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Evaluation of tropical feedstuffs for carbohydrate and protein fractions by CNCP system

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ABSTRACT

Seventeen feed ingredients comprising protein sources (linseed cake-LSC, mustard seed cake-MSC, cotton seed cake-CSC, soybean cake-SBC and groundnut cake-GNC), energy sources (deoiled rice bran-DORB, maize grain-MG, barley grain-BG and wheat bran-WB), legume roughages (berseem, cowpea hay-CH, *Stylosanthes hamata*-SH and *Acacia catechu*-AC) and non-legume roughages (ammoniated wheat straw-AWS, guinea grass-GG, maize fodder -MF and sorghum fodder-SF) were evaluated for carbohydrate and nitrogen fractions as well as mineral contents. In CNCP system, crude protein content of feed is partitioned into 5 fractions (A, B_1, B_2, B_3 and C) and carbohydrate into 4 fractions (A, B_1, B_2 and C) according to degradation rates. The proximate composition, cell wall constituents, carbohydrate and nitrogen fractions of different feeds vary significantly amongst the groups. The CHO, C_{NSC}, C_{B1}, and Cc fractions of carbohydrate were higher in energy, while C_A and C_{B2} fraction of CHO were more in protein sources. Total CHO and C_{B2} fraction of carbohydrates were more in non-legume while C_A, C_{NSC} and Cc fractions were higher in legume roughages. Amongst the studied feedstuffs P_A and P_B fractions of protein were higher in protein sources, while P_{B2}, P_{B3} and P_C fractions were higher in energy sources. Legumes exhibited higher contents of P_{B2}, while non-legume had higher P_A, P_{B1} and P_{B3} fraction of protein. Concentration of macro (%) and micro minerals (ppm) of feed stuffs differed across feeds (energy and protein) and roughages (legumes and non legumes).

It is concluded from the present study that feedstuffs chemical properties for carbohydrate and nitrogen fractions are unique and different. Therefore feed ingredients selection based on CNCPS evaluation will be more logical for formulating efficient diets for livestock.

Key words: Carbohydrate fractions, CNCPS, Feedstuffs, Macro minerals, Micro minerals, Nitrogen fractions

The conventional proximate analysis system of feed evaluation had flaws in fiber and NFE estimation. Van Soest detergent system, though an improvement over proximate analysis but NDF does not confirm as a unit, moreover its constituents and degradability in the rumen varies. Recent researches have revealed that feedstuffs rate of degradation in rumen have profound effect on rumen fermentation end products and subsequently on animal performance. The fractionation of carbohydrate and protein of feed stuffs considering the degradability will be of immense use in determining the rate of degradability, digestibility and rate of passage the ration per se and finally the production of the animal. Analytical procedures for carbohydrate and protein fractionations have been currently fully developed in the Cornell Net Carbohydrate and Protein System (CNCPS). This system is rather primarily based on Van Soest analytical system, with the inclusion of other standard techniques. These fractions describe the feedstuff components that are uniformly degraded in the rumen and digested in the small intestine. Jeya Prakash *et al.* (2003) and Kamble *et al*. (2010) have reported the carbohydrate and nitrogen fractions of Indian feeds. Precision animal agriculture recently being developed in the country and for the preparation of balanced ration through adoption of advanced standards (NRC 2001 and CNCP 2007) substantially more data on precise fractions of carbohydrate and protein fractions is required for the different indigenous feeds. In view of the above, the present study was carried out to develop database on carbohydrate and protein fractions of different feedstuffs.

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MATERIALS AND METHODS

Samples of protein sources (linseed cake-LSC, mustard seed cake-MSC, cotton seed cake-CSC, soybean cake-SBC and groundnut cake-GNC), energy sources (deoiled rice bran-

DORB, maize grain-MG, barley grain-BG and wheat bran-WB), legume roughages (berseem, cowpea hay-CH, *Stylosanthes hamata*-SH and *Acacia catechu*- AC locally known as *khair*) and cereal roughages (ammoniated wheat straw-AWS, guinea grass-GG, maize fodder-MF and sorghum fodder-SF) were collected from different places (grain market, feed store and experimental farm of Indian Grassland and Forage Research Institute, Jhansi, UP) were randomly collected and mixed to have a homogenous sample and dried in hot air oven then ground to pass through 1 mm sieve using Willey mill. Proximate composition and starch were determined as per AOAC (1995) and fiber fraction (NDF, ADF, cellulose, hemi-cellulose and lignin) were estimated as Van Soest *et al*. (1991). Soluble protein, NPN, NDIN and ADIN were estimated following Licitra *et al*. (1996). In CNCP system, crude protein content of feed is partitioned into 5 fractions (A, B_1, B_2, B_3 and C). Fraction A and B_1 are soluble in buffer and B_1 (true protein rapidly degraded in the rumen) is determined as the TCA precipitated fraction of buffer soluble nitrogen. True protein with an intermediate degradation rate (fraction B_2) is the remaining N which is estimated by buffer insoluble protein minus the protein insoluble in neutral detergent. Fraction C contains protein associated with lignin, tannin-protein complexes and Maillard products that are unavailable to the animals is insoluble in the acid detergent (acid detergent insoluble protein-ADIP). Fraction B_3 (slowly degraded true protein) is insoluble in neutral detergent but soluble in acid detergent (NDIP minus ADIP). Carbohydrate can be classified according to degradation rates (A, B_1, B_2 and C). Fraction A is highly degradable (sugar), fraction B_1 is intermediate (starch, pectin and ß-glucans like compounds), fraction B_2 is slowly available cell wall constituents and fraction C is unavailable lignin bound cell wall. These fractions are computed from non-structural carbohydrate (NSC) and structural carbohydrate (SC) and indigestible fibre (C). Different fractions of carbohydrate and protein were calculated by using the equations (Sniffen *et al*. 1992) and data generated due to evaluation of feeds and fodders were statistically analyzed using statistical package SPSS version 10.0.

RESULTS AND DISCUSSION

Proximate constituents and cell wall fractions: Proximate values of evaluated feed sources varied significantly (P<0.01) among the groups (Table 1). The concentration of CP, EE, and ash in CSC, BG and MG were similar to those of Sniffen *et al*. (1992) and Khadaker *et al*. (1997). Crude protein

Table 1. Proximate composition and cell wall constituents of feed ingredients (% DM basis)

Feed ingredients	CP	EE	NDF	ADF	Cellulose	Hemi-cellulose	Lignin	Ash
Protein sources								
LSC	25.89^{a}	2.55^{a}	44.85^{d}	21.00^{c}	11.82^{c}	23.85^{c}	6.73^{d}	9.82^{c}
MSC	35.03^{c}	8.25^{c}	24.46^{b}	17.08^{b}	10.28^{b}	7.37^{a}	5.29^{c}	7.90^{b}
CSC	30.28^{b}	2.40^{a}	40.30^{e}	29.52^{d}	21.88^{d}	10.78^{b}	8.09^{e}	5.85^{a}
SBC	47.63^{e}	6.36^{b}	44.05^{d}	9.28^{a}	7.97^{a}	34.77^{d}	0.42^{a}	6.37^{b}
GNC	42.87^{d}	7.75^{c}	16.70^{a}	9.70^{a}	7.57^{a}	7.00^{a}	2.63^{b}	5.51^{a}
P	***	***	***	***	***	***	***	***
Energy sources								
DORB	6.75^{a}	0.46^{a}	67.70^{c}	51.85^{d}	26.60^{c}	15.85^{a}	14.11^{c}	16.59^{d}
MG	11.90^{c}	5.76^{d}	22.52^{a}	4.29^{a}	3.09^{a}	18.24^{a}	1.31^{a}	0.58^{a}
BG	15.38^{d}	2.58^{b}	22.75^{a}	6.92^{b}	5.69^{b}	15.83^{a}	4.92^{b}	2.90^{b}
WB	9.00^{b}	4.66^{c}	36.10^{b}	10.08^{c}	6.32^{b}	26.02^{b}	2.62^{a}	4.71^{c}
P	***	***	***	***	***	***	***	***
Legume roughage								
Berseem	16.28^{f}	4.46^{b}	36.28^{a}	26.35^{a}	19.90^{b}	9.93^{a}	5.56^{bc}	13.05^{d}
CH	10.06^{c}	4.50^{b}	63.17^{d}	43.57^{d}	27.21^{c}	19.61^{c}	9.61^{d}	14.30^{e}
SH	13.05^{e}	1.20^{a}	54.16^{c}	38.05^{c}	31.34^{d}	16.11^{b}	6.29^{c}	8.75^{a}
AC	13.73^{e}	1.51^{a}	48.12^{d}	25.38^{a}	15.53^{a}	22.73^{c}	9.11^{d}	8.69^{a}
Non legume roughage								
AWS	10.66^{c}	1.47^{a}	63.22^{d}	37.91^{c}	29.97^{c}	25.31^{cd}	5.69^{bc}	12.35^{c}
GG	7.04^{b}	1.02^{a}	76.18^{f}	47.44^{f}	38.49^{e}	28.74^{e}	5.29^{bc}	12.05^{b}
MF	9.39^{c}	1.39^{a}	62.05^{d}	31.99^{b}	27.39^{c}	30.06^{e}	3.13^{a}	7.11^{a}
SF	6.43^{a}	1.58^{a}	71.74^{e}	32.43^{b}	29.72^{c}	39.31^{f}	5.01^{b}	7.08^{a}
P	***	***	***	***	***	***	***	***

Means with different superscripts within a column differ significantly at P<0.01 level of significance.

LSC linseed cake; MSC, mustard seed cake; CSC, cotton seed cake; SBC, soybean cake; GNC, groundnut cake; DORB, deoiled rice bran; MG, maize grain; BG, barley grain; WB, wheat bran; CH, cowpea hay; SH, *Stylosanthes hamata;* AC, *Acacia catechu*; AWS, ammoniated wheat straw; GG, guinea grass; MF, maize fodder; SF, sorghum fodder.

contents of MSC, GNC, CSC, BG, WG, MG and WB reported by Mondal *et al.* (2008), were identical to values of these feeds evaluated in present study. Crude protein in GNC was slightly higher (Singh *et al*. 1995), in MSC is similar (Khandakar and Uddin 2002), but lower in DORB (6.75) and WB (9.00). Values reported for CP in berseem and AWS by Kundu and Mudgal (1985) are similar to present findings. The value of these constituents in SF, SH, GG, berseem and MF recorded in present study are within the range (Singh *et al*. 1995, Mehta and Srinivasulu 2001), while these value in MF, SF and SH were different than those reported earlier (Khandaker and Uddin 2002, Krishnamoorthy *et al.* 1996, Murugan *et al*. 2002).

Concentration of cell wall constituents varied significantly (P<0.01) in the groups of protein sources, energy sources and roughages. The concentration of cell wall constituents in CSC and GNC and SBC were more or less comparable with finding of Singh *et al.* (2002) and in MSC (Khandaker and Uddin 2002, Sharma and Singh 1997). All protein sources had higher cell wall polysaccharides than reported by Dutta and Agrawal (1995). However ADF was similar to the reported value of these workers. The lowest value of cell wall materials (NDF, ADF, cellulose and lignin) in MG was observed among the evaluated energy sources, which was similar to the findings of Sharma and Singh (1997); whereas less NDF was observed in BG and WB (Kamble *et al.* 2010). The cell wall contents of evaluated energy sources were higher than NRC (1989). Berseem had lowest and CH had highest value of cell wall contents amongst the roughages. The cell wall constituents of SH, MF, berseem, GG and SF observed in present study were within the range of earlier workers (Mahanta *et al.* 1999, Khanaker and Uddin 2002) however differed in CH and SF (Singh *et al.* 1995, Ramteke *et al.* 2002). Chemical composition of feeds is affected by several factors such as processing, variety, species and method of estimation.

Macro and micro minerals: Concentration of Ca varied in protein sources, energy sources and in roughages (Table 2). In protein sources the mean concentration of P, Mg and Na was comparable to the reported value of Garg *et al*. (2003) but lower in K. Concentrations of macro minerals (Ca, P, Mg and Na) reported by Garg *et al.* (2002) in GNC and CSC were within the range of observed values. The Ca contents of BG (0.16) and WB (0.20%) were relatively higher than the observed values of Garg *et al.* (2002, 2003) whereas P, Mg, Na and K observed in BG, MG and WB were similar. Among roughages concentration of Ca and Mg was higher in legumes than non-legume, however later had higher

Table 2. Macro mineral (% of DM) and micro mineral (ppm) contents of feed ingredients*

Feed ingredients	Macro minerals (%)					Micro minerals (ppm)						
	Ca	P	Mg	Na	K	Cu	Zn	Mn	Fe	Co	Mo	Se
Protein sources												
LSC	0.11	0.52	0.15	0.02	0.39	13.35	12.60	23.50	560.0	0.70	5.00	21.50
MSC	0.58	1.12	0.36	0.02	0.76	16.50	29.30	48.50	451.0	0.30	3.20	32.00
CSC	0.27	0.55	0.31	0.02	0.94	15.85	38.85	32.50	381.0	0.85	3.50	16.50
SBC	0.28	0.68	0.29	0.01	1.52	22.50	69.00	42.20	464.5	1.20	4.20	22.00
GNC	0.32	0.86	0.26	0.03	0.50	14.20	123.0	33.20	635.0	0.70	5.50	5.50
Mean	0.31	0.75	0.27	0.02	0.82	16.48	54.55	35.98	498.3	0.75	4.28	19.50
Energy sources												
DORB	0.05	0.70	0.39	0.03	0.54	6.60	160.0	102.0	680.	5.00	2.50	25.00
BG	0.16	0.27	0.10	0.02	0.32	8.50	9.85	20.00	197.0	0.04	1.10	11.50
MG	1.20	0.12	0.35	0.14	0.49	6.75	25.95	37.00	458.5	0.45	3.00	38.50
WB	0.20	0.90	0.28	0.02	0.66	10.60	67.00	88.50	322.0	0.25	2.90	15.00
Mean	0.40	0.49	0.28	0.05	0.50	8.11	65.70	61.88	414.38	1.44	2.38	22.50
Legume roughage												
Berseem	0.39	0.26	0.29	0.02	1.53	12.30	6.60	35.80	422.0	0.45	2.50	23.00
CH	1.10	0.15	0.54	0.06	0.68	10.50	14.05	92.00	108.2	0.85	4.00	38.50
SH	0.78	0.18	0.34	0.04	1.38	13.50	61.00	48.30	434.5	0.60	2.20	30.00
AC	0.80	0.13	0.31	0.01	0.53	10.50	90.00	36.00	415.5	0.35	2.50	4.00
Mean	0.76	0.18	0.37	0.03	1.03	11.70	42.91	53.03	345.05	0.56	2.80	23.88
Non legume roughage												
AWS	0.27	0.15	0.13	0.18	1.08	9.50	469.5	24.80	416.0	0.50	4.05	24.00
GG	0.27	0.15	0.31	0.03	1.80	8.50	396.0	35.50	212.5	0.30	2.30	19.00
MF	0.56	0.45	0.36	0.02	0.80	7.00	316.5	56.50	444.5	0.10	3.00	5.00
SF	0.54	0.28	0.40	0.02	1.02	8.50	428.0	35.80	276.0	0.15	3.85	24.00
Mean	0.41	0.26	0.30	0.05	1.18	8.38	402.5	38.15	337.25	0.26	3.30	18.00

•Each value is mean of 3 replications.

concentration of P, Na and K. Berseem, lucerne and *methi* contained higher amount of Ca, whereas Ca, P, Mg, Na and K contents of SF observed in present study were identical to the reported values of Garg *et al*. (2003). Average concentrations of Cu, Mn, Fe and Mo in protein sources were higher than energy sources, however the concentration of some micro minerals (Zn, Co and Se) was more in energy than protein sources. Concentration of Cu, Zn, Mn Fe, Co and Se was more in legumes than non-legumes, while later had higher Mo concentration (3.3 ppm). Concentration of some micro mineral in different groups reported by Garg *et al*. (2003) is not consistent with the present findings; however, concentration of certain minerals was similar to their findings. Concentration of minerals in feeds and fodders depends on different conditions, viz. soil type, plant species, soil pH, crop age, climate, fertilization application rate etc.

Carbohydrate and protein fractions: Protein sources, energy sources and roughages differed significantly (P<0. 01) in concentration of carbohydrate and protein fractions (Table 3). Lignin% of NDF in LSC and SBC were lower than reported values of Sniffen *et al.* (1992) whereas the protein and CHO fractions of CSC were identical to present values. Total CHO% of DM in protein sources was lower than energy sources and roughage and the values of NSC% CHO of protein and energy sources in present study were comparable to reported values (Singh *et al*. 2002). Total CHO% of DM of roughages ranged from 62.86 (berseem) to 84.85 (SF) are similar to reported values (Singh *et al*. 2002, Chaurasia *et al.* 2006, Yu *et al*. 2003). SBC had lower concentration of NPN% of SP (11.84) and SP% of CP (9.01), however CP, NDIP, ADIP, and starch% of NSC of soybean are well comparable, soluble protein% of CP was similar while NDIP% of CP and ADIP% of CP were higher than reported value of Sniffen *et al.* (1992). Singh *et al.* (2002) reported higher value of NDIP% CP and NPN% of SP in MSC, however SP% of CP was comparable. Starch% of NSC, SP% of CP, ADIP% of CP, NPN% of SP and NDIP% of CP in BG and MG are identical to findings of Sniffen *et al*. (1992), Singh *et al*. (2002), whereas starch% of NSC recorded in MG, BG and WB are different than the earlier reported values (Jeya Prakash 1999, Kamble *et al*. 2010). Carbohydrate and protein fractions of WB and BG reported by Singh *et al.* (2002) are not in agreement with the present findings. Lignin% of NDF in non legume (5.13 to 9.34) was lower than in legume (11.7 to 18.93) are in agreement with Sniffen *et al*. (1992). Soluble protein% of CP in the roughages evaluated is comparable to the findings of earlier workers (Sniffen *et al*. 1992, Singh *et al*. 2002, Yu *et al*. 2003). The

Table 3. Carbohydrate and Protein fractions of feed ingredients

Feed ingredients	Lignin (% NDF)	CHO (%DM)	NSC (%DM)	Starch (% NSC)	SP %CP	ADIP %CP	NPN %SP	NDIP % CP
Protein sources								
LSC	15.02^{b}	61.72^{d}	38.40^{b}	75.98^{c}	23.52^{c}	6.45^{c}	24.97^{c}	25.96^{c}
MSC	17.69^{b}	48.81^{c}	56.20^{d}	43.96^{b}	38.97^{d}	5.08^{c}	35.18^{d}	8.78^{a}
CSC	19.05^{c}	61.02^{d}	43.40^{c}	91.02^{d}	21.16^{b}	4.97^{b}	38.68^{d}	8.41^{a}
SBC	.85^{a}	39.14^{a}	13.20^{a}	88.32^{d}	9.01^{a}	1.69^{a}	11.84^{a}	20.92^{b}
GNC	15.89^{b}	43.90^{b}	70.50^{e}	19.89^{a}	60.46^{e}	2.13^{a}	14.84^{b}	6.88^{a}
P	***	***	***	***	***	***	***	***
Energy sources								
DORB	28.48^{d}	65.85^{a}	27.33^{a}	98.37^{c}	38.97^{d}	19.23^{c}	34.35^{b}	47.28^{c}
MG	4.67^{a}	81.75^{c}	74.49^{c}	99.75^{c}	14.30^{a}	4.44^{b}	35.84^{b}	14.08^{a}
BG	21.65^{c}	85.51^{d}	74.75^{c}	79.95^{a}	36.32^{c}	2.64^{a}	34.17^{b}	13.01^{a}
WB	7.44^{b}	75.24^{b}	56.54^{b}	89.21^{b}	18.42^{b}	2.97^{a}	23.63^{a}	22.14^{b}
P	***	***	***	***	***	***	***	***
Legume roughage								
Berseem	15.34^{d}	62.86^{a}	45.83^{e}	19.21^{a}	48.61^{f}	7.67^{a}	67.20^{d}	25.96^{a}
CH	15.45^{d}	67.17^{b}	14.46^{a}	70.56^{d}	5.60^{a}	20.8^{f}	41.75^{c}	54.99^{f}
SH	11.7^{c}	77.00d	34.53^{d}	89.10^{f}	18.35^{c}	12.36^{c}	37.85^{b}	28.78^{b}
AC	18.93^{e}	76.06^{d}	43.81^{e}	30.10^{b}	11.47^{b}	19.83^{e}	77.16^{e}	39.19^{c}
Non legume roughage								
AWS	8.35^{b}	73.5^{c}	18.15^{b}	87.76^{f}	49.15^{f}	7.22^{a}	40.73^{c}	30.38^{b}
GG	9.34^{b}	79.92^{e}	36.67^{d}	36.42^{c}	25.13^{e}	24.87^{g}	92.91^{g}	50.51^{e}
MF	5.13^{a}	82.13^{f}	29.68^{c}	35.42^{c}	21.2^{d}	11.23^{b}	24.62^{a}	47.07^{d}
SF	6.03^{a}	84.85^{g}	19.33^{b}	81.71^{e}	22.18^{d}	16.21^{d}	80.77^{f}	51.39^{e}
P	***	***	***	***	***	***	***	***

Means with different superscripts within a column differ significantly at P<0.01 level of significance.

CHO, total carbohydrate; NSC, non structural carbohydrate; SP, soluble protein; NPN, non protein nitrogen; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein.

Table 4. Carbohydrate sub fractions (% CHO) of feed ingredients

Feed ingredients	C_A	C_{B1}	C_{B2}	C_C
Protein sources				
LSC	9.30^{b}	29.13^{d}	35.35^{d}	26.20^{d}
MSC	31.50^{c}	24.4^{c}	22.50^{b}	21.30^{c}
CSC	3.90^{ab}	39.50^{e}	27.84^{c}	28.75^{e}
SBC	1.50^{a}	11.60^{a}	84.50^{e}	2.30^{a}
GNC	54.90^{d}	13.60^{b}	17.00^{a}	14.40^{b}
P	***	***	***	***
Energy sources				
DORB	0.04^{a}	3.03^{a}	27.34^{c}	69.59^{d}
MG	0.17^{a}	74.32^{d}	22.30^{b}	3.19^{a}
BG	14.98^{c}	59.77^{c}	11.41^{a}	13.83^{c}
WB	6.07^{b}	50.47^{b}	34.87^{d}	8.62^{b}
P	***	***	***	***
Legume roughage				
Berseem	37.07^{e}	8.78^{a}	32.92^{b}	21.27^{de}
CH	4.28^{a}	10.18^{a}	49.93^{c}	35.69^{g}
SH	3.75^{a}	30.78^{e}	45.68^{e}	19.77^{de}
AC	30.59^{d}	13.18^{b}	27.43^{a}	28.75^{f}
Non legume roughage				
AWS	2.24^{a}	16.15^{cd}	64.34^{de}	17.25^{c}
GG	23.32^{e}	13.35^{bc}	48.55^{c}	14.79^{bc}
MF	19.29^{b}	10.50^{a}	60.56^{d}	9.73^{a}
SF	3.58^{a}	15.79^{c}	68.36^{e}	12.27^{ab}
P	***	***	***	***

Means with different superscripts within a column differ significantly at P<0.01 level of significance. C_A, Carbohydrate fraction A; C_{B1}, carbohydrate fraction B1; C_{B2}; carbohydrate fraction B2, C_C, carbohydrate fraction C

Table 5. Nitrogen fractions (% CP) of feed ingredients

Feed ingredients	P_A	P_{B1}	P_{B2}	P_{B3}	P_C
Protein sources					
LSC	6.20^{b}	17.32^{c}	50.51^{c}	19.50^{c}	6.34^{d}
MSC	14.08^{d}	25.22^{d}	52.20^{c}	3.72^{a}	5.08^{c}
CSC	37.24^{e}	11.68^{b}	38.38^{b}	6.80^{b}	5.87^{c}
SBC	1.07^{a}	7.95^{a}	70.05^{d}	18.22^{c}	1.69^{a}
GNC	9.08^{c}	51.53^{e}	32.49^{a}	4.17^{a}	2.70^{b}
P	***	***	***	***	***
Energy sources					
DORB	8.29^{b}	15.85^{b}	28.56^{a}	28.04^{c}	19.23^{c}
MG	5.12^{a}	9.18^{a}	71.61^{d}	9.64^{a}	4.44^{b}
BG	12.39^{c}	23.93^{c}	52.69^{b}	10.36^{a}	2.64^{a}
WB	4.18^{a}	14.08^{b}	59.55^{c}	19.05^{b}	2.67^{a}
P	***	***	***	***	***
Legume roughage					
Berseem	32.92^{h}	15.96^{d}	37.82^{d}	5.89^{a}	7.00^{a}
CH	2.32^{a}	3.27^{ab}	37.53^{d}	34.20^{d}	20.80^{d}
SH	6.94^{c}	11.7^{c}	52.82^{e}	16.42^{b}	12.15^{b}
AC	8.95^{d}	2.51^{ab}	49.33^{e}	19.03^{b}	19.83^{d}
Non legume roughage					
AWS	20.00^{f}	29.14^{e}	20.47^{a}	23.15^{c}	7.22^{a}
GG	23.05^{g}	1.75^{a}	24.68^{b}	25.64^{c}	24.86^{f}
MF	5.21^{b}	15.97^{d}	31.72^{c}	35.84^{d}	11.23^{b}
SF	17.91^{e}	4.26^{b}	26.41^{b}	35.18^{d}	16.21^{e}
P	***	***	***	***	***

Means with different superscripts within a column differ significantly at P<0.01 level of significance. P_A, nitrogen fraction A; P_{B1} nitrogen fraction B1; P_{B2}, nitrogen fraction B2; P_C, nitrogen fraction C.

contents of NPN% of SP, ADIP% of CP and NDIP% of CP observed in legume (and non-legume respectively are comparable (Sniffen *et al.* 1992, Singh *et al.* 2002, Chaurasia *et al.* 2006 and Yu *et al.* 2003).

Carbohydrate-sub fraction: Protein, energy and roughages differed significantly (P<0.01) in carbohydrate sub fractions (Table 4). Fraction C_{B1}, C_{B2} and C_C (82.3, 10.0 and 0.6) of maize grain reported by Chen *et al.* (1999) are comparable with present study, while fraction C_A was higher. Concentrations of fraction C_A and C_{B2} in BG of present study are comparable with Singh *et al.* (2002) but fraction C_C was relatively lower. Intermediate slowly degradable fraction C_{B2} was higher in non-legume than legume had similar trends as recorded by Singh *et al.* (2002). Fraction C_{B2} that mostly representing available cell wall content ranged from 71.0 in timothy Jolielte to alfalfa Pioneer (21.2) as reported by Yu *et al.* (2003) confirms the present findings. C_{B1} ranged from 1.85 in *Sehima nervosum* to 53.10 in *Securenegia virosa* reported by Chaurasia *et al.* (2006) are within the range of present results. Fraction C_C (unavailable fibre) varied from 9.73 in MF to 35.69 in CH of the evaluated roughage corroborates with observations, Singh *et al.* (2002), Chaurasia *et al.* (2006) and Yu *et al.* (2003).

Nitrogen sub-fraction: The concentration of nitrogen fraction (P_A, P_{B1}, P_{B2}, P_{B3} and P_C) amongst the evaluated protein sources, energy sources, legume and non-legume roughages differ significantly (P<0.01; Table 5). Concentration of (P_A+P_{B1}) fractions in LSC, MSC, GNC and SBC were lower; however that in CSC was higher (Sharma and Singh 1997, Mondal and Walli 2003). Intermediately degradable fraction P_{B2} observed in CSC, SBM, GNC, and MSC was higher but P_{B3} in MSC, SBM, CSC and GNC was lower (Mondal and Walli 2003). Fraction P_{B3} estimates the protein associated with the plant cell wall, which accounts for its insolubility (Van Soest 1994, Rebole *et al.* 2001). P_{B3} fraction is slowly degraded in the rumen but digested in high proportion in small intestine (Rebole *et al.* 2001). Fraction P_{B3} varied from 3.72 in MSC to 19.50 in LSC, and was comparable to reported values of Sharma and Singh (1997). Fraction P_C consists of N bound to lignin, Maillard reaction protein and tannin-protein complexes. From a nutritive point of view this fraction appears to be essentially indigestible and amount apparently digested to be essentially indigestible and amount apparently digested is poorly used by the ruminant animals (Rebole *et al.* 2001). Fraction P_C in protein and energy sources is lower than Singh *et al.* (2002) and Kamble *et al.* (2010). The protein fraction P_A+P_{B1} of different energy sources were lower but P_{B2} and P_{B3} fraction of maize grain were comparable to the findings of Sharma and Singh (1997). P_{B2} fraction of wheat bran and barley grain was identical (Singh *et al*. 2002); however P_C fraction in deoiled rice bran, wheat bran and maize grain was higher (Sharma and Singh 1997). Mean concentration of P_{B2} was higher in legume (37.53 to 52.82) than non-legume (20.47 to 31.72) supported the findings of Elizalde *et al*. (1999) whereas fraction P_{B3} (23.15 to 35.84) was higher in non-legume than legume (5.89–34.20) corroborates with the findings of Singh *et al.* (2002) and Chaurasia *et al.* (2006). Legume had higher proportion of insoluble protein and P_{B2} fraction while lower proportion of fraction P_{B3} than grasses (Elizalde *et al*. 1999). Concentration of fraction P_{B3} ranged from 5.89 in berseem to 35.84 in MF and fraction P_C varied from 7.00 in berseem to 24.86 in GG amongst the roughages are comparable with the reported values (Singh *et al*. 2002, Chaurasia *et al.* 2006 and Yu *et al.* 2003). A study was conducted by Yu *et al.* (2003) to see the effect of variety and maturity stage on protein sub fraction in alfalfa and timothy. Fraction P_A, P_{B2} and P_{B3} values were comparable to observations of present study. Protein fractions P_{B1}, P_{B2}, P_{B3} and P_c of berseem recorded by Ghoorchi and Arbabi (2010) are also identical to the nitrogen fractions of this feed stuff observed in present study.

Average CHO, C_{NSC}, C_{B1}, and Cc fractions were higher in energy sources, while C_A and C_{B2} fraction of CHO were more in protein sources. Total CHO and C_{B2} fraction of carbohydrates were more in non-legume while C_A, C_{NSC} and Cc fractions were higher in legume roughages. Mean contents of P_A and P_{B1} fractions of protein were higher in protein sources while P_{B2}, P_{B3} and P_C fractions were higher in energy sources. Legumes exhibited higher contents of P_{B2}, while non-legume had higher P_A, P_{B1} and P_{B3} fraction of protein. Results of study revealed that the wide variability exists in feedstuffs for carbohydrate and nitrogen sub fractions. Therefore feed ingredients selection on this basis will be more logical for formulating more efficient feeding system for ruminants.

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