture was thereby reduced and hence the sun drying time considerably shortened. Sun drying, besides reducing moisture, also is a sterilizing process (Abdelmawla, 1990). During this period, the RCB mixture was turned upside down and well mixed 2 to 3 times a day for 3 days till a 10% moisture content

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was attained. The resulting RCB was ground through a 4.76 mm screen to give RCB containing about 40% dry rumen contents; thereafter, RCB was stored in woven plastic bags.

Digestibility and nitrogen balance study

A metabolism trial was conducted with 16 rams averaging 43.3 kg body weight to determine the digestibility coefficient, the nutritive values and the nitrogen balance of the experimental diets. Rams were equally allotted to four groups and fed *ad libitum* one of the four experimental whole mixed diets. The diets were: a control diet and three diets where RCB was incorporated at the rates of 25, 50 and 100%, replacing an equal amount of the control diet; all four diets were isonitrogenous (table 2). Rams were individually confined in false-bottom metabolic crates to facilitate separate collection of total feces and urine. After a 5 day transition period, during which the experimental diets were gradually introduced, a trial consisting of a 14 day preliminary period followed by a 7 day collection period was conducted. Weights of feed offered and refused were recorded daily, sampled, ground to pass through a 1 mm screen and stored. Feces voided were collected before feeding in the morning, weighed and a 10% aliquot of total feces was dried at 65℃ for 24 hr. The dried samples were ground through a 1-mm screen and stored for later analyses. Total daily urine outputs of each ram was collected in a plastic bucket containing 100 ml 6N HCl to prevent nitrogen losses, recorded and a 10% aliquot was sampled; at the end of collection period, samples of urine of each ram were mixed for nitrogen determination.

Feeding trial

A total of 45 Najdi ram lambs, weighing an average of 29.2 kg, were used to evaluate the effect of dietary inclusion of RCB on the growth performance and carcass characteristics. Lambs were randomly allotted to three dietary treatment groups with 15 lambs per treatment. Lambs of each treatment were equally divided into three replicates; each replicate group was housed in a separate pen. The dietary treatments were: a whole mixed control diet and two diets where RCB meal was incorporated at the rates of 25 and 50%, replacing an equal amount of the whole mixed control diet; all three diets were isonitrogenous (table 2). Ingredients of each diet were then ground through a 4.76 mm screen, mixed thoroughly in a stainless steel vertical mixer in batches of 200 kg to ensure uniformity.

A preliminary feeding period of a 15 day was allowed to accustom the lambs to new surrounding and the designated new diet. An adequate amount of feed was weighed at the beginning of each week into a plastic container for each replicate. From these, a sufficient amount of feed was offered three times daily and adjusted as needed to minimize refusals; remaining refusals of each time were remixed into the fresh diet that was offered next time. Refusals were removed at the end of each week, weighed, sampled for DM determination and then discarded. Throughout the experiment, lamb weight and feed consumption data were weekly recorded.

Lambs were slaughtered after 10 weeks of feeding. Slaughtering was carried at the King Saud University's abattoir after 18 h shrink without feed. At slaughter, the live body weight and warm carcass weight were recorded. Then, the 9-11th rib joint was separated from the right side of each carcass and physically separated into bone and soft tissues. The soft tissues were ground through a 4 mm plate, mixed and reground again. During the second grinding, 5 subsamples 10-12 g were taken from each carcass to obtain a 50-60 g sample that was placed in a plastic bag, frozen and stored at 20℃ pending of chemical analysis.

Chemical and statistical analysis

Samples of rumen contents, barley, experimental feeds, feces, urine and ground soft tissues were analyzed for moisture, ash, ether extract and crude protein according to AOAC (1990). NDF and ADF were determined according to Goering and Van Soest (1970). Chemical compositions, digestibility, growth performance and carcass characteristics data were statistically analyzed by ANOVA using GLM procedures (SAS, 1988) according to the following model:

$$Y_{ij} = U + RCB_i + e_{ij},$$

Where Y_{ij} is the j^{th} replicate mean of the i^{th} RCB inclusion level, U is the common mean, RCBi is the effect of the i^{th} RCB inclusion level, and e_{ij} is the random error. Duncan's multiple range test was used to test for significant differences among means.

RESULTS AND DISCUSSION

Chemical composition

The chemical composition of fresh-collected rumen contents from camels, cattle and sheep are presented in table 1. The DM content ranged from 11.2 to 18.4% in camels, 12.9 to 18.5% in cattle and 14.3 to 19.1% in sheep. There were not much differences in CP of the dried rumen contents within each studied animal; those values ranged from 8.2 to 11.6% in camels, 13.3 to 16.4% in cattle and 13.8 to 16.3% in sheep. Marked variations were found in EE, ADF and NDF contents in all animals. These findings indicated

Table 1. Chemical composition of rumen contents from different species of animals (DM basis, %)

	Animal species						SEM
	Camel	CV%	Cattle	CV%	Sheep	CV%	
Fresh rumen contents, kg	24.1[a]	11.7	18.7[b]	14.6	4.0[c]	11.3	0.75
DM	13.1[b]	8.6	13.6[b]	11.6	16.1[a]	7.0	0.44
CP	11.0[c]	8.2	14.2[b]	9.5	15.0[a]	8.4	0.26
EE	0.9[c]	50.0	1.7[b]	27.0	2.1[a]	22.5	0.09
NDF	65.3[a]	18.7	59.2[b]	27.8	51.6[c]	15.2	0.44
ADF	39.9[a]	22.3	36.7[b]	23.4	31.9[c]	16.8	0.38
Ash	9.2[b]	13.3	11.6[a]	19.5	9.2[b]	10.4	0.32

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

Table 2. Ingredients and chemical composition of experimental diets (DM basis, %)

Item	Barley	RCR in the diet, %[a]			
		0	25	50	100
Ingredient, %					
Alfalfa		3.90	29.2	19.4	
RCB			24.9	49.6	99.0
BArley	100	57.8	43.3	28.9	
Soybean meal		2.2	1.6	1.1	
Mineral premix[b]		0.5	0.5	0.5	0.5
Dicalcium phosphate		0.5	0.5	0.5	0.5
Vitamin A, D, E[c]		+	+	+	+
Chemical composition					
CP	10.90	14.13	14.11	14.11	14.12
EE	1.72	2.03	1.98	1.93	1.85
NDF	25.19	32.74	33.57	34.38	36.45
ADF	6.83	17.80	19.29	20.74	23.96
Lignin	5.91	4.61	5.63	6.55	8.51
Ash	2.54	5.17	5.46	5.75	6.41

[a] RCB= rumen content-barley meal.

[b] Composition per kg of trace mineral salt: $CoSO_4$, 0.68g; $CuSO_4$, 10.4g; $FeSO_4$, 35.7g; ZnO, 7.5g; $MnSO_4$, 10.7g; KI, 0.52g; and NaCl, 934.5g.

[c] Vitamin A, D and E were added to supply 2178, 403 and 22 IU, respectively per kg of diet.

that the composition of rumen contents were quite variable between species and probably influenced by the pre-slaughtered feeding regimen and the length of the holding period between feeding and slaughter. Sommer (1990) studied the influence of the season of the year and the type of feed on the nutritive value of rumen contents and reported that, except for CP, there were no significant seasonal differences in other nutrients; CP was found to be 10.9% in the summer and 12.8% in the winter. Jovanovic and Cuperlovic (1977), Reddy and Reddy (1980) and Khattab et al. (1996) also reported similar results. In general, our data showed that the rumen contents from sheep had the least variations in all proximate compositions compared to camels and cattle.

The average amounts of fresh rumen contents available from camels, cattle and sheep were 24.1, 18.7 and 4.0 kg, respectively. Therefore, about 590 and 84 tons of DM and CP, respectively, are available from the rumen contents of an average of 35716 camels, 9718 cattle and 697270 sheep slaughtered annually in the local slaughterhouses of Riyadh city during the past seven years (Ministry of Municipal and Rural Affair, personal communication). Also, it is obvious that dried rumen contents from sheep accounts over 75% of the total DM produced. The percent DM, CP and EE values were higher ($p<0.05$) in sheep than either camels or cattle, whereas NDF and ADF values were the least ($p<0.05$) in the rumen contents of sheep. This variation was probably a reflection of the differences between various animal species. Similar findings were also recorded by Czerkawski (1976) and

Ghosh and Dey (1993). Generally, the chemical composition of rumen contents was comparable with those values reported for various animals (Reddy and Reddy, 1980; Patra and Ghosh, 1991).

The proximate composition data would indicate that CP content of sheep rumen contents is comparable to the commonly used fodder like alfalfa hay and rhodesgrass hay and appears to be far superior to the commonly used residues in Saudi Arabia like wheat straw. Sommer (1990) found that dried rumen contents have a feeding value equivalent to oats. Also, Kozel (1977) reported that dried rumen contents contained 12.2% CP, 28.7% CF and 33.1% NFE and those values were comparable to the contents of quality meadow hay. The addition of barley grain as an organic carrier to the rumen contents resulted in lower EE, NDF, ADF and ash contents than in rumen contents alone. Accordingly, the proximate components of RCB (table 2) are comparable to many formulated rations prepared for sheep production (SID, 1988). The chemical compositions of the experimental diets are shown in table 2. It appears from the table that CP and EE were similar in all the dietary groups, whereas NDF, ADF, lignin and ash contents gradually increased with the inclusion of increased level of RCB in the diet.

Digestibility and nutritive value

The apparent digestibility and nutritive value of different diets are given in table 3. The digestion coefficient of DM was 73.5% for the control diet containing no RCB. When 25 and 50% of the control diet were replaced by RCB, there were no significant changes. When 100% of the diet was supplied by RCB, there was a significant depression ($p<0.05$) in DM digestibility to 63.8%. This result was probably due to the increased ADF and lignin contents of the diet. Antongiovanni et al. (1973) found that the digestibility of DM was negatively correlated with ADF content in the ration. Also, Patra and Ghosh (1991) offered dried rumen contents to growing kids at 0, 25, 50 and 100% in replacing paragrass and found that DM digestibilities in 25 and 50% diets did not differ, but were higher ($p<0.01$) than in 100% RCB diet group. The significant 28.7% depression ($p<0.05$) in ADF digestibility in the 100% RCB diet in comparison with the control diet was probably due to the high lignin content, since the RCB contained 8.6% lignin. The digestibility of CP was higher ($p<0.05$) for the 25% RCB diet compared to the control diet; however, among the RCB-containing diets there was a trend for small insignificant decrease in digestibility as the level of RCB increased. Similar results were reported by Khattab et al. (1996) who showed that 25 and 50% rumen content-supplemented diets exhibited higher CP digestibility over the control diet. They speculated that the noticeable improvement in the digestibility of the rations containing rumen contents may probably be related to the considerable amounts of semidigested material and/or to unknown factors that enhanced rumen microorganisms. In that connection, several reports indicated that the biological value of microbial protein from the rumen contents was found to be high (Weller, 1957; Abdo et al., 1964; Bergen et al., 1968). Abdo et al. (1964) also emphasized the high concentrations of B-vitamins in the rumen contents.

Digestible CP content was significantly ($p<0.05$) higher in 25% RCB diet than in control diet; no difference in DCP value was observed between the other studied diets. This result was in accordance with the findings reported by Khan et al. (1998) who found

Table 3. Mean apparent digestibility coefficients of various nutrients by lambs fed diets containing graded levels of RCB

Item	RCB in the diet, %[a]				SEM
	0	25	50	100	
DM	73.54[b]	73.34[b]	70.89[b]	63.84[c]	2.10
CP	63.37[c]	70.11[b]	67.80[bc]	65.56[bc]	2.18
EE	71.83	67.03	64.68	64.40	4.09
NFE	83.06[b]	82.21[b]	80.82[b]	75.97[c]	1.81
ADF	43.61[b]	39.98[b]	35.39[c]	31.09[c]	2.68
NDF	62.40[b]	52.70[c]	54.83[c]	56.69[c]	3.37
Nutritive value, %					
DCP	8.16[c]	10.53[b]	9.87[bc]	9.33[bc]	0.47
TDN	71.76[b]	70.74[b]	71.19[b]	64.35[c]	2.15

[a]RCB= rumen content-barley meal.

[b,c]Means in the same row bearing different superscripts differ ($p<0.05$).

that increased CP digestibility resulted in higher DCP content in the diet. Total digestible nutrients (TDN) concentration was significantly ($p<0.05$) lower in 100% diet than other diets. High lignin content in RCB may have affected nutrient digestibility that ultimately resulted in lowering TDN value in 100% RCB diet.

Nitrogen balance

Nitrogen utilization data are presented in table 4. Nitrogen intake was significantly ($p<0.05$) lower for the 100 % RCB diet than for those fed other diets. This was attributed to a lower ($p<0.05$) DM intake in this group. The decrease in DM intake with the 100% RCB diet might be attributed to the corresponding decrease in DM digestibility which is in agreement with the previous findings by Aderibigbe and Church (1980). The fecal and urinary nitrogen excretions in all the dietary groups were not significantly different. The lambs in all groups were in positive nitrogen balance. Although nitrogen retention was higher in animals fed diets containing graded levels of RCB than those fed the diet containing no RCB, the differences were not significant. Khattab et al. (1996) also found that nitrogen retention in sheep fed rations containing dried rumen contents at 25 and 50% of the diets were significantly ($p<0.05$) higher than the control diet.

Feeding performance

All but two of the lambs remained in good health and no digestive disturbance or feed rejection were observed throughout the feeding trial. One lamb, in the 50% RCB-diet group, accidentally broke a leg in the 1st week and was removed from the trial. Another lamb in the same dietary group showed signs of urolithiasis in the 5th week and was also removed from the trial. Comparable lambs for replacement were

Table 4. Nitrogen utilization by lambs fed diets containing graded levels of RCB

Item	RCB in the diet, %[a]				SEM
	0	25	50	100	
No. of lambs	4	4	4	4	
Body weight, kg	45.6	44.3	44.1	45.6	0.42
DM intake, kg	1.48[b]	1.51[b]	1.49[b]	1.41[c]	0.02
Nitrogen intake, g/d	33.44[b]	34.05[b]	33.73[b]	31.81[c]	0.52
Nitrogen excretion, g/d					
Fecal	11.16	10.83	11.20	9.51	1.12
Urinary	9.62	8.74	8.43	8.48	2.05
Nitrogen retention:					
g/d	12.66	14.48	14.10	13.82	1.54
% of N intake	37.9[c]	42.5[b]	41.8[b]	43.4[b]	1.83

[a] RCB= rumen content-barley meal.
[b,c] Means in the same row bearing different superscripts differ ($p<0.05$).

Table 5. Feeding performance of growing lambs fed diets containing graded levels of RCB

Parameters	RCB in the diet, %[a]			SEM
	0	25	50	
No. of lambs	15	15	13	
Initial body weight, kg	29.14	29.15	29.22	0.328
Final body weight, kg	45.04	43.65	43.53	0.605
DM intake, kg/d	1.35	1.39	1.38	0.032
DM intake, kg/ 100 kg body wt.	3.64	3.82	3.79	0.110
Daily weight gain, g	227[c]	207[cd]	204[d]	6.808
Kg DM/ kg gain	5.93[c]	6.74[d]	6.76[d]	0.193
Feed cost, SR/head/d[b]	0.79	0.72	0.62	
Feed cost, SR/kg gain	3.47	3.49	3.06	

[a] RCB= rumen content-barley meal.
[b] 1 US dollar= 3.76 SR.
[c,d] Means in the same row bearing different superscripts differ ($p<0.05$).

not available. Similar results were reported by Tucker et al. (1956) who found that feeding dried rumen contents did not show any evidence of pathological effects in lambs. Also, Jovanovic and Cuperlovic (1977) and Khattab et al. (1996) clearly indicated that the inclusion of rumen contents in the rations of ruminants produced no palatability problems. Feeding performance data are presented in table 5. Final live body weight was not different ($p>0.05$) among treatments. The daily DM intake of all the animals was above 3.6 kg per 100 kg live weight. Average daily DM intakes were higher in lambs fed RCB diets than those fed control diet, but the differences ($p>0.05$) were not significant. In accordance, Tucker et al. (1956), Kamstra et al. (1959), Patra and Ghosh (1991), Ghosh and Dey (1993) and Bikash and Ghosh (1994) reported that daily feed consumption in growing sheep or goats did not statistically differ between the control group and those fed complete feed mixture and rumen contents in different ratios. Total average live weight gains in 70 days feeding trial were 15.9, 14.5 and 14.3 kg for those lambs fed on diets containing 0, 25 and 50% RCB, respectively. However, average daily weight gain was higher ($p<0.05$) in lambs fed the control diet than for those fed the RCB diets. El-Deek et al. (1984) showed that rabbits that were fed on diets containing dried rumen contents tended to gain weight slower than control animals. On the other hand, Khattab et al. (1996) found that DM intake and daily body weight gain in lambs fed on 25 and 50% rumen content-supplemented diets were higher than in control group. The DM requirement per kg live weight gain increased ($p<0.05$) with the replacement of increasing levels of control diet by RCB. This indicated that lambs fed on control diet converted DM more efficiently than those given RCB diets.

Feed cost calculations were based on local feed costs as of November 1998. RCB price used for these calculations was 290 SR/ton DM. Costs were 585, 518 and 451 SR per ton DM for diets containing 0, 25 and 50% RCB, respectively. This clearly indicated that the cost decreased as the RCB increased in diet formula. The 50% RCB diet had the lowest feeding cost for feeding a lamb and per kg of live body weight gain. However, adding RCB to replace one-half the ingredients in control diet saved 0.41 SR for each kg of body weight gain indicating the overall economy of utilizing RCB. In other words, feeding the lambs with 50% RCB-diet instead of the control diet saved 43 and 46% of the alfalfa hay and soybean meal needed for the production of each kg of body weight gain, respectively.

The effects of feeding RCB on the carcass characteristics are presented in table 6. The hot carcass weight and dressing percentage of lambs fed with increasing levels of RCB did not differ, but the weight of kidneys and pelvic fat decreased ($p<0.05$) with the increasing level of RCB in the diet. The inclusion of RCB in the diets did not alter the percentage of protein and ash in the soft tissue of the physically separated 9-11th rib joint, while the percentage of ether extract exhibited a significant ($p<0.05$) decrease with the increasing level of RCB in the diet. Accordingly, the percentage of moisture showed a significant increase ($p<0.05$) as the RCB increased in the diet.

On the basis of feeding studies, it appears that the addition of barley to rumen contents at 3:2 ratio (DM basis) in order to composite RCB may be a feasible

Table 6. Carcass characteristics of lambs fed diets containing graded levels of RCB

Parameters	RCB in the diet, %[a]			SEM
	0	25	50	
Hot carcass weight, kg	23.50	22.88	22.40	0.481
Dressing, %	52.15	52.41	52.08	0.760
Kidneys and pelvic fat, kg	0.92[d]	0.83[de]	0.64[e]	0.082
Soft tissue: boneb	3.12	3.60	3.45	0.214
Chemical composition:c				
Moisture, %	52.44[d]	54.76[de]	57.98[e]	1.874
Protein, %	13.70	14.59	14.38	0.332
Ether extract, %	33.16[d]	29.92[de]	26.89[e]	2.097
Ash, %	0.70	0.73	0.75	0.022

[a] RCB= rumen content-barley meal.

[b] Determined by the physical separation of 9- 11th rib joint.

[c] Chemical analyses of the separated soft tissue of 9- 11th rib joint.

[d,e] Means in the same row bearing different superscripts differ ($p<0.05$).

mean of converting and utilizing ruminal liquor and solid wastes into a palatable and nutritious feed for growing lambs. The substitution of RCB for 50% of the control diet exhibited an overall improvement in the economy of lamb production, where 11.8% reduction in feeding costs was attained for each kilogram of body weight gain. In addition, this method of disposing of ruminal waste provides means of safeguarding the environmental health and stretching feed supplies for ruminant production.

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