Research Article

doi.org/10.56093/ijan.v43i2.178398

Chemical characteristics, In-vitro digestibility and Rumen fermentation of durum and bread wheat straw varieties as potential feed for ruminants

Edited by: Pradeep Kumar Malik
National Institute of Animal Nutrition and Physiology, Bengaluru, Karnataka

Reviewed by: Udeybir Singh Chahal
Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana, Punjab

*Correspondence: SBN Rao
sbnrao@gmail.com

Received: 24th April 2026
Accepted: 16th July 2026
Published: 20th August 2026 (Online)

Citation: Rao SBN, Soren NM, Chandrasekharaiah M, Kumar PGV, Thomas A, Prasad SVS, Neeraja CN and Ram S. Chemical characteristics, In-vitro digestibility and Rumen fermentation of durum and bread wheat straw varieties as potential feed for ruminants. Indian Journal of Animal Nutrition. 2026 August 9; 43(2). doi.org/10.56093/ijan.v43i2.178398

S. B. N. Rao, N. M. Soren, M. Chandrasekharaiah, Punith Kumar, G. V, Athira Thomas, S.V. S. Prasad*, C. N. Neeraja* and Sewa Ram**

ICAR-National Institute of Animal Nutrition and Physiology, Adugodi, Bangalore – 560 030.
***ICAR-Indian Institute of Wheat and Barley Research, Aggarsain Marg, Karnal 132 001, India*
**ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad 500 030, India*
Corresponding author's Email: sbnrao@gmail.com

Wheat straw is one of the abundant agricultural residues used on large scale for ruminant fodder. To supply farmers with high-quality straws, the current study was carried out to evaluate durum and bread wheat straw varieties with regard to their chemical composition, in vitro digestibility, and rumen fermentation parameters. The samples were subjected to the estimation of protein, total ash, crude fiber, and fiber fractions. The mineral content was analyzed by using an atomic absorption spectrophotometer. In vitro digestibility and rumen fermentation parameters were also assessed using standard methods. Results showed that HI-8759, a bio-fortified durum variety released for the central zone, has significantly higher CP (6.66 ± 0.09) than HI-8713 (3.43± 1.11 and less NDF, ADF, and cellulose compared to HI-8713, HI-8737, and HI-8663. HI 8777, another bio-fortified durum wheat variety found for the peninsular zone, contains higher IVDMD and IVOMD than UAS 428. Similarly, WB 02, a bio-fortified bread wheat variety has higher CP (4.63±0.13) levels than HI 1633 (3.26±0.03) and HI 1605 (2.86 ±0.14). Furthermore, it contains more IVDMD, IVOMD, and ME than HI 1544. Overall, the cellulose content is higher ($P<0.01$) in durum compared to bread wheat straw. *In vitro* digestibility revealed that durum wheat straw varieties have significantly higher TGP, IVDMD, IVOMD, and ME than bread wheat varieties, indicating that durum wheat is more digestible. 1000 grain weight is positively correlated to straw NDF, cellulose, total gas production, ME, acetate, propionate, butyrate and TVFA concentrations.

Keywords : Wheat Straw; Bio-fortification; *In vitro* evaluation; Rumen fermentation and digestibility

Introduction

Wheat straw is an important renewable bioresource for producing ruminant feed and bioenergy due to its high production and high carbohydrate content (Battaglia et al., 2020, van Kuijk et al., 2015a). Wheat straw, rice straw, and corn stover are the most abundant lingocellulosic biomasses among agricultural residues in the world, used mainly as feed for livestock or agricultural supplements. Wheat straw consists mainly of cellulose (28%–39%), hemicelluloses (23%–24%), lignin (16%–25%), and fewer contents of ash and protein (Alvarez et al., 2021). Wheat straw is the fibrous crop residue left after removing the grain through threshing. Due to the higher content of indigestible fiber, these are low in energy and protein, and hence the nutritive value is low, which limits their effective utilization. To overcome these limitations, farmers in North India fed wheat straw, which is commonly fed to the cattle and buffaloes in the form of Sani (a wet mixture of grain, cakes, chopped green fodder, and wheat straw soaked overnight). Erickson et al. (1982) found that there was a significant difference between straw from different barley genotypes. Rao et al. (2022) evaluated rice straw of different bio-fortified varieties and landraces and found differences in chemical composition, in vitro dry matter digestibility, and fermentation metabolites. Keeping in mind the effect of varieties on the energy value of straw, farmers currently prefer to adopt cultivars that produce superior quality straw as well as high grain yield.

Wheat (Triticum aestivum) is grown in India under irrigation conditions to the tune of 31.6 million hectares with a production of 107.86 million tons in 2021 (Agricultural Statistics at a Glance, 2022). With a grain-to-straw ratio of 1:1.23 (Giridhar et al. 2013), the potential availability of wheat straw is 132.7 million tons. Practically wheat straw alone can provide the roughage needs of 72 million cattle and buffaloes (assuming 5 kg of wheat straw per head), which are quite substantial. The majority of wheat cultivated is used to make Chapathi (Bread). However, for pasta purposes, another important wheat species grown in Central India is i.e., durum wheat (Triticum durum). Several Indian durum varieties are of high nutritive value with higher protein, yellow pigment, and essential micronutrients like iron and zinc. The yellow pigment imparts a yellow hue to the pasta made from durum semolina, and which imparts good human health due to the antioxidant properties of the carotenoids present. Many wheat varieties (bread and durum) having potential yield and nutritional quality parameters (more protein, iron, and zinc) were released for peninsular, central, and rain-fed zones with limited irrigation and late-sown conditions of central India (Prasad and Prakasha, 2020). In the present study, twelve released varieties of wheat straw (six durum and six bread) obtained from IARI Regional Station in Indore (M.P) were analyzed for chemical composition, in vitro evaluation, fermentation metabolites.

Materials and Methods

Description of the plant material

Twelve released varieties of wheat straw obtained from IARI Regional Station in Indore (M.P) were used. They comprised of six durum wheat (*Triticum durum*) varieties (HI8713, HI8737, HI8663, HI8759, UAS 428, HI 8777) and six bread wheat (*Triticum aestivum*) varieties (HI1544, HI1634, HI1531, HI1605, WB02 and HI1633).

doi.org/10.56093/ijan.v43i2.178398

HI8737, UAS428 and HI 1633 are recommended for North Eastern plain and Peninsular zone of India. WB02- BFV NWPZ is for North Western plain zone and the remaining verities are recommended for the central zone of the country.

Evaluation of chemical Composition

The samples were ground in Cyclotec Mill (Foss) using 1 mm sieve. The samples were analyzed for crude Protein (990.03: AOAC, 2012), total ash (942.05: AOAC, 2012) and crude fiber (962.09: AOAC, 2012) and fibre fractions like NDF, ADF, hemi-cellulose, cellulose and lignin (Van Soest *et al.* 1991).

Mineral estimation

About 1 g of feed sample was digested by 9 ml of tri-acid mixture (HNO_3: $HCLO_4$:H_2SO_4 - 3:2:1) in a 100 ml Kjeldahl flask containing glass beads to avoid bumping at very low heat initially and then at high temperature till the contents clear and perchloric acid fumes cease to come out. Then the digested sample was diluted with distilled water and filtered through Whatman filter paper No 42 and the final volume was made up to 25 ml (AOAC, 2005). The contents of different minerals in the samples were analyzed by using an atomic absorption spectrophotometer (Shimadzu-7880). A stock solution containing 1000 ppm of Zn mineral was purchased from Merck Chemicals. The operating parameters for estimation of Zn were: Zn hollow cathode lamp: Wavelength, 213.9 nm: slit width, 0.7 nm: lamp current, 8.0 mA: vapor type, air/acetylene.

Evaluation of *in vitro* gas production

The rumen liquor was collected from the fistulated crossbred cattle before the offering of feed and water in the morning at the experimental livestock unit of the institute in a double-walled (thermos) flask flushed with CO_2 and maintained at 39°C in the incubator. The rumen liquor was then strained with four-layered muslin cloth and added (440 ml) to the buffer. The buffer was prepared by mixing 486 ml of distilled water, 0.13 ml of micro mineral solution, 244 ml of rumen buffer solution, 244 ml of macro mineral solution, 1.26 ml of Resazurin solution, 2.13 ml of 1N NaOH, 0.293 g of Sodium sulfide, and 49.3 ml of distilled water (prepared fresh and added just before incubation). The medium mixture solution was pre-warmed to 39ºC and bubbled with CO_2 just before addition to rumen liquor. Air-equilibrated feed samples (200±10 mg) were incubated in 100 ml calibrated syringes at 39°C for 24 h with 30 ml mixed rumen suspension containing rumen buffer and rumen liquor in a ratio 2:1 (Menke and Steingass 1988) with parallel incubation of a blank without a feed sample. The syringes were shaken every 30 minutes till 2 h and thereafter every 2 h up to 8 h to initiate proper mixing of substrate with inoculum. Each sample was incubated in ten tubes over two independent runs. The total incubation period of 24 h was given, and at the end of incubation, the level of the piston was again recorded. The total gas production during the incubation period was calculated by subtracting the initial reading from the final reading and correcting for corresponding blanks.

Calculation:

Total Gas Production (ml/200mg)in 24 hours=(V-V0-G0)
V= Reading after 24hr; V0= Reading after 1st reading; Go= Gas produced in blank syringes

Evaluation of *in vitro* digestibility

To determine the substrate digestibility, contents of syringes after incubation were refluxed for 1 h with neutral detergent solution, filtered, and oven dried at 60°C for 48 h to determine the in vitro dry matter digestibility (IVDMD). Subsequently, the residue obtained after double-strength neutral detergent solution treatment was incinerated at 600°C for 3 h to estimate the in vitro true organic matter digestibility (IVOMD), and metabolizable energy (Menke and Steingass 1988) was calculated using formula.

$$ME=2.2+0.136\ GP+0.057CP+0.0029EE$$

Where:

ME=Metabolizable Energy (MJ/Kg DM); GP=Net Gas Production ml/200 mg substrate in 24 hours; CP= Crude Protein (%); EE=Ether Extract (%)

Rumen fermentation parameters

The fatty acids like acetate, propionate, butyrate, iso-butyrate, valerate, and iso-valerate in the incubation medium were estimated using the procedure described by Cottyn and Boucque, (1968), where a gas chromatograph (Agilent – 7890A) equipped with a flame ionization detector (FID) capillary column (Agilent J&W DB-WAX GC column 40mmX0.18mmX0.18µm) was used.

Statistical Analysis

The various parameters considered were compared between and within broad groups of durum and wheat using one way analysis of variance. Similarly, correlation co-efficients were calculated among all the parameters using Statistical Package for the Social Sciences software (PASW Statistics Release 18.0.0 (Jul 30 2009). The significance level of 0.05 was used to compare treatment means (Snedecor and Cochran 1994).

RESULTS AND DISCUSSION

Chemical Composition

Durum

HI-8759, a bio-fortified variety released for the central zone has significantly higher CP than HI-8713 and comparable CP with HI-8737 and HI-8663. HI-8777, a bio-fortified variety found in the North Eastern Plain Zone and Peninsular zone has less CP than UAS 428. HI-8777 has lower EE than HI-8737 and HI-8663 and is comparable with HI-8713, whereas HI-8777 has similar EE to UAS-428. The total ash ranged from 7.29 in UAS 428 to 9.88 in HI 8663. HI-8759 has more Zn than HI-8713 and is comparable with HI-8737 and HI-8663. However, UAS 428 has more Zn than its bio-fortified counterpart (HI-8713) (Table 1a).

HI-8759 has less NDF and ADF compared to HI-8713, whereas HI8777 has more NDF, ADF, and cellulose compared to UAS428. Hemi-cellulose in HI8759 is higher than HI8737 and HI8663, whereas HI8777 and UAS428 have comparable hemi-cellulose content (Table 1b).

Table 1 a. Proximate Composition (%) of different varieties of durum wheat straw

Variety	Dry Matter	Crude Protein	Ether Extract	Total Ash	Acid Insoluble	Ash Zinc (mg/kg)
HI 8759	93.22 ± 0.01	6.66^{a} ± 0.09	0.86^{bc}±0.08	9.50^{a}±0.28	4.09^{a} ± 0.11	18.0
HI 8713	91.39 ± 0.01	3.43^{bc} ± 1.11	0.68^{c} ± .02	8.25^{b}±0.18	3.90^{ab} ± 0.07	10.3
HI 8737	93.87 ± 0.01	4.50^{ab} ± 0.12	1.42^{a} ±0.04	9.88^{a}±0.13	3.50^{b} ± 0.07	14.3
HI 8663	93.22 ± 0.01	5.43^{ab} ± 0.18	1.20^{ab}±0.07	9.88^{a}±0.13	3.50^{a} ± 0.07	16.1
HI 8777	93.69 ± 0.01	1.36^{c} ± 0.17	0.52^{c} ±0.04	9.08^{a}±0.08	4.19^{a} ± 0.06	13.6
UAS 428	93.91 ± 0.01	6.70^{a} ± 0.17	0.79^{bc}±0.04	7.29^{c}±0.20	4.06^{a} ± 0.14	17.8
Significance	-	**	**	**	**	-
P Value	-	P<0.01	P<0.01	P<0.01	P<0.01	-

**- Highly Significant (P<0.01); Values bearing different superscripts a, b, c,in a column differ significantly at the indicated level.

doi.org/10.56093/ijan.v43i2.178398

Table 1 b. Fiber components (% DMB) of different varieties of durum wheat straw

Variety	Neutral Detergent Fiber	Acid Detergent Fiber	Cellulose	Hemi cellulose	Acid Detergent Lignin
HI 8759	69.60[b] ± 0.24	36.03[c] ±0.44	33.57[a] ± 0.70	28.38[d] ± 0.58	7.65±0.13
HI 87137	7.96[a] ± 0.90	43.02[a] ±0.90	34.94[a] ± 0.00	35.13[ab] ± 0.78	7.89±0.13
HI 8737	69.51[b] ± 1.07	45.03[a] ± 0.69	24.48[b] ± 1.77	37.01[a] ± 0.62	8.02±0.07
HI 8663	68.24[b] ± 0.25	40.25[b] ± 0.50	27.99[b] ± 0.76	32.16[bc] ± 0.51	8.09±0.01
HI 8777	75.90[a] ± 0.56	43.03[a] ± 0.26	32.87[a] ± 0.31	35.38[a] ± 0.56	7.65±0.30
UAS 428	69.65[b] ±0.32	37.23[c] ± 0.29	32.42[a] ± 0.03	29.20[cd] ± 0.66	8.03±0.37
Significance	**	**	*	**	NS
P Value	P<0.01	P<0.01	P<0.05	0.01	0.52

NS-Not-Significant (P>0.05); **- Highly Significant (P<0.01); Values bearing different superscripts a, b, c, d in a column differ significantly at the indicated level.

Bread

WB-02, a bio-fortified bread wheat variety released for the Northwestern Plain Zones of the country, has comparable CP, lower EE, and Zn to its counterpart HI-1544 (Table 2a). However, HI-1633, a bio-fortified variety released for the late-sown conditions of the Peninsular zone of India has more Zn than its counterpart HI-1634. HI-1605, released for limited irrigation systems of Central India, has more iron and zinc with less CP than its counterpart, HI-1531.

WB-02 and HI-1544 bread wheat varieties have similar fiber fractions. HI-1634, identified for late-sown and irrigated conditions of Central India has high NDF, cellulose, hemicellulose, and low lignin. HI-1605 and HI-1531, identified for limited water systems have similar fiber fractions (Table 2b).

Table 2 a. Proximate Composition (%) of different varieties of bread type wheat straw

VarietyDry	MatterCrude	ProteinEther	ExtractTotal	AshAcid	Insoluble Ash	Zinc (mg/kg)
Wb02	94.09 ± 0.01	4.63[b] ±0.13	0.93[bc] ±0.14	9.99[b]±0.23	5.91[a]± 0.15	8.14
HI 1544	93.11 ± 0.01	4.20[b] ±0.17	1.61[a]±0.05	8.29[d]±0.10	2.79[c]±0.06	22.1
HI 1633	92.74 ± 0.01	3.26[cd]±0.03	0.50[d] ±0.03	10.52[b]±0.06	6.19[a]± 0.06	45.6
HI 1634	93.38 ± 0.01	3.76[bc] ±0.28	0.65[bcd] ±0.05	9.43[c]±0.04	3.59[b]± 0.01	13.7
HI 1605	91.94 ± 0.01	2.86[d] ±0.14	0.96[b] ±0.05	8.10[d]±0.05	3.06[c]± 0.01	14.2
HI 1531	93.86 ± 0.01	6.73[a] ±0.23	0.58[cd] ±0.06	11.07[a]±0.05	3.53[b]± 0.04	12.8
Significance	-	**	**	**	**	-
P Value	-	P<0.01	P<0.01	P<0.01	P<0.01	-

Table 2 b. Fiber components (% DMB) of different varieties of bread type wheat straw

Variety	Neutral Detergent	Fiber Acid Detergent Fiber	Cellulose	Hemi cellulose	Acid Detergent Lignin
Wb02	67.60 [ab] ± 1.43	41.97 ± 0.05	35.49[ab] ± 0.10	25.63[ab] ± 1.37	6.47[b] ± 0.15
HI 1544	66.72[b] ± 0.19	40.16 ± 1.03	33.39[a] ± 1.40	26.55[a] ± 0.83	6.77[b] ± 0.37
HI 1633	66.34[b] ± 0.43	43.53 ± 0.49	35.29[ab] ± 0.53	22.80[b] ± 0.06	8.23[a] ± 0.03
HI 1634	72.82[a] ± 0.58	44.81 ± 1.31	39.00[a] ± 1.13	28.01[a] ± 0.73	5.81[b] ± 0.17
HI 1605	69.97[ab] ± 2.15	43.47 ± 1.89	35.29[ab] ± 1.35	26.50[a] ± 0.25	8.17[a] ± 0.54
HI 1531	69.22[ab] ± 0.50	40.23 ± 0.26	31.26[b] ± 0.31	28.99[a] ± 0.24	8.96[a] ± 0.04
Significance	**	NS	**	**	**
P Value	P<0.01	P=0.05	P<0.01	P<0.01	P<0.01

NS-Not-Significant (P>0.05); **- Highly Significant (P<0.01); Values bearing different superscripts a, b in a column differ significantly at the indicated level.

Comparisons among durum and wheat varieties

All the studied characteristics were compared between durum and bread varieties (Table 3). But were slightly higher (P>0.05) in durum wheat straw varieties than bread wheat straw. However, the cellulose content of straw was significantly (P<0.05) higher in durum wheat straw.

Table 3. Comparisons between durum and bread wheat straw

Parameter	Durum	Bread	Significance	P value
Dry Matter	93.21±0.38 (91.39-93.91)	93.18±0.32 (91.94-94.09)	NS	0.95
Crude Protein	4.68±0.48 (1.36-6.70)	4.24±0.56 (2.86-6.73)	NS	0.67
Ether Extract	0.91±0.13 (0.52-1.42)	0.87±0.16 (0.50-1.61)	NS	0.86

doi.org/10.56093/ijan.v43i2.178398

Total Ash	8.98±0.41 (7.29-9.88)	9.56±0.48 (8.10-11.07)	NS	0.38
Acid Insoluble Ash	3.87±0.12 (3.50-4.19)	4.18±0.60 (2.79-6.19)	NS	0.63
Neutral Detergent Fiber	71.81±1.65 (68.24-77.96)	68.77±0.99 (66.34-72.82)	NS	0.15
Acid Detergent Fiber	40.76±1.45 (36.03-45.03)	42.36±0.77 (40.16-44.81)	NS	0.36
Hemi Cellulose	31.05±1.62 (24.48-34.94)	34.95±1.04 (31.26-39.00)	NS	0.07
Cellulose	32.88±1.44 (28.38-37.01)	26.41±0.87 (22.80-28.99)	**	0.003
Acid Detergent Fiber	7.89±0.07 (7.65-8.09)	7.40±0.500 (5.81-9.05)	NS	0.36

NS-Not-Significant (P>0.05); **- Highly Significant (P<0.01)

In vitro digestibility parameters

HI-8759, a durum wheat straw has more ME and is lower (P<0.05) in IVDMD and IVOMD than HI-8713. HI 8777, a bio-fortified variety durum wheat is higher in IVDMD and IVOMD than UAS 428 with similar ME (Table 4

Table 4. *In vitro* digestibility parameters for durum wheat straw

Variety	TGP	IVDMD	IVOMD	ME
HI 8759	30.72 ± 0.96	34.08^{d} ± 0.87	40.99^{c} ± 1.88	6.75^{a} ± 0.13
HI 8713	27.72 ± 0.40	42.73^{b} ± 1.46	45.96^{b} ± 1.27	6.15^{bc} ± 0.07
HI 8737	27.38 ± 0.71	49.05^{a} ± 0.58	51.53^{a} ± 0.56	6.18^{bc} ± 0.09
HI 8663	28.50 ± 0.44	47.51^{a} ± 0.67	50.46^{a} ± 0.46	6.38^{b} ± 0.05
HI 8777	28.05 ± 0.48	48.07^{a} ± 0.57	51.02^{a} ± 0.48	6.09^{c} ± 0.06
UAS 428	25.05 ± 0.80	37.94^{c} ± 1.09	40.31^{c} ± 0.94	6.10^{c} ± 0.07
Significance	NS	**	**	**
P Value	0.12	P<0.01	P<0.01	P<0.01

NS-Not-Significant (P>0.05); **- Highly Significant (P<0.01); Values bearing different superscripts a, b, c in a column differ significantly at the indicated level. TGP- Total Gas Production ml/200mg substrate; IVDMD - In vitro dry matter digestibility; IVOMD - In vitro organic matter digestibility; ME - Metabolizable Energy.

WB-02 has more IVDMD, IVOMD and ME compared to HI 1544. HI-1633 and HI-1634 identified for late-sown irrigated conditions of Central India have similar IVDMD, IVOMD and ME. IVDMD and IVOMD were higher in HI-153 as compared to HI-1605 (Table 5).

Almost all the characteristics of in vitro digestibility (TGP, IVOMD, ME) were significantly higher in durum wheat straw varieties compared to bread wheat varieties (Table 6).

Table 5. *In vitro* digestibility parameters for bread wheat straw

Variety	TGP	IVDMD	IVOMD	ME
Wb0	223.38 ± 0.73	43.57^{ab} ± 1.49	44.63^{ab} ± 0.65	5.64^{a} ± 0.74
HI 1544	22.83 ± 0.73	34.77^{d} ± 1.34	38.58^{c} ± 0.62	5.55a ± 0.60
HI 1633	20.16 ± 0.68	37.70^{cd} ± 1.75	41.21^{bc} ± 0.81	5.13^{b} ± 0.93
HI 1634	21.94 ± 0.48	39.97^{bc} ± 1.40	40.85^{bc} ± 0.81	5.40^{ab} ± 0.78
HI 1605	22.77 ± 2.80	16.25^{e} ± 1.55	25.86^{d} ± 1.06	5.46^{ab} ± 0.97
HI 1531	22.27 ± 0.33	44.87^{a} ± 1.40	46.82^{a} ± 1.40	5.62^{a} ± 0.27
Significance	NS	**	**	**
P Value	0.943	P<0.01	P<0.01	P<0.01

NS-Not-Significant (P>0.05); **- Highly Significant (P<0.01); Values bearing different superscripts a, b, c in a column differ significantly at the indicated level. TGP- Total Gas Production ml/200mg substrate; IVDMD - In vitro dry matter digestibility; IVOMD - In vitro organic matter digestibility; ME - Metabolizable Energy.

Table 6. Comparisons of *In vitro* digestibility parameters between durum and bread wheat varieties

Parameter	Durum	Bread	Significance	P value
TGP	27.90 ± 0.747 (25.05 - 30.72)	22.22 ± 0.459 (20.16 - 23.38)	**	0.001
IVDMD	43.23 ± 2.500 (34.08 - 49.05)	36.19 ± 4.266 (16.25 - 44.87)	NS	0.185
IVOMD	46.71 ± 2.082 (40.31 - 51.53)	39.66 ± 3.007 (25.86 - 46.82)	*	0.083
ME	6.27 ± 0.104 (6.09 - 6.75)	5.46 ± 0.771 (5.13 - 5.64)	**	0.001

NS-Not-Significant (P>0.05);*-Significant (P<0.05) **- Highly Significant (P<0.01); TGP- Total Gas Production ml/200mg substrate; IVDMD - In vitro dry matter digestibility; IVOMD - In vitro organic matter digestibility; ME - Metabolizable Energy.

Rumen fermentation parameters

The volatile fatty acids were similar in all bread and durum varieties. TVFA ranged from 30.8 in HI-8737 to 35.6 in HI-8713 (durum wheat straw), and from 27.0 in HI-1605 to 35.1 in HI-1531 (bread wheat varieties (Table 7 and 8). Acetate, propionate (P<0.01), butyrate, and TVFA (P<0.05) are higher in durum wheat straw compared to bread wheat straw (Table 9).

Table 7. Volatile fatty acid proportions (mM/1000 ml incubation medium) in case of durum wheat straw varieties

Variety	Acetate	Propionate	Iso- butyrate	Butyrate	Iso-valerate	Valerate	Total
HI-8759	23.9±3.28	7.25±1.06	0.24±0.05	1.98±0.42	0.39 ± 0.10	0.78±0.16	34.5±4.50
HI-8713	24.7±2.87	7.45±0.85	0.26±0.07	1.97±0.43	0.43±0.12	0.85±0.24	35.6±4.55
HI-8737	21.4±2.24	6.70±0.68	0.19±0.05	1.53±0.19	0.30±0.08	0.66±0.14	30.8±3.04
HI-8663	24.5±0.97	7.74±0.22	0.17±0.03	1.71±0.11	0.27±0.06	0.68±0.08	35.0±1.46
HI-8777	24.9±1.13	7.45±0.27	0.16±0.03	1.69±0.13	0.26±0.06	0.68±0.09	35.1±1.71
UAS-428	21.6±0.68	6.37±0.35	0.19±0.04	1.49±0.04	0.34±0.08	0.63±0.05	30.6±0.75
Significance	NS	NS	NS	NS	NS	NS	NS
P value	0.73	0.67	0.60	0.68	0.68	0.87	0.75

NS-Not-Significant (P>0.05)

Table 8. Volatile fatty acid proportions (mM/1000 ml incubation medium) in case of durum wheat straw varieties

Variety	Acetate	Propionate	Iso- butyrate	Butyrate	Iso-valerate	Valerate	Total
WB-02	19.1±1.36	5.67±0.39	0.21±0.04	1.40±0.19	0.34±0.08	0.68±0.14	27.4±1.6
HI-1544	21.0±1.80	5.69±0.50	0.25±0.02	1.59±0.01	0.46±0.02	0.82±0.10	29.8±2.1
HI-1633	20.0±3.21	5.65±0.76	0.21±0.04	1.51±0.27	0.35±0.08	0.72±0.18	28.5±4.3
HI-1634	19.7±2.56	5.75±0.80	0.19±0.03	1.45±0.15	0.30±0.06	0.65±0.09	28.1±3.3
HI-1605	18.8±0.59	5.14±0.24	0.24±0.05	1.57±0.14	0.41±0.09	0.79±0.15	27.0±0.8
HI-1531	25.0±2.33	6.96±0.69	0.25±0.08	1.66±0.46	0.41±0.15	0.89±0.29	35.1±4
Significance	NS	NS	NS	NS	NS	NS	NS
P Value	0.41	0.44	0.93	0.98	0.82	0.91	0.44

NS-Not-Significant (P>0.05);

Table 9. Comparison in case of VFA concentrations (mM/1000 ml incubation medium) between bread and durum varieties of wheat straw

Parameter	Durum	Bread	Significance	P value
Acetate	23.49 ± 0.646 (21.40 - 24.90)	20.60 ± 0.934 (18.80 - 25.00)	**	0.002
Propionate	7.16 ± 0.212 (6.37 - 7.74)	5.18 ± 0.247 (5.14 - 6.96)	**	0.002
Isobutyrate	0.20 ± 0.162 (0.16 - 0.26)	0.22 ± 0.010 (0.19 - 0.25)	NS	0.252
Butyrate	1.78 ± 0.085 (1.49 - 1.98)	1.53 - 0.039 (1.40 - 1.66)	*	0.061
Isovalerate	0.33 ± 0.027 (0.26 - 0.43)	0.37 ± 0.023 (0.30 - 0.46)	NS	0.231
Valerate	0.71 ± 0.034 (0.63 - 0.85)	0.75 ± 0.037 (0.65 - 0.89)	NS	0.394
Total	33.60 ± 0.928 (30.60 - 35.60)	29.31 ± 1.222 (27.00 - 35.10)	*	0.02

NS-Not-Significant (P>0.05); *- Significant (P<0.05) **- Highly Significant (P<0.01);

Correlations between grain yield and straw quality

1000 grain weight is positively correlated to straw NDF, cellulose, total gas production, ME, acetate, propionate, butyrate, and TVFA concentrations (Table 10). Total grain yield is positively correlated straw yield and total biomass yield. Straw yield and total biomass yield further positively correlated with butyrate concentration

Table 10. Correlations between grain yield with straw quality parameters

Parameter	R^2	P value
1000 grain wt. X Straw NDF	0.57*	0.05
1000 grain wt. X Straw Cellulose	0.60*	0.04
1000 grain wt. X Total Gas Production	0.69**	0.01
1000 grain wt. X ME	0.61*	0.03
1000 grain wt. X Acetate	0.58*	0.04
1000 grain wt. X Propionate	0.59*	0.04
1000 grain wt. X Butyrate	0.58	*0.04
1000 grain wt. X Total VFA	0.59*	0.04

Discussion

To the best of our knowledge, we are reporting for the first time regarding comparative nutritional values of durum and bread wheat varieties. Very little information is available on these aspects. The chemical composition of proximate and VanSoest constituents reported in this study is somewhat similar to Vaswani et al. (2013), with some deviation in the case of CP, ADF, and hemicellulose. IVDMD and IVOMD values described in this study were lower than values recorded by Ali and Singh, (2003) and Vaswani et al. (2013). Vadiveloo et al. (1992) evaluated botanical fractions such as inflorescence, stem, leaf blade, and leaf sheath of four varieties of rice straw (MRl, MR71, MR84 and MR27) and discovered that IVD, crude protein, and acid insoluble ash are important traits to consider when comparing different varieties. The acid detergent lignin (ADL) content did not differ significantly among different varieties of durum and bread wheat varieties. Most papers reporting lignin contents in rice straw have used acid-detergent lignin by either the sulfuric acid or permanganate versions. There are undoubtedly soluble phenolics in rice straw that need investigation. Rao et al. (2022) evaluated 13 varieties of rice straw and found that straw CP was negatively correlated with CF of straw and positively correlated with iron and zinc content of brown rice and zinc content of polished rice. CF of rice straw was negatively correlated with important plant breeding parameters such as single plant dry weight, flag leaf length, iron content of brown rice, zinc content of both brown and polished rice. Improved bio-fortified breeding lines had more zinc than bio-fortified varieties indicating further scope of improvement of zinc content in straw. In vitro organic matter digestibility (IVOMD) ranged from 37.9 in DRR Dhan 45 to 49.6 in DRR Dhan49 with an average of 43.0 in different bio-fortified varieties.

Dai et al. (2016) suggested overall Harvest Index (HI) of 0.45 suggests that over half the above ground biomass is potentially available as feedstock annually. However, differences in straw yield and HI were detected among wheat classes and regions and HI is inversely proportional to straw yield. Durum wheat produced on an average 7.3 tons straw per hectare which is lower than soft red winter wheat and soft red spring wheat varieties. These variations are attributable to differences in agronomic conditions, rainfall distribution across these locations, and the genetic differences between entries in the individual trials.

The varieties evaluated in the present study are developed for their suitability for different climatic situations of Central Indian climate like late sowing and limited irrigation conditions. The variations observed in different nutritional parameters are due to the factors like altitude and intensity of irrigation (Bainton et al. 1991; Williams et al. 1996). It is likely that environmental effects dwarf the genetic effects (Schiere et al., 2004). Sohane and Singh (2000) have crossed low and high digestibility lines and indicate that selection for quality is possible. Keno et al. (2021) observed differences on feed intake, digestibility, body weight gain and feed-to-gain ratio among lambs fed straws from different barley varieties, pointing to the importance of genetic variation in the feeding value of barley straw. Wang et al. (2020) found that water-soluble carbohydrates, crude proteins, phosphorus, and nitrogen are closely associated attributes responsible for nutritional properties. Effort in plant breeding has been to develop short varieties with higher grain yield. This development has reduced straw quantity but not nutritive value (VanSoest, 2006). Tropical breeds of cattle show faster rate of passage compared to temperate breed (Mann et al. 1987) suggesting inherent capacity of indigenous cattle to digest poor quality roughages. Under these circumstances, crop residues will come to the rescue of farmers to exploit inherent digestive capability of Indigenous cattle.

The measure of VFA reflects fermentation potential of straw. Acetate is the end product of cellulose fermentation and propionate is the end product of soluble carbohydrate. Total VFA gives a measure of fermentation of complex carbohydrates present in the straw. In the present study, significant positive correlations were obtained between grain yield and straw quality and fermentation parameters. Similar to the findings, Joshi et al. (2019) found significant positive correlations with weak association between straw NDF and ADF in a wheat population of 287 diverse spring wheat lines. Earlier we (Rao et al. 2022) have evaluated different rice straw varieities and found similarities in fermentation pattern as indicated different volatile fatty acids with positive correlations (P>0.05) between plant quality parameters like single plant dry weight (r=0.42) and Iron content in Brown Rice (r=0.42).

CONCLUSION

Durum wheat straw varieties have significantly higher Cellulose, TGP, IVDMD, IVOMD and ME compared to bread wheat varieties. 1000 grain weight (g) is positively correlated to straw NDF, Cellulose, total gas production, ME, Acetate, Propionate, butyrate and TVFA.

References

Ali, N. and Singh, M. 2003. '*In sacco* nutritional evaluation of wheat straw varieties', *Animal Nutrition and Feed Technology*, 3, 67–74.

Álvarez, C., Mullen, A.M., Pojić, M., Dapčević Hadnađev, T.D. and Papageorgiou, M. 2021. 'Classification and target compounds', in Charis, M. and Galanakis, E. (eds.) *Food waste recovery – processing technologies, industrial techniques, and applications*. Academic Press, 21–49. doi:10.1016/B978-0-12-820563-1.00024-X.

AOAC (2005), AOAC Official methods of Analysis, 18th ed. Association of Official Analytical Chemists, Washinton, DC.

AOAC International. 2012. *Official methods of analysis*. 19th edn. Arlington, VA: Association of Official Analytical Chemists.

Cottyn, B.G. and Boucque, C.V. 1968. 'Rapid method for the gas chromatographic determination of volatile fatty acids in rumen fluid', *Journal of Agricultural and Food Chemistry*, 16, 105–107.

Dai, J., Bean, B., Brown, B., Bruening, W., Edwards, J., Flowers, M., Karow, R., Lee, C., Morgan, G., Ottman, M., Ransom, J. and Wiersma, J. 2016. 'Harvest index and straw yield of five classes of wheat', *Biomass and Bioenergy*, 85, 223–227. doi:10.1016/j.biombioe.2015.12.023.

Department of Agriculture & Farmers Welfare. 2022. *Agricultural statistics at a glance, 2022. Wheat: Area, production and yield during 2020–21*. Directorate of Economics & Statistics, Ministry of Agriculture & Farmers Welfare, Krishi Bhavan, New Delhi, 53.

Giridhar, K. and Anandan, S. 2013. 'Remote sensing techniques for estimation of crop residues and biomass from grasslands', in Sampath, K.T., Ghosh, J. and Bhatta, R. (eds.) *Animal nutrition & reproductive physiology (recent concepts)*. Delhi: Satish Serial Publishing House, 547–556.

Joshi, A.K., Kumar, U., Mishra, V.K., Chand, R., Chatrath, R., Naik, R., Biradar, S., Singh, P.R., Budhlakoti, N., Devulapalli, R. and Blümmel, M. 2019. 'Variations in straw fodder quality and grain–straw relationships in a mapping population of 287 diverse spring wheat lines', *Field Crops Research*, 243, 107627.

Keno, M.T., Tolemariam, T., Demeke, S., Wamatu, J., Alkhtib, A. and Janssens, G.P.J. 2021. 'Effect of barley variety on feed intake, digestibility, body weight gain and carcass characteristics in fattening lambs', *Animals (Basel)*, 11(6), 1773.

Mann, D.L., Goode, L. and Pond, K.R. 1987. 'Voluntary intake, gain, digestibility, rate of passage and gastro-intestinal tract fill in tropical and temperate breeds of sheep', *Journal of Animal Science*, 64, 880–886.

Menke, K.H. and Steingass, H. 1988. 'Estimation of the energetic feed value obtained from chemical analysis and in vitro gas production using rumen fluid', *Animal Research and Development*, 28, 7–55.

Prasad, S.V.S. and Prakasha, T.L. 2020. 'Wheat varieties identified for release', *Madhya Bharat Wheat News*, 6(2), 1–9.

Rao, S.B.N., Suman, K., Chirravuri, C.N., Sundaram, R.M., Nalina, M., Chandrasekharaiah, M., Parthipan, S. and Soren, N.M. 2022. 'Nutritional evaluation of different rice (Oryza sativa) straw of bio-fortified varieties, bio-fortified breeding lines and breeding lines', *Indian Journal of Animal Science*, 92, 390–393.

Schiere, J.B., Joshi, A.L., Seetharam, A., Oosting, S.J., Goodchild, A.V., Deinum, B. and Van Keulen, H. 2004. 'Review paper: Grain and straw for whole plant value, implications for crop management and genetic improvement strategies', *Experimental Agriculture*, 40, 277–294.

Sohane, R.K. and Singh, M. 2000. 'Genetic variability and prediction of nutritive value of rice straw of different cultivars', *Indian Journal of Animal Nutrition*, 17, 271–278.

Vadiveloo, J. 1992. 'Varietal differences in the chemical composition and in vitro digestibility of rice straw', *Journal of Agricultural Science*, 119(1), 27–33. doi:10.1017/S0021859600071513.

Van Soest, P.J. 2006. 'Rice straw, the role of silica and treatments to improve quality – Review', *Animal Feed Science and Technology*, 130, 137–171.

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, 3583–3597.

Vaswani, S., Kumar, R., Roy, D. and Kumar, M. 2013. 'In vitro evaluation of wheat straw varieties for chemical composition, gas production and digestibility', *Indian Journal of Animal Research*, 47, 555–557.

Wang, X., Zengling, Y., Yang, Z., Liu, X., Huang, G., Xiao, W. and Han, L. 2020. 'The composition characteristics of different crop straw types and their multivariate analysis and comparison', *Waste Management*, 110, 87–97. doi:10.1016/j.wasman.2020.05.018.