World Journal of Agricultural Sciences 6 (3): 309-312, 2010
ISSN 1817-3047

Characterization of Rice Straw for Different Parts

[1,2]Caijin Huang, , [1]Lujia Han, [1]Xian liu and [3]Lingjuan Ma

[1]College of Engineering, China Agricultural University, Beijing 100083
[2]Chinese Academy of Agricultural Mechanization Sciences, Beijing 100083
[3]China Agricultural Machinery Testing Center, Ministry of Agriculture, Beijing 100122

Abstract: Utilization of rice straw in various approaches had been an important measure to increase economical benefits from agricultural production. To explore the resource efficiently, a better understanding of the characteristics of rice straw as detailed as possible is necessary for the choice making. In this study, the straw samples from Heilongjiang province of China were evenly cut to two halves for laboratory analysis. Results showed that the contents of ash, N, K, Ca and Mg were increased in the upper parts and the contents of volatile matter, fixed carbon, lignin, calorific value, P, Na and Fe in the upper parts were lower than those in the lower parts.

Key words: Rice straw · Energy relevant properties · Fertilizer relevant properties

INTRODUCTION

Heilongjiang province, which is located in the northeast of China, is well known for its great rice production and high rice grain quality. With annual yield of about 11.22 million tons of grain [1], the straw output of Heilongjiang reached 7 million tons if the grain-to-straw ratio [2] was employed for calculation.

Present utilization of rice straw mainly focuses on feed, fertilizer and energy conversion. Feed use of rice straw include direct feed with untreated straw, silage, ammonia treatment and so on. Using straw for fertilizer can be either by straw-returning or composting. And energy conversion of rice straw was usually practised by direct combustion, gasification, briquetting, liquefaction (biochemical conversion to produce ethanol and thermo-chemical conversion to produce bio-oil) [3]. The decision of which technique to apply is often close related to the characteristics of straw.

Characterizations of rice straw were frequently reported by literatures. Study of Jin and Chen [4] suggested that the total ash, insoluble ash (silicon), cellulose, hemicellulose and Klason lignin contents varied greatly among rice straw samples from the different rice straw varieties, the various tissue parts and the different producing area. More specifically, Vadiveloo [5] found that the leaf ranked higher in nutritive value than the stem before and after chemical treatment. From the point of view of breeding application, varieties that with high leaf content were therefore favoured to promote the utilisation of rice straw as a ruminant feed.

However, separating leaf from stem is an intractable and relatively expensive task for current lever of mechanical process. Usual way of utilization is to take the whole plant of straw into a single process, which lead to many problematic obstacles since different parts varied much in relevant properties. In this study, straw samples were simply cut to halves and several components relevant to straw utilizations were analyzed to help decide which utilization method is more reasonable for each part.

MATERIALS AND METHODS

Samples Collection and Preparation: Five varieties of rice straw, collected from local farms in Heilongjiang Province of China, were harvested in the year of 2006. Widely grown in Heilongjiang and the rest of northeastern China, the collected varieties were named Jingyou 9, Yinyou 3, Yinyou, Longgeng 14 and Xiangdao, respectively. The samples were all reaped at maturity, approximately 10 cm above the ground.

The rice straw samples were directly cut to two halves rather than divided up into leaf and stem based on morphology. Then each half of the sample was presented to 24 hours' oven drying at 70° and milled in a standard laboratory knife mill to pass 1.0 mm screen. The dried milled samples were stored in a desiccator before chemical analysis.

Corresponding Author: Caijin Huang, College of Engineering, China Agricultural University, Beijing 100083

Laboratory Analysis: Prepared samples were sent to chemical analysis, determining the contents of ash, volatile matter, fixed carbon, lignin, calorific value, N, P, K, Na, Ca, Mg and Fe. Among the components and properties, ash, volatile matter, fixed carbon, lignin, calorific value were classified into energy relevant properties; and N, P, K, Na, Ca, Mg and Fe were classified into fertilizer relevant properties.

Ash content of rice straw was determined as residual weight after calcining at 550° [6]. volatile matter was determined by heating the straw sample to 900±5° under anaerobic condition in a muffle furnace [7]. and the fixed carbon content is determined by subtracting the percentages of ash and volatile matter from a sample. Lignin content was measured by the method of Van Soest based on the dry weight [8] The calorific value [9] of the straw was measured using an automatic adiabatic bomb calorimeter [10].

Nitrogen of rice straw was determined by combustion method with a Vario EL II analyzer (Elementar Analysensysteme GmbH, Germany). To quantify the contents of K, Na, Ca, Mg and Fe, straw samples were digested using Ethos Touch Control advanced microwave labstation (Milestone Italy, equipped with HPR 1000/6S rotor) with 1200 W microwave oven. Recommended by the manufacturer, the microwave-assisted acid digestion of straw was performed according to the Milestone research report (code 18). About 0.5 g of dried milled straw sample was digested with 6 ml of concentrated nitric acid and 1 ml of concentrated hydrogen peroxide in a closed reactor in microwave oven. The resulting solution was quantitatively transferred into a 100 ml calibrated flask, where it was diluted to volume with ultra pure deionized water. Blanks were prepared with the same reagents undergoing a similar treatment. Finally, all solutions were stored in polyethylene bottles at 4°C.

For K, Na, Ca, Mg and Fe quantification, 0.5, 1, 1.5, 2 and 2.5 ml of the resulting solutions were diluted at 50 ml calibrated flask and determined by flame atomic absorption spectrometry (AAS Vario6, Analytik Jena AG Germany). In Ca and Mg quantification, 1ml of lanthanum chloride solution was added to the calibrated flask as releasing agent.

All the components were measured in duplicates. On dry basis the contents of ash, volatile matter, fixed carbon, lignin and nitrogen were expressed in weight percentage, calorific value in J/g, K, Na, Ca, Mg and Fe in mg g^{-1}, respectively.

RESULTS AND DISCUSSION

Energy Relevant Properties of Rice Straw: According to the previous classification, energy relevant properties and fertilizer relevant properties of five varieties of rice straw were listed in Table 1 and Table 2, respectively.

Calorific values of the rice straw samples were between 15000 J/g and 16500 J/g, indicating that about 2 kg of rice straw was similar to 1 kg of standard coal. The upper parts were comparatively richer in ash, but have lower contents of volatile matter, fixed carbon, lignin and calorific value. Judging from the contents, the lower part of rice straw is better than the upper part for energy conversion.

The differences of energy relevant properties between the upper parts and the lower parts were not independent. Except for the supplemental relationship among ash, volatile matter and fixed carbon, one property may positively or negatively relate to another property. For example, calorific value is often reported to be negative correlative with ash content and positive correlative with lignin content [11]. In this study the authors plotted the calorific value of rice straw against the contents of ash and lignin in Fig. 1. Both of the pairs presented high correlation, similar with literature report.

Table 1: Energy relevant properties of the upper parts and the lower parts of rice straw

Varieties	Parts	Ash (%)	VM (%)	FC (%)	LIG (%)	CV (J/g)
Jingyou 9	Upper part	12.33	71.88	15.79	4.21	16137
	Lower part	9.71	73.84	16.45	5.72	16328
Yinyou	Upper part	13.81	70.39	15.80	5.38	15910
	Lower part	11.00	71.79	17.21	5.96	16051
Yinyou 3	Upper part	16.10	68.82	15.08	4.46	15381
	Lower part	12.84	71.04	16.12	4.57	15521
Longgeng 14	Upper part	15.52	68.89	15.59	4.55	15568
	Lower part	14.26	69.56	16.18	5.08	15700
Xiangdao	Upper part	12.41	71.69	15.90	6.25	16103
	Lower part	10.46	73.13	16.41	7.69	16269

Table 2: Fertilizer relevant properties of the upper parts and the lower parts of rice straw

Varieties	Parts	N (%)	P (mg g^{-1})	K (mg g^{-1})	Na (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	Fe (mg g^{-1})
Jingyou 9	Upper part	0.72	1.40	16.40	0.60	3.51	2.30	0.16
	Lower part	0.66	2.44	7.16	4.67	1.70	1.66	0.39
Yinyou	Upper part	1.05	1.21	17.33	0.41	3.46	2.22	0.18
	Lower part	1.01	2.05	11.14	3.98	1.79	1.68	0.67
Yinyou 3	Upper part	0.90	1.06	18.80	0.40	2.12	1.46	0.18
	Lower part	0.63	2.05	14.11	2.61	1.09	1.32	0.26
Longgeng 14	Upper part	1.00	1.33	20.21	0.67	2.71	2.04	0.23
	Lower part	0.93	2.53	17.59	3.81	1.59	2.10	0.48
Xiangdao	Upper part	0.94	1.51	16.52	1.24	3.65	2.64	0.23
	Lower part	0.82	3.17	8.85	7.04	1.68	2.12	0.99

Table 3: Pearson correlations among fertilizer elements

	N	P	K	Na	Ca	Mg	Fe
N		NS	NS	NS	NS	NS	NS
P	-0.35		*	***	*	NS	**
K	0.48	-0.75*		**	NS	NS	*
Na	-0.29	0.97***	-0.83**		*	NS	***
Ca	0.40	-0.66*	0.48	-0.67*		**	NS
Mg	0.39	-0.10	0.25	-0.16	0.77**		NS
Fe	0.01	0.86**	-0.67*	0.92***	-0.52	-0.04	

NS, not significant * $p<0.05$ ** $p<0.01$ *** $p<0.001$

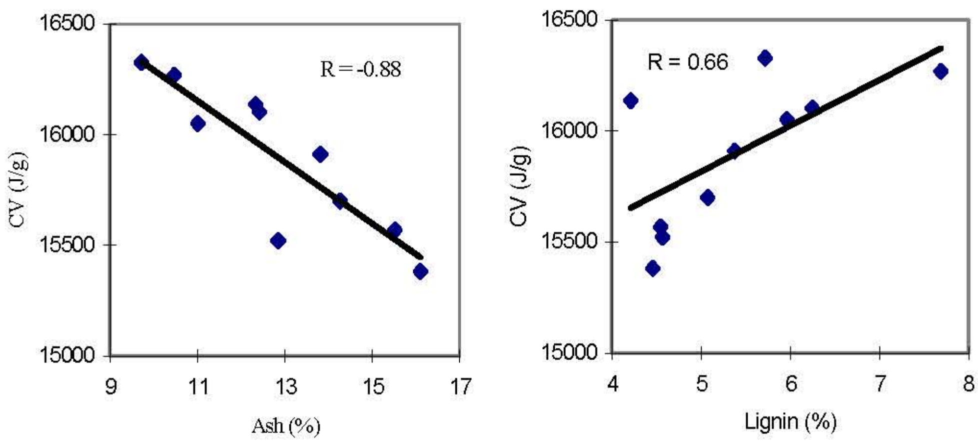

Fig. 1: Correlation between calorific value and ash, between calorific value

The calorific value of Jingyou 9, Yinyou and Xiangdao were significantly higher than those of Yinyou 3 and Longgeng 14 ($p<0.05$). For comprehensive evaluation of crop production, the energy in rice straw should be calculated combined with grain yield.

Fertilizer Relevant Properties of Rice Straw: The contents of N, P, K, Na, Ca, Mg and Fe in the upper parts and the lower parts were listed in Table 2. Results showed that the main fertilizer compositions in rice straw were N and K, whose contents were both around 1%. On average, the contents of P, K, Ca, Mg and Fe were quite stable among different varieties and higher variations were observed for N and Na. Comparatively, the contents of N, K, Ca, Mg in the upper parts were higher than those in the lower parts, the contents of P, Na, Fe in the upper parts were lower that those in the lower parts.

The accumulation and distribution of fertilizer elements in rice straw were influenced by many factors, such as soil conditions and varieties. The relationships among fertilizer elements were investigated by Pearson correlation (Table 3). The correlations between P and Ca, between K and Fe, between Na and Ca were significant at 0.05 lever; the correlations between P and Na, between P and Fe, between K and Na, between Na and Fe, between Ca and Mg were significant at 0.01 lever.

DISCUSSION

The characteristics of rice straw have much impact on the utilization techniques. The analysis of different halves suggested that the lower parts were more suitable for energy conversion than the upper parts. For fertilizer use, generally rice straw was returned to increase N, P and K contents of soil [12, 13], since that total content of N, P and K was an important index for the evaluation of organic ferterlizer. It was therefore suggested from the compositional comparison that the upper parts were more preferable for fertilizer.

CONCLUSION

Rice straw samples from Heilongjiang province of China were cut evenly into halves and characterized in both energy relevant properties and fertilizer relevant properties. For energy conversion, the lower parts were advantageous due to the higher calorific value and lower contents of K, Ca and Mg. For fertilizer relevant properties, the upper parts have greater N, K, Ca and Mg but less P, Na and Fe.

REFERENCES

1. Ministry of Agriculture of PR China. 2006. China Agriculture Yearbook 2006. Beijing: China Agriculture Press,
2. MOA/DOE Project Expert Team. 1998. Assessment of biomass resource availability in China. Beijing: China Environmental Science. Press,
3. Zeng, X., Y. Ma and L. Ma. 2007. Utilization of straw in biomass energy in China. Renewable and Sustainable Energy Revi., 11: 976-987.
4. Jin, S. and H. Chen, 2007. Near-infrared analysis of the chemical composition of rice straw. Industrial Crops and Products, 26(2): 207-211.
5. Vadiveloo, J., 2000. Nutritional properties of the leaf and stem of rice straw. Animal Feed Science and Technol., 83: 57-65.
6. CEN/T 14775-2002. Solid Biofuels-Methods for the determination of ash content.
7. CEN/T 15148-2004. Solid Biofuels-Methods for the determination of the content of volatile Matter,
8. Van Soest, P.J., J.B. Robertson and B.A. Lewis, 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3568-3597.
9. CEN/T 14912-2002. Solid Biofuels-Methods for the determination of calorific value.
10. Dimitrakopoulos, A.P. and P.I. Panov, 2001. Pyric properties of some dominant Mediterranean vegetation species. International Journal of Wildland Fire, 10(1): 23-27.
11. Sheng, C. and J.L.T. Azevedo, 2005. Estimating the higher heating value of biomass fuels from basic analysis data. Biomass and Bioene., 28: 499-507.
12. Nie, J., J. Zhou, H. Wang, X. Chen and C. Du. 2007. Effect of Long-Term Rice Straw Return on Soil Glomalin, Carbon and Nitrogen. Pedosphere : An International. J., 17(3): 295-302.
13. Hong, C., Y. Wei, J. H uang, R. Wang and X. Yang, 2003. Effects of total crop straw return on soil fertility and field ecological environment. J. Zhejiang University (Agriculture and Life Sciences). 29(6): 627-633.