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Evaluation of legume and cereal fodders for carbohydrate and protein fractions, nutrient digestibility, energy and forage quality

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Abstract

In the present study commonly used 5 legume (berseem, lucerne, desmenthus, lablab and stylosanthes) and 8 cereal (barley green, oat green, guinea grass, wheat straw, paddy straw, pearl millet stover, maize stover and sorghum stover) fodders were evaluated for proximate constituents, fiber contents, carbohydrate and protein fractions besides the *in vitro* nutrient (DM, CP, NDF and ADF) digestibility. These fodders were also screened for their relative feed value (RFV), relative feed quality (RFQ), rumen degradable protein (RDP) value and energy value. Carbohydrate and protein fraction traits of fodders were utilized in regression equation to predict the RFQ. Concentration of NDF, ADF and cellulose was more (P<0.05) in cereal fodders, while CP and lignin contents were (P<0.05) more in legumes. Carbohydrate soluble fraction (C_A) and rapidly degradable fraction (C_{B1}) were higher (P<0.05) in legume fodders (14.5 and 19.2) than cereals (2.4 and 11.4%). Protein low degradable fraction (P_{B3}) and undegradable fraction (P_C) were significantly (P<0.05) higher in cereals (22.3 and 21.7) than legume fodders (9.5 and 12.6% CP). TDN value varied from 39 to 59% in cereal fodders and 50 to 60% in legume fodders. DMI was high in legumes (1.8-2.9%), while in the cereals it varied from 1.6 to 1.8. Feed quality values as RFV and RFQ varied from 72 to 153 and 74 to 142% in legumes while 47 to 82 and 50 to 85% in cereal fodders. For quality determination, RFQ was correlated with carbohydrate fraction alone and gave R^2 value 0.9 while with protein and carbohydrate fraction it gave R^2=0.98 (P<0.01). Legumes are good source of total protein, rumen degradable protein and had more nutrients utilization than cereal fodders. Protein and carbohydrate fractions can be utilized to determine the more précised RFQ vales of fodders.

Keywords: Carbohydrate, Energy, Fodders, Protein fractions, Relative feed quality

Introduction

Feed components do not follow similar pattern of degradation and digestion in rumen and intestine. Rate of degradation of different fractions of feeds provide more precise information on nutrients availability to the animal. The carbohydrate and protein fractions of fodders/feeds as per Cornell net carbohydrate and protein system (CNCPS) describe the degradation pattern and digestion in rumen and small intestine respectively (Sniffen *et al.*, 1992). In feed formulation, the table values of TDN are often referred, which result in inaccuracy in ration formulation due to variation in composition within the same feed/fodder. Published TDN values are only appropriate when the nutrient composition of the feed or fodder used is essentially the same as that of used in the digestibility trial. Conducting animal trial for individual fodders/feeds to evaluate their nutritive value for animals is time consuming and not a practicable approach to have information from large fodders in short duration. In NRC (2001) a summative approach was suggested and followed in which truly digestible non fiber carbohydrate, CP, EE and NDF were used to derive the TDN values (Weiss *et al.*, 1992). Voluntary DMI (VDMI), relative feed values (RFV) are indices of forage quality and the basis of RFV is voluntary intake of digestible DM (Moore, 1994). Moore and Undersander (2002) proposed relative forage quality (RFQ) as the more precise alternative to RFV. RFQ is also an estimate of voluntary intake of available energy when forage is fed as sole source of energy and protein. In this study carbohydrate and protein fractions have been correlated with RFQ values to develop the regression equation. Information is available on the chemical constituents, carbohydrate and protein fractions with nutrients digestibility for these fodders, while information is scanty on the RFQ and RDP values of these fodders. Keeping this in mind, the present study was undertaken to evaluate commonly used fodders for different nutritional attributes for their use in formulation of animal diets for different production functions.

Materials and Methods

Sample collection and processing: Samples of common legumes *viz.*, berseem (*Trifolium alaxendrinum*), lucerne (*Medicao sativa*), desmenthus (*Desmenthus virgatus*), dolichos (*Lablab purpureus*), stylosanthes (*Stylosanthes hamata*) and cereal fodders namely barley fodder (*Hordeum vulgare*), oats fodder (*Avena sativa*), guinea grass (*Panicum maximum*), wheat straw (*Triticum aestivum),* paddy straw (*Oryza sativa*), pearl millet stover (PMS), maize stover (MS) and sorghum stover (SST) were collected from Central Research Farm of IGFRI, Jhansi. The samples were dried in hot air oven at 70 ^{0}C until constant weight, ground to pass through 1mm sieve using electrically operated Willey mill and stored in plastic sample bottles of 200 ml capacity for further analysis.

Chemical analysis: Crud protein, EE and ash contents were determined following method of AOAC (2000), while fiber fractions (NDF, ADF, cellulose and lignin) contents were estimated as per Van Soest *et al.* (1991). NDF was assayed without α-amylase and expressed exclusive of residual ash. Lignin was estimated by separate hydrolysis of acid detergent residue in 72% H_2SO_4 for 3h (Van Soest *et al.*, 1991). Estimation of starch was done as per the procedure applicable to grains, stock feeds, and cereals given in AOAC (2000). Starch extract was prepared by direct acid hydrolysis method and glucose in aliquot of filtrate was determined. Then starch was estimated by multiplying 0.925 with the weight of glucose obtained. Neutral detergent insoluble protein (NDICP) and acid detergent insoluble protein (ADICP) were determined by analyzing the CP content of the residual NDF and ADF (Licitra *et al.*, 1996). Phosphate buffer soluble protein (SOLP) was estimated through the CP analysis of the residue obtained after treating 0.5g of sample in borate phosphate buffer. Similarly TCA precipitable protein was analyzed (Licitra *et al.*, 1996) by using trichloroacetic acid. Carbohydrate and protein fractions were calculated using equations given by Sniffen *et al.* (1992).

Estimations and statistical analysis: TDN (%) and ME (Mcal/g) contents of fodders were calculated from chemical composition (CP, EE, NDF, NDICP, non fibrous carbohydrate (NFC)) based equations (NRC, 2001). For determining nutrients digestibility, DM, CP, NDF and ADF were estimated in the residue samples of fodders left after 24 h of incubation in rumen liquor (collected from fistulated cattle maintained on wheat straw: concentrate diet) under optimum temperature (39^{0}C), pH and anaerobic condition *in vitro*. The DMI and RFV were calculated using the equation 1 and 2 (Moore, 1994) in which the DM digestibility value from *in vitro* analysis study was used. For RFQ calculation equation 3 (Moore and Undersander, 2002) was used. The RDP and RUP were analyzed from the protein fractions as per NRC (2001). The fractional degradation rate of the three B fractions were B_1 (120-400 %/h), B_2 (3–16 %/h) and B_3 (0.06–0.55 %/h) (NRC, 2001). The median value of the given range of k_d was used in the equation 4 and 5 to calculate the RDP and RUP of the fodders. Statistical analysis was done as per Snedecor and Cochran (1994). The RFQ was regressed with carbohydrate and protein fractions.

Dry matter intake (% of BW) = 120 / (% NDF) (1)

RFV = (DDM x DMI) / 1.29 (2)

RFQ = (DMI, % of BW) * (TDN, % of DM) / 1.23 (3)

RDP = A + B1 [kdB1/(kdB1+ kp)] + B2 [kdB2/(kdB2+ kp)]+ B3 [kdB3/(kdB3 + kp)] (4)

RUP = B1 [kp / (kdB1 + kp)] + B2 [kp / (kdB2 + kp)] + B3 [kp / (kdB3 + kp)] + C (5)

Results and Discussion

***Chemical composition*:** Cell wall contents (NDF, ADF and cellulose) were higher (P<0.05) in cereals (73.8, 46.4 and 35.9%) than legume fodders (49.14, 34.7 and 26.0%; Table 1). On the other hand mean concentration of CP and lignin %NDF was higher (P<0.05) in legumes (19.5 and 16.8) than cereal fodders (7.5 and 8.4 %). Similarly Brown and Pitman (1991) also reported more NDF, ADF and cellulose for grasses than legumes. NDF, CP and lignin contents in BF and WS fodders of present study were in agreement to the values of Das and Singh (1999) and different to the values of Kanani *et al.* (2006), which might be due to variation in stage of fodder maturity and crop growth conditions (temperature and soil moisture). Pearl millet stover NDF and ADF contents of present study (76.2 and 44.1%) were more or less similar to values of Choudhary *et al.* (2019). Ether extract content of legumes varied from 1.7% to 2.6%, while that of cereals from 1.0 to 2.7%, respectively. The results on the relative concentration of protein, ether extract and cell wall fractions in legume and cereal fodders was also supported by reported values of Jayanegara *et al.* (2011) on grasses and legumes.

Carbohydrate fractions*:* Total carbohydrate (CHO) and structural carbohydrates (SC) were significantly (P<0.05) higher in cereals (80.60 and 70.40 %) than legume fodders (69.90 and 44.79%), while non-structural carbohydrates (NSC) were higher in later than former

Table 1. Proximate constituents (% DM) of common legume and cereal fodders

Fodders	NDF*	ADF*	Lignin % NDF*	Cellulose*	CP*	EE	Ash*
Legumes							
Lucerne	45.0	21.3	16.4	18.2	19.4	1.7	7.4
Berseem	41.1	30.9	15.2	23.2	18.8	2.6	9.8
Desmenthus	51.0	36.3	14.8	22.0	20.2	2.1	9.5
Lablab	43.5	35.1	20.2	31.2	21.4	2.2	10.2
Stylosanthes	65.1	49.7	17.5	35.4	17.9	2.1	5.6
Mean	49.1	34.7	16.8	26.0	19.5	2.1	8.5
SEM	4.32	4.60	0.97	3.17	0.60	0.14	0.87
Cereals							
Barley green	68.0	35.7	4.0	33.3	11.7	1.5	9.0
Oat green	72.0	46.6	9.8	41.5	9.5	1.8	6.0
Guinea grass	73.2	40.0	5.4	30.7	8.2	1.4	11.4
Wheat straw	75.7	53.6	12.5	39.8	3.2	1.0	10.6
Paddy straw	76.1	60.3	11.2	36.4	5.9	2.7	16.1
Pearl millet stover	76.2	44.1	7.1	33.2	7.9	1.2	9.6
Maize stover	73.2	45.7	11.1	36.1	7.3	1.6	9.5
Sorghum stover	76.2	44.9	6.2	36.2	6.0	1.5	10.5
Mean	73.8	46.4	8.4	35.9	7.5	1.6	10.3
SEM	1.02	2.70	1.11	1.25	0.90	0.18	1.00

*(P<0.05)

Table 2. Carbohydrate and its fractions (% CHO) of common fodders

Fodders	CHO* % DM	NSC* % DM	SC* % DM	Starch* % NSC	C_A*	C_{B1}*	C_{B2}*	C_C*
Legumes								
Lucerne	71.50	30.28	41.22	49.3	19.4	18.8	34.0	27.8
Berseem	68.80	32.78	36.02	29.3	34.9	14.5	30.0	20.6
Desmenthus	68.20	22.78	45.42	85.6	4.5	26.4	7.3	61.8
Lablab	66.20	26.79	39.41	74.5	10.9	31.9	32.5	24.7
Stylosanthes	74.40	12.40	62.00	61.0	2.8	4.4	57.9	34.8
Mean	69.90	25.11	44.79	59.9	14.5	19.2	32.3	33.9
SEM	1.43	3.58	4.57	9.83	5.89	4.78	8.05	7.36
Cereals								9.3
Barley green	77.80	14.27	63.53	91.9	1.4	15.3	74.0	
Oat green	82.70	14.98	67.72	61.3	7.1	11.2	61.6	20.2
Guinea grass	79.00	8.73	70.27	54.3	5.1	6.0	77.0	11.9
Wheat straw	85.20	11.21	73.99	97.3	0.3	12.4	66.7	29.6
Paddy straw	75.30	2.46	72.84	93.4	1.1	15.5	56.0	27.4
Pearl millet stover	81.30	8.55	72.75	90.8	1.0	9.5	74.0	15.5
Maize stover	81.60	11.08	70.52	90.1	1.3	12.2	62.6	23.8
Sorghum stover	82.00	9.04	72.96	85.4	1.6	9.4	75.3	13.7
Mean	80.60	10.20	70.40	83.1	2.4	11.4	68.4	18.9
SEM	1.10	1.38	1.23	5.67	0.85	1.12	2.74	2.64

*(P<0.05)

group of fodders (Table 2). Contents of soluble carbohydrate fraction (C_A) and rapidly degradable carbohydrate fraction (C_{B1}) were higher ($P<0.05$) in legume fodders (14.5 and 19.2) than cereals (2.4 and 11.4 %). Straws and stovers had very low (<2%) C_A fraction except oats fodder (7.1) revealing their less soluble carbohydrate content. So, these fodders should not be supplemented with higher NPN source. Carbohydrate fraction C (C_C) which is unavailable to the animal was higher ($P<0.05$) in legumes (33.9) than cereals (18.9%)

and it was due to higher lignin contents in legumes. Carbohydrate fractions for dry and green fodders (cereal and legumes) and crop residues were within the range of values as reported earlier (Singh *et al*., 2011; 2012; Bovera *et al*., 2003; Das *et al*., 2015; Singh *et al*., 2018).

Protein fractions and rumen degradable protein: Concentration of soluble protein (SP%CP) and non protein nitrogen (NPN%SP) were comparable in both legume and cereal fodders (Table 3), while NDIP%CP and ADIP%CP were higher in cereal and legume fodders, respectively. Mean concentration of P_A and P_{B1} was 11.7 and 14.3 in legumes; and 12.1 and 13.8 %CP in cereals, respectively. Slow degradable protein fraction (P_{B3}) and unavailable protein fraction (P_C) was significantly (P<0.05) higher in cereals (22.3 and 21.7) than legume fodders (9.5 and 12.6 %CP), respectively. So, a significant portion of their protein is not available to the animals though, straws/stovers and cereal fodders are not the good source of protein. Kamble *et al.* (2011) reported protein fractions of straws comparable to present findings. Values of protein fractions of different fodders evaluated here were within the reported values of earlier workers (Singh *et al*., 2002; Singh *et al*., 2011; 2012; Das *et al*., 2015). In legumes higher (P<0.05) contents of rumen degradable protein (RDP 73.2%) than cereals (57.8%) may be ascertained to lower concentration of protein P_{B3} and P_C fractions as recorded in present study.

Nutrients digestibility, energy value and quality: Mean *in vitro* digestibility of DM, CP and NDF was significantly (P<0.05) higher in legumes (63.0, 77.3 and 64.0%) than cereal fodders (46.9, 57.1and 53.3%; Table 4), respectively, while ADF digestibility was 5.4% units more in legumes than cereals. In case of cereals *IVDMD* was lowest in WS (38.2%) while highest value observed in OF (62.9%). CP digestibility of WS was lowest (36%) while others showed medium values indicating better digestibility. In vitro digestibility of CP, OM, NDF and ADF of grasses and legumes reported by Brown and Pitman (1991) were within the range of our values. Higher digestibility of legume than cereal fodders may be ascertained to their lower NDF, ADF and cellulose contents. Legume straws had 10% more DM digestibility than cereal straws reported earlier (Haddad and Hussain, 2001; Lopez *et al*., 2005) substantiated the present findings. Further, DM digestion of forages is highly dependent on structural factors such as the relative proportion of cell types present in the plant tissues and the existence of factors restricting microbial access to cell walls (Chesson, 1993). Berseem dry matter digestibility (67.5%) recorded in present study was within the range (56.84-68.08%) of dry matter digestibility of 20 berseem genotypes observed earlier (Yucel, 2019).

Table 3. Protein fractions and rumen degradable protein values of fodders

Fodders	SP% CP	ADICP* % CP	NPN %SP	NDICP* % CP	P_A % CP	P_{B1} % CP	P_{B2}* % CP	P_{B3}* % CP	P_C* % CP	RUP %*	RDP %*
Legumes											
Lucerne	25.6	27.8	74.7	19.5	19.1	6.5	55.0	10.7	8.7	26.8	73.2
Berseem	43.9	20.6	31.3	27.0	13.7	30.2	29.1	11.9	15.1	29.8	70.2
Desmenthus	26.1	61.8	20.8	27.6	5.4	20.7	46.3	16.8	10.8	32.2	67.8
Lablab	22.4	24.7	65.6	19.1	14.7	7.7	58.5	0.5	18.6	29.2	70.8
Stylosanthes	12.4	34.8	46.2	17.3	5.7	6.6	70.3	7.5	9.8	28.0	72.0
Mean	26.1	33.9	47.7	22.1	11.7	14.3	51.8	9.5	12.6	29.2	70.8
SEM	5.11	7.36	10.14	2.16	2.69	4.80	6.88	2.70	1.86	0.91	0.91
Cereals											
Barley green	15.3	9.3	64.5	38.2	9.8	5.4	46.6	30.9	7.2	39.6	60.4
Oat green	20.5	20.2	47.3	45.1	9.7	10.8	34.4	29.5	15.6	44.8	55.2
Guinea grass	25.5	11.9	47.6	35.7	12.1	13.4	38.8	14.3	21.4	39.5	60.5
Wheat straw	50.4	29.6	34.3	53.3	17.3	33.1	6.3	28.5	14.8	34.7	65.3
Paddy straw	16.2	27.4	63.1	55.3	10.2	6.0	28.4	13.2	42.1	38.5	61.5
Pearl millet stover	27.6	15.5	50.2	43.7	13.9	13.8	28.7	18.1	25.6	57.5	42.5
Maize stover	30.2	23.8	27.3	36.7	8.2	21.9	33.2	20.0	16.7	44.9	55.1
Sorghum stover	21.5	13.7	72.0	54.0	15.5	6.0	24.4	23.9	30.1	38.3	61.7
Mean	25.9	18.9	50.8	45.3	12.1	13.8	30.1	22.3	21.7	42.2	57.8
SEM	3.95	2.64	5.40	2.86	1.13	3.38	4.18	2.45	3.83	2.49	2.49

*(P<0.05)

Table 4. *In vitro* nutrients degradability (%), energy value, intake and RFQ of fodders

Fodders	DMD*	CPD*	NDFD*	ADFD*	TDN* %	ME (Mcal /Kg)	DMI*%	RFV*%	RFQ*%
Legumes									
Lucerne	70.2	87.7	73.5	57.8	59.0	2.2	2.7	145.1	128.0
Berseem	67.5	76.0	64.1	53.9	59.8	2.2	2.9	152.9	141.9
Desmenthus	60.2	73.7	58.3	42.8	55.4	2.1	2.4	109.8	105.9
Lablab	66.4	87.1	63.3	60.9	54.5	2.0	2.8	142.0	122.2
Stylosanthes	50.5	62.2	60.9	45.6	49.3	1.8	1.8	72.1	73.9
Mean	63.0	77.3	64.0	52.2	55.6	2.0	2.5	124.4	114.4
SEM	3.53	4.74	2.58	3.49	1.88	0.08	0.20	15.04	11.68
Cereals									
Barley green	60.0	80.8	73.6	66.2	58.8	2.1	1.8	82.3	84.5
Oat green	62.9	71.2	66.1	60.7	52.8	1.8	1.7	81.3	71.6
Guinea grass	52.4	49.1	52.7	41.8	51.2	1.7	1.6	66.6	68.3
Wheat straw	38.2	36.0	52.0	41.9	41.4	1.2	1.6	47.0	53.3
Paddy straw	39.0	55.5	55.0	53.0	39.6	1.2	1.6	47.7	50.7
Pearl millet stover	41.4	65.3	39.3	33.0	49.3	1.6	1.6	50.6	63.1
Maize stover	38.2	47.5	43.7	38.0	47.0	1.5	1.6	48.5	62.6
Sorghum stover	43.2	51.2	43.9	39.6	50.1	1.6	1.6	52.7	64.2
Mean	46.9	57.1	53.3	46.8	48.8	1.6	1.6	59.6	64.8
SEM	3.57	5.11	4.13	4.17	2.18	0.11	0.03	5.32	3.74

*(P<0.05)

Energy contents (TDN and ME) and dry matter intake were more (P<0.05) in legumes than cereals (Table 4). Lower TDN and intake values for cereals might be due to more fiber and low *in vitro* nutrient digestibility of this group of fodders. Jung and Allen (1995) described the plant cell wall characteristics affecting intake and digestibility of forages in ruminants. Fodder quality values as relative feed value (RFV) and relative feed quality (RFQ) were higher (P<0.05) for legumes (124.4 and 114.4) than cereal fodders (59.6 and 64.8%). Relative forage quality (RFQ) which is a better indicator of quality to RFV, was highest in berseem (141.9%) followed by lucerne (128%), desmenthus (105.9%) and lowest in stylosanthes (73.9%) among the legumes. In cereals, highest RFQ value was observed for barley green (84.5%) and lower for paddy straw (50.7%) and wheat straw (53.3%). The RFV value indicated that lablab, lucerne and berseem are good fodders if fed *ad lib* to the animals as evident from their higher intake and efficient nutrient utilization. The RFQ data revealed that berseem could be fed during early lactation where as lucerne and lablab during later part of lactation and to heifers, and desmenthus to heifers and dry cows (Undersander, 2003). The RFQ of cereal fodders along with stylosanthes was less than 85 which made them fall into utility category those are most unlikely to provide a sufficient basis for a nutritionally adequate and cost-effective ration (Hancock, 2010). Among cereal fodders barley straw had higher voluntary DMI (1.8) and RFQ (84.5), though none of these can support even the maintenance requirement of the animals as a sole feed source. These RFQ data should not be used to develop a ration rather provides a reasonable first approximation as to whether the selected forage will provide a cost effective base to the diet being fed to the animal. Kishore and Parthasarathy (2012) reported TDN (%), RFV and RFQ of various straws such as rice (42.3, 65 and 55), maize (47.8, 82 and 70) and sorghum (45.7, 73 and 63%) which are comparable to present data except the higher RFV of maize and sorghum stover, which might be due to the higher NDF in the later 2 fodders used in this study. The DMI and RFV values of berseem recorded in present study were within the values of 20 berseem genotypes reported by Yucel (2019).

In the present study RFQ value was correlated with the different carbohydrate fractions and the following regression equation was developed with R^2 value (coefficient of determination) 0.9 (P<0.0004). Similarly when RFQ was correlated with carbohydrate and protein fractions, regression equation was significant (P<0.01) with R^2 value 0.98. It indicated that laboratory analysis of fodders for carbohydrate and protein fractions could be good predictor of fodders RFQ.

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$$RFQ= 204.43+0.64C_A-0.12C_{B1}-1.6C_{B2}-1.44C_C \quad (R^2= 0.9, \text{Significance } F= 0.0004) \quad (6)$$

$$RFQ=4361.23-1.97C_A-2.24C_{B1}-3.54C_{B2}-3.38C_C-38.02P_A-39.3P_{B1}-39.52P_{B2}-39.83P_{B3}-40.59P_C \quad (R^2=0.98, \text{Significance } F= 0.01) \quad (7)$$

Conclusion

Study revealed that legumes were rich in protein, low in fiber contents and had more nutrients digestibility and rumen degradable protein than cereal fodders. RFQ of fodders can be determined more precisely using protein and carbohydrate fractions. Legumes had higher NSC, C_A and C_C carbohydrate fractions and lower NDIP, P_{B3} and P_C protein fraction than cereals. Further the values of TDN, DMI, RFQ and RFV were higher for legumes than cereals making former more nutritious than later group of fodders.

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