A STUDY ON NUTRITIONAL CHARACTERISTICS OF RICE STRAW IN CHINA

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Summary

The agronomic, morphologic and nutritive measurements were determined for ten varieties of the early-, medium- and late- maturing rice from five types of soil in south of China. The results are shown that (1) The higher contents of neutral detergent fibre (NDF), cellulose (CEL), hemicellulose (HC) and lignin (LIG), but lower curde protein (CP) and neutral detergent solubles (NDS) contents were noted for the whole plant of rice straw during maturation; (2) As far as the feed nutritive value, segments (S) is highest, then leaf blades (LB), leaf sheaths (LS) lowest. However, LB and LS are constituted about 75% of whole plant, the nutritive value of rice straw is depended upon the nutritive quality of LB and LS; (3) The dry matter disappearances (DMD) values of different spots of rice straw are different, the eary-maturing highest, then the medium; the late- lowest; (4) The DMD value of different fractions is different, S highest, then LB, LS lowest; (5) The different retention time in rumen, the DMD value of rice straw is different. As time following, the DMD value increased gradually, during 48-72 h, the DMD value achieves close to highest; (6) The grain yield (r = −0.91), plant height (r = −0.87) and full-filling grain percent (r = −0.75) are correlated negatively with DMD value, but the leaf/stem (r = 0.59) and the proportion of stem (r = 0.58) are correlated positively with DMD value. The relations between chemical compositions and DMD value are:

Early-: DMD = 7.372 + 0.055 DM − 0.532 CP − 2.487 NDF + 1.143 ADF + 0.214 CEL + 1.456 HC + 0.718 LIG (r = 0.61).

Medium-: DMD = 333.927 + 2.026 DM − 0.224 CP − 4.602 NDF + 4.524 ADF + 0.149 CEL + 2.923 HC + 0.035 LIG (r = 0.79).

Late-: DMD = 133.284 + 0.282 DM − 3.455 CP − 22.185 NDF + 24.267 ADF + 0.316 CEL − 23.288 HC + 0.945 LIG (r = 0.79).

Therefore, it is possible to predict the nutritive value of rice straw on the basis of the agronomic, morphologic measurements and chemical compositions and the relationship with DMD value.
(**Key Words**: Nutritional Characteristics, Rice Straw, China)

Introduction

Rice straw is a major crop residue resource. One estimate (FAO, 1983) is that the annual yield is about 500 million tons, of which about 172 million tons (34%) is produced in China. Most of this straw (probale two thirds of it) is burnt as an energy resource and only about 12% is fed to ruminants. Therefore, it is common concern of animal science researchers as to how to efficiently utilize rice straw.

There has been no systematic study of the nutritive value of rice straw in China. Abroad, pretreatments of rice straw have been undertaken to improve the nutritive value of rice straw, but these methods are very difficult and costly. The aim of the present study was to investigate the extent of variation in the nutritive value of rice straw in south of China and to determine relationship between certain agronomic, morphologic and chemical compositions measurements, and dry matter disappearance (DMD). The purpose was to seek new ways for improving the nutritive value and utilization of rice straw without pretreatment, so as to improve the efficiency of utilization under condition occurring in China.

Ten cultivars of rice were grown in five soil types in Hunan province, southern China. The

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five soil types were (a) Paddy soil derived from quaternary red earth (R.E); (2) Paddy soil derived from red sandstone (R.S); (3) Paddy soil derived from slaty shale (S.S); (4) Paddy soil derived from granite (G); (5) Paddy soil derived from lime stone (L.S). The rice varieties were classified as early-, medium- and late- maturing rice. The early maturing varieties were Zhefu 802 (Z_{802}), Xiang Zaoxian 4 (X_4), V.you 49 (V_{49}) and V.you 35 (V_{35}). The medium-maturing varieties were Shan You 63 ($S.Y_{63}$), Xian Gai 63 ($X.G_{63}$) and D.you 63 ($D.Y_{63}$). The late maturing varieties were V.you 64 (V_{64}), Xiang Wan Xian 1 ($X.W_1$) and Yuchi 238-1 (Y_{238-1}).

Materials and Methods

Methods of collecting samples

The harvesting procedure involved selecting 50 individual plants at random in July or August (early maturing-), August or September (medium maturing-) and October or November (late maturing-) respectively, beginning one metre from the edge of a block. Adjacent rows within a block were not harvested. Subsequently, the samples were packed into plastic bags. The samples for chemical analysis were taken after drying. The harvested plants were separated into large and small tillers. Tillers selected as typical were dissected into stem segments (S), leaf blades (LB), leaf sheaths (LS), nodes and ears (Nodes and ears were not analysed). According to their mophological position from top to bottom the upper three stem segments, leaf blades and leaf sheaths of Z_{802}, $S.Y_{63}$ and V_{64} plants were separated and designated S_{1-3}, LB_{1-3} and LS_{1-3} respectively. After drying in a forced draught oven at 60-70℃, the samples were ground in the laboratory mill to pass through a 1 mm screen.

Analytical procedures

1. Agronomic measurements

The thousand grain weight (g) and full-filling grain percent (%) were counted by common method.

2. Morphological measurements

The morphological measurements taken were plant height (mm), the mean length (cm) and weight of S_1, S_2 and S_3, the weight of LB, LS and S (g).

3. Nutritive measurements

(1) Chemical composition: The samples were placed in a forced draught oven at 100℃ for 5-6 hours to determine dry matter (DM). Total nitrogen (TN) was determined by the Kjeldahl method (AOAC, 1975). Total ash was determined by ignition at 600℃ for 3 hours. Detergent fibre fractions (neutral detergent fibre, NDF; acid detergent fibre, ADF; 72% lignin and residual ash) were determined using the method of Goering and Van Soest (1972). Neutral detergent solubles (NDS) were calculated as (100-NDF), hemicellulose as (NDF-ADF) and cellulose as (ADF-72% acid residue).

(2) Dry matter disappearance (DMD) and crude protein disappearance (CPD) in sacco: Three mature Maotou wether goats, filled with permanent rumen fistulae, were used. The samples, weighting 1.5 2.0 g were put into nylon bags (30-40 μm, size), then filled the tube into rumen. The DMD and CPD values were taken as the amount which disappeared after 48 hours. In some cases, DMD values for 6, 12, 24, 36, 48 and 72 h were determined so as to compare the rates of digestion.

4. Statistical analyses

Differences between measurements were analyzed by means of the LSD-method. The relations between agronomic, morphologic nutritive measurements and DMD values were calculated by means of linear regression analysis.

Results

Variability in agronomic and morphological measurements

1. Variation in agronomic and morphological measurements

Table 1 shown that (1) There were differences in plant height, grain yield, thousand grain weight and full-filling grain percent of the different varieties. For example, the plant height, grain yield and full-filling grain percent are up to significant difference ($p < 0.05$); (2) medium-maturing rice was tallest, and late maturing plants were taller than early-maturing rice. The grain yield and thousand grain weight of medium-maturing rice were the highest. Early maturing rice was higher in these characteristics than that of late

TABLE 1. AGRONOMIC AND MORPHOLOGICAL MEASUREMENTS OF RICE VARIETIES

Measurement	Variety												
	Early maturing					Medium maturing				Late maturing			
	Z_{802}	$X.Z_4$	V_{49}	$V_{[illegible]}$	mean + SE	$S.Y_{63}$	$X.G_{[illegible]}$	$D.Y_{[illegible]}$	mean ± SE	$V_{[illegible]}$	$X.W_1$	$Y_{[illegible]}$	mean ± SE
Plant height (cm)	74.4	67.5	89.9	95.4	81.8± 11.3	91.8	116	99.7	102.5± 10.1	90.1	94.5	89.8	91.5± 2.1
Yield (kg/ha)	5,893	4,888	7,860	8,220	6,715.5±688.5	8,025	7,612	7,125	7,587.5±212.3	6,600	6,267	5,538	6,135±250.3
Thousand grain weight (g)	23.4	26.2	28.4	27.9	26.5+ 2.0	29	25	29	27.7± 1.9	28	23.5	21.8	24.5± 2.6
Full-filling grain percent (%)	87	63.5	79.1	84.9	73.6± 9.2	63.8	78.1	85	75.6± 8.8	82.5	88	81.7	84.1± 2.8
Proportion of stem in whole plant (%)	41.3	40.6	31.1	43.6	39.2+ 1.8	25.2	23.6	26	24.9± 1.0	24.9	26.8	27	26.2+ 0.9
Proportion of leaf blade in whole plant	30.1	35.7	32.3	31.8	32.5± 2.0	27.2	38.7	33.6	33.2± 4.7	34.4	35	32.5	34.0± 1.1
Proportion of leaf sheath in whole plant	28.6	23.8	36.5	24.6	28.4+ 5.5	37.6	37.7	40.4	38.6± 1.3	40.9	38.2	40.6	39.9± 1.2

TABLE 2. THE MEAN VALUES OF MEASUREMENT OF SEGMENTS OF RICE STRAW

Rice type	Early maturing (Z_{802})				Medium maturing ($S.Y_{63}$)				Late maturing (Y_{64})			
Segment	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean	S_1	S_2	S_3	mean
Mean weight (g)	0.314	0.313	0.16	0.262	0.203	0.183	0.159	0.181	0.089	0.028	0.076	0.082
Mean length ± SE (cm)	6.9(3.3)	7.4(2.1)	6.8(2.0)	17.03	6.5(5.4)	9.6(2.6)	2.9(2.5)	23	25.8	13.8	10.1	16.57
Liear density (10-2 g/cm)	1.17	1.3	2.37	1.8	0.56	0.93	1.23	0.9	0.35	0.59	0.75	0.56

maturing rice. The order of full-filling grain percent was late- early- medum- maturing. There was a very significant positive relationship ($p < 0.01$, $r = 0.86$) between grain yield and the thousand grain weight. Such correlations did not occur between plant height or full-filling grain percent and grain yield; (3) Differences occurred in the proportions of each fraction (leaf sheath; leaf blade and stem) of the whole plant. In the medium and late maturing varieties, the proportion of each fraction were leaf sheath > leaf blade > stem. Combined leaf blade and leaf sheath constituted about 75% of the total rice straw. For the early maturing rice varieties, the proportions of each fraction were in order stem, leaf blade, leaf sheath.

2. Variation in different stem segments

The measurements of different segments from each fraction are shown in table 2.

The results in table 2 showed that the mean of length of weight, decreased significantly ($p < 0.05$) from top to bottom, but linear density increased gradually. The height of early maturing rice was least and medium maturing rice was the tallest. The linear density of stem segments of early maturing rice was significantly higher ($p < 0.01$) than that of medium maturing rice. In general, there was a negative correlation between segment length and linear density.

Variability in the chemical composition

1. Comparison of the whole plant

Values for the chemical composition were arranged of the total plant of early, medium and late maturing rice are show in tables 3A, 3B, 3C respectively.

Table 3 shown that (1) the CP content of

TABLE 3(A). CHEMICAL COMPOSITIONS OF WHOLE PLANT OF EARLY MATURING RICE (% DM)

Type of soil	Variety	DM	CP	NDF	NDS	ADF	LIG	CEL	HC	TA
R.E.	Z_{802}	89.6	2.8	62.8	37.2	42.9	3.8	32.6	19.9	13.6
	$X.Z_4$	89.4	6.7	59.3	40.9	39.6	5.6	28.5	19.6	14.5
R.S.	Z_{802}	89.0	4.1	61.5	38.5	41.5	3.9	32.1	20.0	14.1
	V_{49}	88.9	6.7	62.7	37.2	40.1	5.3	29.7	22.9	12.8
S.S	Z_{802}	89.0	2.9	70.8	29.2	46.8	4.3	34.2	24.0	15.5
	V_{35}	89.5	3.4	64.8	35.2	46.3	3.7	34.9	18.6	16.1
	Z_{802}	89.0	3.6	61.6	38.4	42.2	3.5	33.5	19.3	16.3
G.	$X.Z_4$	88.5	3.9	64.1	35.8	42.8	3.7	34.6	21.2	13.8
	V_{49}	88.6	5.2	64.7	35.3	41.0	3.7	33.3	23.7	11.6
	Z_{802}	88.8	5.6	57.8	42.1	36.3	3.9	29.0	21.5	10.3
L.S.	$X.Z_4$	89.1	4.6	62.4	37.6	40.3	4.5	33.2	22.1	10.6
	V_{49}	90.7	5.0	60.1	41.0	39.6	2.9	31.9	20.4	13.1
Mean		89.1	4.6	62.7	37.4	41.6	4.1	31.3	21.0	13.5
+SE		0.1	0.4	0.9	1.0	0.8	0.2	0.6	0.5	0.6

TABLE 3(B). CHEMICAL COMPOSITIONS OF WHOLE PLANT OF MEDIUM MATURING RICE (% DM)

Type of soil	Variety	DM	CP	NDF	NDS	ADF	LIG	CEL	HC	TA
R.E.	$S.Y_{63}$	99.6	4.5	72.6	27.4	52.1	5.8	35.4	20.5	19.1
	$X.G_{63}$	89.3	4.1	72.1	27.9	48.6	6.2	33.9	23.5	16.1
R.S.	$S.Y_{63}$	89.7	4.3	72.3	22.7	52.2	6.9	37.4	20.1	14.2
S.S	$D.Y_{63}$	89.9	3.0	75.6	24.4	56.8	7.1	41.6	18.7	14.7
	$S.Y_{63}$	90.6	3.5	72.9	27.1	54.6	5.7	40.6	18.4	14.7
L.S.	$D.Y_{63}$	90.1	4.9	73.2	26.8	56.4	6.2	44.1	16.8	13.0
Mean		90.0	4.0	73.1	26.1	53.4	6.3	38.8	19.7	15.2
±SE		0.2	0.3	0.5	0.8	1.2	0.2	1.5	0.9	0.8

TABLE 3(C). CHEMICAL COMPOSITIONS OF WHOLE PLANT OF LATE MATURING RICE (% DM)

Type of soil	Variety	DM	CP	NDF	NDS	ADF	LIG	CEL	HC	TA
	V_{64}	93.8	7.0	65.0	35.0	41.3	5.6	31.2	23.6	16.1
R.E.	$X.W_1$	92.7	4.7	64.5	35.5	41.0	4.4	31.9	23.5	14.0
	Y_{238-1}	92.1	5.1	65.5	34.5	43.3	5.4	29.5	22.2	16.2
	V_{64}	93.3	5.8	63.1	36.9	41.4	4.7	30.8	21.7	14.0
R.S.	$X.W_1$	92.2	5.8	65.9	34.1	45.0	4.6	33.2	20.8	14.5
	Y_{238-1}	92.2	5.0	70.2	29.8	47.6	4.6	32.5	22.5	17.1
	V_{64}	92.6	4.4	68.8	31.2	48.1	4.7	34.4	23.5	12.4
G.	$X.W_1$	91.8	5.3	61.1	38.9	41.7	4.0	30.7	19.4	12.2
	Y_{238-1}	93.1	5.6	65.4	34.6	44.4	5.4	26.7	21.0	14.2
	V_{64}	92.9	6.2	60.5	39.5	43.9	6.8	31.8	16.6	12.8
L.S.	$X.W_1$	92.3	7.8	64.6	35.4	41.2	6.8	29.8	23.4	11.6
	Y_{238-1}	93.7	5.7	65.8	34.2	43.2	4.8	30.9	22.7	14.6
Mean		92.8	5.5	65.9	34.1	44.0	5.2	31.4	21.9	14.5
±SE		0.2	0.3	0.9	0.9	0.7	0.3	0.5	0.6	0.6

TABLE 4. CHEMICAL COMPOSITIONS OF DIFFERENT FRACTIONS OF RICE STRAW (MEAN ± SE) (% DM)

		Early maturing	Medium maturing	Late maturing
	S	88.4 ± 0.7	90.1 ± 0.7	93.9 ± 1.5
DM	LB	89.7 ± 0.3	91.0 ± 0.5	92.0 ± 0.8
	LS	89.0 ± 0.2	89.0 ± 0.6	92.8 ± 0.8
	S	2.3 ± 0.3[a]	2.0 ± 0.5[a]	3.1 ± 0.7[a]
CP	LB	7.6 ± 1.7[c]	7.1 ± 1.7[c]	7.8 ± 1.6[c]
	LS	4.1 ± 1.0[a]	2.8 ± 0.6[a]	5.1 ± 1.2[a]
	S	62.9 ± 3.0[a]	71.6 ± 2.2[c]	64.9 ± 4.9[a]
NDF	LB	57.6 ± 2.3[a]	70.0 ± 2.0[a]	61.1 ± 2.3[a]
	LS	68.1 + 0.7[c]	78.5 ± 2.8[c]	71.9 ± 2.5[c]
	S	37.1 ± 1.5[a]	28.4[c]	35.1[c]
NDS	LB	42.6 ± 2.5[c]	30.0[c]	38.9[c]
	LS	32.0 + 0.8[a]	21.5[a]	28.1[a]
	S	43.8 ± 2.2[c]	53.1 ± 4.2[a]	43.6 ± 3.6[a]
ADF	LB	36.9 ± 3.6[a]	49.3 ± 2.6[a]	39.8 ± 3.5[a]
	LS	46.4 ± 2.0[c]	56.5 + 2.6[c]	48.4 + 2.5[c]
	S	3.8 ± 0.09[a]	6.1 ± 0.9[a]	4.5 ± 2.3[a]
LIG	LB	4.6 ± 0.2[c]	7.7 ± 0.7[c]	5.5 ± 0.8[c]
	LS	3.7 ± 0.5[a]	5.5 ± 1.1[a]	5.5 ± 1.7[c]
	S	37.0 ± 1.2[c]	43.6 ± 6.1[c]	35.4 ± 3.4[c]
CEL	LB	24.6 ± 1.4[a]	30.4 ± 7.7[a]	25.5 ± 1.9[a]
	LS	35.9 ± 1.0[c]	41.5 ± 5.4[c]	34.6 ± 2.3[c]
	S	21.4 ± 1.2	18.5 ± 2.6	21.3 ± 1.9
HC	LB	20.7 ± 1.5	20.6 ± 2.7	21.2 ± 2.1
	LS	21.6 ± 1.3	22.0 ± 4.1	23.5 ± 2.0
	S	14.2 ± 1.6	15.0 ± 1.8	13.9 ± 1.8
TA	LB	14.5 ± 1.4	16.7 ± 2.0	16.0 ± 3.1
	LS	14.2 ± 1.9	14.0 ± 2.1	14.1 ± 2.7

Significant difference ($p < 0.01$) between a and c.

all straws were low, ranging 4.1 to 5.5%; (2) the NDF content of medium maturing rice was significantly higher than that of the early matruing and late maturing varieties; (3) the NDS content of varieties rice straw ranged from 25-35%; (4) the lignin content of early maturing rice straw was significantly less than that of the medium-, late- maturing varieties; (5) each chemical component showed a wide range overall. For example, the CP content ranged from 2.8 (R.E.Z_{802}) to 7.8% (L.S.XW_1); the NDF content from 59.2% (R.E.XZ_4) to 75.6% (S.S.DY_{63}).

2. Comparison of different morphological fractions

The results in table 4 showed that (1) the CP and NDS contents of leaf blade were significantly higher than the corresponding values for leaf sheath and stem ($p < 0.05$). However, NDF, ADF and CEL content were significantly lower ($p < 0.05$). There was a trend towards higher LIG content in the leaf blade. For medium maturing rice, the lignin content of the leaf blade was significantly higher ($p < 0.01$) than that of the stem and leaf sheath. (2) Significant differences occured in the content of NDF, ADF of leaf sheath and those of the leaf blade or the stem ($p < 0.01$). There were no significnat differences ($p > 0.05$) in the NDF and ADF contents of the leaf blade and stem.

Table 5 showed that (1) From top to bottom, there was a tendency for the CP, NDS and TA contents of each segment to decrease and for the NDF, ADF, LIG and CEL contents to increase. (2) The CP and NDS contents of the leaf blade were significantly higher ($p < 0.05$) than those of the sheath and stem, but the NDF, ADF and CEL contents of the leaf blade were lowest. There were higher CP and NDS contents in the leaf blade and higher cellulose contents in the leaf sheath and stem. (3) The lignin contents of different segments of the stem were increased in order of $S_1<S_2<S_3$, and there was a significant

TABLE 5(A). CHEMICAL COMPOSITIONS OF DIFFERENT FRACTIONS OF EARLY MATURING RICE (% DM)

Fractions	S			LB			LS		
Segment	S_1	S_2	S_3	LB_1	LB_2	LB_3	LS_1	LS_2	LS_3
DM	88.4	89.5	90.9	90.5	90.0	90.5	90.4	90.3	89.6
CP	1.6	1.5	1.3	5.2	3.6	3.3	3.4	2.2	2.7
NDF	59.2	61.1	64.3	61.0	57.9	60.4	68.6	68.9	67.6
NDS	40.8	38.9	35.7	39.0	42.1	39.6	31.4	31.1	32.4
ADF	41.9	44.3	44.3	39.4	38.3	37.9	348.1	47.6	47.5
LIG	3.4	3.9	4.6	5.6	4.7	5.0	4.7	4.1	3.7
HC	17.4	16.8	20.2	21.6	19.6	22.5	20.5	21.3	20.1
CEL	36.4	37.3	36.5	22.8	25.5	26.0	35.7	34.8	35.2
TA	13.5	12.2	11.9	13.4	15.3	13.4	14.3	13.6	15.3

TABLE 5(B). CHEMICAL COMPOSITIONS OF DIFFERENT FRACTIONS OF MEDIUM MATURING RICE (% DM)

Fractions	S			LB			LS		
Segment	S_1	S_2	S_3	LB_1	LB_2	LB_3	LS_1	LS_2	LS_3
DM	88.3	89.0	89.6	90.5	89.0	89.1	89.6	89.4	89.6
CP	2.7	2.0	2.1	11.5	8.9	6.4	3.1	2.7	2.1
NDF	66.1	71.0	73.1	68.7	69.2	69.4	77.9	77.8	80.0
NDS	33.9	29.0	26.9	31.3	30.8	30.6	22.1	22.2	20.0
ADF	47.5	51.2	53.0	45.2	44.9	47.1	51.6	56.7	58.7
LIG	4.0	4.5	5.2	8.5	6.9	6.6	4.6	4.0	6.5
HC	38.8	41.3	42.0	22.5	26.5	29.0	34.9	40.4	40.2
CEL	18.7	19.8	20.0	22.5	24.3	22.4	26.3	21.2	21.3
TA	20.2	17.4	16.9	19.9	18.1	17.0	18.4	17.4	18.0

TABLE 5(C). CHEMICAL COMPOSITIONS OF DIFFERENT FRACTIONS OF LATE MATURING RICE (% DM)

Fractions	S			LB			LS		
Segment	S_1	S_2	S_3	LB_1	LB_2	LB_3	LS_1	LS_2	LS_3
DM	91.1	95.0	96.0	91.9	90.5	91.1	93.2	93.5	92.9
CP	3.2	3.6	2.8	5.1	4.6	4.4	2.3	2.5	2.8
NDF	68.1	69.7	66.0	63.3	63.4	60.9	77.9	76.0	74.2
NDS	31.9	30.3	34.0	36.7	36.6	39.1	22.1	24.0	25.8
ADF	44.7	47.5	45.8	42.8	42.2	41.8	52.0	52.2	50.8
LIG	3.6	3.5	4.3	4.8	5.5	5.8	5.7	4.3	5.1
HC	38.2	40.5	37.3	24.9	26.8	24.3	37.3	38.0	35.0
CEL	23.4	22.2	20.2	20.5	21.2	19.2	25.9	23.7	23.4
TA	15.1	15.1	16.2	20.8	18.2	17.9	14.6	16.7	17.6

difference between S_1 and S_2 ($p < 0.05$). There was less lignin in the stem than in the leaf blade and leaf sheath.

Variability in rumen dry matter disappearance (DMD) and crude protein disappearance (CPD).

1. Comparison of the DMD and CPD values in whole plant and different fractions

The results in table 6 showed that (1) There were significant differences ($p < 0.05$) for whole plant DMD values from different varieties in the order of early maturing highest, the medium maturing higher, the late maturing lowest. However, there were no significant differences between the CPD value of the whole plants; (2) The DMD of stem was higher than that of the leaf sheath and blade.

2. Comparison of the DMD and CPD values of different segments from each fraction

The results in table 7 showed that there were significant differences ($p < 0.05$) between the DMD values of different segments from each fraction, generally S>LB>LS. Meanwhile, as far as the stem, the DMD value of segment S_2

TABLE 6. DMD AND CPD OF FRACTIONS AND OF THE WHOLE PLANT OF RICE STRAW (% DM)

		S	LB	LS	Whole plant
Early maturing	DMD	55.9 ± 5.5	47.7 ± 5.8	40.4 ± 7.6	49.0 ± 3.0
(Z_{802})	CPD	43.7 ± 12.3	49.1 ± 8.7	43.6 ± 8.4	45.1 + 7.0
Medium maturing	DMD	50.5 ± 2.9	39.1 ± 2.9	38.0 ± 6.3	41.8 ± 4.3
($S.Y_{63}$)	CPD	29.0 ± 17.7	41.5 ± 10.8	27.0 ± 5.6	28.7 ± 9.5
Late maturing	DMD	51.8 + 6.6	33.4 + 10.6	25.4 + 4.5	35.7 ± 3.7
(Y_{231-8})	CPD	55.3 ± 6.5	38.2 ± 9.8	39.8 ± 15.1	43.7 ± 7.7

TABLE 7. DMD AND CPD FROM DIFFERENT SEGMENT OF RICE STRAW (% DM)

Fractions		S			LB			LS		
Segment		S_1	S_2	S_3	LB_1	LB_2	LB_3	LS_1	LS_2	LS_3
Z_{802}	DMD	60.5	56.4	NA	53.4	52.9	41.7	48.0	44.8	44.2
	CPD	4.5	20.3	NA	40.7	46.1	20.4	54.0	36.4	39.2
$S.Y_{63}$	DMD	47.4	38.5	40.2	36.4	40.9	42.4	43.3	42.7	36.3
	CPD	13.1	24.3	44.6	25.7	29.2	26.0	36.1	36.1	6.5
Y[illegible]	DMD	41.0	58.2	41.0	41.2	40.6	34.4	29.8	31.0	18.1
	CPD	56.7	61.0	57.1	46.5	45.7	17.4	40.1	42.2	NA*

* NA — No analysis.

is highest, than S_1 and S_3 are lower relatively. There were definite differences for the CPD values of different segments, but not regularity. The negative value occurred for CPD value of LS_3.

3. Changes in the DMD values with times

The DMD value of different fractions at 6, 12, 24, 36. 48, 72 h are shown in table 8 and figure 1. The DMD values of different fractions were different at the same time in the order stem>leaf blade>leaf sheath. Before 24 h, the DMD values of stem and leaf blade increased rapidly, at 24-48 h, it increased continuously with smaller range, and at 48-72 h, it increased slowly. Before 24 h, the DMD value of leaf sheath increased rather quickly and it increased rapidly at 36-48 h, and at 48-72 h, it increased with smaller range. In general, with DMD value for rice straw decreased in the order S>LB>LS (figure 1).

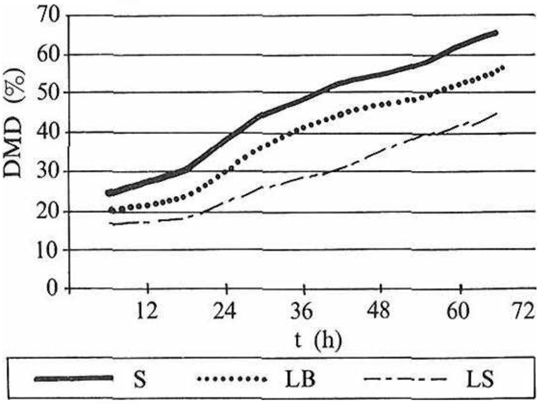

Figure 1. DMD value of each fraction of rice straw at different time.

TABLE 8. DMD VALUE OF EACH FRACTION OF RICE STRAW AT DIFFERENT TIME (% DM)

		6 h	12 h	24 h	36 h	48 h	72 h
Z_{802}	S	25.4	32.6	53.0	57.5	55.9	64.8
	LB	18.0	23.4	43.3	40.5	47.7	59.8
	LS	15.8	16.4	26.2	26.7	40.4	38.6
$S.G_{63}$	S	31.2	36.8	42.1	48.1	54.4	61.2
	LB	22.7	26.9	37.3	43.0	48.0	50.1
	LS	19.2	22.5	29.1	32.5	39.7	48.3
Y_{231-1}	S	18.4	22.4	39.2	54.1	62.8	71.0
	LB	21.4	21.3	31.9	42.6	50.9	58.6
	LS	13.9	17.0	23.0	33.5	37.1	46.3
mean	S	25.0	30.6	44.8	53.2	57.7	65.7
	LB	20.7	23.9	37.6	45.1	48.9	56.2
	LS	16.3	18.6	26.1	30.9	39.1	44.4

Discussion

1. Variation in the nutrititive value

(1) varitey

The results showed that (a) the nutritive value was different for the different sorts of rice straw. For example, the mean of NDF value of early maturing rice is 10.4 unit lower than that of the medium-, and medium- is 7.2 unit higher than that of the late- varieties (table 3). The mean of DMD value of early- is 13.3 unit higher than that of the late- varieites (table 6); (b) the nutritive value is different on account of different varieties even though the same kind of rice. For example, the NDF value of the early- Z[illegible] is 70.8%, the NDF value of V_{49} is 10.7 unit lower than that of Z_{802}. The lignin content of $D.Y_{63}$ in medium variety is 1.5 unit higher than that of $S.Y_{63}$. As far as the late- varieties, the crude protein content is 3.6 unit higher than that of V_{64} (table 3). These results are consistent with Doyle et al. (1986).

(2) Fractions in plant

The nutritive value of all fractions in plant varies with variety. For example, the CP content of LB in early variety rice is 5.3 unit higher than that of S; The NDF value of LS in medium- is 8.5 unit higher than that of LB; The NDS content of LS in late maturing is 10.8 unit higher than that of LS (table 4); As far as the medium $X.Y_{63}$, its DMD value (48 h) of S is 12.5 higher than that of LS (table 6). In summary, the nutritive value of different fractions of rice straw decreased in the order S>LB>LS.

2. Possibility of predicting the nutritive value of rice straw

The results showed that it is possible to predict the nutritive value of rice straw according to the relationship between DMD value and the agronomic, morphologic measurements and chemical composition.

(1) The relationship between the DMD value and agronomic and morphologic measurements. It is shown by the correlative analysis that are relativity between the plant height, grain yield, full-filling grain percent, thousand grain weight, leaf/stem and the proportion of all fractions with DMD value (48 h). For example, the significantly negatitive corelations are noted between the grain yield (r = −0.91), plant height (r = −0.87) and full-filling grain percent (r = −0.75) and DMD value (48 h); but the positive correlations are noted between the leaf/stem (r = 0.59) and proportion of S (r = 0.58) and DMD value. These results are similar to the results reported by Kent and Pearce (1988).

(2) Relationship between the DMD value and chemical composition. It is also revealed by correlative analysis that there are certain relation between the chemical compositions and DMD value (48 h). For example, the relations between the chemical compositions and DMD value are:

Early-: DMD = 7.372 + 0.055 DM − 0.532 CP − 2.487 NDF + 1.143 ADF + 0.214 CEL + 1.456 HC + 0.718 LIG (r = 0.61).

Medium-: DMD = 333.927+2.026 DM − 0.224 CP − 4.602 NDF + 4.524 ADF + 0.149 CEL + 2.923 HC + 0.035 LIG (r = 0.79).

Late-: DMD = 133.284 + 0.282 DM − 3.455 CP − 22.185 NDF + 24.267 ADF + 0.316 CEL − 23.288 HC + 0.945 LIG (r = 0.79).

Therefore, it is possible to predict the nutritive value of rice straw on the basis of the relationship between the agronomic, morphologic measurements, chemical compositions and DMD values.

Conclusion

Although there are differences between rice varieties in the proportion of different fractions in the whole plant. The cell wall (NDF, CEL, HC and LIG) contents of whole plant rice straw are higher than that of CP and NDS during maturation. The nutritive value of rice straw in all the varieties rice are different. The nutritive values in the different fractions vary with stem is highest, then LB and LS the lowest. The DMD value of rice straw vary with early- maturing rice highest, then medium- maturing, followed by late-maturing. The DMD values in the different fractions also vary, S is highest, then LB and LS the lowest, differences that are consistent with varieties in the chemical composition. In general, DMD value increased up to 72 h in the rumen.

There are relations between the plant height, grain yeild, full-filling grain percent, thousand grain weight, leaf/stem and the proportion of all fractions and DMD values (48 h). Significant negative correlations are noted between the grain yield (r = −0.91), plant height (r = −0.87) and full-filling grain percent (r = −0.75), but the positive correlations are noted between the leaf/stem (r = 0.59) and proportion of S (r = 0.58) and DMD values. The relativity between the chemical compositions and DMD values is:

Early-: DMD = 7.372 + 0.055 DM − 0.532 CP − 2.487 NDF + 1.143 ADF + 0.214 CEL + 1.456 HC + 0.718 LIG (r = 0.61).

Medium-: DMD = 333.927 + 2.026 DM − 0.224 CP − 4.602 NDF + 4.524 ADF + 0.149 CEL + 2.923 HC + 0.035 LIG (r = 0.79).

Late-: DMD = 133.284 + 0.282 DM − 3.455 CP − 22.185 NDF + 24.267 ADF + 0.316 CEL − 23.288 HC + 0.945 LIG (r = 0.79).

Therefore, it is possible to predict the nutritive value of rice straw on the basis of the relation ship between the agronomic, morphologic measurements, chemical compositions and DMD values.

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