Influence of Feeding Processed Cottonseed Meal on Meat and Wool Production of Lambs

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ABSTRACT : In order to assess the effect of feeding raw or processed cotton *(Gossypium)* seed meal (CSM) on meat and wool production, 30 male crossbred lambs (3-4 months) of uniform body weight were assigned equally to five dietary treatments in a completely randomised design. The CSM was processed by three different methods i.e., cooking the meal at 100°C for 45 minutes, treatment with 1% calcium hydroxide ($Ca(OH)_2$) for 24 h and iron treatment in the ratio of 1 part free gossypol (FG) to 0.3 parts of iron for 30 minutes. The lambs were fed isonitrogenous and isocaloric concentrate mixtures, containing 30% deoiled peanut meal (reference diet) and 40% of either raw, cooked, $Ca(OH)_2$ or iron treated CSM for 180 days. The raw and variously processed CSM replaced about 50% nitrogen of reference concentrate mixture. The concentrate mixtures were fed to meet 80% of the protein requirements (NRC, 1985) along with *ad libitum* chopped maize (*Zea mays*) hay. The slaughter weight, empty body weight and carcass weight was higher ($p \leq 0.01$) in lambs fed cooked CSM incorporated diets, compared to diets containing deoiled peanut meal (DPNM). These parameters were not influenced by feeding diets containing either raw, $Ca(OH)_2$ or iron treated CSM in comparison DPNM diets. The carcass length, loin eye area and edible and inedible portion of carcass and the meat: bone ratio in whole carcass were also not affected by feeding CSM based diets. Among various primal cuts, the yield of legs was lower ($p \leq 0.05$) from raw CSM fed lambs in comparison to DPNM fed lambs. The fat content in the *Longissimus dorsi* muscle was reduced ($p \leq 0.05$) in lambs fed processed CSM based diets compared to those fed DPNM diet. Replacing DPNM with either raw or processed CSM based diets did not influence the sensory attributes and overall acceptability of meat. The wool yield was higher ($p \leq 0.05$) in iron treated CSM fed lambs. The fibre length and fibre diameter were comparable among lambs on various dietary regimes. Among lambs fed variously processed CSM diets, the feed cost per kg of edible meat production was lower ($p \leq 0.05$) on $Ca(OH)_2$ treated CSM, followed by cooked CSM diet and then on raw CSM based diets compared to DPNM diet. The CSM after 1% $Ca(OH)_2$ treatment or cooking for 45 minutes appears to be a satisfactory protein supplement in lamb diets for meat and wool production to replace at least 50% nitrogen of scarce and costly peanut meal. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 1 : 26-33)***

Key Words : Peanut Meal, Cottonseed Meal, Wool, Meat, Lambs

INTRODUCTION

Reduced pastures and short supply of concentrate poses a serious threat for the development of sheep production into an economic enterprise in India. Despite a marginal increase in the availability of energy and protein rich feeds, there is still a shortage of 45% in concentrates, 30% in green fodder and 42% in dry fodder availability (Prasad, 1997) for livestock feeding. Thus the problem of meeting the nutritional requirements of the sheep population of 56.5 million (FAO, 1997a) would be alleviated to some extent by enhancing the utilization of various agricultural byproducts such as cottonseed meal.

India ranks third in Cotton (*Gossypium*) production in the world. Estimates indicate an availability of about 4300×10^3 t of undecorticated cottonseed meal (CSM), if all the 5430×10^3 t annually produced cottonseeds (FAO, 1997b) are crushed for oil extraction. The presence of gossypol, a polyphenolic compound, limits the utilisation of CSM in livestock feeding. Feeding of CSM has resulted in growth depression and mortality in lambs (Danke et al., 1965; Calhoun et al., 1990), beef cattle (Brosh et al., 1989) and Holstein steers (Thonney and Hogue, 1985). Papadopoulos et al. (1987) observed significantly ($p \leq 0.01$) lowered meat cut ratios in fattening pigs due to 75% replacement of soyabean meal (SBM) with CSM.

Various measures like solvent extraction, soaking, cooking, autoclaving, addition of iron and calcium salts and lysine supplementation, etc., were tried to reduce the free gossypol (FG) content in CSM and to make it a wholesome protein supplement. Several solvents like acetone, acidic butanol, aniline, hexane, isopropanol were successful in reducing the gosypol of CSM to quite low levels, but these solvents are costly and their recovery is difficult. Soaking the meal in water (Shah et al., 1986) and autoclaving/pressure cooking (Baliga and Lyman, 1957; Nagalakshmi, 1997) were effective in gossypol reduction, but the former resulted in loss of protein while latter method was not economically feasible. Cooking of CSM for 10 minutes in boiling water before mixing in swine diets

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reduced the FG content by 44% (Jarquin et al., 1966). The metallic ions of calcium and iron were also effective in gossypol detoxification due to chelate formation (Shah et al., 1986). The FG content was reduced by 25 and 54% respectively when 0.5% calcium hydroxide ($Ca(OH)_2$) added to 42% CSM containing diets (Braham et al., 1967) or when CSM was treated with 1.0% $Ca(OH)_2$ (Shah et al., 1986). Addition of 1, 1-2 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 broilers and layers (Waldroup, 1981) due to formation of ferrous gossypol chelate, passing the digestive tract intact. Considering the practical feasibility and economics of the processing methods three processing methods viz., cooking, calcium and iron treatment were selected for reducing the FG content of the CSM. The present investigations were undertaken to study the feasibility of feeding variously processed CSM as a partial substitute for costly and scarce deoiled peanut meal (DPNM) for wool and meat production in lambs.

MATERIALS AND METHODS

Animals and housing management

Thirty, 3-4 months old local crossbred male lambs of uniform body weight (BW) (8.63 kg±0.404, SE) were allocated to 5 groups of 6 lambs each in a completely randomised design. The lambs were housed individually in pens located in a well ventilated, cement floored barn, each provided with a feed bin and water trough. They were vaccinated against '*Peste des Petits* in ruminants' (PPR) before the start of experiment and against sheep pox and haemorrhagic septicaemia before the onset of the rainy season. All the lambs were dewormed and drenched with an antihelmintic at monthly intervals through the experimental period (180 days).

Processing of CSM

One kg of CSM contained 287.4 g CP, 269.4 g crude fibre (CF), 5.7 g total gossypol (TG) and 2.7 g FG. The processing methods employed in the present study were cooking for 45 minutes, 1.0% $Ca(OH)_2$ and ferrous sulphate (1FG:0.3Fe) treatments. Cooked CSM was prepared by boiling the meal in water (100°C) for 45 minutes at the ratio of 1 meal:1.5 water. The $Ca(OH)_2$ treated CSM was prepared by soaking the meal in a 1% $Ca(OH)_2$ solution for 24 h (1 meal:1 $Ca(OH)_2$ solution). The iron treated CSM was prepared by soaking the meal for half an hour in a solution (1:1, w/v) containing 0.3 parts iron for each part of FG present in the CSM. All the processed meals were then sun dried and ground. The FG content in CSM after cooking, $Ca(OH)_2$ and iron treatment was reduced to 1.6, 2.0 and 2.1 g/kg, respectively.

Feeds and feeding

Five approximately isonitrogenous and isocaloric concentrate mixtures (table 1) were formulated. The concentrate mixture of the reference diet contained 30% DPNM, while the other four mixtures had 40% of either raw, cooked, $Ca(OH)_2$ or iron treated CSM to provide

Table 1. Dietary ingredient and chemical composition of concentrate mixtures* and maize hay

Attribute	DPNM	Cottonseed meal				Maize hay
		Raw	Cooked	$Ca(OH)_2$	Iron	
Ingredient (% in air dry feed)						
Maize	30.0	30.0	34.0	34.0	32.0	
Deoiled PNM	30.0	15.0	15.5	14.0	15.5	
Raw CSM	-	40.0	-	-	-	
Cooked CSM	-	-	40.0	-	-	
Calcium hydroxide treated CSM	-	-	-	40.0	-	
Iron treated CSM	-	-	-	-	40.0	
Wheat bran	37.0	12.0	7.5	9.0	9.5	
Mineral mixture	2.0	2.0	2.0	2.0	2.0	
Common salt	1.0	1.0	1.0	1.0	1.0	
Analysed chemical composition (% in DM)						
Crude protein	22.7	23.6	23.3	22.1	23.7	7.57
Ether extract	2.18	1.64	1.99	1.26	1.55	1.26
Crude fibre	6.63	13.77	13.88	11.80	13.84	28.10
Total ash	7.67	7.52	7.62	8.29	7.75	10.04
Calcium	0.78	1.14	1.01	1.29	1.11	2.13
Iron	0.088	0.054	0.054	0.055	0.106	0.070
Gross energy (kcal/g)	4.73	4.66	4.63	4.50	4.73	4.60
TDN[a]	65.7	65.6	65.6	65.7	65.7	-

* Supplemented additional vitamin mixture to provide 3,000 IU vitamin A and 300 IU vitamin D/kg.
[a] Calculated values.

approximately 50% of the total nitrogen of the reference concentrate mixture.

The lambs were offered daily weighed quantities of the concentrate mixtures betweeen 08:30 and 09:00 h so as to meet 80% of total protein requirements (NRC, 1985). In addition, *ad libitum* maize (*Zea mays*) hay was fed in the afternoon. The quantity of concentrates to be offered daily was adjusted fortnightly as per BW recorded at the end of every fortnight. Fresh clean water was provided *ad libitum*.

Slaughter of lambs

The lambs were slaughtered at the end of the study, by the *Halal* method (Gracey, 1981) after an overnight fast with free access to water. After skinning and evisceration, the carcass length (Yeates et al., 1975), weight of hot carcass, empty body weight (slaughter weight without gut fill) and organ weights were recorded. The bone, muscle and fat of the hot carcass was separated manually, weighed and expressed as percentages of carcass weight. The weight of edibles (carcass, liver, heart, kidneys, testes, dressed head and feet) and the inedible offals (blood, empty gastrointestinal tract, skin, spleen and lungs with trachea) were recorded.

Loin eye area (cm^2) was determined by tracing the cut section of *Longissimus dorsi* (LD) muscle between the 10^{th} and 11^{th} rib on butter paper and measuring with the help of graph paper partitioned to 1 mm. The LD muscle from the right side of carcass from each lamb was pooled according to group and deep frozen (-18±2°C) for organoleptic evaluation, while the LD muscle from the left side of carcass were individually deep-frozen (-18±2°C) for chemical analysis.

Organoleptic evaluation

Pooled LD muscle samples from each group were pressure cooked with salt (1.5% w/w) and without salt and subjected to organoleptic evaluation on a 7 point Hedonic scale (Keeton, 1983) by a panel of semitrained judges to evaluate appearance, odour, taste, texture, tenderness, juiciness and overall acceptability.

Wool measurements

A right midside patch of approximately 10×10 cm was clipped closely at the beginning (day 1) and later on 180th day from the same area to estimate the wool growth. After clipping 3 lengths and 3 widths of each unstretched patch area was measured to arrive at an average area of clipped patch. At the same time, a small anterior area of skin adjacent to the mid side patch was also clipped. Length of 5 small staples of wool were measured and averaged to obtain staple length.

Wool growth was estimated as per the method of Williams and Butt (1989). Clipped wool was cleaned sequentially in light petroleum spirit, ethanol, water and dried overnight at 95°C and weighed. Wool growth was expressed as mg/100 cm^2/day.

Wool fibre diameter was estimated using a projection microscope using scale of 250X. Approximately 0.4 mm snippets were cut from the thoroughly mixed cleaned wool, with the help of microtome. Microtome was preconditioned under standard atmospheric conditions of 65±2% relative humidity and 27±2°C temperature for 24 h. About 300 individual fibres were examined under the microscope.

Analytical procedure

The chemical composition of meat and feed samples was determined as per AOAC (1990) methods. The protein content of the samples was determined by Kjeldahl's method using Tecator nitrogen analyser (Model 1026). The fat in the feed and meat samples was estimated using Tecator soxtec system (Model HT 1041). The ash was estimated by igniting the samples at 550°C using Thermolyne 48000. The total and FG content of raw and processed CSM were estimated by spectrophotometric method using gossypol acetate (Sigma chemicals) as standard, as per the procedures described by Botsoglou and Kufidis (1990) and Botsoglou (1991) respectively.

Feed cost of meat production

Feed cost of each treatment was calculated using the ingredient and processing cost prevailing at the time of experimentation. The total feed cost was obtained by summing up the cost of the total concentrate and hay consumed throughout the feeding trial. The edible meat (kg) produced during the feeding trial was obtained by multiplying the total weight gain by the percentage of edible meat in the slaughter weight. The feed cost of edible meat produced (FCEM) was determined by dividing the total feed cost by the edible meat (kg) production.

Statistical analysis

The data were subjected to analysis of variance (Snedecor and Cochran, 1967) using completely randomised design. The different means were compared with Tukey's test.

RESULTS

Feeding of cooked CSM containing diets increased ($p \leq 0.01$) the slaughter weight, and empty body weight of lambs (table 2) in comparison to the DPNM or iron treated CSM incorporated diets fed lambs. The weight of hot carcass was highest ($p \leq 0.01$) in lambs fed diets containing cooked CSM followed by those fed $Ca(OH)_2$ treated and raw CSM based diets. But when carcass weight was

Table 2. Carcass characteristics of lambs fed raw and variously processed cottonseed meal n=6, error df=25

Attribute	DPNM	Cottonseed meal				SEM	F value
		Raw	Cooked	$Ca(OH)_2$	Iron		
Slaughter and dressing characteristics							
Pre slaughter weight (SW) (kg)	19.6^{bc}	23.0^{ab}	25.2^{a}	22.3^{abc}	19.1^{c}	0.522	10.963**
Empty body weight (EBW) (kg)	14.2^{b}	16.5^{ab}	17.7^{a}	16.4^{ab}	14.2^{b}	0.342	7.801**
Carcass weight (kg)	8.46^{b}	9.43^{ab}	10.59^{a}	9.82^{ab}	8.34^{b}	0.221	6.353**
Dressed weight (% SW)	43.2	41.1	42.2	44.1	43.4	0.506	0.379
Dressed weight (% EBW)	59.4	57.1	60.0	59.8	58.5	0.606	0.749
Carcass length (cm)	52.9	55.6	56.4	55.5	52.4	0.720	1.272
Loin eye area (Sq.cm)	7.31	7.64	7.97	6.57	6.96	0.229	1.191
Edible (% SW)	55.5	54.2	53.3	56.8	56.2	0.543	1.490
Inedible:Edible	2.21	2.07	1.85	2.17	2.06	0.459	2.127
Yield of visceral organs (g/100 g SW)							
Pluck	3.47	3.28	3.33	3.36	3.46	0.064	30.00
Liver	1.21	1.20	1.18	1.22	1.30	0.025	0.623
Kidney	0.24^{b}	0.22^{b}	0.23^{b}	0.24^{b}	0.34^{a}	0.010	8.118*
Heart	0.35	0.33	0.32	0.32	0.34	0.008	0.609
Testes	0.49	0.70	0.49	0.64	0.56	0.033	1.781
GIT (full)	28.0	28.1	28.3	26.5	24.8	0.560	1.467
GIT (Empty)	8.13	8.18	9.03	8.97	9.53	0.472	0.292
Spleen	0.13	0.15	0.15	0.18	0.20	0.014	0.683
Lungs with trachea	1.90	1.75	1.82	1.83	1.82	0.053	0.189
Leaf fat	0.66	0.59	0.42	0.40	0.41	0.039	2.120
Head (kg)	1.43	1.66	1.61	1.69	1.43	0.035	3.312
Skin (kg)	2.39^{b}	3.05^{ab}	3.32^{a}	2.56^{ab}	2.52^{ab}	0.111	3.371*
Blood (g)	675	738	742	617	677	20.20	1.393
Trout & Hooves (g)	522	588	590	578	537	13.55	1.099
Bone (% carcass weight)	31.5	31.7	29.1	31.9	33.2	0.752	0.749
Meat (% carcass weight)	63.8	61.7	65.3	63.7	63.4	0.762	0.474
Fat (% carcass weight)	4.65	6.58	5.67	4.50	3.42	0.397	2.746
Bone:meat	2.03	1.95	2.29	2.03	1.92	0.073	0.733

Means with different superscripts in a row differ significantly: *$p \leq 0.05$ and **$p \leq 0.01$.

expressed as a percentage of slaughter and empty body weight, such differences was not observed among different treatments. Inclusion of raw or processed CSM in the diets of lambs did not affect ($p \geq 0.05$) the carcass length, loin eye area, edible percentage or the ratio of edible: inedible, yield of bone, meat, fat or the bone: meat ratio in whole carcass. Similarly, dietary differences did not affect the weight of pluck (weight of lungs with trachea, liver and heart), liver, heart, testes, leaf fat, gastrointestinal tract, spleen, lungs with trachea and head. The percentage weight of kidneys was higher ($p \leq 0.05$) in lambs fed the diet containing iron treated CSM than all other treatments, while the skin weighed more ($p \leq 0.05$) in lambs fed cooked CSM containing diets compared to those fed on reference diet.

The yield of legs from lambs fed on raw CSM incorporated diets was lower ($p \leq 0.05$) than those fed the reference diet while the yield of legs from lambs fed processed CSM based diets were comparable to reference group. The yields of other wholesale cuts were not significantly affected by the treatments employed in the study (table 3).

Though the percentage of moisture in fresh meat was similar among various dietary groups, the meat of lambs fed on iron treatment CSM incorporated diets contained more protein ($p \leq 0.05$) as compared to that from lambs on the reference and raw CSM based diets (table 4). The fat content in meat was reduced ($p \leq 0.05$) in lambs fed processed CSM based diets compared to DPNM group. Incorporation of cooked or $Ca(OH)_2$ treated CSM in concentrate mixtures of lamb diets increased ($p \leq 0.05$) the ash content of meat compared to reference group. But, the meat ash content was similar in lambs fed raw or iron treated CSM compared to the reference diet.

No abnormal sensory attributes were imparted to the meat due to incorporation of raw or processed CSM in lamb diets (table 5). The percentage cooking losses due to

Table 3. Yield of various wholesale cuts (g/100 g carcass weight) from lambs fed on raw or variously processed cottonseed meal n=6, error df=25

Cuts	DPNM	Cottonseed meal				SEM	F value
		Raw	Cooked	$Ca(OH)_2$	Iron		
Legs	36.4[a]	33.6[b]	34.9[ab]	35.3[ab]	35.4[ab]	0.286	3.475
Loin	11.4	12.1	11.6	11.9	10.9	0.274	0.569
Rack	5.94	6.11	6.25	5.88	6.14	0.160	0.161
Breast	19.1	20.6	18.5	20.2	19.8	0.314	1.551
Shoulder	18.7	18.2	19.2	18.7	18.9	0.413	0.129
Neck	8.40	9.23	9.56	8.06	9.13	0.271	1.055

Means with different superscript in a row differ significantly: $p \leq 0.05$.

Table 4. Chemical composition of *Longissimus dorsi* muscle (g/100 g) from lambs fed on raw or variously processed cottonseed meal n=6, error df=25

Constituent	DPNM	Cottonseed meal				SEM	F value
		Raw	Cooked	$Ca(OH)_2$	Iron		
Moisture	70.2	71.4	71.3	71.0	70.6	0.201	1.236
Crude protein	22.1[b]	22.5[b]	23.7[ab]	23.0[ab]	24.6[a]	0.236	6.010
Fat	5.62[a]	4.23[ab]	3.23[b]	3.30[b]	3.33[b]	0.278	3.751
Ash	1.27[c]	1.56[bc]	2.37[a]	2.05[ab]	1.51[bc]	0.102	7.159

Means with different superscripts in a row differ significantly: $p \leq 0.05$.

Table 5. Organoleptic evaluation* (7 point Hedonic scale) of pressure cooked *Longissimus dorsi* muscle without and with salt from lambs fed raw or variously processed cottonseed meal

Attribute	DPNM	Cottonseed meal			
		Raw	Cooked	$Ca(OH)_2$	Iron
Without salt					
Appearance	5.57	5.29	5.86	6.00	5.71
Odour	5.71	5.43	5.43	5.14	5.43
Taste	5.00	4.71	5.00	4.71	5.29
Texture	5.29	5.00	5.57	5.57	5.57
Tenderness	5.71	5.29	5.57	5.43	5.86
Juiciness	5.86	5.29	5.57	5.43	5.71
Overall acceptability	5.14	5.00	5.29	5.43	5.71
With 1.5g salt/100 g meat					
Appearance	6.00	6.14	6.00	5.86	6.00
Odour	6.00	5.86	6.14	5.71	5.86
Taste	6.14	5.86	6.29	5.57	5.71
Texture	6.00	6.14	6.00	5.71	5.43
Tenderness	6.14	6.43	6.29	5.28	5.43
Juiciness	6.00	6.00	6.29	5.43	5.71
Overall acceptability	6.00	6.00	6.29	5.71	5.71

* Judged on basis of 7 point Hedonic scale by semi trained panel.

pressure cooking of meat (without and with salt) from lambs fed on DPNM, raw, cooked, $Ca(OH)_2$ and iron treated CSM based diets were 33.5, 36.1; 35.5, 39.6; 38.5, 35.2; 34.1, 33.1 and 30.9 and 34.5, respectively.

The wool fibre diameter and staple length were not affected by the incorporation of raw or processed CSM in diets of lambs as they were comparable with the values obtained in the reference diet fed lambs (table 6). The wool yield was significantly ($p<0.05$) higher in lambs fed iron treated CSM diet in comparison to those fed the reference diet. The wool production in lambs fed raw, cooked or Ca $(OH)_2$ treated groups was similar to that of reference group lambs.

The FCEM in lambs on various diets is presented in table 7. The cost of feed consumed and also edible meat production was higher ($p \leq 0.01$) in lambs fed raw, cooked and $Ca(OH)_2$ treated CSM containing rations as compared to lambs fed DPNM and iron treated CSM diets. The FCEM

Table 6. Wool characteristics of lambs fed raw or variously processed cottonseed meal n=6, error df=25

Attribute	DPNM	Cottonseed meal				SEM	F value
		Raw	Cooked	$Ca(OH)_2$	Iron		
Wool growth (mg/100cm^2 day)	63.7[b]	84.9[ab]	64.6[b]	82.0[ab]	92.8[a]	3.32	15.541
Staple length (cm)	5.34	6.96	7.09	6.59	6.92	0.313	1.051
Fibre diameter (μ)	26.2	27.8	28.5	26.5	26.6	0.334	2.103

Means with different superscripts in a row differ significantly: $p \leq 0.05$.

Table 7. Feed cost of edible meat production (FCEM) in lambs fed raw or variously processed cottonseed meal n=6, error df=25

Attribute	DPNM	Cottonseed meal				SEM	F value
		Raw	Cooked	$Ca(OH)_2$	Iron		
Concentrate intake (kg)	43.9[b]	50.5[a]	54.5[a]	50.6[a]	42.6[b]	0.967	18.206**
Hay intake (kg)	37.0[b]	47.3[ab]	53.5[a]	44.1[ab]	38.23[b]	1.509	7.765**
Total feed cost (Rs)	233[b]	273[a]	301[a]	272[a]	235[b]	5.43	23.707**
Edible meat (kg)	5.77[b]	7.69[a]	8.42[a]	7.74[a]	5.86[b]	0.238	15.313**
FCEM (Rs/kg)	40.7[a]	36.0[bc]	35.9[bc]	35.2[c]	40.4[ab]	0.768	3.404*

Means with different superscripts in a row differ significantly: * $p<0.05$ and ** $p<0.01$. 1 \$ = Rs. 42.50.

was significantly ($p \leq 0.05$) lower in groups fed $Ca(OH)_2$ treated, cooked or raw CSM based diets compared to the reference diet, while the FCEM was similar between the reference and iron treated CSM groups.

DISCUSSION

Incorporation of 40% raw CSM (2.7 g FG/kg CSM) in a concentrate mixture fed to lambs did not affect the slaughter characteristics and chemical composition of meat, except for the lower ($p \leq 0.05$) yield of legs compared to reference group lambs (table 2). The FG present in raw CSM did not show any adverse affect on carcass traits. This might be due to the binding of FG to soluble proteins in rumen, the resultant bond being resistant to proteolytic enzymes and bound gossypol excreted in faeces (Reiser and Fu, 1962). Detoxification of the ingested FG (302.83 mg/day) in rumen may not be complete; a portion of the FG ingested probably must have bypassed the detoxification mechanism, as indicated by the histopathological lesions in testis and epididymis (Nagalakshmi et al., 2000) and suppression of immune responses (Nagalakshmi et al., 2001) in lambs fed the diet containing raw CSM. But, the escaped FG was not sufficient to affect any of the dressing and slaughter characteristics. Similar to the present findings, Kandylis et al. (1992) reported no effect on dressing percentage, carcass gain, edible and inedible carcass characteristics in lambs fed a diet with 30% cottonseed cake (CSC) when compared with SBM fed lambs. Incorporation of CSM in place of DPNM or SBM had no significant effect on the carcass length, loin eye area in pigs (Ikurior and Fetuga, 1988) and wholesale cuts in pigs (Ikurior and Fetuga, 1988; Qui et al., 1986). Japanese quails (Tserbene-Gouse and Giannakopoulos, 1989) and broiler chicks (Christake, 1992; Giannakopoulos et al., 1993).

Higher ($p \leq 0.01$) slaughter and carcass weights observed in lambs fed cooked CSM in comparison to those of reference group lambs might be due to reduced rumen degradability of CSM protein and reduction in FG content due to cooking. The protein of CSM is slowly degradable in the rumen (45 to 61%) (Cronje, 1983; Hennesy et al., 1983; Subba Rao et al., 1989) in comparison to DPNM protein (72%) (Orskov, 1982; Subba Rao et al., 1989). Also, the heat treatment of CSM while cooking might have further decreased the rumen degradability (Tagari et al., 1962; Broderick, 1975). Cooking of CSM for 45 minutes reduced the FG content by 40.7%. Similarly, a reduction of 44% of FG was observed by Jarquin et al. (1966) when screw pressed CSM was cooked for 10 minutes in boiling water and by 54% by Nagalakshmi (1997) when undecorticated CSM was pressure-cooked for 15 minutes. The availability of more balanced amino acids for absorption at intestinal level and reduction in FG content by 40.7% due to boiling of CSM for 45 minutes might have resulted in higher ($p \leq 0.01$) slaughter weight and carcass weight in lambs fed diets containing cooked CSM in comparison to DPNM diet fed lambs. Among other groups, lambs fed on iron treated CSM diet significantly ($p \leq 0.01$) reduced the slaughter weight compared to those fed raw CSM based diets. The reduced performance of lambs fed iron treated CSM containing diet, could be due to higher concentration of iron (889 mg/kg), which was considerably higher than the tolerance levels (500 mg/kg) for lambs (NRC, 1980). The decreased weight of lambs fed iron treated CSM diet, probably due to reduced feed intake (Nagalakshmi, 1997), resulted in lower ($p \leq 0.01$) slaughter weight compared to raw CSM fed lambs. The significant increase in the weight of kidneys (table 2) in iron treated CSM group may be attributed to hypertrophy and or hyperplasia of the organ due to deposition of the iron in kidneys (Grace and Lee, 1990).

The wool growth in lambs fed 40% iron treated CSM diet was significantly ($p \leq 0.01$) higher than that of other groups. The growth of wool in lambs fed diets containing raw CSM or CSM processed by cooking or $Ca(OH)_2$ was comparable to that of reference lambs. This might be due to differences in the repartitioning of nutrients. The lambs fed diets containing 40% iron treated CSM grew with a lower ($p \leq 0.01$) average daily gain of 57.6 g than other CSM fed lambs (76.0 to 87.8 g) (Nagalakshmi, 1997). Thus a major proportion of nutrients must have been utilised towards wool growth in lambs fed iron treated CSM diet resulting in higher ($p \leq 0.05$) wool growth than those observed in cooked CSM and DPNM fed lambs. Similarly, equiprotein substitution of CSM for DPNM in diets of Angora rabbits did not affect their wool production (Singh and Negi, 1987). On other hand, improved rate of wool growth (0.82 and 0.88 mg/cm^2/day) was observed by Warren et al. (1988) in wethers fed either 25 or 50% whole cottonseed, respectively, when compared to feeding control diet (0.65 mg/cm^2/day).

In spite of the higher ($p \leq 0.01$) cost of feed consumed by the lambs on raw, cooked and $Ca(OH)_2$ treated CSM incorporated diets, the FCEM was found to be lower ($p \leq 0.05$) on these diets in comparison to the reference diet. The inclusion of $Ca(OH)_2$ treated CSM in lamb diets reduced the FCEM by 80 paisa in comparison to raw CSM at a similar level of inclusion.

CONCLUSIONS

Basing on the quality and quantity of meat and wool produced it may be concluded that CSM may serve as a suitable substitute to replace at least 50% of costly and scarce DPNM in the diets of growing lambs reared for meat and wool production. Incorporation of calcium hydroxide treated or cooked CSM in diets for lambs proved more economical than inclusion of raw CSM or DPNM as protein source.

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