Carbohydrate and Protein Fractionations of commonly used forages and agro-industrial byproducts as per Cornell Net Carbohydrate and Protein system (CNCPS)

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Abstract

The present study was aimed to evaluate chemical composition viz. carbohydrate and protein fractions of some forages and agro-industrial byproducts commonly used for ruminant ration in tropical countries. Five forage samples namely berseem (*Trifolium alexandrinum*), maize (*Zea mays*), oat (*Avena sativa*), sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*); and four agro-industrial byproducts viz. sugarcane tops (*Saccharum officinarum*), oat hay, wheat straw (*Triticum aestivum*) and paddy (rice) straw (*Oryza sativa*) were evaluated by using Cornell net carbohydrate and protein (CNCP) system. Among various carbohydrate fractions, CA (Instantly/fast degradable fraction) was found highest in berseem (34.24%) and lowest in oat hay (2.63%); whereas CB1 values (Intermediately degradable fraction) ranged from 11.46% (berseem) to 3.73% (pearl millet). CB2 (Slowly degradable fraction) was highest in sugarcane tops (73.46%) and lowest in berseem (34.25%). CC which refers as undegradable carbohydrate fraction was found highest in oat hay (25.99%), but lowest in sugarcane tops (10.09%). On the other hand, protein fractions, PA (Instantaneously degradable) was found highest in sugarcane tops (39.79%) and the lowest value was there for paddy straw (9.79%). On the contrary, paddy straw contained highest PB3, which accounts for slowly degradable fraction of protein as 36.47% and the lowest value was in sugarcane tops (4.73%). Non-degradable fraction (PC) was found highest in wheat straw (30.66%) and lowest in oat (10.56%). The CNCP analysis dictated the nutrient utilization potential of the given forages and agro-industrial byproducts. Therefore, having lower CC fraction, sugarcane tops and sorghum may supply higher content of carbohydrates, however, lower PC content of oat and pearl millet make them good protein sources to ruminant ration.

Keywords: Forages; Agro-industrial byproducts; CNCPS; Carbohydrate fractions; Protein fractions

Introduction

Forage and agro-industrial byproducts are playing an important role in ruminant feeding system around the world by providing affordable feed resources with very low competition with human food and converted by ruminants into milk and meat with highly bio-available nutrients (Van Soest, 1994; Givens et al., 2000; Chaudhry, 2008; Mohamed et al 2021). For livestock sector, low availability of good quality ingredients such as rich concentrates meals in tropical countries leads to the efficient use of forages and agro-industrial byproducts resources (Mahesh et al., 2021). Although some areas of the country are bestowed with nutritious green fodders such as berseem, leucerne, maize etc. however, the majority of the farmers have to deal with agricultural byproducts viz. paddy straw, wheat straw, stovers, sugarcane tops and tree leaves. Unlike traditional nutritive evaluation methods, the Cornell net carbohydrate and protein system (CNCPS) not only dictate about the compositional specificities of the feed samples, but can also predict the availability of the nutrients to the animals (Dixit et al., 2016). It is used to evaluate carbohydrate and protein fractions that stimulate rate of carbohydrate and protein degradation in the rumen (Fox et al., 1995). Without conducting laborious and expensive *in vivo* experiments, several types of feedstuffs like forages, concentrates and agro industrial by-products can be evaluated using CNCPS (Das et al., 2015; Dixit et al., 2016; Mahesh et al., 2017). CNCPS helps to derive protein fractions to estimate *in vitro* metabolizable protein (IVMP) and utilizable amino acid (uAA) content of ruminant feed ingredients which determines the protein value of the feed to animal without performing *in vivo* trials (Gupta et al., 2011; Prusty et al., 2019). The objective of the present study was to evaluate carbohydrate and protein fractions of nine commonly used forages and agro-industrial byproducts prevailing mainly in Northern region of India, using CNCPS.

Material and Methods

Sample collection and preparation

Nine samples of forges were collected from forage section of the National Dairy Research Institute (NDRI), Karnal, India. That can be divided into two categories: Green forages selected were Berseem, Egyptian clover, Maize, oat, sorghum, pear millet and sugarcane tops; whereas dry roughages included oat hay, wheat straw and paddy (paddy) straw. Feed samples were dried in hot air oven at 600C for 48-72 h until constant weight was attained. The dried samples were ground using electrically operated Willey mill. The ground samples were kept for further analysis.

Chemical analysis

Proximate analysis of Feedstuffs as dry matter (DM), total ash (TA), organic matter (OM), crude protein (CP), and ether extract (EE) were done according to AOAC (2005). Cell wall constituent fractions such as NDF (Neutral detergent fibre), ADF (Acid detergent fibre), lignin and were estimated according to Van Soest et al., (1991). Starch was determined according to Knudsen (1997). Nitrogen fractions determination: Soluble protein (SP), non-protein nitrogen (NPN), neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen (ADIN) were estimated according to Licitra et al. (1996). Calculations of carbohydrate and protein fractions were done according to CNCPS (Sniffen et. al., 1992). Calculation of tdNFC (Truly digestible non fibrous carbohydrate), tdCP (Truly digestible crude protein); tdFA (Truly digestible fatty acids); tdNDF (Truly digestible neutral detergent fibre), TDN (Total digestible nutrients), RUP (Rumen undegradable protein) and RDP (Rumen degradable protein) were done according to NRC (2001).

Statistical analysis

Significance differences among groups were checked using GLM procedure (one way analysis of variance) of SAS (1996). Duncan's new multiple range test was used to compare among means (Duncan, 1955).

Results and Discussion

Chemical composition of forages and agro-industrial byproducts

Chemical composition of nine forage and agro-industrial byproducts samples is presented in Table (1). The highest OM% was in sugarcane tops (91.77%) and the lowest one was for paddy straw (85.44%). The lowest CP% was found in paddy straw (2.45%) and the highest value was found in berseem (17.69%). Soluble protein (SP) values varied from 24.45% for maize to 58.25% for sugarcane tops. Values of neutral detergent insoluble nitrogen (NDIN) were the highest in paddy straw (62.59%) and sugarcane top (18.85%) was the lowest. In case of ADICP (% CP) was found to be lowest in oat (10.56%) and highest in wheat straw (30.66%). Maximum amount of NPN (% SP) was found in maize (80.41%) while the minimum was found in paddy straw (28.77%). Lowest NDF% was observed in berseem (43.82%) while the highest was in wheat straw (75.03%). ADF% values were ranged from 57.37% for paddy straw to 32.40% for berseem. Lignin (% NDF) was comparable among the green fodders with the exception of berseem which contained highest amount (13.4%) and sugarcane tops which contained lowest amount (4.94%). Ether extract

Table 1: Chemical composition of forages and agro-industrial byproducts (% Dry matter basis)

Feed sample	OM	CHO	Starch	NDF	ADF	EE	CP	Total SP (%CP)	NPN (% SP)	NDICP (% CP)	ADICP (% CP)	Lignin (% NDF)	GE* (MJ/kgDM)
Pearl millet	86.43	77.36	3.73	60.43	46.33	1.47	7.60	50.56	62.65	36.93	14.63	9.42	16.01
Sorghum	91.6	80.18	5.29	55.61	40.42	1.64	9.78	43.07	35.14	45.27	22.53	8.56	17.10
Berseem	89.84	70.32	11.46	43.82	32.40	1.84	17.69	48.39	65.21	31.93	22.68	13.4	17.34
Maize	88.36	75.31	6.31	54.32	43.39	1.54	11.50	24.45	80.41	30.59	16.48	9.85	16.62
Oat	87.68	74.03	10.84	53.50	47.86	2.10	11.54	38.01	40.72	46.45	10.56	10.80	16.62
Sugarcane tops	91.77	83.46	9.63	70.97	38.62	1.64	6.60	58.25	68.32	18.85	14.11	4.94	16.92
Oat hay	88.91	77.63	7.86	73.24	48.24	1.80	9.48	48.60	44.95	39.57	20.7	11.48	16.64
Wheat straw	91.01	87.41	9.06	75.03	52.21	0.94	2.66	30.66	65.50	44.63	30.66	8.82	16.39
Paddy Straw	85.44	81.14	4.36	74.63	57.37	1.84	2.45	34.02	28.77	62.59	26.12	9.53	15.59

Table 4: Nutritive values of forages and agro-industrial byproducts

Feed sample	tdNFC	tdCP	tdFA	tdNDF	TDN (%DM)	DE (MJ/kg)	ME (MJ/kg)	RDP (% DM)	RUP (%DM)
Pearl millet	19.34^{d}±0.44	6.38^{e}±0.03	0.47^{f}±0.01	30.63e±0.17	50.41^{e}±0.27	9.20^{e}±0.05	7.38^{e}±0.05	4.93^{d}±0.02	2.66^{d}±0.02
Sorghum	25.77^{b}±0.29	7.47^{d}±0.01	0.64^{d}±0.01	29.17^{f}±0.18	56.84^{ab}±0.12	10.39^{b}±0.02	8.59^{b}±0.02	6.25^{b}±0.02	3.53^{c}±0.01
Berseem	31.50^{a}±0.17	13.47^{a}±0.22	0.84^{c}±0.04	17.28^{i}±0.17	57.14^{a}±0.21	10.79^{a}±0.04	9.00^{a}±0.05	12.00^{a}±0.21	5.68^{b}±0.06
Maize	24.02^{c}±0.20	9.44^{c}±0.11	0.54^{e}±0.01	26.48^{g}±0.10	54.16^{d}±0.28	10.04^{d}±0.05	8.23^{d}±0.05	4.55^{e}±0.05	6.96^{a}±0.07
Oat	25.38^{b}±0.17	10.17^{b}±0.05	1.10^{a}±0.02	24.04h±0.11	55.06^{c}±0.12	10.23^{c}±0.02	8.44^{c}±0.02	5.84^{c}±0.04	5.70^{b}±0.03
Sugarcane tops	13.46^{f}±0.23	5.58^{f}±0.07	0.64^{d}±0.02	42.90^{a}±0.07	56.37^{b}±0.11	10.20^{c}±0.01	8.39^{c}±0.02	4.64^{e}±0.05	1.97^{f}±0.03
Oat Hay	14.14^{e}±0.40	5.82^{f}±0.03	0.80^{c}±0.01	39.62^{c}±.30	55.40^{c}±0.30	8.81^{g}±0.05	6.99^{g}±0.05	5.04^{d}±0.02	2.43^{e}±0.01
Wheat straw	13.29^{f}±0.30	1.84^{g}±0.01	0.94^{b}±0.02	40.33^{b}±.06	50.56^{e}±.10	8.96^{f}±0.02	7.13^{f}±0.02	1.53^{f}±0.01	1.13^{g}±0.01
Paddy straw	7.89^{g}±0.23	1.79^{g} ±0.05	0.84^{c}±0.03	39.03c±0.17	43.60^{f}±0.14	7.73^{h}±0.03	5.91^{h}±0.03	1.46^{f}±0.04	1.00^{h}±0.03

Means bearing different superscripts (a, b, c, d, e, f, g, h, i) within a column differ significantly (P<0.05); tdNFC (Truly digestible non fibrous carbohydrate); tdCP (Truly digestible crude protein); tdFA (Truly digestible fatty acids); tdNDF (Truly digestible neutral detergent fibre); TDN (Total digestible nutrients); DE (Digestible energy); ME (Metabolizable energy); RDP (Rumen degradable protein); RUP (Rumen undegradable protein)

Table 2: Carbohydrate fractions of forages and agro-industrial byproducts (%CHO basis)

Feed sample	CA	CB1	CB2	CC
Pearl millet	21.77^{e} ±0.43	3.73^{i} ±0.15	56.83^{e} ±0.43	17.67^{f} ±0.09
Sorghum	30.87^{b} ±0.08	5.29^{g} ±0.02	49.58^{g} ±0.10	14.25^{h} ±0.03
Berseem	34.24^{a} ±0.24	11.46^{a} ±.041	34.25^{i} ±0.43	20.04^{c} ±0.29
Maize	26.24^{c} ±0.19	6.31^{f} ±0.05	50.39^{f} ±0.12	17.06^{g} ±0.11
Oat	24.13^{d} ±0.22	10.84^{b} ±0.08	46.28^{h} ±0.26	18.74^{d} ±0.07
Sugarcane tops	6.82^{f} ±0.26	9.63^{c} ±.015	73.46^{a} ±0.19	10.09^{i} ±0.09
Wheat straw	6.45^{f} ±0.35	9.06^{d} ±.010	66.32^{c} ±0.30	18.17^{e} ±0.06
Paddy Straw	5.57^{g} ±0.28	4.36^{h} ±.021	69.05^{b} ±0.23	21.03^{b} ±0.07
Oat hay	2.63^{h}±0.07	7.86^{e} ±0.11	63.52^{d} ±0.11	25.99^{a} ±0.16

Means bearing different superscripts (a, b, c, d, e, f, g, h, i) within a column differ significantly (P<0.05
CA (Instantly/fast degradable fraction); CB1 (Intermediately degradable fraction); CB2 (Slowly degradable fraction); CC (Undegradable fraction)

Table 3: Protein fraction of forages and agro-industrial byproducts (%CP basis)

Feed sample	PA	PB1	PB2	PB3	PC
Pearl millet	31.68^{b} ±.16	18.89^{e} ±.14	12.51^{f} ±.15	22.30^{b} ±.32	14.63^{f} ±.31
sorghum	15.13^{e} ±.37	27.94^{a} ±.37	11.66^{g} ±.06	22.74^{b} ±.12	22.53^{c} ±.16
Berseem	31.56^{b} ±.13	16.83^{g} ±.05	19.68^{d} ±.41	9.26^{e} ± .39	22.68^{c} ±.15
Maize	19.68^{d} ±.10	4.79^{i} ±.02	44.95^{a} ±.12	14.11^{d} ±.31	16.47^{e} ±.27
Oat	15.48^{e} ±.04	22.53^{d} ±.04	15.53^{e} ±.07	35.89^{a} ±.17	10.56^{h} ±.07
Sugarcane tops	39.79^{a} ±.12	18.45^{f} ±.01	22.91^{c} ±.07	4.73^{f} ±.12	14.11^{g} ± .03
Wheat straw	20.08^{d} ±.14	10.57^{h} ±.06	24.71^{b} ±.18	13.97^{d} ±.28	30.66^{a} ±.26
Paddy Straw	9.79^{f} ±.02	24.23^{c} ±.09	3.39^{h} ± .23	36.47^{a} ±.15	26.12^{b} ±.05
Oat hay	21.85^{c} ±.04	26.75^{b} ±.03	11.83^{g} ±.03	18.86^{c} ±.035	20.71^{d} ±.02

Means bearing different superscripts (a, b, c, d, e, f, g, h, i) within a column differ significantly (P<0.05) PA (Instantaneously degradable); PB1 (Rapidly degradable); PB2 (Intermediately degradable); PB3 (Slowly degradable); PC (Non-degradable)

(EE%) varied from 0.94% (wheat straw) to 2.10% (oat). Ash% content was highest in paddy straw (14.56%) and lowest in sugarcane tops (8.23%). Gross energy values were ranged from 17.34 (MJ/kg DM) in Berseem as the highest value to the lowest value in paddy straw (15.59 MJ/kgDM). Berseem had higher content of CP, whereas similar EE and NDF than previous reports (Tahir et al., 2019); however, similar TDN values coincided with (Dixit et al., 2015). Kaithwas et al., (2020) reported higher values of CP% and comparable values of NDF% for Berseem, wheat straw and paddy straw. Prusty et al., (2013) reported similar values of NDICP (% DM), NDF%, and ash% in pearl millet, sorghum, berseem, maize, wheat straw and paddy straw. Kamble et al., (2011) reported similar values of NDF in oat, wheat straw and sugarcane tops, and similar values of CHO% were reported in maize, berseem paddy straw and wheat straw and higher values were reported in oat and sugarcane tops. The differences in feed chemical composition values in present study and among several studies may be due to variations in plant genotype (several plant verities) and environmental factors (Soil type, irrigation, temperature, sampling and analytical method). Previous literature reported lower CP and similar TDN values on case of maize fodder (Dixit et al., 2021).

Carbohydrate fractions

The results of carbohydrate fractions of different forages and agro-industrial byproducts are shown in the Table 2. CA (Instantly/fast degradable fraction) was ranged as maximum value in berseem (34.24%) and minimum in oat hay (2.63%). CB1 (Intermediately degradable fraction) was ranged from 11.46% (berseem) to 3.73% (pearl millet). CB2 (Slowly degradable fraction) was maximum in sugarcane top (73.46%) and Berseem showed minimum (34.25%). While CC (Undegradable fraction) was maximum in oat hay (25.99%) and lowest was found in sugarcane tops (10.09%) among the feed samples. Kaithwas et al., (2020) reported low values for CA (0.3 and 1.1%) and high values of CC (29.6 and 27.4%) in wheat straw and paddy straw, respectively. Prusty et al., (2013) reported similar values of fraction CB1 in sorghum, wheat straw and sugarcane tops and CB2 in paddy straw and wheat straw. The values of fraction CA and CB1 was found higher in oat and maize and lower in wheat straw, paddy straw and sugarcane tops and CB2 and CC in wheat straw and paddy straw were in accordance with findings of Kamble et al., (2011).

Protein fractions

The results of protein fractions of fodders (% CP) are shown in the Table (3). PA (Instantaneously degradable) in sugarcane tops was the highest (39.79%) whereas the lowest PA found in paddy straw (9.79%). PB1 fraction (Rapidly degradable) was highest in sorghum (27.94%) while PB2 (Intermediately degradable) was higher in maize (44.95%) and lowest value of PB1 and PB2 was found in wheat straw (10.57%) and paddy straw (3.39%) respectively. PB3 (Slowly degradable) varied from 4.73 % (sugarcane top) to 36.47% (paddy straw). Highest amount of PC (Not degradable) were observed in wheat straw (30.66%) while lowest observed in oat (10.56 %). Kaithwas et al., (2020) reported similar results in wheat straw and paddy straw and lower results in berseem for PA compared with the present study. Prusty et al., (2013) reported lower PA and PB1 in pearl millet, sugarcane tops, wheat straw, paddy straw also they reported higher values of PB2 in oat, sugarcane tops, wheat straw, and paddy straw as well as lower in pearl millet and berseem and similar values were found in sorghum and maize and similar values of PC were found in pearl millet, maize, oat, and sugarcane tops. Kamble et al. (2011) reported higher values of PA in oat, maize and paddy straw and lower values for sugarcane tops.

TDN, RDP and RUP of forages and agro-industrial byproducts

The nutritive values data regarding tdNFC, tdCP, tdFA, tdNDF, TDN, DE, ME, RDP and RUP of forages and agricultural-byproducts have been shown in Table 4. Berseem contained highest tdNFC (%) and tdCP (%) values (31.50 and 13.47%). Values of tdNDF% were different among roughage samples with sugarcane tops having the highest (42.90%) and lowest in berseem (17.29%). Lowest amount of TDN% was found in paddy straw (43.60%) while highest was found in berseem (57.14%). DE (MJ/kg) and ME (MJ/kg) was found lowest in paddy straw (7.73 and 5.91 MJ/kg respectively) while highest value was found in berseem (10.29 and 9.00). RDP (%DM) value found highest in berseem (12%) and lowest in paddy straw (1.46%). Higher values of RUP (% DM) were found in maize (6.96) and lowest in paddy straw (1%). Kaithwas et al., (2020) reported comparable results in TDN (59.8, 41.4 and 39.6%) for berseem, wheat straw and paddy straw, respectively. The lower values of DE and ME of wheat straw have been found in the previous reports (Dixit et al., 2022).

Conclusion

It can be concluded that CNCPS can be used to evaluate carbohydrate and protein fractions and to predict the nutritive potential of forages to ruminants. Based on our findings, it was concluded that forages and agricultural byproducts may have different availability of nutrients to the animals while having similar CHO and CP contents. Therefore, the carbohydrate and protein fractions of the feed ingredients should be kept in mind at the time of ration formulation for ruminants.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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