

Relative Performance of Fattening Lambs on Raw and Processed Cottonseed Meal Incorporated Diets

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ABSTRACT : In order to find the feasibility of feeding raw or processed cotton (*Gossypium*) seed meal (CSM), 30 male crossbred lambs were randomly assigned to 5 dietary treatments with 6 animals each. Lambs were fed each of the isonitrogenous and isocaloric concentrate mixtures containing 30% deoiled groundnut cake (DGNC) (reference diet), 40% raw, 45 minute cooked, 1% Ca(OH)₂ or iron (1 part free gossypol:0.3 parts iron) treated CSM (replacing about 50% nitrogen moiety of reference concentrate mixture). The concentrate mixture was fed to meet 80% of CP requirements (NRC, 1985) along with *ad libitum* maize (*Zea mays*) hay for 180 days. Incorporation of raw or processed CSM did not affect the palatability of diets as evidenced by higher ($p < 0.01$) or comparable overall daily intakes of DM and protein (CP and Digestible CP) per kg $W^{0.75}$ by lambs in comparison to reference group. Intakes of DE and ME increased ($p < 0.01$) due to inclusion Ca(OH)₂ treated CSM in diets, while the intakes were lower ($p < 0.01$) on iron treated CSM based diet when compared with reference diet. The intakes of DM, CP, TDN, DE and ME by reference and experimental lambs were higher than the requirements stipulated by NRC (1985). The growth rate was highest ($p < 0.01$) in lambs fed on diets with cooked CSM followed by those fed raw or Ca(OH)₂ treated CSM based diets. The growth of lambs fed on iron treated CSM diets was depressed ($p < 0.01$) in comparison to that of other experimental lambs probably due to increased iron intake (889 mg/kg DM of diet) which was much higher than the toxic levels of 500 ppm (NRC, 1980). The lambs on various diets utilized DM with similar efficiency while the utilization of energy (TDN, DE and ME) was more efficient ($p < 0.01$) when the diets contained raw or cooked CSM in comparison to that of reference diet. The lambs fed raw and Ca(OH)₂ treated CSM incorporated diets utilized DCP with higher ($p < 0.01$) efficiency than the lambs fed reference diet. The feed cost per kg weight gain was lower ($p < 0.01$) on raw, cooked and Ca(OH)₂ treated CSM based diets in comparison to reference diet. Cooking of CSM for 45 minutes further reduced the feed cost of weight gain. (*Asian-Aust. J. Anim. Sci.* 2003, Vol 16, No. 1 : 29-35)

Key Words : Cottonseed Meal, Groundnut Cake, Gossypol, Lambs, Feeding Value

INTRODUCTION

The chronic shortage and escalating prices of conventional feedstuffs in developing countries, like India, drew the attention of Animal Nutritionists to search for alternative unconventional agro-industrial by-products, which are unsuitable for human consumption. Cotton (*Gossypium*) seed meal (CSM) is one such by-product of cotton oil industry with an estimated availability of 4,300 × 10³ t in India. India ranks third in the world regarding cottonseed production with an annual production of 5,430 × 10³ t (FAO, 1997). The huge quantities of CSM are therefore available as a renewable resource for livestock feeding. But its feeding has resulted in growth depression and mortality in calves (Rogers et al., 1975), lambs (Danke et al., 1965; Calhoun et al., 1990) and occasionally in mature ruminants (Huston et al., 1990) due to the presence of gossypol, a toxic polyphenolic compound in CSM.

Many workers (Rahma and Narsinga, 1984; Shah et al., 1986; Reid et al., 1987) tried solvents like acetone, acidic

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butanol, aniline, hexane, isopropanol to minimize the free gossypol (FG) in CSM. These solvents were effective in FG content reduction, but these solvents were costly and the recovery of solvent after extraction is difficult. Physical processing methods like water soaking (Shah et al., 1986), autoclaving (Baliga and Lyman, 1957) and pressure cooking (Nagalakshmi, 1997) were though effective in gossypol reduction the former resulted in loss of protein while latter two methods were not economically feasible. Jarquin et al. (1966) observed a 44% reduction of FG content in CSM when it was cooked for 10 min. in boiling water. Treatment of CSM with 1.0% Ca(OH)₂ (Shah et al., 1986) or addition of 0.5% Ca(OH)₂ to 42% CSM containing diets (Braham et al., 1967) reduced the FG content by 54% and 25%, respectively. Addition of 1, 1 to 2 and 4 parts of iron for each part of FG in the diets was found effective in alleviating the suppressing effect in swine (Tanksley and Knabe, 1981) and in broilers and layers (Waldroup, 1981) due to formation of ferrous gossypol chelate, passing the digestive tract intact. Taking into consideration the practical feasibility and economics of processing methods, cooking, Ca(OH)₂ and iron treatments were the three processing methods selected for reducing the FG content of the CSM. The present investigations were undertaken to compare the performance of fattening lambs fed on diets containing raw and processed CSM.

MATERIALS AND METHODS

Processing of CSM

The CSM used in the present study contained 28.74% CP, 26.94% crude fibre, 0.57% total gossypol (TG) and 0.27% FG (Table 1). Cooked CSM was obtained after cooking the meal for 45 minutes in boiling water (100°C) in the ratio of 1:1.5 (w/v). The Ca(OH)₂ treated CSM was prepared by soaking the meal for 24 h in water (w/v, 1:1) containing Ca (OH)₂ @ 1% (w/w of meal). The iron treated CSM was prepared by soaking the meal in water (1:1, w/v) in which calculated amount of FeSO₄ 7H₂O was dissolved for 30 minutes so as to contain 0.3 parts of iron for each part of FG present in CSM. These variously processed meals were then Sun dried and ground.

Feeds

Five isonitrogenous and isocaloric concentrate mixtures (Table 2) basing on analysed chemical composition of ingredients were formulated. The concentrate mixture of reference diet contained 30% of deoiled groundnut cake (DGNC) while the rest four mixtures of experimental diets contained 40% of either raw, cooked, Ca(OH)₂ treated or iron treated CSM to replace approximately 50% nitrogen moiety of the reference concentrate mixture.

Animals, housing and feeding management

Thirty healthy, 3-4 months old male lambs were distributed on basis of body weight to five groups of six lambs each in a completely randomised design. Animals were housed in well-ventilated cement floored barns each provided with individual feeder and waterer. They were vaccinated against *Peste de petis*, sheep pox and haemorrhagic septicaemia. Lambs were dewormed and drenched with antihelmintic at monthly intervals. The respective concentrate mixtures (Table 2) were offered daily between 8:30 and 9:00 h, in amounts to meet 80% of the total protein requirements (NRC, 1985). Maize (*Zea mays*) hay was fed for *ad libitum* consumption in afternoon. The

quantity of concentrates to be offered daily was adjusted for body weights and an average daily gain of 100g recorded at every fortnightly (15 days) interval throughout 180 days of experimental period. Clean and fresh drinking water was provided *ad libitum*.

Feed consumption

Each lamb was daily offered weighed quantities of respective concentrate mixture and *ad libitum* maize hay. The residues were weighed every day before offering concentrate to find out daily feed intake.

Body weights and feed efficiency

All lambs were weighed individually at every fortnight interval before feeding and watering for two consecutive days in the morning to assess body weight changes and the growth rate. Efficiency of nutrient utilization was calculated as unit intake per unit gain.

Analytical procedure

The TG and FG content of raw and processed CSM were estimated as per the procedure described by Botsoglou and Kufidis (1990) and Botsoglou (1991), respectively. The feed ingredients and composite diets were analysed for proximate constituents (AOAC, 1990), calcium (Talapatra et al., 1940), phosphorus (Ward and Johnston, 1962), fibre fractions (Van Soest et al., 1991) and gross energy as per the procedure described in the manual of Gallenkamp Automatic Ballistic Bomb calorimeter. The values for digestibility of the nutrients and energy content of the rations to calculate the nutrient intakes and its efficiency of utilization were taken from the values reported by Nagalakshmi (1997).

Cost benefit analysis

Feed cost for unit liveweight gain (FCWG) of lambs under each treatment was calculated using the ingredient and processing costs prevailing at the time of experimentation. The total feed cost was obtained by

Table 1. Chemical composition of DGNC, maize hay, raw and processed CSM (percent in DM)

Ingredient	Cottonseed meal				DGNC	Maize hay
	Raw	Cooked	Ca(OH) ₂ treated	Iron treated		
Crude protein	28.74	31.66	28.34	29.74	45.22	7.57
Ether extract	2.05	1.71	2.01	2.12	1.45	1.26
Crude fibre	26.94	29.84	29.65	26.00	10.02	28.10
Nitrogen free extract	37.01	31.50	32.29	36.69	38.22	53.03
Total ash	5.26	5.83	6.71	5.45	5.09	10.04
Iron	0.019	0.059	0.027	0.079	-	0.070
Neutral detergent fibre	48.93	53.03	52.83	49.54	-	62.78
Acid detergent fibre	33.34	36.04	38.02	34.33	-	33.76
Cellulose	26.41	27.89	28.61	26.40	-	29.64
Total gossypol	0.57	0.53	0.64	0.54	-	-
Free gossypol	0.27	0.16	0.20	0.21	-	-

Table 2. Ingredient and chemical composition (%) of concentrate mixtures

Attribute	Reference	Cottonseed meal			
		Raw	Cooked	Ca(OH) ₂ treated	Iron treated
Maize	30.00	30.00	34.00	34.00	32.00
Deoiled GNC	30.00	15.00	15.50	14.00	15.50
Raw CSM	-	40.00	-	-	-
Cooked CSM	-	-	40.00	-	-
Calcium hydroxide CSM	-	-	-	40.00	-
Iron treated CSM	-	-	-	-	40.00
Wheat bran	37.00	12.00	7.50	9.00	9.50
Mineral mixture	2.00	2.00	2.00	2.00	2.00
Common salt	1.00	1.00	1.00	1.00	1.00
Chemical composition (% DM)					
Organic matter	92.33	92.48	92.38	91.71	93.25
Crude protein	22.66	23.60	23.29	22.06	23.74
Ether extract	2.18	1.64	1.99	1.26	1.55
Nitrogen free extract	60.86	53.47	53.22	56.59	53.12
Total carbohydrates	67.49	67.24	67.10	68.39	66.96
Calcium	0.78	1.14	1.01	1.29	1.11
Phosphorus	0.76	0.72	0.87	0.78	0.71
Iron	0.088	0.054	0.054	0.055	0.106
Neutral detergent fibre	32.07	49.36	42.43	44.71	42.96
Acid detergent fibre	10.58	26.55	19.90	22.64	18.69
Cellulose	7.84	20.19	16.60	17.09	14.64
Gross energy (kcal/g)	4.73	4.66	4.63	4.50	4.73
TDN ^a	65.70	65.58	65.63	65.71	65.70

Added 6 g Vitablend AD₃/100 kg concentrate mixture containing vitamin A 50,000 I.U and D₃ 5,000 I.U per each gram.

^a Calculated values (% in air dry basis).

summing up the cost of concentrate and hay quantitatively consumed throughout the feeding trial. Feed cost of live weight gain was arrived by dividing total feed cost (Rs) with total live weight gain (kg).

Statistical analysis

The data were subjected to the test of significance using completely randomised design as per Snedecor and Cochran (1980). The means were compared using Duncan's multiple range test (Duncan, 1955).

RESULTS

The chemical composition, fibre fractions and gossypol content of CSM before and after processing by various methods are presented in Table 1. The CP content of raw CSM was 28.74% and in DGNC it was 45.22%. The CP content of raw and most of the processed CSM was

almost half that of the DGNC. The concentration of rest of the nutrients including fibre fractions among DGNC and CSM varied closely. Raw CSM contained 0.27% of FG which was reduced to 0.16, 0.20 and 0.21%, respectively after cooking, Ca(OH)₂ and iron treatments.

The concentrate mixtures of reference and test diets were isonitrogenous and isocaloric (Table 2). The concentration of iron was higher in iron treated CSM containing diets (0.106%) in comparison to other diets (range, 0.054 to 0.088%). The ADF content was nearly double in CSM containing concentrates in comparison to reference concentrate. Inclusion of raw or processed CSM in concentrate mixture increased the cellulose content by 2 to 3 times.

Data on average daily weight gain (ADG) and fortnightly body weight changes in lambs on reference and CSM containing rations are shown in Table 3 and Figure 1. The lambs fed diets formulated with raw, cooked and

Table 3. Body weight changes and average daily gain in lambs fed raw and processed CSM

Attribute	Reference	Cottonseed meal				SEM
		Raw	Cooked	Ca(OH) ₂ treated	Iron treated	
Initial body weight (kg)	8.63	8.59	8.62	8.39	8.56	0.173
Final body weight (kg)	19.02 ^c	22.77 ^b	24.44 ^a	22.07 ^b	18.98 ^c	0.463
Gain in body weight (kg)	10.39 ^c	14.18 ^b	15.81 ^a	13.68 ^b	10.43 ^c	0.451
Average daily gain (g)	57.72 ^c	78.77 ^b	87.83 ^a	75.99 ^b	57.60 ^c	2.515
Regression equation* <i>y</i>	8.893+0.831 <i>x</i>	8.525+1.194 <i>x</i>	9.319+1.278 <i>x</i>	8.299+1.132 <i>x</i>	8.041+0.886 <i>x</i>	

Means with different superscripts in a row differ significantly: $p < 0.01$.

$Y = a + bx$; *y*: Body weight (kg), *x*: Age in fortnights, ^a Intercept, ^b Regression coefficient.

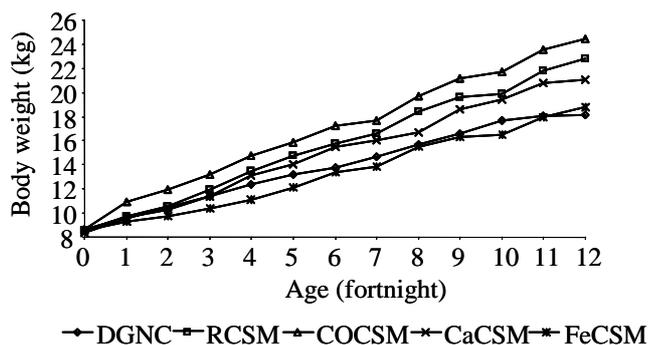


Figure 1. Fortnightly body weight changes in lambs fed raw and processed CSM.

Ca(OH)₂ treated CSM grew significantly ($p < 0.01$) higher than the lambs fed reference diet. Among the above three groups, the final body weight of lambs fed cooked CSM was found highest ($p < 0.01$) with a daily gain of 87.83 g. Inclusion of iron treated CSM in lamb diets though significantly ($p < 0.01$) depressed the weight gains, it was found comparable to weight gain of reference group lambs.

The overall average daily intakes of dry matter (DM), protein (CP and digestible CP) and energy (TDN, DE and ME) during the entire experimental period are depicted in Table 4. The lambs fed diets incorporated with either raw, cooked or Ca(OH)₂ treated CSM consumed more ($p < 0.01$) DM through concentrate than those fed on reference diet. The consumption of DM through concentrate in lambs on iron treated CSM containing diet was depressed significantly ($p < 0.01$), irrespective of mode of expression, as compared to the lambs on other CSM diets, but was comparable to the intakes of reference lambs. Almost the same trend as that of concentrate intake was noticed regarding hay intakes which resulted in a similar significant ($p < 0.01$) variation in the total DM intakes among various groups. Inclusion of cooked CSM in concentrate mixture

increased ($p < 0.01$) the consumption of protein (CP and digestible CP) for each kgW^{0.75} in comparison to other diets. Intakes of DE and ME was higher in lambs fed on Ca(OH)₂ treated CSM based diet when compared with the intakes of reference, raw and iron treated CSM incorporated diets.

The lambs on reference and CSM diets utilized DM with similar efficiency (Table 5). The lambs were more efficient in utilizing TDN ($p < 0.01$), DE ($p < 0.01$) and ME ($p < 0.01$) when fed raw or cooked CSM diets in comparison to lambs on reference diet (Table 5). The efficiency of DCP utilization was higher ($p < 0.01$) in raw and Ca(OH)₂ treated CSM fed lambs when compared to that of lambs fed reference and iron treated CSM diet.

The cost of total feed consumed was highest ($p < 0.01$) for lambs fed cooked CSM incorporated diet, intermediate for raw and Ca(OH)₂ treated CSM containing diet, lowest for reference and iron treated CSM incorporated diets (Table 6). The FCWG was lowest ($p < 0.01$) with raw, cooked and Ca(OH)₂ treated CSM incorporated diets. The cooked CSM proved more economical than feeding of raw CSM to lambs, as it reduced the feed cost by 49 paisa per each kg of weight gain.

DISCUSSION

The FG concentration in CSM depends mainly on type of processing in addition to seed variety, location and stage of maturity etc. The raw CSM, in the present study, had 0.27% FG (Table 1) against the reported values of 0.225% and 0.258% found in direct solvent extracted CSM by Lindsey et al. (1980) and Tanksley et al. (1981), respectively. Whereas, Calhoun and coworkers (1990) reported a higher value of 0.364% in direct solvent extracted CSM.

A linear increase in live body weight was observed in lambs on all the diets throughout the feeding trial (Figure 1).

Table 4. Average daily dry matter and nutrient intake by lambs fed raw and processed CSM

Attribute	Reference	Cottonseed meal				SEM
		Raw	Cooked	Ca(OH) ₂ treated	Iron treated	
DM intake (g/day)						
Concentrate**	244.1 ^c	280.5 ^b	303.0 ^a	281.1 ^b	236.4 ^c	5.37
Hay**	218.3 ^c	262.9 ^{ab}	259.1 ^a	234.2 ^{bc}	220.8 ^c	8.39
Total**	449.7 ^c	543.4 ^b	601.6 ^a	524.3 ^b	448.8 ^c	12.59
DM intake (g/kg W ^{0.75})						
Concentrate**	33.98 ^{bc}	35.61 ^{ab}	36.99 ^a	36.48 ^a	33.18 ^c	0.402
Hay*	29.62 ^b	33.47 ^{ab}	32.30 ^a	31.75 ^{ab}	29.61 ^b	0.836
Total**	62.71 ^b	69.08 ^a	71.62 ^a	68.00 ^a	62.79 ^b	0.979
Daily Nutrient intake (g or kcal/kg W ^{0.75})						
CP**	9.58 ^c	10.56 ^{bc}	11.85 ^a	10.73 ^b	10.07 ^{bc}	0.172
DCP**	6.32 ^b	6.55 ^b	7.39 ^a	6.53 ^b	6.34 ^b	0.096
TDN**	37.22 ^b	36.90 ^b	42.42 ^a	39.21 ^{ab}	32.91 ^c	0.680
DE**	189.9 ^c	194.2 ^{bc}	210.1 ^{ab}	227.1 ^a	162.1 ^d	4.47
ME**	163.0 ^b	166.5 ^b	174.6 ^b	196.5 ^a	135.7 ^c	4.01

Means bearing different superscripts in a row differ significantly: * $p < 0.05$ and ** $p < 0.01$.

Table 5. Efficiency of nutrient utilization in lambs fed raw and processed CSM

Nutrient	Reference	Cottonseed meal				SEM
		Raw	Cooked	Ca(OH) ₂ treated	Iron treated	
Dry matter	7.82	6.99	6.84	6.95	7.78	0.147
Crude protein*	1.17 ^{ab}	1.06 ^b	1.07 ^b	1.08 ^b	1.25 ^a	0.023
Digestible crude protein**	0.79 ^{ab}	0.66 ^c	0.69 ^{bc}	0.67 ^c	0.82 ^a	0.020
Total digestible nutrients**	4.64 ^a	3.73 ^b	3.94 ^b	4.01 ^{ab}	4.08 ^{ab}	0.093
Digestible energy**	23.68 ^a	19.64 ^c	19.51 ^c	23.21 ^{ab}	20.07 ^{bc}	0.49
Metabolizable energy**	20.18 ^a	16.84 ^b	16.25 ^b	20.08 ^a	16.81 ^b	0.44

Means bearing different superscripts in a row differ significantly: * p<0.05; ** p<0.01.

The ADG (g) from 'b' values obtained by regressing body weight (kg) on age (fortnight) were comparable among lambs on various diets (Table 3) and exhibited a similar trend as that of observed weight gain. However, growth rate of lambs on all the diets was lower than the anticipated ADG of 100 g despite higher intakes of DM, CP, TDN, DE and ME than the NRC (1985) stipulated requirements. The energy and protein intakes observed in the present study therefore, appears not to be the limiting factors for optimum growth expression and lowered growth rates in lambs on all the diets could be attributed to their genetic potential.

Growth depression was observed in calves (Hollon et al., 1958), pigs (La Rue et al., 1985; Papadopoulos et al., 1987), poultry (Fitzsimmens et al., 1989) due to feeding of CSM. Intake of FG up to 302.8 mg daily (20.2 mg/kg body weight) due to feeding of raw CSM diet for 180 days did not hamper the growth rate in lambs. This might be due to the binding of FG to soluble proteins in rumen. The bond not being broken by proteolytic enzymes secreted in lower gut and thus excreted as bound gossypol (Reiser and Fu, 1962). But not all the ingested FG is detoxified in rumen, some of it bypasses the rumen, as evident by suppression of body immune response (Nagalakshmi et al., 2001) along with histopathological lesions in testes and epididymis (Nagalakshmi et al., 2000) due to feeding of 40% raw CSM containing diet and death of lambs due to ingestion of 42.72 mg FG/kg body weight when fed 23% direct solvent extracted CSM containing diets (Calhoun et al., 1990). This indicated that the amount of FG escaping from the rumen in the present study was not sufficient to exert its impact on growth of lambs. Though few lambs died of gossypol poisoning due to feeding of diets containing 23% CSM for 56 days no growth depression was observed in studies of Calhoun and coworkers (1990), corroborating with the present findings. The source of FG intake also effects the gossypol tolerance in lambs. A daily intake of 20 mg FG/kg body weight in form of gossypol acetic acid (gelatin capsule) resulted in anorexia and chronic growth depression and death of all lambs within 15 days period (Huston et al., 1990). Whereas such effect was not observed in the present study and in the studies of Huston et al (1990) when the same amount of FG was taken in the form of CSM

or cottonseed, respectively.

Significantly (p<0.01) higher body weight gains in lambs fed raw, cooked and Ca(OH)₂ treated CSM containing diets in comparison to reference diet might be due to the slow rumen degradability (45 to 61%) of CSM (Cronje, 1983; Hennesy et al., 1983; Subba Rao et al., 1989). This would have provided more amino acids for absorption and supported higher ADG compared to DGNC which has an estimated degradation of 72% (Orskov, 1982; Subba Rao et al., 1989). The complementary relationship between CSM and DGNC present in the test diets might be another reason for better growth rates in above diets in present investigation. About 3-10% faster weight gain was seen in lambs fed 15% cottonseed cake along with 10% soyabean meal (SBM) than SBM alone (Kandyliis et al., 1992). Similarly, Moise and Wysocki (1981) observed better growth in fillies (0.77 kg/day) when fed rations containing 10% CSM and 10% SBM than those (0.66 kg/day) receiving 20% CSM.

Pelleting of whole cottonseed without steam resulted in 67% decreased in FG content (Lindsey et al., 1980) and supported improved growth rates in calves. Similarly, a reduction of 47.47% of FG in CSM due to cooking for 45 minutes increased (p<0.01) weight gains of lambs in comparison to lambs fed raw CSM incorporated diets in the present investigation. Incorporation of iron treated CSM at 40% inclusion level, depressed the weight of lambs. Such negative effects of iron supplementation on weight gains were reported in lambs due to consumption of about 210-280 ppm in diet (NRC, 1980). The lambs on iron treated CSM fed diets consumed 889 ppm iron which was much above the maximum tolerance levels of 500 ppm (NRC, 1980) for lambs. A similar growth reduction was noticed in broilers by Mc Ghee et al. (1965) and El Boushy et al. (1989) due to feeding higher dietary concentrations of iron (1,600 and 520 ppm, respectively). The experimental concentrate mixtures containing either raw or processed CSM were palatable as evident from the intakes, which were either similar or higher to the intakes of reference lambs (Table 4). Similarly, the DM intake was not affected by inclusion of CSM in diets of calves (Fiems et al., 1986), lambs (Kandyliis et al., 1992), pigs (Papadopoulos et al., 1987; Ikurior and Fetuga, 1988; Balogun et al., 1990).

Table 6. Feed cost of live weight gain of diets containing raw and processed CSM

Attribute	Reference	Cottonseed meal				SEM
		Raw	Cooked	Ca(OH) ₂ treated	Iron treated	
Concentrate intake (kg)	43.93 ^c	50.50 ^b	54.53 ^a	50.59 ^b	42.55 ^c	0.967
Hay intake (kg)	37.02 ^c	47.32 ^{ab}	53.49 ^a	44.09 ^{bc}	38.23 ^c	1.509
Total feed cost (Rs.)	232.4 ^c	273.4 ^b	301.4 ^a	271.5 ^b	234.8 ^c	5.43
Total live weight gain (kg)	10.39 ^c	14.18 ^b	15.81 ^a	13.68 ^b	10.43 ^c	0.451
FCWG (Rs./kg)	22.51 ^a	19.44 ^b	18.95 ^b	20.00 ^b	22.67 ^a	0.422

Means bearing different superscripts in a row differ significantly: $p < 0.01$.

The higher intake of FG had no adverse affect on feed consumption in crossbred wethers when diets contained 26% hexane extracted CSM (Danke et al., 1965) and further processing of hexane extracted CSM with hexane-acetone-water-azeotrope (51:46:3) did not improve the consumption.

The intake of total DM was higher by 57.6 to 87.8% and TDN intake was almost similar to the stipulated requirements of Kearn (1982). Whereas the CP and DCP intakes were lower by 4.6 to 14.0% and 23.6 to 30.2%, respectively than above stipulated requirements. The intakes of DM, protein (CP) and energy (TDN, DE and ME) in lambs on reference and test diets were, on the other hand, found to be higher than the stipulated NRC (1985) requirements.

The observed depression ($p < 0.05$) in feed efficiency in calves (Fiems et al., 1986) and pigs (Papadopoulos et al., 1987), when CSM was substituted with SBM was not noticed in the present study (Table 5). Moreover, except for iron treated CSM group the efficiencies of protein and energy utilization were found to be higher ($p < 0.01$) in lambs fed CSM based diets than in that fed DGNC alone due to synergistic effect of CSM and DGNC. Similar results were reported by Kandylis et al. (1992) in lambs fed diets containing 15% cottonseed cake along with SBM as compared to those fed reference diets containing SBM alone. The poor growth rates observed in iron treated CSM fed lambs, might have resulted in lower efficiencies of nutrient utilization in comparison to other CSM fed lambs.

The feed cost per unit live weight gain (FCWG) is mostly dependent on cost of feed and efficiency of feed utilization. In spite of incurring higher ($p < 0.01$) cost of ration consumption on raw, cooked and Ca(OH)₂ treated CSM incorporated diets, the FCWG was found to be lower ($p < 0.01$) on these diets (Table 6). The inclusion of cooked CSM in lamb diets reduced the FCWG by 49 paise in comparison to raw CSM at similar level of inclusion.

CONCLUSIONS

The processing methods employed in the present study reduced the FG content by about 22.2 to 40.5% in CSM. The overall performance of lamb's fed cooked CSM proved to be the best and though statistically insignificant it reduced the feed cost for each kg weight gain by 49 paise in

comparison to inclusion of raw CSM. Incorporation of iron treated (1FG:0.3 iron) CSM in concentrate mixtures of fattening lambs diet at 40% level proved to be toxic and reduced the growth rate.

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