Variability in the Nutritional Value of Paddy Straw (*Oryza sativa*) varieties

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Abstract

Study was conducted to evaluate locally cultivated varieties of paddy straw regarding their nutrient and anti-nutrient profile. Twelve varieties of paddy straw were collected from University farm and were analyzed for proximate chemical composition, calcium, phosphorus, fiber fractions and incriminating factors (silica, lignin and oxalate). The paddy straw varieties differed significantly in terms of proximate composition, fibre fractions and anti-nutritional factors despite their common agro-climatic and geological origin. It may be concluded from the results of the present study that varietal differences exist among locally available paddy straw in terms of chemical composition, anti-nutritional factors.

Key Words : Anti nutritional factor; Lignin; Oxalate; Paddy straw; Silica.

Introduction

Livestock play important role in supplementing the farmer's income by providing us milk, meat and other useable products. On one side, we have scarcity and seasonality in the availability of quality fodder for the livestock's, and on the other side, million's ton of polysaccharides rich paddy straw is considered as waste. China, Mongolia and other south east Asian countries use more than 30-40% of paddy straw to feed the 90% ruminants (Devendra and Thomas, 2002). In small farmers usually have 1-2 acre area of land for crop production which limit the land available for green fodder production. Small Farmers stored the paddy straw of previous year in the form of heap and thereafter use it as feed for ruminants during the lean period and also during sowing season of main crops. While in the northern states of India such as Punjab, Haryana and parts of western UP paddy straw disposal is a big concern for the authorities and for the farmers' also. Farmer's usually burn it, which causes environment pollution. To some extents, paddy straw residue can be incorporated in the ration of the livestock. But, the paddy straw has limited use as animal fodder due to high silica, oxalic and low digestible protein content (Juliano 1985; Nori et al 2006, Halim & Ramlan 2006). Paddy straw has poor nutritive value due to the presence of high level of oxalic acid, silica and lignin than other cereals straw (Sarnklog et al 2010 and Juliano 1985). The palatability of paddy straw is also limited. The cellulose of paddy straw exist in the form of cellulose-lignin linkage with metabolic bonds which limit its solubilization and digestibility by the rumen microbes. About 1-1.5 kg of straw is produced from every kilogram of the grain harvested (Maiorella, 1985). In worldwide, paddy is cultivated on about 165 million ha area, producing about 740 MMT of rice grain per annum, approximately 1,500 MMT of paddy straw is concurrently produced as a residue (FAO, 2015). In India, paddy is cultivated on about 43 million ha area. India has to produce 114 MMT of rice by the year 2030 to meet the food grain requirement of burgeoning population (Devi and Ponnarasi, 2009), which will further push up the residue availability. Area having scarcity of quality fodder often has availability of paddy straw in suitable amount. The rumen of livestock's contains complex microbes which play dynamics role in degrading complex polysaccharides of crop residue in to the absorbable nutrients in the animals. The deficit of fodder is expected to increase from 23.46 per cent (138 MMT) in year 2010 to 24.92 percent (162 MMT) in year 2025 (Grover and Kumar, 2012). As there is shortage of arable land for fodder production; only alternative way is to improve the nutritive value of the available crop residues. Differences among different paddy straw varieties with respect to nutritional profile have been reported from significant to little or no variation (Van Soest, 1985; Juliano, 1985). Therefore, the present study was plan to assess the nutritional variability in the locally cultivable varieties of paddy straw in the Jammu area of J&K.

Materials and Methods

The present study was conducted in the Division of Animal Nutrition of F.V.Sc. & A.H., SKUAST-J, R.S. Pura, Jammu. The city Jammu is situated at an altitude of 270 meters above mean sea level, latitude and longitude position being 32^{o} 38" N and 74^{o}44" E, respectively. The study locale is a paddy belt growing basmati variety.

The representative sample of twelve locally cultivated varieties (SJR -5, K -39, Basmati 564, IET 1410, Giza 14, Pusa 1121Basmati 1509, Basmati 370, Ranbir basmati, Ratna, SJR 51 and K-343) of paddy straw were collected from All India Coordinated Research Project on Paddy, SKUAST-Jammu and Division of Plant Breeding, Chatha campus, SKUAST-Jammu and from nearby areas (Table 1). Approximately 3kg of hand chopped straw of each variety were oven dried to a constant weight, and then ground in laboratory grinder (Willy mill) using 1-2mm sieve for further analysis. Triplicate sample of each straw variety were taken and its chemical analysis were done in the lab.

The Proximate analysis was done in the Division of Animal Nutrition Lab, F.V.Sc & AH, R.S.Pura following AOAC 1995 and level of fiber constituent were analyzed as per Van Soest (2005). The level of silica in different paddy straw is estimated by measuring the amount of acid insoluble ash left, in according to procedure suggested by Goering and Van Soest (1970). The estimation of lignin was done by using as methods -Van Soest and Robertson (1985) and oxalate were analyzed by following procedure as advised by Baker (1952).

Table 1: Paddy straw varieties sampled for *in vitro* analysis

S. No.	Name of variety	Source
1	SJR-5	Division of Plant Breeding, SKUAST-Jammu
2	K-39	Division of Plant Breeding, SKUAST-Jammu
3	Basmati 564	Division of Plant Breeding, SKUAST-Jammu
4	IET-1410	AICRP on Paddy
5	Giza-14	Division of Plant Breeding, SKUAST-Jammu
6	Pusa-1121	Division of Plant Breeding, SKUAST-Jammu
7	Basmati 1509	AICRP on Paddy
8	Basmati 370	AICRP on Paddy
9	RanbirBasmati	AICRP on Paddy
10	Ratna	R.S.Pura locale
11	SJR-51	Division of Plant Breeding, SKUAST-Jammu
12	K-343	Division of Plant Breeding, SKUAST-Jammu

Statistical Analysis The data obtained from the phase I and II was subjected to one way ANOVA whereas data obtained in the phase III (*in vivo* trial) was subjected to multivariate analysis with provision to nullify residue effect (Snedecor and Cochran, 1989). The means bearing significant difference were ranked as per Duncan (1955).

Results and Discussion

Proximate Composition of different Varieties of Paddy Straw

The Proximate composition of analyzed paddy straw varieties (as per cent DM except DM) and mineral composition of tested paddy straw varieties is presented in Table 2. These values are the averages mean of the triplicates values of each individual varieties.

The dry matter (%) in present study ranged from 91.38±0.54 (IET-1410) to 94.25±0.58 (Giza -14) with an overall mean value of 93.11±0.19%. Likewise, organic matter (%) was found lower in SJR-5 (84.63±0.62) whereas IET -1410 (87.52±0.51) and SJR-51 (87.66±0.54) has the highest values ($P<0.05$). Varieties analyzed differed significantly ($P>0.05$) in terms of proximate composition despite their common agro-climatic and geological origin. The values obtained in the table 1 shows significant difference for different fractions among different rice straw varieties. The obtained results are consistent with the finding of previous reports pertaining to paddy straw varieties from different locations (Rahman et al., 2010; Shen et al. 1998; Rahal et al. 1997; Fall et al. 1987; Orskov et al., 1990; Vadiveloo and Phang, 1996; Abou-el-Enin et al., 1999 and Agbagla-Dohnani et al., 2001). There is considerable genetic variation among varieties relative to straw quality (Vadiveloo, 1992; Singh and Singh, 1995; Van Soest, 2006). These differences has been attributed to growing season, maturity duration, leaf to stem ratio and fertilization pattern (Sarnklong et al., 2010).

The crude protein content (%) was highest in Basmati 370 (4.95±0.09) and lowest in Giza 14 (2.75±0.16) and CP content of other varieties contained within the range of variation. Paddy straw is a poor source of nitrogen and ether extract (Doyle et al., 1986). This was also corroborated by the results of present study, which were consistent with the reports of Fall et al.(1987); Orskov et al.(1990) and Agbagla –Dohnani et al.,(2001) but contrary to Rahal et al.,(1997) and Dong et al., (2013),who reported a higher level of CP ranging from 5.0 to 8.3 per cent, higher ash content as compared to other ligno-cellulosic feedstuffs, resulting in lower OM content. Similar, trend was observed in the present study with all the varieties. Ash content ranged from lowest value of IET-1410 (12.42±0.63) to highest of Ranbir Basmati (14.55±0.67) with a mean value of 13.42±0.69 percent. The obtained results are in agreement with Walli et al., (1988), Adya et al., (1995) and Rahal et al.,(1997) for Indian paddy straw varieties , with Nakashima and Orskov(1990) and Warly et al.,(1992) for Japanese paddy straw varieties; with Vadiveloo and Phang (1996) (18-20.7%) for Malaysian paddy straw varieties and with Abou-el-Enin et al., (1999) (18.6%) for Californian paddy straw varieties.

Table 2: Proximate composition of analyzed paddy straw varieties (as % DM except DM)

S.N.	Name of variety	DM	OM	CP	EE %	Total Ash	Calcium	Phosphorus
1	SJR -5	92.69^{abc}± 0.60	84.63^{a}± 0.62	4.41^{c}± 0.23	2.25^{f}± 0.09	14.44^{bc} ± 0.06	0.31^{bc} ± 0.01	0.09^{a} ± 0.01
2	K -39	93.01^{abc}± 0.79	86.54^{ab}± 0.45	3.57^{b}± 0.21	2.16^{ef}± 0.04	13.59^{abc} ± 0.56	0.28^{ab} ± 0.00	0.08^{a} ± 0.01
3	Basmati 564	94.04^{bc}± 0.48	86.89^{ab}± 0.59	3.20^{b}± 0.12	1.74^{c}± 0.06	13.09^{abc} ± 0.60	0.37^{e} ± 0.01	0.09^{a} ± 0.01
4	IET 1410	91.38^{a}± 0.54	87.52^{b}± 0.51	4.54^{cd}± 0.16	1.94^{d}± 0.05	12.42^{a} ± 0.63	0.29^{ab} ± 0.01	0.08^{a} ± 0.01
5	Giza 14	94.25^{c}± 0.58	86.17^{ab}± 0.60	2.75^{a}± 0.16	1.64^{bc}± 0.06	13.79^{abc} ± 0.58	0.28^{ab} ± 0.01	0.08^{a} ± 0.01
6	Pusa 1121	94.12^{bc}± 0.24	86.34^{ab}±1.10	3.52^{b}± 0.11	1.51^{ab}± 0.06	13.73^{abc} ± 0.47	0.31^{bc} ± 0.01	0.10^{ab} ± 0.01
7	Basmati 1509	94.08^{bc}± 0.37	87.40^{ab}±1.10	4.31^{c}± 0.11	1.44^{a}± 0.02	12.82^{abc} ± 0.33	0.27^{ab} ± 0.01	0.08^{a} ± 0.01
8	Basmati 370	92.70^{abc}± 0.69	87.44^{ab}±1.70	4.95^{d}± 0.09	2.17^{ef}± 0.03	12.60^{a} ± 0.33	0.36^{de} ± 0.01	0.10^{ab} ± 0.01
9	Ranbir basmati	92.54^{abc}± 0.42	85.79^{ab}± 0.60	4.33^{c}± 0.10	2.05^{de}± 0.02	14.55^{c} ± 0.67	0.34^{cd} ± 0.01	0.12^{b} ± 0.01
10	Ratna	92.35^{ab}± 0.32	86.28^{ab}± 0.56	4.08^{c}± 0.13	1.91^{d}± 0.06	13.79^{abc} ± 0.06	0.27^{a} ± 0.01	0.08^{a} ± 0.01
11	SJR 51	92.76^{abc}± 0.58	87.66^{b}± 0.54	3.23^{b}± 0.17	1.49^{ab}± 0.06	12.72^{ab} ± 0.67	0.28^{ab}± 0.01	0.08^{a} ± 0.01
12	K-343	93.45^{bc}± 0.61	86.65^{ab}± 0.57	3.63^{b}± 0.17	1.62^{bc}± 0.06	13.54^{abc} ± 0.60	0.29^{ab} ± 0.01	0.10^{ab} ± 0.01
	Mean	93.11± 0.19	86.61± 0.24	3.87± 0.11	1.82± 0.04	13.42± 0.69	0.30± 0.01	0.09± 0.00

DM: Dry matter, OM: Organic matter, CP:Crude protein, EE: Ether extract, TA: Total ash, Ca: Calcium, P: Phosphorous
a,b,c,d,e,f Values bearing different superscripts within a column differ significantly (P<0.05) *Each value is mean of 3 observations

Table 3: Fiber Fraction of Analyzed Paddy Straw Varieties (% DM)

S.N.	Varieties	NDF	ADF
1	SJR -5	77.94^{e}±0.89	51.28^{cd}±0.57
2	K-39	74.46^{bcd}±0.99	44.51^{a}±0.66
3	Basmati 564	71.48^{ab}±1.13	50.36^{cd}±0.96
4	IET 1410	73.21^{bc}±1.59	51.43^{cd}±1.20
5	Gizza 14	78.09^{e}±0.90	58.47^{e}±0.42
6	Pusa 1121	75.58^{cde}±1.06	53.17^{d}±0.82
7	Basmati 1509	72.34^{bc}±1.31	52.33^{cd}±0.78
8	Basmati 370	69.03^{a}±0.80	47.44^{b}±0.64
9	Ranbir basmati	73.67^{bc}±0.66	44.58^{a}±1.15
10	Ratna	77.38^{de}±0.61	45.49^{ab}±0.66
11	SJR-51	73.39^{bc}±1.13	50.27^{abc}±1.03
12	K-343	74.64^{bcd}±0.60	44.10^{a}±1.13
	Mean	74.27±0.50	49.45± 0.73

NDF:Neutral Detergent Fibre, ADF:Acid Detergent Fibre, CP:Crude Protein; Values bearing different superscripts within a column differ significantly (P<0.05); a,b,c,d,eValues bearing different superscripts within a column differ significantly (P<0.05) *Each value is an average of 3 observations

Table 4 Anti-Nutritional factors in analyzed paddy straw varieties (as % DM)

S.N.	Name of varieties	Silica	Lignin	Oxalates
1	SJR -5	8.65^{c}± 0.45	6.42^{abc}± 0.56	1.51^{bc}± 0.02
2	K -39	7.34^{b}± 0.51	5.81^{ab}± 0.40	1.41^{a}± 0.02
3	Basmati 564	7.28^{b}± 0.29	6.25^{abc}± 0.26	1.34^{a}± 0.02
4	IET 1410	9.78^{d}± 0.58	6.74^{abc}± 0.17	1.40^{a}± 0.01
5	Gizza 14	5.15^{a}± 0.56	7.97^{c}± 0.39	1.57^{bc}± 0.01
6	Pusa 1121	7.48^{b}± 0.56	8.13^{c}± 0.67	1.38^{a}± 0.01
7	Basmati 1509	9.66^{d}± 0.45	6.50^{abc}± 0.54	1.49^{b}± 0.03
8	Basmati 370	9.51^{d}± 0.58	6.44^{abc}± 0.37	1.40^{a}± 0.03
9	Ranbir basmati	9.29^{d}± 0.53	5.19^{a}± 0.49	1.38^{a}± 0.01
10	Ratna	9.20^{d}± 0.59	7.22^{bc}±1.09	1.58^{c}± 0.02
11	SJR 51	8.31^{c}±1.03	6.98^{abc}±1.06	1.57^{bc}± 0.02
12	K-343	7.01^{b}± 0.62	5.62^{ab}± 0.36	1.56^{bc}± 0.03
	Mean	8.19± 0.27	6.59± 0.19	1.47± 0.01

a,b,c,d Values bearing different superscripts within a column differ significantly (P<0.05) *Each value is an average of 3 observations

The level of ether extract (EE) ranged from 1.44±0.02 to 2.25±0.09%, whereas level of calcium and phosphorus were within range of 0.27±0.01 to 0.37±0.01% and 0.08±0.01 to 0.10± 0.01, respectively. Paddy straw is known to be a poor source of minerals (Sarnklong et al., 2010). Results finding of the present study also indicated the same, with low calcium content, extremely low phosphorus content and a fairly wide ratio (~3.33:1.00) between calcium and phosphorus. The Calcium percent was lowest in Ratna (0.27±0.01%) while highest content was observed in Basmati-564 (0.37±0.01%). The results are consistent with Rahman et al.,(2010) who reported a similar range 0.16 to 0.24 5 percent of calcium among six different varieties of paddy straw but result was contradicted with finding of Shen et al., (1998) who reported an overall mean value of 0.53 percent. The level of phosphorus percent in present study show fairly constant level in SJR-5, K-39, Basmati-564, IET-1410, Giza-14, Basmati 1509, Ratna and SJR-51 while Ranbir Basmati shows highest level of phosphorus percentage (0.12%) percent. Results are similar with the finding of Shen et al., (1998), who observed values varying from 0.08-0.12 percent of phosphorus in different paddy straw varieties.

Fibre fractions of different varieties of paddy straw

The fibre fraction of analyzed paddy straw varieties is presented in Table 3. The NDF (Neutral Detergent Fibre) and ADF (Acid Detergent Fiber) values in the tested paddy straw varieties ranged from 69.03–77.94 % DM and 44.10–58.47% DM, respectively. Among the analyzed varieties, SJR-5, Giza 14 and Ratna contained higher level of NDF (77.94±0.89, 78.09±0.90 and 78.38±0.61% of DM, respectively) Basmati 370 variety contained lowest percent of NDF (69.03±0.80) and Giza-14 (78.09±0.90) having highest percent with an overall mean value of 74.27±0.50 percent. Similar range was observed by Rahal et al., (1997) who reported an NDF range of 67.9 to 73.8 percent but results of present finding are inconsistent with finding of Rahman et al., (2010) who reported a higher level of NDF percent ranging from 72.16 to 77.57 percent. Similarly Agbagla –Dohnani et al., (2001) observed a higher level of NDF percent ranging from76.3 to 81.4 with mean value of 79.3.

The Giza-14 having highest ADF percent (58.47 ±042) and lowest percent were found in K-39 and Ratna paddy straw variety (44.51±0.66 and 44.58±1.15) respectively. The ADF overall mean value of all varieties were 49.45±0.73 percent. The results are consistent with the finding of Agbagla –Dohnani et al., (2001) who observed an ADF level ranging from 44.5 to 53.1percent with an overall mean value of 48.9 percent similar finding has been reported by Rahman et al., (2000) but reported range value were narrow ranging from 41.38 to 46.32 but our results are contradicted with finding of Dong et al.,(2013) who observed a lower value of ADF percent ranging from 35.41 to 41.14 percent.

Anti-Nutritional Factors in different Varieties of Paddy Straw

The level of silica, lignin and oxalate were assessed and their values are detailed in Table 4. In the present study, level of silica ranged from lowest of 5.15 percent in Giza-14 to highest of 9.78 percent in IET-1410 with an overall mean value of 8.19 per cent. Silica content is known to vary with the variety (Vadiveloo, 1992) and its availability from the soil (Agbagla-Dohnani et al., 2003). Silica reduces palatability and also the ruminal degradability of paddy straw as it restricts access of ruminal microorganisms to the nutrients (Bae et al., 1997). The results are in agreement with finding of Agbagla-Dohnani et al., (2001) who also observed an similar range (5.2 to 8.1%) of silica level in different varieties of paddy straw with a mean value of 6.8 %, our result are also consistent with Sannasgala et al., (1985) who reported similar result with wider range of silica level in different paddy straw varieties ranging from 6.7 to 10 .3 with overall mean value of 7.3 per cent.

However, the lignin content ranged from 5.19 – 8.13 % DM with lowest level ($P<0.05$) found in Ranbir basmati (5.19±0.49%) and highest value in Pusa -1121(8.13±0.67%). Lignin, most abundant natural aromatic organic polymer is known to have important effects on livestock production through effects on degradability and feed intake (Sarnklong et al., 2010). Lignin located between the cellulose microfibrils inhibits the rate and degree of microbial degradation (Iiyama et al., 1990).Lowest lignin content was found in Ranbir Basmati (5.19±0.49) and highest level of lignin was founded in Pusa-1121 (8.13±0.6) and Giza-14 (7.97±0.39) varieties with an overall mean value of 6.59±0.19 percent. Results are consistent with the finding of Rahman et al., (2010), Yulistiani et al., (2015) and Sannasgala et al., (1985), however, Agbagla-Dohnani et al., (2001) reported considerably higher level with wider variation in lignin level ranging from 6.3-12.8 percent in different paddy straw varieties with having overall mean value of 9.3 percent.

Oxalate content in tested paddy straw varieties showed a very narrow range (1.34–1.58%), with minimum value in Basmati-370 (1.34±0.02) and highest value in Ratna (1.58±0.02), SJR 51 (1.57±0.02), Giza

14 (1.57±0.01), K-343 (1.56±0.03) and SJR-5 (1.51±0.02) varieties ($P<0.05$). The oxalate content of other varieties viz. K-39, Basmati564, IET-1410, Pusa-1121, Basmati-370 and Ranbir Basmati are statistically similar. Soluble oxalate is one of a number of anti-nutrients in forage plants. It exerts its effects by binding calcium (Ca), magnesium (Mg) and other trace minerals such as iron (Fe), making them unavailable for assimilation (Talapatra et al., 1948; Watts, 1959a,b; Gorb and Maksakow, 1962). This leads to disturbances in Ca and phosphorus (P) metabolism and causes excessive mobilization of bone mineral (Rahman and Kawamura, 2011). Xu et al., (2006) reported that 40-50 per cent of the paddy straw oxalate is found in the soluble form. The oxalate content in paddy straw varieties in the present study was ranged from 1.34±0.02 to 1.58±0.02 with overall mean value of 1.47±0.01. K-39 paddy straw having lowest (1.41±0.02) percent of oxalate while Ratna having highest percent (1.58±0.02) of oxalate. This is in agreement with Libert and Franceschi (1987), who reported1.0 to 2.5 per cent of oxalate. However, Ji and Peng (2005) reported a higher value of 3.0-6.0 per cent of oxalates in paddy straw.

Conclusion

Based on results obtained from *in vitro* study and proximate analysis of twelve diffrent paddy straw varieties Basmati -370 followed Ranbir Basmati, Basmati -564 shows better results in terms of IVDMD and nutritive value in comparison to other varities. The results shows differences among different paddy straw varieties with respect to nutritional profile from significant to little or no variation. This emphasizes the possibility of improvement in the nutritive value of paddy straw without pre-treatment or by selecting the varieties having higher nutrients and its digestibility

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