

Effect of feeding raw or water soaked rapeseed cake on carcass characteristics and meat quality in kids

M PALANIVEL¹, K SHARMA², NARAYAN DUTTA³ and S K MENDIRATTA⁴

Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh 243 122 India

Received: 28 May 2009; Accepted: 7 November 2009

ABSTRACT

Growing male kids (18) of 11.10 ± 0.77 kg BW, 6 months age were randomly assigned to 3 dietary treatments of 6 each. Groundnut cake of the concentrate mixture of control group (GNC) was replaced by rapeseed-mustard cake (RMC) in group 2 and 3, but the concentrate in group 3 was soaked with water (1:3) overnight and fed as mixed ration (*sani*) with wheat straw. In other groups, respective concentrate mixtures were offered in the morning and wheat straw was offered *ad lib*. During an experimental period of 180 days, fortnightly body weight changes of kids were recorded. The glucosinolates (GLS) content of RMC was $149.50 \mu\text{mol/g DM}$ which was reduced by 31.96% after overnight water soaking. DM intake in group 3 was reduced as compared to other groups. All the kids were slaughtered at the end of the experimental feeding. Preslaughter weight (PSW), carcass yield, carcass length and loin eye area of kids were similar between control and group 2, while all of these were significantly ($P < 0.05$) lower in group 3 than that in control group. While yield of wholesale cuts and, edible and non-edible visceral organs were comparable among groups, weight (g/kg of PSW) of liver and pluck was significantly higher in groups 2 and 3 than in control group. Chemical composition, physico-chemical properties and thiocyanate concentration of *Longissimus dorsi* (LD) muscle did not differ significantly among groups. Organoleptic scores of pressure cooked LD muscle sample with salt (1.5% w/w) were comparable among the groups; however, tenderness score was slightly poor in groups 2 and 3. It may be concluded that despite reduction in GLS content of RMC based supplement by overnight water soaking, its feeding as mixed ration (*sani*) to growing kids had no positive effect in terms of meat quality attributes.

Key words: Carcass characteristics, Glucosinolates, Growing kids, Rapeseed-mustard cake, Water soaking

High glucosinolates (GLS) content in the Indian varieties (*Brassica juncea*) of rapeseed–mustard cake limit its potential as a protein supplement in the ruminant rations (TERI 2003, Ravichandiran *et al.* 2008). Upon ingestion, these intact thioglucoside compounds are enzymatically (endogenous; exogenous) hydrolysed into toxic metabolites such as thiocyanate, isothiocyanates and nitriles which are deposited in large amount in the vital organs and muscles (Pailan and Singhal 2004) in addition to exerting adverse effect on DM intake, growth performance and subsequently carcass yield of young ruminants. In a recent study, the kids fed high GLS (6.2%) mustard cake based diet produced low dressed carcass weight (400 to 421 g/kg) as compared to control (461 g/kg) which could be attributed to lower PSW as the result of low DM intake by kids fed high GLS mustard cake based diet (Pailan and Singhal 2004).

The adverse effects of high GLS content of RMC can be reduced or eliminated by plant breeding, proper processing or combination of both (Liu *et al.* 1995). It has been reported that soaking water of RMC is a cheap and conventional processing technique resulting in substantial reduction (36%) of GLS content by endogenous enzymatic hydrolysis into volatile metabolites (Tyagi *et al.* 1997). The present study was therefore, planned to evaluate effect of feeding raw or water soaked RMC based diet on the carcass characteristics and meat quality attributes in growing kids.

MATERIALS AND METHODS

Experimental animals and diets: Eighteen intact male kids (9 Jamunapari and 9 Barbari; 3 each per treatment) of about 6 months old with an average body weight of 11.10 ± 0.77 kg, were randomly allocated to 3 dietary treatments, viz. Control, group 2 and group 3 containing groundnut cake as major protein source, 100% replacement of groundnut cake with RMC, and overnight water soaked RMC concentrate mixture fed as mixed ration (*sani*), respectively. All the kids were dewormed prior to experimental feeding and reared

Present address: ¹Indira Street, Kangikoil Road, Erode, Tamil Nadu 638052.

²Formerly Head, ³ Senior Scientist, Division of Animal Nutrition, ⁴ Senior Scientist, LPT Division.

under uniform managerial conditions throughout the experimental period of 180 days.

Feeding procedure: The kids were housed in a well-ventilated shed having a provision made for individual feeding. They were fed for maintenance and an expected daily weight gain of 50 g/d as per the stipulated nutrients requirement (Kearl 1982). The kids of control and group 2 were offered measured quantities of respective concentrate mixture in the morning at 10.00 AM. Wheat straw was offered *ad lib.* after ensuring complete consumption of the concentrate. About 200g green fodder (oats/maize) was provided to each kids for their vitamin A requirement. The body weights of all the kids were recorded fortnightly in the morning, before feeding and watering and amount of concentrate mixture offered to each animal was revised accordingly. The animals were provided fresh and clean tap water free choice twice daily.

Carcass studies: After 180 days of experimental feeding, all kids were fasted overnight with free access to water and slaughtered by standard procedures in the experimental abattoir of the Institute after recording pre slaughter weight (PSW). The carcass length (cm) was measured (Yeates *et al.* 1975). Weights of carcass (before and after evisceration), gastro-intestinal tract (full and empty), vital organs, viz. thyroid, liver, kidneys, lungs with trachea, heart and spleen were recorded. The carcass was divided into 7 primal wholesale cuts as per ISI (1963). Loin eye area (cm²) was determined by tracing on the cut section of longissimus dorsi (LD) muscle between the 10th and 11th rib using a butter paper. Weight of edible and non-edible offals were recorded and expressed as g/kg PSW. The LD muscle from left side of the carcass from each animal in respective treatment was pooled and deep frozen for organoleptic evaluation later. The LD muscle from the other side of carcass was individually preserved by deep freezing (–20°C) until further analysis. Samples of kidney, liver, lung and thyroid gland were collected from each carcass and preserved for analysis of thiocyanate concentration.

Chemical analysis: The samples of feed offered and residues left were analysed for proximate principles (AOAC 2000) and fibre fractions (Van Soest *et al.* 1991). The total GLS content (μmol/g DM) in the extract of raw and overnight water soaked (1:3 w/v) and sun-dried RMC was analysed using HPLC following desulphoglucosinolates method (Sang and Truscott 1984). The gradient of acetonitrile and water was kept at a flow rate of 4ml/min by using the wavelength at 226nm.

Representative samples of thawed and minced LD muscle were analysed for chemical composition (AOAC 2000), pH value using digital pH meter, shear force value (SFV) using Warner-Bratzler shear force apparatus (Chrystall *et al.* 1973) water holding capacity (WHC) by centrifugation technique (Wardhw *et al.* 1973) and muscle pigments by acid haematin method (Hornsey 1956). Thiocyanate concentration (μg/g)

of vital organs and LD muscle samples was determined using tissue extract (Bowler 1944).

Organoleptic evaluation: Pooled LD muscle samples from each treatment group were pressure cooked with salt (15% w/w) and subjected to organoleptic evaluation. The sensory attributes, viz. appearance, flavour/taste, texture/tenderness, juiciness and overall acceptability of cooked meat samples were assessed by 8 semi-trained panelists, using an 8 point hedonic scale as described by Piggott (1984).

The data were subjected to one way analysis of variance as per Snedecor and Cochran (1989). Differences among the means were ranked using Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Chemical composition: The chemical composition of wheat straw offered as basal feed was within the normal range reported earlier (Sharma *et al.* 2004, Dey and Sehgal 2005). The concentrate mixtures were isonitrogenous and comparable with respect to other parameters related to their proximate composition and fibre fractions (Table 1). Total GLS content (149.50μmol/g DM) of rapeseed-mustard cake was high and comparable to the values reported for Indian varieties of RMC (Banday and Verma 2003; TERI 2003). Overnight water soaking of RMC reduced GLS content by 31.96%. Similar reduction in GLS content of water soaked RMC was reported by Singhal and Senani (1991) and Tyagi *et al.* (1997) following the water soaking of mustard cake for a period of 12 h.

Voluntary feed intake: Intake (g/d) of concentrate moiety was lower (P<0.01) in RMC fed groups compared to control (Table 2), which could be attributed to the bitter taste and pungent odour of GLS metabolites in the diet (Bell 1984, Tripathi and Mishra 2007, Ravichandran *et al.* 2008). Wheat

Table 1. Ingredients and chemical composition of feeds offered to kids

Attributes	Concentrate mixture			Wheat straw
	Control	Group 2	Group 3	
<i>Ingredients composition (% as such basis)</i>				
Maize	30.00	29.00	29.00	–
GNC	30.00	–	–	–
RMC	–	43.00	43.00	–
Wheat bran	37.00	25.00	25.00	–
Mineral mixture	2.00	2.00	2.00	–
Salt	1.00	1.00	1.00	–
<i>Chemical composition (% DM)</i>				
OM	91.95	91.15	91.15	91.20
CP	22.70	22.90	22.90	3.68
EE	2.18	2.11	2.11	0.76
Total Ash	7.45	8.04	8.04	8.15
NDF	35.31	37.43	37.43	80.10
ADF	13.37	13.04	13.04	50.74
GLS (μmol/g DM)	–	64.28	43.74	–

straw intake (g/d) was significant ($P<0.05$) lower in RMC than primarily due to low DM intake from moistened straw moiety as reported by Peacock (1996) who suggested that DM intake have shown to be lower in goats fed high moistened feed and fodders.

Slaughter and carcass characteristics: The slaughter weight (PSW and EBW) of kids fed group 2 diet was comparable to control or group 3, while it was lower ($P<0.05$) in group 3 than control group (Table 2) due to lower DM intake. The carcass weights (kg) taken after skinning and evisceration respectively, were comparable between control and group 2 treatments, while these were lower ($P<0.05$) in group 3. Dressed carcass weight of kids was similar between control and group 2 (462.8 vs 461.8 g/kg of PSW) and these values were comparable to values reported earlier in Barbari kids (Sebsibe and Mathur 2000). However, dressed carcass weight was lower ($P<0.01$) in group 3 which could be attributed to lower PSW as dressed carcass weight is reported to be directly related to PSW (Sen *et al.* 2004).

The carcass length (cm) and loin eye area (cm²) were significantly ($P<0.05$) lower in group 3 than in control group, though both parameters in group 2 and control were comparable. The lowest loin eye area was (4.77 cm²) in group 3 and highest 6.24 cm² in control. These observations are in agreement with these of Pal Agnihotri (1999) in goats. They

Table 2. DM intake, carcass characteristics and yield of wholesale cuts in growing kids fed raw or water soaked RMC

Attributes	Treatments			SEM
	Control	Group 2	Group 3	
<i>DM intake (g/d)</i>				
Concentrate**	192.46 ^a	166.17 ^b	159.04 ^b	4.07
Wheat straw*	136.98 ^a	142.66 ^a	111.66 ^b	4.60
Total DM*	329.44 ^a	308.83 ^a	270.69 ^b	9.00
<i>Carcass characteristics</i>				
Pre slaughter weight (kg)*	15.10 ^a	14.27 ^{ab}	11.34 ^b	0.71
Carcass weight after skinning (kg)*	6.99 ^a	6.59 ^a	4.69 ^b	0.37
Carcass weight after evisceration (kg)*	6.12 ^a	6.02 ^a	4.04 ^b	0.36
Dressed carcass weight** (g/kg of PSW)	462.8 ^a	461.8 ^a	413.4 ^b	96.1
Carcass length (cm)*	52.80 ^a	51.50 ^{ab}	45.33 ^b	1.44
Loin eye area (cm ²)*	6.24 ^a	5.78 ^{ab}	4.77 ^b	0.24
<i>Yield of whole sale cuts (g/kg of dressed carcass weight)</i>				
Legs	329.93	317.46	324.61	6.21
Loin	71.87	66.24	69.52	2.07
Rack	85.52	94.38	82.89	2.83
Flank	30.33	27.11	33.31	0.91
Breast & Shank	199.93	197.04	200.03	2.66
Shoulder	205.21	218.27	213.07	3.43
Neck	81.92	75.53	74.02	2.62

^{ab}Mean values bearing different superscripts within a row differ significantly; * ($P<0.05$), ** ($P<0.01$).

Table 3. Yield of visceral organs and edible: non-edible ratio in growing kids fed raw or water soaked RMC

Aattributes	Treatments			SEM
	Control	Group 2	Group 3	
<i>Yield of visceral organs (g/kg of PSW)</i>				
Pluck*	35.73 ^b	40.81 ^a	40.53 ^a	1.42
Liver*	17.42 ^b	19.82 ^a	19.57 ^a	0.67
Heart	4.41	4.20	4.52	0.22
Lung with trachea	14.05	16.82	16.52	1.27
Kidney	5.17	5.23	5.05	0.21
Testes	7.24	7.31	6.52	0.44
Head	79.63	79.63	84.62	1.42
Feet	32.91	30.72	35.83	1.23
GIT (Ful)	316.42	306.58	319.42	6.45
GIT (Empty)	83.72	86.51	86.03	4.83
Spleen	1.34	1.42	1.56	0.11
Blood	34.79	29.83	31.07	1.43
Skin	87.32	85.51	75.61	3.94
Thyroid	0.070	0.072	0.073	0.002
<i>Edible: non-edible ratio</i>	2.51	2.79	2.48	0.09

^{ab}Mean values bearing different superscripts within a row differ significantly; * ($P<0.05$), ** ($P<0.01$).

further observed that animals with heavier carcass weight within each weight category having higher loin eye area resulted in better dressed carcass weight. The yield of wholesale cuts (g/kg of carcass weight) was comparable among dietary treatments. Leg contributed maximum to hot carcass followed by shoulder, breast and shank, irrespective of the dietary treatments as recorded in Barbari male kids (Agnihotri and Pal 1997).

Yield of visceral organs: The weight of visceral organs, thyroid and GIT (g/kg of PSW), and edible:non edible ratio did not differ significantly ($P>0.05$) among the treatments (Table 3). However, weight of pluck (liver, lungs with trachea and heart) was higher ($P<0.05$) in RMC fed groups due to liver enlargement ($P<0.05$). The present results are in agreement with, earlier reports in different species fed with RMC (Papas *et al.* 1979, Bourdon and Aumaitre 1990). Higher GLS content of RMC based diets increased the liver size since liver is the major organ detoxifying the GLS derivatives (Mandiki *et al.* 2002).

Chemical composition and physico-chemical properties of meat: The chemical composition of LD muscle was comparable ($P>0.05$) among the treatments (Table 4) and the mean moisture, protein, fat and ash content of LD muscle were similar to the reported values in Barbari kids (Agnihotri and Pal 1997). Physicochemical properties of LD muscle did not vary among the treatments. However, shear force value (SFV) of LD muscle (<5.5kg/cm²) in RMC fed groups was usually considered as objectionably tough (Shackelford *et al.* 1991). The variation in SFV may be attributed to the differences in post-mortem carcass treatment, age, live weight and the types of muscles used (Dhanda *et al.* 1999)

Table 4. Chemical composition, physico-chemical and sensory attributes of meat and thiocyanate concentration of vital organs in growing kids fed raw or water soaked RMC

Aattributes	Treatments			SEM
	Control	Group 2	Group 3	
<i>Chemical composition (% on fresh basis)</i>				
Moisture	75.22	75.25	77.01	0.62
Protein	20.95	20.91	19.51	0.50
Fat	2.81	2.78	2.25	0.14
Total ash	0.88	1.04	1.06	0.16
<i>Physico-chemical properties</i>				
pH	5.51	5.13	5.22	0.03
SFV (kg/cm ²)	4.79	6.25	5.92	0.32
WHC (ml/100 g)	11.99	9.99	10.55	1.02
Pigments (ppm)	93.30	71.74	82.31	6.07
<i>Sensory attributes</i>				
Appearance	7.17	6.79	6.80	0.14
Flavour/taste	7.09	6.78	6.79	0.12
Juiciness	6.93	6.45	6.51	0.13
Texture/tenderness*	7.00 ^a	6.33 ^b	6.35 ^b	0.13
Overall acceptability	7.12	6.75	6.77	0.11
<i>Thiocyanate concentration (µg/g)</i>				
LD muscle	2.92	3.07	2.91	0.23
Kidney*	10.30 ^b	14.82 ^a	13.34 ^a	0.76
Thyroid*	11.33 ^b	17.21 ^a	15.53 ^a	0.72
Lung	4.90	6.69	6.18	1.33
Liver	7.41 ^b	12.91 ^a	12.04 ^a	0.35

^{ab}Mean values bearing different superscripts within a row differ significantly; *P<0.05.

Organoleptic evaluation: Organoleptic scores obtained for sensory attributes of pressure cooked meat sample were similar among the treatments (Table 4). However, score obtained for texture/tenderness of meat was slightly poor (P<0.05) in RMC fed groups, which was a direct reflection of high SFV (Sen *et al.* 2004). As animals attain comparatively heavier weight in control group, their concurrent deposition of 'marbling' fat increases juiciness, thereby improving the perceived tenderness as observed in control group as compared to RMC fed groups (Seideman 1986). Comparatively, higher consumption (P<0.05) of concentrate in control group might also be a contributory factor for improving tenderness of meat (McClure *et al.* 1994). Feeding of raw or water soaked RMC had no adverse effect on carcass flavour as previously reported by Hill (1991) in lambs fed RMC based diet.

Thiocyanate concentration of vital organs and LD muscle: Thiocyanate is a major derivative of GLS which gets transferred to different vital organs upon ingestion of GLS (Nicolas Mabon *et al.* 1999, Pailan and Singhal 2004). Although thiocyanate concentration (µg/g) in vital organs, viz. thyroid, kidneys and liver tissues was higher (P<0.05) in RMC fed groups, its concentration in muscular tissues (LD muscle) was very low (2.91 to 3.07 µg/g) and did not

differ significantly among treatments. Thyroid and kidney have the trend to accumulate thiocyanate, and kidneys can be considered as a way of thiocyanate elimination.

It may be concluded that groundnut cake can be replaced with RMC in the diet of the growing kids without adverse impact on the carcass yield and meat quality attributes. Despite reduction in the substantial amount of GLS content of RMC by overnight water soaking, its feeding as mixed ration (*sani*) to growing kids had no positive effect in terms of meat quality attributes; rather PSW and subsequently carcass yield of kids were reduced due to low DM intake from high moistened straw moiety.

ACKNOWLEDGEMENT

The authors are thankful to Director, IVRI, Izatnagar, for necessary facilities provided to complete this study successfully in time. Financial assistance provided by ICAR, New Delhi, is duly acknowledged.

REFERENCES

- Agnihotri M K and Pal U K. 1997. Carcass characteristics and composition of Barbari male goats. *Indian Veterinary Journal* **74**: 403–06.
- AOAC. 2000. *Official Methods of Analysis*. 17th edn. Association of Official Analytical Chemist, Washington, DC.
- Bandy M T and Verma S V S. 2003. *In vitro* detoxification of rapeseed meal. *Indian Journal of Animal Nutrition* **20**: 70–75.
- Bell J M. 1984. Nutrients and toxicants in rapeseed meal: a review. *Journal of Animal Sciences* **58**: 996–1010.
- Bourdon D and Aumaitre A. 1990. Low-glucosinolate rapeseed and rapeseed meals: effect of technological treatment on chemical composition, digestible energy content and feeding value for growing pigs. *Animal Feed Science and Technology* **30**: 175–91.
- Bowler R G. 1944. The determination of thiocyanate in blood serum. *Biochemical Journal* **38**: 385–88.
- Chrystall B, Culioli J, Honikel K O, Moller A J, Purslow P, Schwagele F, Shorthose R and Uytterhaegen L. 1994. Recommendation of references methods for assessment of meat tenderness. *Proceedings of the 40th International Congress of Meat Science and Technology*. pp. 1–7. The Hague, The Netherlands.
- Dey A and Sehgal J P. 2005. Validity of acid detergent lignin and acid insoluble ash as internal markers for prediction of nutrient digestibility. *Indian Veterinary Medical Journal* **29**: 60–62.
- Dhanda J S, Taylor D G, Murray P J and McCosker J E. 1999. The influence of goat genotype on the production of Capretto and Chevon carcasses. 2. Meat quality. *Meat Science* **52**: 363–67.
- Duncan D B. 1955. Multiple range and multiple 'F' test. *Biometrics* **11**: 1–42.
- Jensen S K, Liu Y G and Eggum B O. 1995. The effect of heat treatment on glucosinolates and nutritional value of rapeseed meal in rats. *Animal Feed Science and Technology* **53**: 17–28.
- Hill R. 1991. Rapeseed meal in the diets of ruminants. *Nutrition Abstracts and Reviews (Series B)* **61**: 139–55.
- Hornsey H C. 1956. Colour of cooked cured pork. I. Estimation of the nitric oxide-Haem Pigments. *Journal of the Science of Food*

- and Agriculture **11**: 534–40.
- ISI. 1963. *Indian standard specifications for mutton and goat flesh—fresh, chilled and frozen*: IS 2536. Bureau of Indian Standards, New Delhi, India.
- Kearl L C. 1982. *Nutrient Requirement of Ruminants in Developing Countries*, International Feed Stuffs Institute, Utah Agricultural Experimental Station, Utah State University, Logan, USA.
- Liu Y G, Jensen S K and Eggum B O. 1995. The influence of seed size on digestibility and growth performance of broiler chickens fed full-fat rapeseed. *Journal of Science of Food and Agriculture* **67**: 135–40.
- Mandiki S N M, Derycke G, Bister J L, Mabon N, Wathelet J P, Marlier M and Paquay R. 2002. Chemical changes and influences of rapeseed antinutritional factors on gestating and lactating ewes. 1. Animal performances and plasma hormones and glucose. *Animal Feed Science and Technology* **98**: 25–35.
- McClure K E, Van Keuren R W and Althouse P G. 1994. Performance and carcass characteristics of weaned lambs either grazed on orchard grass, ryegrass, or alfalfa or fed all concentrate diets in dry lot. *Journal of Animal Science* **72**: 3230–37.
- Nicolas Mabon, Wathelet J P, Guy Derycke, Mandiki S N M, Bister J L, Michel Marlier and Raymond P. 1999. Correlation between breakdown products of glucosinolates and the amount of rapeseed meal introduced in the diets of 80 lambs and 32 bulls. Evolution of 5-vinyl-1, 3-oxazolidine-2-thione (5-VOT) and thiocyanate ions in biological fluids and organs. *Proceedings of the 10th International Rapeseed Congress*, Canberra, Australia. pp. 189.
- Pailan G H and Singhal K K. 2004. Effect of dietary glucosinolates on the vital organs and carcass characteristics in kids. *Indian Journal of Animal Nutrition* **21**: 89–94.
- Pal U K and Agnihotri M K. 1999. Effect of age by carcass weight classification on carcass traits, curability and fat partitioning of Barbari male goats. *Indian Journal of Animal Sciences* **69**: 255–57.
- Papas A, Ingalls J R and Campbell L D. 1979. Studies on the effects of rapeseed meal on thyroid status of cattle, glucosinolate and iodine content of milk and other parameters. *Journal of Nutrition* **109**: 1129–39.
- Peacock C. 1996. *Improving Goat Production in the Tropics*. A manual for development workers. An Oxfam/FARM-Africa publication, U K.
- Piggot J R. 1984. *Sensory Analysis of Foods*. pp. 389. Elsevier Applied Science Publishers Ltd., London.
- Ravichandran S, Sharma K, Dutta N, Pattanaik A K, Chauhan J S and Agnihotri A. 2008. Comparative assessment of soybean meal with high and low glucosinolate rapeseed–mustard cake as protein supplement on performance of growing crossbred calves. *Journal of Science of Food and Agriculture* **88**: 832–38.
- Sang J P and Truscott R J W. 1984. Liquid chromatographic determination of glucosinolates in rapeseed as desulphoglucosinolates. *Journal of Association of Official Analytical Chemists* **67**: 829–33.
- Sebsibe A and Mathur M M. 2000. Growth and carcass characteristics of Barbari kids as influenced by concentrate supplementation. *The opportunities and challenges on enhancing Goat production in East Africa*. (Eds) Merkel R C, Abebe G and Goetsch A L. Debub University, Awassa, Ethiopia, pp. 144–50.
- Seideman S C. 1986. Methods of expressing collagen characteristics and their relationship to meat tenderness and muscle fibre types. *Journal of Food Science* **51**: 273–76.
- Sen K C, Ray S N and Ranjhan S K. 1978. *Nutritive Value of Indian Cattle Feeds and the Feeding of Animals*. 6th edn, pp. 24. ICAR, New Delhi, India.
- Sen A R, Santra A and Karim S A. 2004. Carcass yield, composition and meat quality attributes of sheep and goat under semi-arid conditions. *Meat Science* **66**: 757–63.
- Shackelford S D, Morgan J B, Cross H R and Savell J W. 1991. Identification of threshold levels for Warner-Bratzler shear press in beef top loin steaks. *Journal of Muscle Foods* **2**: 289–96.
- Sharma K, Dutta N and Naulia U. 2004. An on-farm appraisal of feeding urea treated straw to buffaloes during late pregnancy and lactation in a mixed farming system. *Livestock Research for Rural Development* **16**: 1–7.
- Singhal K K and Senani S. 1991. Effect of soaking mustard cake in water on glucosinolates content and nitrogen solubility. *VI Animal Nutrition Research Worker's Conference*. pp. 276. Bangalore, India.
- Snedecor G W and Cochran W G. 1989. *Statistical Methods*. 6th edn. The Iowa State University Press, Ames, Iowa.
- TERI (Tata Energy and Research Institute). 2003. NATP on sustainable management of plant biodiversity chemical characterization of rapeseed–mustard for glucosinolate content. Project Report No. 99BB64. pp.58. National Bureau of Plant Genetic Resources, ICAR, New Delhi.
- Tripathi M K and Mishra A S. 2007. Glucosinolates in animal nutrition: a review. *Animal Feed Science and Technology* **132**: 1–27.
- Tyagi A K, Tripathi M K and Karim S A. 1997. Effect of soaking on glucosinolate of mustard-cake and its utilization in sheep feeding. *Indian Journal of Animal Sciences* **67**: 76–77.
- Van Soest P J, Robertson J B and Lewis B A. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* **74**: 3584–97.
- Wardlaw F R, McCaskill L H and Acton J C. 1973. Effect of postmortem muscle changes on poultry meat loaf properties. *Journal of Food Science* **38**: 421–24.
- Yeates N T M, Edey T N and Hill M K. 1975. *Animal Science: Reproduction, Climate, Meat and Wool*. pp. 226–27. Pergamon Press, Australia.