Rice and wheat straw fodder trading in India: possible lessons for rice and wheat improvement

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Abstract

Rice and wheat are globally dominant staple cereals and supply a substantial proportion of caloric intake in Low and Middle Income Countries (LMICs). Straw byproducts from these cereals form the basal diet for ruminant livestock across much of the developing world. Work with other cereals demonstrates the value placed on cereal straws and stovers by smallholder farmers indicated by their willingness to pay a quality premium. Despite this, breeding efforts have tended to disregard straw quality. Little is known about the marketing arrangements and the price dynamics for wheat and rice straws in LMICs. This study aimed to quantify volume and price of wheat and rice straw sales in Patna markets in Northern India. A survey was conducted covering 17 trading locations in Patna and Hajipur in 2008. 24 traders were surveyed with 12 trading only wheat straw, 11 trading only rice straw and 1 trading both straws. A detailed trader characterization survey was implemented to gather information on the history and structure of the business, suppliers, processing arrangements, customers and monthly trading volumes over the previous 12 months. Traders were then visited once per month for 12 months for collection of straw samples and price information. Results showed that traders had developed a series of 5 quality classes for straws based on sensory characteristics. There was reasonable agreement between trader quality class and specific sensory traits, notably “brightness”, “tastiness” and “purity” and quality classes also ranked similarly to prices for straws. Availability of straws of different qualities varied by month although straws of intermediate quality were available during most months and were the most prevalent straws in the markets surveyed. Taken across months, there was a price premium of 7% in both rice and wheat straw for the “best” quality straw compared with “medium” quality straw. Wheat straw traded for prices around 19% higher than rice straw on average. This price differential between wheat and rice straw was associated with higher nutritional quality. Within species, differences in nutritive value between straw quality classes were small. There were significant correlations between price and nutritional traits although these mainly related to differences between species rather than differences within species. Extrapolations from comparisons of available straw qualities in multidimensional rice and wheat improvement suggests that the value of traded rice and wheat straws could be increased by more than 60% by promotion of superior rice and wheat dual purpose cultivars.

1 Introduction

Rice is a significant contributor to global food security and provides 19% of global per capita caloric intake and 27% of the calorie intake in low-and middle-income countries (LMIC's), (Lomax, 2015). Accounting for 20% of human caloric food intake, wheat is second only to rice in the diets of LMIC consumers and is the primary source of protein (Braun et al., 2010). Rice and wheat are also major components of crop livestock systems which supply much of the world's food and support millions of small farmers globally (Herrero et al., 2009). Less known and appreciated is the fact that rice and wheat straws, which are often considered as by-products of rice and wheat production are the main basal feed source for dairy animals on the Indo-Gangetic Plane (Samireddypalle and Sampath, 2014) and are tradable commodities in their own right (Teufel et al., 2010). Anandan et al (2019) calculated that in India, rice straw contributes 21.9% to dry matter feed resources though the contribution could be as low as 0.9% in Rajasthan and as high as 58.7% in Assam. Wheat straw contributed 15.1% to feed dry matter in India with the contribution being negligible in many Southern states but reaching 43.7% and 38.9% in Haryana and Punjab, respectively. Rice straw and wheat straw are the major crop residues used for feeding ruminants in India and their combined contribution ranges from 10 to 64 % of total feed resources across the different states. At national level they constitute 37% of the total feed resources.

Despite the prevalence of mixed crop livestock systems in LMIC's, crop improvement and livestock research efforts tend to proceed on parallel tracks without much interaction. The crop improvement community can remain unaware of the importance of crop by-products to farmer livelihoods. In rain-fed crops such as sorghum and pearl millet it was shown that two factors can alert the crop improvement sector to the importance of crop by products: fodder market surveys (Kelley et al. 1991) and the rejection of new cultivars by farmers because of the quality and quality of the byproducts, the straws and stovers (Kelley et al., 1993 and 1996).

Surveys of sorghum stover trading in India in the 1980's and 1990's have revealed that the monetary value of the grains relative to the stover halved from 6:1 to 3:1 from the 1970s to 1990s (Kelley et al., 1991). In addition, Kelley et al. (1991) observed over a 4-year period (1986, 1987, 1988 and 1989) in the sorghum growing area of Maharashtra that, at the same time and place, stover quality, or at least the customers' perceptions of it, played a huge role in stover pricing. Kelley et al. (1991) reported that stover from sorghum landraces achieved on average prices that were 41% higher than those of modern cultivars. Put differently adoption of modern cultivars can be jeopardized by poor stover quality traits. The findings from these fodder market surveys directly, though with a time delay, affected sorghum improvement in that the breeders started to incorporate stover traits into breeding and selection (Lenne et al., 2003) and finally new cultivar release procedures. In summary, it is clear that (1) stover quantity matters since the value of stover relative to grain is beginning to converge and (2) stover quality matters since price premiums paid for superior stover quality at markets exceeded 40%. These two factors have convinced sorghum improvement experts that these two traits merit attention. The present work surveys the trading of wheat straw in the Eastern Gangetic Plains to explore if a similar re-orientation of rice and wheat improvement might be warranted.

2 Material and Methods

2.1 Trader identification and characterisation

In early 2008, wheat and paddy straw trading locations in Patna were identified with the help of local experts. Subsequently, 17 such locations were selected in Patna and Hajipur, the twin cities straddling the river Ganges. The locations were categorised according to their accessibility into main roads (e.g. Anjanpur in Patna) and side roads (e.g. Babu Bazar in Patna). Within each location, traders were purposively selected focusing on those who trade all year round, have their own storage facilities, sell directly to livestock keepers and showed willingness to support the study. Where possible, traders offering more than one quality of straw and both wheat and paddy straw were selected, but this was only achieved with 1 trader in Patna. In addition, 12 traders trading only wheat straw (out of which 1 trader ceased trading during the survey period and was therefore excluded) and 11 traders trading only paddy straw were identified. After trader identification, characterisation data were collected from all selected traders with a short questionnaire, including basic personal and straw trading characteristics. At the end of the sample collection period, a more detailed questionnaire was applied to the traders, covering the history and structure of their straw trading business, details on their suppliers, information on any further processing and information on their customers including monthly volumes of straw traded throughout the past 12 months.

2.2 Traits

During trader identification, their assessment of wheat straw deliveries was discussed in order to better understand their definitions of wheat straw quality. In particular, traders were asked to provide a list of traits which they perceived as determining overall quality in order to determine an appropriate price. The straw traits most commonly reported were: length of chopped particles, softness, degree of contamination (e.g. with dirt or weeds), colour (bright or dull) and dryness and what the traders called "tastiness". These were then included in subsequent data collection.

2.3 Sample collection

From June 2008 to June 2009 each trader was visited once a month. During each visit, straw samples were taken of the two straw qualities currently being traded. If the trader was selling more than two qualities the qualities with the highest and lowest prices were selected. For each sample, 4 sub-samples were collected and analysed separately. In addition, a sample characterisation sheet was filled for each sample. This included quality characteristics as perceived by the trader, information on source and variety of the straw as well as its retail price. The perceived quality characteristics included an overall quality category as well as a numerical assessment of each quality trait on a scale of 1 (best) to 5 (worst).

2.4 Laboratory fodder analysis

Rice and wheat straw samples were analyzed by Near Infrared Spectroscopy (NIRS), calibrated for this experiment against conventional wet laboratory analyses. The NIRS instrument used was a FOSS Forage Analyzer 5000 with software package WinISI II. Representative subsets of rice and wheat straw were selected based on WinISI software and were analyzed conventionally for N by Kjeldhal, NDF and ADF by Goering and Van Soest (1970) and IVOMD and ME by Menke and Steingass (1988). The agreements between NIRS predicted values and conventionally analyzed values were expressed as R^2 and standard error of prediction (SEP), see Padmakumar et al (2019) for NIRS predictions of fodder quality of rice straw and Joshi et al. (2019) for wheat straw.

3. Results

3.1 Rice and wheat straw traders, their sensory straw quality traits and quality price relations

Numbers of rice and wheat straw trader relative to straw suppliers and straw buyers and estimated daily transactions are reported in Table 1. Trading activity was higher in rice than in wheat straw and associations of a specific variety from which a straw was obtained occurred almost twice as often in rice than in wheat (64.5 vs 34.5%).

Table 1 about here

The relative importance given by traders to the sensory traits short, soft, pure, bright and dry is listed in Table 2. Brightness was ranked highest in both rice and wheat straw while softness was ranked lowest in both straw types. Dryness was ranked intermediate in rice straw but low in wheat straw while the ranking for pureness was low in in rice straw but high to intermediate in wheat straw (Table 2).

Table 2 about here

The associations between sensory straw quality traits and perceived quality classes and their respective prices are reported in Table 3. Straw traders nominated five straw quality classes in rice straw namely Best (B), Good (G), Medium (M), Low (L) and Lowest (LL) and four quality classes in wheat straw namely B, G, M and L (Table 3). Except for quality classes below M that is L and LL, which were only sold by a single trader, the ranking for sensory traits agreed with the attribution to quality classes and straw pricing was aligned with the quality classes.

Table 3 about here

In both rice and wheat, straws of intermediate quality G were the most prevalent straws and were available each month. Rice straws of the highest B quality were available only in 8 out of 13 months and straws of the lowest M quality were available 11 out of 13 months. Wheat straws of the quality class B were continuously available and after G quality the most traded ones. Wheat straws of M quality were available 11 out of 13 months (Table 4).

Table 4 about here

In both rice and wheat straws, those of quality class G were also the ones most traded by volume (Figure 1). In both straws, overall traded volumes tended to decrease in February/March reaching a comparatively low point about May.

Figure 1 about here

3.2 Rice and wheat straw pricing in relation to month of trading and major quality class

While prices averaged across 13 months generally agreed with the B, G and M classification being 262, 262 and 246 INR / 100 kg respectively in rice straw and 316, 306 and 295 INR/100 kg in wheat straw respectively, average price differences between straw of classes B and M were about 7% in both rice and wheat straw while the average wheat straw price was about 19% higher than the average rice straw price (Table 5).

Table 5 about here

Monthly pricing was sometimes inconsistent with quality classes and straws of class B could sometimes be sold at lower prices than those of class G while straws of class M could sometimes be sold at prices higher than those of class G (Figure 2). Rice and wheat straw prices were highest in the second half of 2008 declining in the first half of 2009 reaching a low in April/May.

Figure 2 about here

3.3 Rice and wheat straw laboratory fodder quality traits and their relations with straw pricing

Nitrogen contents of rice and wheat straw of B, G and M classes at months of collections are presented in Table 6. Nitrogen contents ranged from 0.59 to 0.96% and from 0.58 to 0.80% in rice and wheat straw, respectively. Monthly nitrogen contents were only inconsistently associated with straw quality classes and nitrogen contents of B quality class could be lower than those the M class (Table 6).

Table 6 about here

Similarly, ADF contents of rice and wheat straws of the B class collected monthly could be higher than those of the G and M class, Table 7. ADF contents ranged from 50.6 to 54.2% and from 49.0 to 53.4% in rice and wheat straws, respectively.

Table 7 about here

The IVOMD of the monthly collected rice and wheat straw are presented in Table 8. IVOMD ranged from 37.2 to 43.8% in rice straws and from 43.1 to 47.9% in wheat straws. As for nitrogen and ADF contents, IVOMDs did not consistently align with straw quality and IVOMD could be higher in G and M classes than in B class.

Table 8 about here

Average straw nitrogen (N) content, acid detergent fiber (ADF), *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) content in different quality classes of rice and wheat straw traded in Patna are reported in Table 6. Except for straw N, laboratory fodder quality was superior in wheat straw compared with rice straw. However, within crop trait differences between the quality classes were small and for example the differences in ADF and IVOMD were less than one percentage point. (Table 9).

Table 9 about here

Correlations (r) between average straw N content, ADF, IVOMD and ME content and prices in different quality classes of rice and wheat straw traded in Patna are reported in Table 7. The correlations between ADF, IVOMD and ME and prices were significant ($P < 0.002$) with the highest correlation observed between ADF and prices

Table 10 about here

While the correlations in Table 10 were affected by the different overall quality and different prices of rice and wheat straw, ADF seems reasonably strongly associated with pricing also within rice and wheat straws (Figure 3).

Figure 3 about here

4. Discussion

4.1. Valuation of rice and wheat straw

Rice and wheat straw trading represent a significant enterprise within the urban and peri-urban dairy production system in Patna, with the 24 fodder traders surveyed transacting between about 6 and 10 tons daily of each of the straws (Table 2). In the survey, the average rice and wheat straw prices were 2.57 and 3.06 INR per kg, respectively (Table 6). In the year of the survey (2008 to 2009) the average minimum support price (MSP) for rice and wheat grain in India were 9.15 and 10.8 INR per kg (www.theteamwork.com), respectively, resulting in an average grain to straw price ratio of about 3.5: 1 in both crops. Investigating a wide range of rice cultivars, Subudhi et al. (2019) reported an average grain yield of 4541 kg/ha with an average straw yield of 7158 kg/ha. Using average rice straw prices of 2.57 INR/kg and average MSP grain prices of 9.15 INR/kg, gross rice straw value would be slightly less than half that of the grain value (18 397 INR/ha vs 41 550 INR/ha). Similarly in a wide range of wheat cultivars with an average grain and straw yield of 3 255 and 6 189 kg/ha (Blümmel et al., 2019a) the gross straw would be slightly more than half the grain value (18 931 vs 35 154 kg/ha). While these average gross income calculations are simplified, they nevertheless demonstrate that rice and wheat straw can contribute significantly to overall income from rice and wheat cropping in the IGP of India. Grain and straw yields are only moderately correlated in rice (Subudhi et al., 2019) and wheat (Blümmel et al., 2019a) and straw yield cannot therefore be adequately predicted by grain yield (which is routinely obtained in crop improvement). Rice and wheat improvement programmes should therefore consider including total biomass yield in their data measurements. High straw yields (along with high grain yields) would not only be advantageous for livestock feed resources but would also reduce potential competition between straw use for livestock and soil fertility improvement (Baudron et al., 2014; Duncan et al., 2016).

Both rice and wheat straw fodder traders distinguished between three major quality classes – B, G and M – using sensory criteria (Table 2) and allocated price premiums for quality classes (Table 3).

Distinction for quality differences had also been observed in sorghum stover trading (Kelley et al 1991/1993; Blümmel and Rao, 2006) though the observations from sorghum stover differed in several ways from the observations in rice and wheat straw trading. First, quality differences were associated with cultivar type, improved cultivars vs landraces in the case of Kelley et al 1991/1993, or cultivars per se in the case of Blümmel and Rao (2006). Second, average price premiums for quality in sorghum stover ranged from 25 to more than 40% while in rice and wheat straw average price premiums were in the region of only 7%. Third, price premiums for sorghum stover remained consistent over several years (Blümmel et al., 2019b) while in the rice and wheat straw pricing seen in the current work, prices were often inconsistent with quality classes and straws of class B could sometimes be sold at lower prices than those of class G. Similarly, straws of class M could sometimes be sold at prices higher than those of class G (Figure 2). This could mean that sensory straw quality criteria are less robust than quality distinctions derived by cultivar type or cultivar per se.

Price premiums for straw quality were more consistent in valuations between rice and wheat straws with an average price advantage of wheat over rice straw of close to 20%. Attributing lower fodder quality to rice than to wheat straw agrees with average sensory traits applied by the fodder traders and as weighted by the Likert scale values (Table 3). For rice straw, average Likert values for B, G and M were 1.3, 1.8 and 2.2, respectively, while the analogous values for wheat straw would be 1.2, 1.8 and 2.0, respectively (calculated from Table 3). These data suggest an overall agreement over a range of averaged observations between sensory traits and pricing in rice and wheat straw trading confirming their usefulness to traders in making straw transactions.

4.2. Laboratory fodder quality traits and rice and wheat straw valuation

While sensory traits assist fodder traders and their customers, they are problematic for routine straw quality assessments for logistical and normative reasons. Objective and precisely measurable laboratory traits are needed. Fodder quality is ultimately only determined by livestock production and productivity, but livestock performance trials are unsuitable for routine feed and fodder quality analysis. This is particularly the case in crop improvement programmes where many samples must be analysed, and where initially the biomass availability is low. Simple laboratory fodder quality traits are needed but these traits must be well correlated with actual livestock performance measurements. "Simple" here refers not only to logistical and economical laboratory demand but to the need for traits to be comprehensible to, and usable by, crop scientists, seed producers, fodder traders and development practitioners with limited background in livestock nutrition. In the present work nitrogen content, IVOMD and ME were used as positive straw quality indicators and ADF as a negative indicator, traits well correlated to livestock productivity in straw-fed livestock (Sharma et al., 2010). However, these traits did not align with pricing of monthly quality classes as seen for example in nitrogen content (Table 6), or and ADF and IVOMD (Table 7, 8). This is not unexpected since fodder traders' own quality classifications were not always consistent with pricing (Table 5). Except for nitrogen, laboratory fodder quality traits and pricing did agree when both observations were averaged across the months (Table 10 and Figure 3). These findings agree with observations for sorghum fodder trading where nitrogen was un-related to pricing while IVOMD was significantly correlated with it (Blümmel and Rao, 2006). This is likely because supplementation of nitrogen-deficient straws with nitrogen supplements would be required even for straws with nitrogen content at the high end of the natural range and price premiums for higher nitrogen content for straws might be unrewarding. The significant correlation between average ADF and IVOMD and prices agree with previous findings showing strong correlations between IVOMD and pricing in sorghum stover trading (Blümmel and Rao, 2006). The findings are also consistent with the often-observed correlations between these two traits and livestock performance of straw-fed livestock. IVOMD is also a quality trait that can be easily communicated to non - livestock specialist as an indicator of the proportion an animal can use from a given feed (Sharma et al., 2010). However, in the present work the significant correlation between average ADF and IVOMD and prices were influenced by the differences in straw quality and prices between rice and wheat straw as such rather than by quality difference between classes of straw quality within a crop (Table 9). Put differently, to identify the most appropriate laboratory fodder quality trait for distinguishing rice and wheat quality in fodder market trading still requires more work.

4.3. Opportunities for improvement of the fodder quality of traded rice and wheat straws

The overall average IVOMD of the traded straws were 40.0 and 46.3% in rice and wheat straw respectively with average ADF content of 52.3 and 51.1% in rice and wheat straw respectively. These values are generally similar to the average IVOMDs and ADFs content reported in a wide range of rice and wheat straws investigated as part of multidimensional crop improvement efforts. For rice straw, Subudhi et al. (2019) and Virk et al. (2019) both reported IVOMDs of 42.0%. For wheat straws Blümmel at al. (2019a) reported an average IVOMD of 48.2%. Thus, average IVOMD of traded rice and wheat straws were just about 2% units lower than in straws in a very wide range of rice and wheat cultivars used in crop improvement.

While the average quality traits in rice and what straws in multidimensional crop improvement programmes were generally similar to the quality traits in traded straw the observed trait ranges in the former suggest that quality in traded straws could be increased, particularly in rice straw. s et al.

(Subudhi et al 2019) reported ranges in ADF from 48.0 to 54.2% and in IVOMD from 38.2 to 45.6%. Even greater ranges were reported by Virk et al. (2019) for both ADF content (47.4 to 57.7%) and IVOMD (34.8 to 49.9%). Applying the regression equation reported in Figure 3, a rice straw with an ADF content of 47.4.% could be valued at about 437 INR/100 kg. For wheat straws investigated in multidimensional crop improvement programmes (Blümmel at al. 2019a) reported smaller cultivar-dependent ranges in straw quality traits than in most key cereal and legume crops. Still the lowest ADF and the highest IVOMD in this work were 45.2 and 49.2% respectively. Inserting the ADF value of 45.2% into the equation stated in Figure 3 would result in a straw price estimate of 517 INR / 100 kg. These estimated price responses to rice and wheat straw quality improvement appear high, however they are supported by ex-ante assessments and fodder market studies of sorghum trading. Kristjanson and Zerbini (1999) calculated that a one-percentage point increase in digestibility in sorghum stover would increase milk, meat and draught power outputs ranging from 6 to 8%. These ex-ante estimates were broadly supported by fodder market prices of sorghum stover where a difference in digestibility of 5% points was associated with price premiums of 25% and higher (Blümmel and Rao, 2006). Premium sorghum quality stovers are now traded in India for more than 1 000 INR / 100 kg. Above estimates of straw prices of about 500 INR / 100 kg are therefore entirely reasonable.

5. Conclusions

Our results show that the monetary value from rice and wheat straw trading could significantly contribute to income from rice and wheat cropping. Rice and wheat straw traders distinguished straw within and between the two crops. Taken across months, there was a price premium of 7% in both rice and wheat straw for the “best” quality straw compared with “medium” quality straw, but wheat straw traded for prices around 19% higher than rice straw on average. Extrapolations from comparisons of available straw qualities in multidimensional rice and wheat improvement programmes suggest that the value of traded rice and wheat straws could be increased by more than 60% by promotion of superior rice and wheat dual purpose cultivars. However, further work is required to experimentally supply fodder traders with rice and wheat straws from superior quality dual purpose cultivars to verify or refute these assumptions.

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Table 1: Straw trader characteristics in Patna (median value in bracket))

Crop	n (traders)	suppliers / trader	customers / trader	sales / trader, kg/d	qualities / trader, #	known varieties, % samples
Rice	12	20.0 (9.2)	30.0 (15.0)	908 (452)	1.0 (0.0)	64.5 (26.0)
Wheat	12	2.0 (5.0)	20.0 (51.2)	442 (435)	1.0 (0.0)	34.5 (31.5)

Note: one trader, selling both paddy and wheat straw, is included under both cops

Table 2: Average ranks of the importance of straw traits according to traders

Crop	N	Short	Soft	Pure	Bright	Dry
Rice	12	5.0	6.0	3.3	2.4	2.7
Wheat	12	2.8	4.1	2.4	2.3	3.4

Table 3: Trader classification of rice and wheat straw according to quality classes (QC) Best (B), Good (G), Medium (M), Low (L) and Lowest (LL) by sensory criteria and associated prices (INR/100 kg) using mean Likert scale values

Crop	QC	n	Short	Soft	Pure	Bright	Dry	Tasty
Rice	B	30	1.9 (0.06)	1.3 (0.11)	1.1 (0.05)	1.2 (0.07)	1.3 (0.08)	1.1 (0.06)
	G	100	1.9 (0.03)	1.8 (0.08)	1.9 (0.07)	2.0 (0.06)	1.5 (0.08)	1.7 (0.06)
	M	31	2.0 (0.03)	2.5 (0.09)	2.3 (0.16)	2.4 (0.15)	2.0 (0.18)	2.2 (0.11)
	L	1	1.0 (NA)	3.0 (NA)	4.0 (NA)	5.0 (NA)	4.0 (NA)	4.0 (NA)
	LL	1	2.0 (NA)	3.0 (NA)	5.0 (NA)	5.0 (NA)	1.0 (NA)	5.0 (NA)
Wheat	B	46	1.2 (0.06)	1.2 (0.05)	1.2 (0.06)	1.3 (0.07)	1.3 (0.07)	1.0 (0.00)
	G	77	1.9 (0.07)	1.7 (0.08)	1.9 (0.07)	2.0 (0.07)	1.5 (0.08)	1.5 (0.06)
	M	38	2.4 (0.08)	1.9 (0.09)	2.1 (0.11)	2.2 (0.11)	1.4 (0.11)	1.9 (0.10)
	L	1	3.0 (NA)	3.0 (NA)	2.0 (NA)	3.0 (NA)	1.0 (NA)	2.0 (NA)

Table 4: Number of rice and wheat straws of quality classes Best (B), Good (G) and Medium (M) quality traded in Patna fodder markets from June 2008 to June 2009.

Quality	Jun 08	Jul 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09
Rice straw													
B	4			6	5	1	3	2				2	3
G	7	8	7	4	7	10	7	10	4	11	9	5	3
M	1	2	5	2		1	2		5	1	3	2	6
							Wheat straw						
B	6	4	8	5	3	4	2	3	3	3	4	1	2
G	4	6	4	6	6	3	7	9	5	6	4	5	7
M	2	2		1	3	5	3		4	3	4	6	2

Table 5: Monthly costs (INR/100 kg) of rice and wheat straw in relation to quality classes Best (B), Good (G) and Medium (M) traded in Patna fodder markets from June 2008 to June 2009. Values in brackets are standard errors

Quality	Jun 08	Jul 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09
							Rice Straw						
B	269 (24)			300 (0)	290 (22)	300 (NA)	275 (25)	262 (18)				200 (0)	200 (0)
G	279 (27)	318 (20)	300 (14)	307 (12)	307 (12)	283 (17)	282 (19)	263 (32)	250 (41)	206 (18)	206 (11)	210 (14)	217 (29)
M	250 (NA)	300 (0)	289 (13)			275 (NA)	263 (18)		210 (14)	225 (NA)	208 (14)	200 (0)	208 (13)
							Wheat Straw						
B	300 (0)	350 ((41)	381 (37)	370 (27)	333 (58)	300 (NA)	300 (71)	317 (29)	300 (0)	267 (29)	238 (25)	300 (NA)	300 (0)
G	288 (25)	368 (38)	356 (0)	338 (38)	363 (44)	317 (29)	293 (19)	308 (35)	290 (22)	262 (38)	244 (13)	265 (22)	286 (13)
M	300 (NA)	350 (0)		350 (NA)	333 (58)	315 (49)	300 (0)		275 (29)	283 (29)	212 (25)	250 (0)	275 (35)

Table 6: Nitrogen content (%) of rice and wheat straw of different quality classes traded monthly in Patna during the fodder market survey period

Quality	Jun 08	Jul 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09
							Rice Straw						
B	0.89 (.08)			0.75 (.05)	0.67 (.16)	0.70	0.59 (.07)	0.70 (.02)				0.83 (.07)	0.94 (.08)
G	0.96 (.15)	0.85 (.14)	0.73 (.07)	0.68 (.07)	0.77 (.12)	0.68 (.06)	0.59 (.08)	0.68 (.11)	0.59 (.04)	0.65 (.16)	0.80 (.04)	0.84 (.07)	0.88 (.08)
M	0.89	0.82 (.02)	0.70 (.12)	0.67 (.05)		0.59	0.65		0.67 (.04)	0.70	0.81 (.13)	0.84 (.03)	0.84 (.09)
							Wheat Straw						
B	0.63 (.04)	0.66 (.09)	0.74 (.05)	0.68 (.06)	0.69 (.02)	0.80 (.05)	0.74 (.05)	0.76 (.08)	0.64 (.06)	0.72 (.11)	0.61 (.03)	0.62	0.77 (.15)
G	0.64 (.05)	0.65 (.11)	0.72 (.07)	0.71 (.07)	0.73 (.07)	0.75 (.03)	0.80 (.09)	0.75 (.06)	0.72 (.06)	0.75 (.08)	0.59 (.05)	0.66 (.07)	0.73 (.11)
M	0.76 (.13)	0.67		0.71	0.75 (.05)	0.74 (.04)	0.73 (.11)		0.72 (.09)	0.71 (.03)	0.58 (.03)	0.61 (.06)	0.57 (.1)

Table 7: Acid detergent fiber content (%) of rice and wheat straw of different quality classes traded monthly in Patna during the fodder market survey period

Quality	Jun 08	Jul 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09
							Rice Straw						
B				51.8 (0.8)	52.7 (0.9)	54.2	51.6 (0.8)	52.6 (1.2)				52.7 (0.1)	50.6 (0.9)
G		52.7 (0.7)	51.1 (0.9)	52.4 (1.3)	51.7 (0.5)	52.7 (0.9)	52.5 (1.3)	52.1 (0.7)	52.2 (0.6)	51.7 (1.1)	51.8 (1.1)	52.3 (1.3)	52.9 (1.0)
M		53.3 (0.3)	54.0 (0.5)	52.1 (0.2)		52.8	53.3 (0.6)		51.6 (0.3)	51.8	52.4 (1.3)	52.4 (0.4)	51.8 (0.4)
							Wheat Straw						
B	52.0 (0.8)	51.8(0.9)	50.5(0.8)	50.8 (0.9)	50.5 (1.3)	50.1 (0.8)	51.1 (0.4)	49.0 (1.3)	50.8 (0.7)	51.0 (0.6)	50.4 (1.0)	49.9	50.2 (1.9)
G	52.7 (0.8)	51.8 (2.1)	51.0(0.6)	50.9(0.8)	50.5 (0.9)	50.9(0.4)	50.8(1.0)	50.5 (0.6)	50.4 (1.2)	50.5 (1.1)	50.7 (0.2)	51.5 (1.3)	49.9 (1.5)
M	53.4(0.8)	51.7(0.9)		50.2	51.1 (0.5)	50.8 (0.5)	51.7 (1.1)		50.8 (0.4)	50.1 (0.6)	51.4 (1.1)	53.2 (0.8)	51.7 (0.1)

Table 8: *In vitro* organic matter digestibility (%) wheat straw of different quality classes traded monthly in Patna during the fodder market survey period

Quality	Jun 08	Jul 08	Aug 08	Sep 08	Oct 08	Nov 08	Dec 08	Jan 09	Feb 09	Mar 09	Apr 09	May 09	Jun 09
Rice Straw													
B	43.8 (2.1)			39.5 (1.1)	37.2 (2.0)	39.0	39.9 (0.8)	40.3 (0.1)				40.8 (0.6)	40.5 (1.5)
G	43.8 (1.7)	39.0 (1.3)	39.2 (1.8)	39.7 (1.4)	38.1 (1.2)	38.9 (0.8)	39.6 (1.0)	40.4 (1.3)	40.1 (0.)9	39.3 (0.7)	41.0 (0.6)	40.3 (1.1)	41.2 (1.3)
M	42.8	38.5 (1.7)	39.5 (0.7)	37.7 (0.8)		37.1	40.3 (0.8)		38.5 (0.4)	39.6	40.9	40.0 (1.3)	41.2 (1.6)
Wheat Straw													
B	44.6 (1.1)	46.9 (0.4)	46.8 (0.8)	46.2 (0.7)	44.7 (0.7)	45.6 (0.8)	46.9 (0.3)	44.9 (0.5)	46.8 (1.1)	47.3 (1.4)	47.8 (0.5)	47.9	47.0 (0.7)
G	43.1 (1.2)	47.9 (0.5)	45.7 (1.1)	46.0 (0.8)	45.6 (1.3)	44.9 (0.9)	46.7 (1.1)	45.8 (0.5)	46.4 (1.2)	47.1 (1.4)	47.9 (0.4)	47.5 (1.2)	47.1 (0.7)
M	44.5 (0.9)	47.0 (1.2)		46.7	45.6 (0.3)	45.5 (0.8)	45.5 (0.4)		45.1 (0.5)	47.0 (1.3)	47.9 (0.3)	47.2 (0.7)	47.0 (0.5)

Table 9: Average prices, straw nitrogen (N) content, acid detergent fiber (ADF), *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) content in different quality classes of rice and wheat straw traded in Patna

Straw	Quality	Cost (INR/100 kg)	N (%)	ADF (%)	IVOMD (%)	ME (MJ/kg)
Rice	B	262	0.76 (0.08)	52.3 (0.76)	40.1 (1.2)	5.68 (0.18)
Rice	G	262	0.75 (0.09)	52.2 (0.96)	40.1 (1.2)	5.61 (0.20)
Rice	M	246	0.74 (0.06)	52.5 (0.50)	39.7 (1.0)	5.51 (0.17)
Wheat	B	316	0.70 (0.01)	50.7 (0.16)	46.4 (0.84)	6.77 (0.14)
Wheat	G	306	0.71 (0.01)	50.9 (0.14)	46.3 (0.94)	6.75 (0.15)
Wheat	M	295	0.68 (0.02)	51.6 (0.21)	46.3 (0.70)	6.76 (0.13)

Table 10: Correlations (r) between straw nitrogen (N) content, acid detergent fiber (ADF), *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) content and prices in different quality classes of rice and wheat straw traded in Patna

Variable	N (%)	ADF (%)	IVOMD (%)	ME (MJ/kg)
r	-0.80	-0.98	0.96	0.96
P < F	0.06	0.0007	0.002	0.002

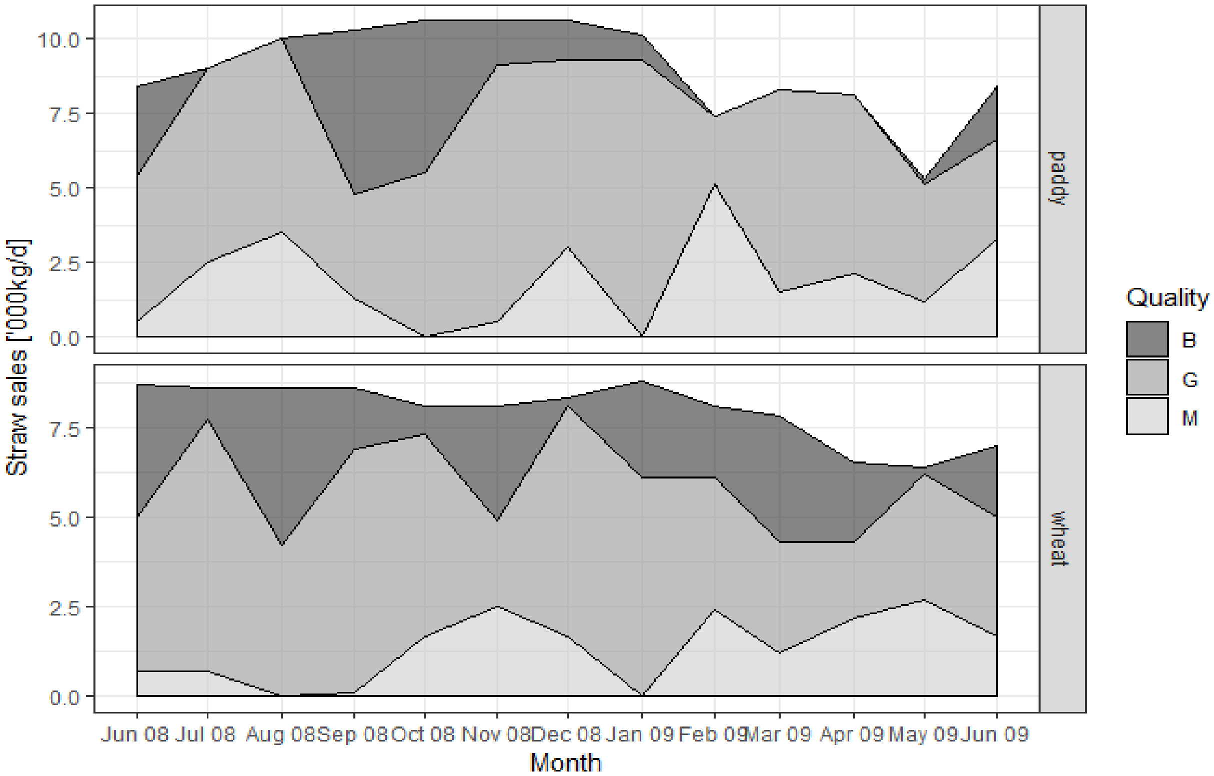

Figure 1: Monthly volume of wheat and rice straw sales by perceived quality in Patna

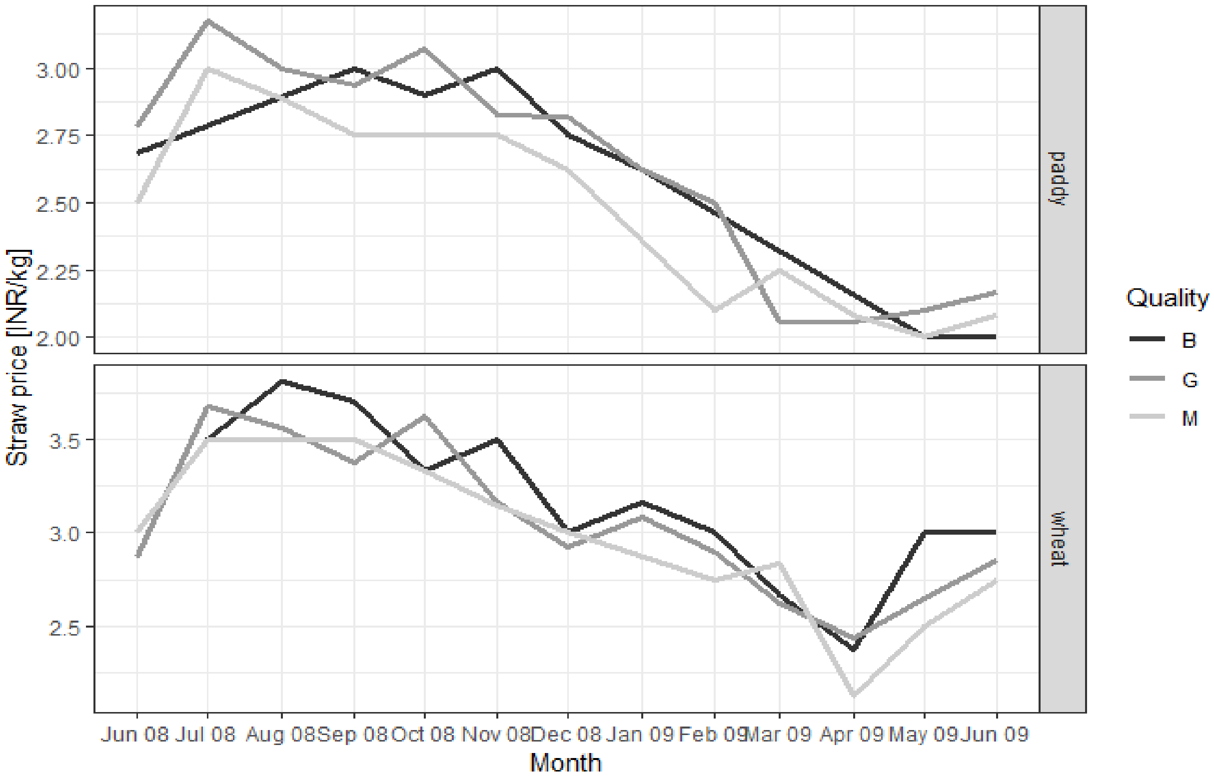

Figure 2: Monthly wheat and paddy straw prices by perceived quality in Patna

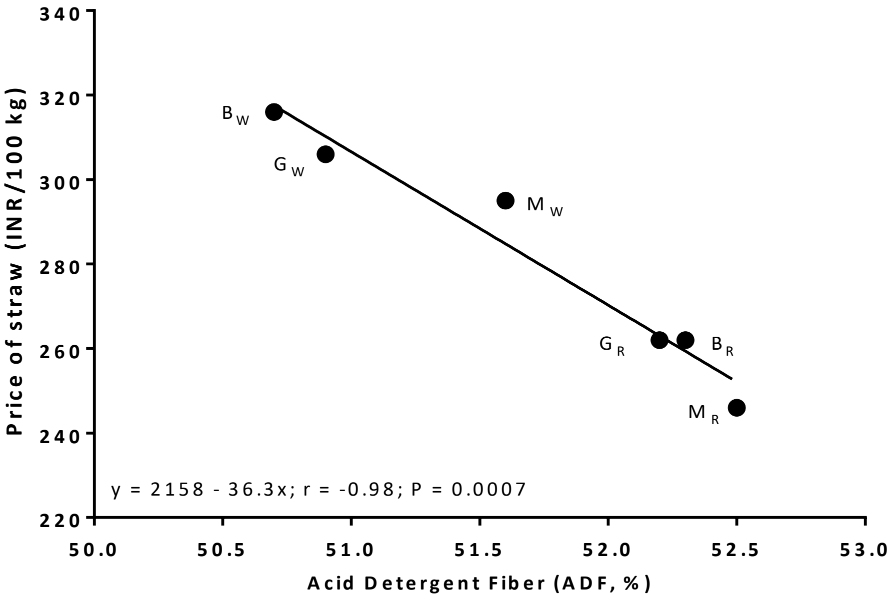

Figure 3: Relationship between ADF content of Best (B_R), Good (G_R) and Medium (M_R) rice straw of Best (B_W), Good (G_W) and Medium (M_W) wheat straw and their prices