POSSIBILITY AND POSSIBLE METHODS OF IMPROVING THE NUTRITIVE VALUE OF CEREAL STRAW WITHOUT PRETREATMENT (A REVIEW)

Xing Tingxian[1]

Changsha Institute of Agricultural Modernization,
Academia Sinica, Changsha, Hunan Province,
The People's Republic of China.

Summary

In view of the wide range that occurs in the nutritive value of cereal straw, the factors that may contribute are discussed under the heading of: (a) genetic factors; (b) environment factors affecting the pattern of plant growth; and (c) management factors associated with grain harvest and threshing and straw storage.

The possible ways of improving the nutritive value of cereal straw without pretreatment may be achieved by selecting and breeding better cereal straw, by controlling environmental factors, by controlling management practices and by appropriate supplementation strategies to alleviate deficiencies of essential nutrients. Thus improvement in the nutritive value of cereal straw would be attained without pretreatment.

(**Key Words:** Cereal Straw, Nutritive Value, Digestibility, Cellulose, Neutral Detergent Fibre (NDF), Dry Matter)

1. Introduction

In general, cereal straws as feedstuffs for ruminants are of low quality and this often results in low voluntary intakes. Therefore, it has been a long term aim of many researchers to improve the nutritive value of them for feeding animals. Over the last decade or so, considerable interest and effort has been directed towards the possibilities of pretreating cereal straw by chemical, physical or biological means to improve the nutritive value. Pretreatment processes can improve the feeding value of straw by increasing its digestible energy content, and/or by increasing feed intake. Under experimental conditions, pretreatments have been shown to be successful in improving the utilization of cereal straws, thereby increasing animal performance. For example, when rice straw was treated with sodium hydroxide (10% NaOH), the *in vitro* dry matter digestibility increased 20-30 units (Chandra and Jackson, 1971; Robb, 1976-78). Ensiled rice straw treated with 4% urea for four weeks, resulted in increased intakes by buffalo of 26g DM/$Kg^{W0.75}$ (Jayasuriya, 1980) compared with untreated rice straw. However, because of high cost, few of these treatment methods have been adopted in practice. Schiere et al.(1983, 1984) have determined the economics of feeding straw either untreated (US) or treated with 4% urea (TS). The total digestible nutrients (TDN) (%DM) of TS was increased 7 units; the intake by cow (350 kg (W) was also increased 2.8 kg/d. compared with US. However the price of total digestible nutrients (TDN) of TS was increased 543% compared with US (control group). In general, if full advantage is not taken of the increased intake of treated straw, the economics may not favour TS over untreated straw. The most likely situation where pretreatment might be justified is with lactating cows where the increased milk production results in a higher cash return for the farmer.

The economic evaluation of various straw processing methods conducted by Ranjhan (1983) throughout South-East Asia showed that grinding and pelleting of straw (physical pretreatment) was not economically feasible. The practice of soaking straw and offering it with a concentrate mixture increased the palatability and nutritive value: chemical treatments such as sodium hydroxide

[1]Address reprint requests to Mr. Xing Tingxian, Associate Professor in Animal Nutrition, Changsha Institute of Agricultural Modernization, Academia Sinica, Changsha, Hunan Province, The People's Republic of China.

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treatment are expensive and may not be economical. *The production of single cell protein (microbial treatment)*, utilising straw as the base material, was also explored. The general conclusion was that *the methods of physical and chemical treatment of* cereal straws for improving nutritive value are not useful for most farms in South-East Asian countries.

Data on the chemical composition and digestibility of untreated cereal straws indicate that wide variation occurs in samples from different sources. For example, the range in *in vitro* organic matter digestibility that has been reported for wheat straw is from 21% (Braman and Abe, 1977) to about 60% (Levy et al., 1977), while that for rice straw is from 35% (Vijchulata and Sanpote, 1982) to 55% (Cheva-Isarakul and Cheva-Isarakul, 1983; Wanapat, 1985). The intakes by cattle have ranged from 1.2kg/100kg liveweight (Cheva-Isarakul and Cheva-Isarakul, 1983) to 2.6kg/100kg liveweight (Wanapat et al., 1984). Therefore, it is pertinent to ask, firstly, what are the causes of such variation? and secondly, is it possible to improve the nutritive values of cereal straws without pretreatment? Also is there a simple method of identifying which straws are high in quality and which ones are low? In order to consider these questions it is necessary to examine the factors that may affect the quality of straw as it is fed to animals.

2. Factors affecting cereal straw quality

The factors that cause variation in cereal straw quality are either genetic, environmental or a result of any genotype environment interactions. This may be further expressed as the net effect on intake and digestibility of the particular variety chosen, and the effects of management and *pattern of growth of the plant, and of harvesting*, threshing, and storage of the crop residue.

It is extremely important to realize when interpreting the differences in digestibilities for the different varieties cited in the literature, that environmental effects are always super imposed on any genetic differences. Thus apparent differences between varieties must be interpreted with caution.

A. Genetic factors affecting cereal straw quality.

(1) Do different species or varieties have different nutritive values?

Firstly, it is very easy to understand that different species have different nutritive values because of widely differing chemical composition. Several comparisons of the composition of different cereal straws have been made, and in some cases, pronounced differences have been reported (table 1).

Many workers have reported that cereal straw of different varieties have given different nutritive compositions. In some cases, pronounced differences have been reported. For example, Sanasgala and Jayasuriya (1984) obtained an *in vitro* organic matter digestibility (IVOMD) a value of 30% for rice straw of variety BW 266-7 and 45% for that of the variety BG 380-2. Roxas et al.(1985) reported that IVOMD of rice straw variety H4 as 39% and that of variety IR 36 as 51%. Roxas et al. (1984) reported that crude protein content of rice straw varied from 4.8 to 8.7; with a mean

TABLE 1. COMPOSITION OF CEREAL STRAWS

	Percentage of dry matter								
	Dry matter	Ash	Crude protein	ADF	Cell walls	Cellulose	Hemi-cellulose	Lignin	Crude fibre
Cereal straws									
Barley	89.4	6.4	2.9	53.6	77.3	40.7	23.8	8.0	41.6
Oat	89.2	4.4	4.1	57.1	82.3	44.0	25.2	11.2	41.0
Rice	95.0	19.4	3.2	45.9	80.7	39.6	34.3	6.3	35.1
Sorghum	93.5	6.0	3.4	49.4	81.4	42.2	31.6	7.6	41.8
Triticale		5.6	2.9	58.6	80.6	44.9	22.0	9.7	–
Wheat	91.0	6.4	2.6	57.5	80.2	43.2	22.4	9.5	43.6

Source: Bhattacharya & Taylor, 1975; Gohl, 1975; Leche & Groenedyk, 1978; Muller, 1978; National Research Council, 1971; Ranjhan, 1978; Rexen, 1979; Sen, Ray & Ranjhan, 1978; Van Soest & Robertson, 1976.

TABLE 2. CRUDE PROTEIN, CRUDE FIBRE AND GROSS ENERGY OF STRAWS FROM DIFFERENT VARIETIES OF RICE. ALL VALUES ARE EXPRESSED ON A DRY MATTER BASIS

Variety		Protein (%)	Crude Fibre (%)	Ash (%)	Gross Energy (MJ/kg)
IR 5	PRO	6.56	31.8	26.7	13.7
	UP	7.19	31.0	26.0	13.7
IR 20	PRO	6.81	32.5	25.5	23.8
	UP	6.89	31.7	28.9	13.5
IR 24	PRO	7.14	30.6	28.6	13.3
	UP	8.46	29.0	26.3	23.7
IR 28	PRO	8.40	29.5	25.7	13.4
	UP	7.24	28.3	26.0	14.3
IR 30	PRO	6.90	30.4	25.1	14.4
	UP	8.06	29.3	26.0	14.6
IR 32	PRO	6.41	29.7	25.3	12.9
	UP	6.10	28.4	25.6	13.3
IR 36	PRO	8.25	29.9	23.3	14.0
	UP	6.71	31.7	21.4	14.0
IR 38	PRO*	7.13	30.6	24.5	14.0
	UP	8.04	30.2	24.7	14.1
IR 40	PRO	8.60	29.5	26.0	13.8
	UP	7.48	27.6	26.0	13.8
IR 42	PRO	6.71	30.1	26.4	13.2
	UP	5.65	30.3	25.0	13.4
IR 44	PRO	6.11	31.1	25.8	13.3
	UP	5.25	30.9	24.5	13.3
IR 46	PRO	5.04	30.7	25.7	12.9
	UP	4.75	31.8	23.5	13.7
IR 48	PRO	6.20	29.2	24.2	13.2
	UP	4.94	30.4	24.7	13.2
IR 50	PRO	6.96	29.9	26.7	13.4
	UP	6.67	31.0	24.1	14.1
IR 52	PRO	7.32	28.6	27.5	13.3
	UP	7.49	32.5	24.3	13.9
Mean	PRO**	6.96	30.4	25.9	13.5
	UP	6.86	30.2	25.0	13.0

*PRO = protected by Carbofuran and Brodan
UP = unprotected
**No significant differences occurred between straw from protected and unprotected plots
Source: Roxas et al. (1984)

value of 6.9%. The chemical composition of rice straw of different varieties was shown in tables 2 and 3.

Devendra et al. (1986) reported some differences in the chemical composition and IVOMD of the main parts of rice straw lending support to the contention that real differences occur between varieties (table 4).

Roxas et al. (1984) also reported that wide variation occurs in the *in vitro* dry matter and organic matter digestibilities of rice straw of different varieties (table 5).

(2) Differences between morphological fractions and their position on the plant.

TABLE 3. CELL WALL COMPONENTS OF STRAW FROM DIFFERENT VARIETIES OF RICE. ALL VALUES ARE EXPRESSED ON A DRY MATTER BASIS

Variety		Neutral-Detergent Fibre (%)	Acid-Detergent Fibre (%)	Cellulose (%)	Hemi-Cellulose (%)	Lignin (%)	Silica (%)
IR 5	PRO	65.8	56.0	31.2	9.8	6.3	18.6
	UP	67.6	53.9	31.2	13.6	6.8	15.8
IR 20	PRO	60.6	56.0	34.3	4.5	7.0	14.8
	UP	58.1	55.8	31.4	2.4	7.2	17.7
IR 24	PRO	60.5	55.8	30.9	4.7	6.6	18.3
	UP	56.3	52.1	26.8	4.3	6.8	18.5
IR 28	PRO	57.4	52.9	29.4	4.5	6.6	16.9
	UP	57.4	53.4	29.0	4.0	6.5	18.0
IR 30	PRO	56.8	54.5	30.8	2.3	6.0	17.7
	UP	59.0	54.2	29.8	4.8	5.3	19.1
IR 32	PRO	56.9	54.3	30.3	2.6	5.9	18.2
	UP	55.5	52.1	26.7	3.4	6.3	19.0
IR 36	PRO	60.2	57.7	32.5	2.5	10.3	14.9
	UP	61.2	53.3	29.2	7.3	10.2	13.9
IR 38	PRO	71.4	54.6	27.7	18.8	10.1	16.8
	UP	63.3	60.6	34.6	2.7	9.5	16.4
IR 40	PRO	64.7	61.1	32.6	3.7	10.8	17.7
	UP	62.0	52.5	25.1	9.5	11.5	15.9
IR 42	PRO	58.0	53.9	29.6	4.1	5.5	18.7
	UP	55.3	54.6	28.2	0.7	6.9	19.6
IR 44	PRO	68.7	55.5	31.3	13.2	6.0	18.2
	UP	61.4	56.0	29.9	5.4	6.4	19.8
IR 46	PRO	59.1	44.2	24.3	14.9	7.1	22.7
	UP	56.7	55.7	32.3	1.0	6.6	16.8
IR 48	PRO	53.8	41.3	25.7	12.5	5.9	19.7
	UP	56.7	55.8	31.0	0.9	5.1	19.7
IR 50	PRO	57.4	53.3	27.4	4.2	9.9	16.0
	UP	69.6	58.7	33.2	10.9	10.0	15.5
IR 52	PRO	66.1	61.3	31.2	4.8	12.0	18.0
	UP	61.1	59.2	33.2	1.9	10.7	15.3
Mean	PRO*	61.2	54.2	29.9	7.1	7.7	17.8
	UP	60.1	55.2	30.1	4.9	7.7	17.4

*No significant differences occurred between straws from protected and unprotected plots.
Source: Roxas et al. (1984)

The major plant parts in cereal straws are the leaf blades, the leaf sheaths and the stem. The stem may be divided into internodes and nodes. The study of individual plant parts has given some estimates of the variation of quality that occurs within the plant. To examine this, Winugroho (1981) dissected 78 samples of mature wheat plants into seven fractions, grain, hust, rachis, stem, internode, stem node, leaf blade and leaf sheath. The IVOMD value of non-grain fractions are shown in table 6.

These results illustrate the wide differences that occur between the different parts of the mature wheat plant and, in particular, that the digestibility of the stem internode is much lower than that of the other components.

TABLE 4. CHEMICAL COMPOSITION (% DRY MATTER) AND *IN VITRO* ORGANIC DIGESTIBILITY (IVOMD, %) OF RICE STRAW OF DIFFERENT VARIETIES

Variety		Crude protein	Total ash	Neutral detergent fibre	Acid detergent fibre	Hemi-cellulose	Cellulose	Lignin	Residual ash	Silica	IVOMD
Kadaria (a)	In*	2.8	16	82	64	17	48	6	10	10	40
	Sh	3.9	25	82	62	21	37	5	20	20	48
	Bl	4.8	22	80	56	24	31	6	19	19	47
Kadaria (b)	In	1.5	13	83	55	28	38	4	13	-	34
	Sh	2.1	18	83	61	22	49	6	6	-	38
	Bl	3.9	18	78	50	28	30	6	14	-	31
Sri Malaysia (a)	In	3.4	14	83	59	25	47	4	8	-	45
	Sh	3.6	18	85	56	29	40	4	12	-	44
	Bl	3.8	16	81	52	29	34	4	14	-	41
Sri Malaysia (b)	In	2.2	19	77	64	13	49	5	10	10	51
	Sh	3.5	23	83	58	24	39	4	16	15	52
	Bl	4.6	19	76	50	25	31	6	14	14	52
Sri Malaysia II	In	2.4	16	85	62	22	48	5	9	-	42
	Sh	3.3	22	84	58	27	34	4	19	-	50
	Bl	3.4	21	79	54	25	31	5	18	-	53
Sekencang (a)	In	2.3	17	78	63	15	49	5	9	9	42
	Sh	2.8	22	80	58	21	39	4	16	16	46
	Bl	3.3	22	73	51	22	28	6	17	17	46
Sekencang (b)	In	2.2	14	80	60	20	48	5	7	7	46
	Sh	3.1	19	81	56	25	37	4	14	14	54
	Bl	3.9	20	74	50	25	28	8	15	14	59
Setanjung (a)	In	2.7	14	81	63	18	50	5	8	8	42
	Sh	3.8	18	80	56	24	40	4	12	12	41
	Bl	5.6	15	76	50	26	32	7	11	10	46
Setanjung (b)	In	1.9	14	81	56	25	45	4	7	6	40
	Sh	3.1	16	84	56	29	41	4	10	10	39
	Bl	4.2	14	76	47	29	33	5	9	9	39
Sri Setanjung	In	2.1	14	81	56	25	44	5	6	6	41
	Sh	4.0	14	85	54	31	39	5	10	10	43
	Bl	5.4	14	76	48	29	31	7	10	9	49
MR1 (a)	In	2.1	13	83	61	23	48	6	7	7	39
	Sh	2.4	16	86	57	29	42	4	10	10	44
	Bl	3.5	13	79	50	30	35	6	8	8	47
MR1 (b)	In	2.6	12	81	59	23	47	5	6	6	41
	Sh	4.2	14	84	55	28	41	5	9	9	41
	Bl	5.3	12	74	48	27	32	8	8	7	37
MR71 (a)	In	2.6	12	81	61	20	50	5	6	5	45
	Sh	3.0	15	82	58	24	44	4	10	10	46
	Bl	4.6	14	76	51	25	35	6	10	10	49
MR71 (b)	In	2.3	13	83	62	21	50	6	6	5	40
	Sh	2.6	16	85	58	27	42	5	11	10	44
	Bl	3.6	15	77	50	27	34	6	10	10	39
Mahsuri (a)	In	1.7	11	83	63	20	51	6	6	6	35
	Sh	2.0	15	85	55	30	39	4	12	11	44
	Bl	3.8	14	76	49	27	32	7	10	10	34

TABLE 4. CONTINUED

Variety		Crude protein	Total ash	Neutral detergent fibre	Acid detergent fibre	Hemi-cellulose	Cellulose	Lignin	Residual ash	Silica	IVOMD
Mahsuri (b)	In	2.3	15	79	61	18	48	6	7	7	41
	Sh	2.7	18	83	57	26	38	5	14	14	48
	Bl	3.7	21	77	53	23	30	7	17	16	46
Jaya	In	2.2	19	76	60	16	46	5	9	9	42
	Sh	3.3	22	78	56	22	35	4	17	17	40
	Bl	4.5	21	73	50	23	27	7	16	16	36
Masria	In	3.3	20	79	60	19	45	5	11	11	51
	Sh	4.4	26	79	58	21	33	5	20	20	51
	Bl	4.5	25	75	54	21	27	7	20	20	43
Pulut Malaysia	In	3.2	16	77	58	19	47	4	8	-	54
1	Sh	3.8	22	82	57	24	38	4	15	-	53
	Bl	3.9	20	79	55	24	30	8	17	-	49
Murni	In	6.4	17	82	58	24	42	5	11	10	43
	Sh	6.9	24	81	57	24	33	5	20	20	36
	Bl	8.6	22	76	52	24	28	6	18	18	36
IR42	In	2.9	13	79	58	21	48	4	6	6	50
	Sh	3.3	17	84	55	28	40	4	12	12	56
	Bl	4.5	13	76	50	25	34	7	9	9	52
Ria	In	3.6	19	77	58	20	43	5	11	11	40
	Sh	4.4	25	77	55	22	35	5	16	16	44
	Bl	4.6	24	71	51	20	28	6	17	17	43
Malinja	In	2.6	16	80	60	21	47	5	7	7	36
	Sh	2.8	24	81	59	22	38	6	15	15	41
	Bl	4.1	23	77	55	22	32	5	18	17	37
Sekembang	In	4.1	16	79	61	18	46	7	8	8	37
	Sh	5.9	22	83	59	24	39	5	16	15	39
	Bl	7.7	20	79	54	25	30	6	17	17	34

(a) (b) The same variety grown under different conditions or in a different location.
*In = stem internode; Sh = leaf sheath; Bl = leaf blade
(Source: Devendra, Kent and Pearce, 1986)

Fractions of mature barley plants and oat plants probably plants and oat plants probably show differences similar to wheat, but in rice straw the stem is usually more digestible than the leaf. This is illustrated again by the data of Winugroho (1981) from 35 samples of mature rice plants (table 7).

Kshanika et al. (1984) reported that nine varieties of rice straw separated into five morphological components to determine their chemical composition and *in vitro* organic matter digestibility (IVOMD) (table 8). These results showed that wide variability in the composition of different plant parts existed. Crude protein content varied from 3.1 to 5.6%, being lowest in stem and highest in leaves. While the variation in NDF was marginal (73-76%) considerable variation occurred in ADF (38-50%). The IVOMD was highest for the nodes (47%) and lowest for the leaf and leaf sheath (31-32%).

This indicated variation in the cellulose, hemicellulose and crude protein content for different parts of straw from different varieties. It also indicated that nodes of rice straw tended to have a higher digestibility than other plant parts, But, Winugroho (1981) and Purser (1982) have shown

TABLE 5. *IN VITRO* DRY MATTER (IVDMD) AND ORGANIC MATTER (IVOMD) DIGESTIBILITIES OF STRAW FROM DIFFERENT RICE VARIETIES

Variety		IVDMD (%)	IVOMD (%)
IR 5	PRO	35.9	37.0
	UP	38.2	38.7
IR 20	PRO	35.9	35.1
	UP	33.1	31.1
IR 24	PRO	34.1	34.4
	UP	35.6	36.3
IR 28	PRO	37.7	38.3
	UP	39.1	40.3
IR 32	PRO	40.0	42.1
	UP	39.0	42.3
IR 36	PRO	35.5	37.5
	UP	34.1	34.9
IR 38	PRO	33.1	31.8
	UP	30.9	30.9
IR 40	PRO	33.3	32.5
	UP	31.4	30.0
IR 42	PRO	39.0	41.4
	UP	38.9	41.9
IR 44	PRO	39.0	41.0
	UP	39.3	42.2
IR 46	PRO	39.9	41.5
	UP	42.9	45.8
IR 48	PRO	41.0	42.6
	UP	40.7	43.8
IR 50	PRO	34.8	33.6
	UP	37.1	37.8
IR 52	PRO	33.3	33.2
	UP	36.0	33.6
Mean*	PRO	36.8	37.4
	UP	36.8	37.7

*No significant differences occurred between straws from protected and unprotected plots

Source : Roxas et al (1984)
PRO = protected by Carbofuran Brodan
UP = unprotected

TABLE 6 *IN VITRO* ORGANIC MATTER DIGESTIBILITY (IVOMD) VALUES OF FRACTIONS OF MATURE WHEAT PLANTS

Fraction	IVOMD %		
	Mean	Standard deviation	Range
Husk	53	5.0	44-66
Rachis	43	4.1	34-52
Stem internode	27	2.8	21-35
Stem node	41	3.7	34-50
Leaf blade	68	4.1	58-77
Leaf sheath	53	3.9	45-63
Stem (internode+node)	29	2.3	24-36
Leaf (blade+sheath)	59	3.7	51-68
Whole plant, excluding grain	43	2.9	36-50

Source: Winugroho (1981)

TABLE 7. *IN VITRO* ORGANIC MATTER DIGESTIBILTY (IVOMD) VALUES OF FRACTIONS OF MUTURE RICE PLANTS

Fraction	IVOMD %		
	Mean	Standard deviation	Range
Husk	20	3.7	16-38
Rachis	28	3.2	22-36
Stem internode	54	6.6	42-77
Stem node	58	4.5	43-70
Leaf blade	52	3.4	45-60
Leaf sheath	45	3.4	38-56
Stem (internode+node)	55	6.0	43-75
Leaf (blade+sheath)	48	2.8	41-56
Whole plant, excluding grain	43	3.7	36-53

Source: Winugroho (1981)

that the leaf is much more digestible than the stem.

Devendra et al. (1986) reported the composition and IVMD values of 24 varieties of rice straw collected in Malaysia for internodes, leaf sheaths and leaf blades (table 9). One sample yielded IVMD values for internodes, sheaths and blades of 46, 54 and 59%, respectively, while another yielded values of 51, 51 and 42%, respectively. Thus, the digestibility of the leaf blades may be appreciably higher or appreciably lower than of the internodes in material from different sources.

Many studies have been conducted on bulk samples of parts, such as leaves, internodes, nodes or whole stems. It is possible to get a clearer view of the variation in quality by investigating parts from specified positions on the plant, e.g. flag leaves separate from second, third etc. The same also applied to stem parts, that is, to study changes in the top segment (which will be the youngest) to the bottom segment (oldest). Digestibilities of leaf sheaths, nodes and internodes at the top of plants were more digestible than those of the corresponding fractions lower down (Krueger et al., 1969. Willman et al., 1982). Hacker et al. (1981) reported that, because of their positions on the culm, the youngest leaves of grass or cereal straw were more digestible than the older ones (figure 1) and generally all the vegetative parts were highly digestible at an early stage of development (Terry and Tilley, 1964). Therefore one may expect the upper parts of plants to be generally more digestible than the lower components.

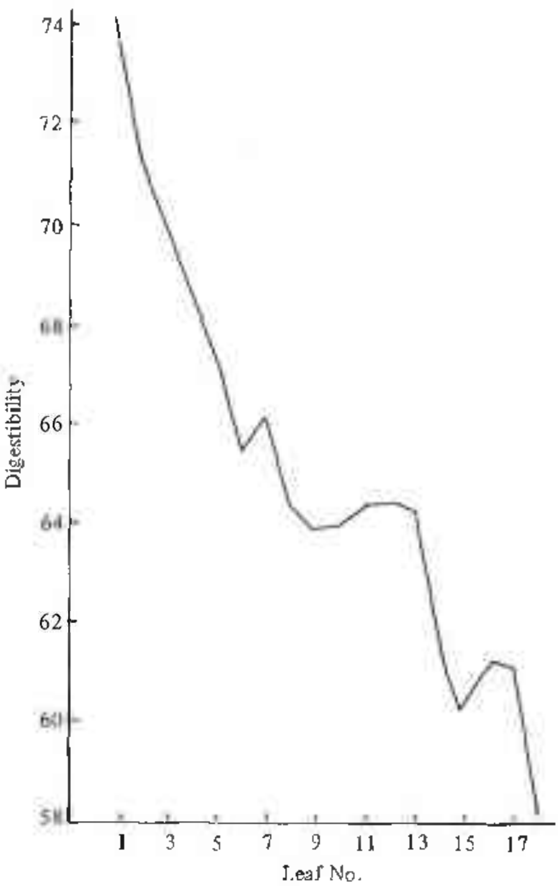

Figure 1. Digestibility of successive leaves of *Pennisetum typhoides* from the top (1) to bottom (18) of the culm (after Burion, 1956).

Source: Hacker and Minson (1981)

(3) Within morphological fractions; cell contents compared with cell walls.

The cell contents of cereal straw, can be estimated as neutral detergent solubles (NDS=100-NDF), this includes soluble protein, non-protein nitrogen compounds, sugars, starch, lipids and minerals (Van Soest, 1982). The NDS content in rice straw ranges from 14 to 46%. Generally, the digestibility of the NDS is high, being reported as 98% (Van Soest, 1976) and 86 to 92% (Moir, 1974, 1982) for a wide range of grasses; 92% for rice straw internodes (Pearce, 1984) and Wilman et al. (1977) have reported values close to 100%.

Because of the generally high digestibility of cell contents, its level can influence the organic matter digestibility of straw to a great extent. Where the NDS is very highly digestible, its proportions in the feed can have an important effect on the overall utilization of that feed. This may be all the more important in the utilization of fibrous materials.

The main components of the cell wall are cellulose, hemicellulose, lignin and residual ash. The mean content of rice straw ranged from 30 to 51% of the dry matter (Roxas et al., 1984; Cheva-Isarakul et al., 1985); hemicellulose content ranged from 6 to 28% (Roxas et al., 1984; Sannasgala et al., 1984) and lignin content from 4 to 10% (Wanapat et al., 1982; Sannasgala et al., 1985). Kent (unpublished data) has obtained cell wall digestibility value of rice straw internodes measured *in vitro*, ranging from approximately 35 to 50%. In addition, the cell wall in different parts of plants may be widely different in their digestibility.

The ratio of cell contents to cell wall varies from plant to plant and different plant parts. In general, leaf cell walls (except rice straw) are more digestible than stem cell walls, so that the plants with a higher leaf to stem ratio are expected to be more digestible (Morrison, 1979). The different types of cells may also have walls of different chemical compositions, and digestibility. This may account for differences in digestibility between or within a plant part (Gordon et al., 1977; Morrison, 1979).

(4) Within cell contents, what are different?

TABLE 8. MEAN CHEMICAL COMPOSITION AND *IN VITRO* ORGANIC MATTER DIGESTIBILITY (IVOMD) OF THE ENTIRE PLANT AND VARIOUS PLANT PARTS FROM NINE VARIETIES OF RICE

Plant component	Crude protein (%)	Crude fibre (%)	Ash (%)	IVOMD (%)
Entire plant	5.4±0.92(3.8-6.6)	35.0±5.1(30.2-45.0)	12.1±2.6(6.7-15.6)	35.4±4.8(30.4-45.1)
Leaf	5.6±0.52(4.5-6.4)	30.3±2.9(26.1-36.8)	11.2±1.5(9.1-13.4)	31.9±10.1(20.2-51.7)
Leaf Sheath	3.9±0.74(2.2-4.5)	33.9±1.96(30.6-36.1)	11.2±1.5(8.6-12.9)	30.9±6.9(23.6-45.3)
Stem	3.1±0.84(2.3-5.1)	38.2±3.1(32.8-41.8)	9.6±7(6.2-11.9)	43.5±5.5(34.7-50.4)
Nodes	5.2±1.30(3.6-7.2)	27.9±2.9(23.2-31.4)	10.6±2.3(4.9-12.7)	47.0±4.8(41.8-55.3)
Panicle	4.5±0.67(3.5-5.4)	33.2±3.1(27.5-37.0)	8.0±4.1(1.5-17.1)	34.2±7.1(27.3-46.7)

	Neutral detergent fibre (%)	Acid detergent fibre (%)	Cellulose (%)	Hemicellulose (%)	Silica (%)
Entire plant	76.6±3.2(72.2-80.6)	48.9±2.1(45.4-51.9)	38.9±2.2(36.2-42.5)	27.7±8.1(22.8-33.7)	7.1±1.1(4.6-8.4)
Leaf	73.2±4.5(54.4-77.9)	44.9±2.2(43.1-49.5)	27.8±4.3(20.8-33.3)	31.7±3.9(20.4-38.6)	5.8±3.0(0.7-9.1)
Leaf-Sheath	76.0±3.9(67.2-79.8)	50.0±3.7(40.2-53.2)	33.7±5.8(23.5-43.9)	27.8±4.3(20.8-33.3)	5.7±3.2(0.4-9.0)
Stem	74.2±5.9(64.9-80.8)	49.8±4.5(44.2-55.9)	36.9±9.4(21.8-48.8)	33.3±5.8(23.5-43.9)	2.1±1.4(0.3-4.3)
Nodes	73.1±3.5(67.9-78.7)	38.3±3.6(36.1-47.6)	30.6±3.7(24.3-35.6)	36.9±9.4(21.8-48.8)	4.1±2.4(0.4-7.3)
Panicle	75.1±6.3(63.8-81.8)	48.1±4.5(40.4-54.5)	35.1±5.6(26.6-43.3)	30.6±3.7(24.3-35.5)	3.6±1.9(0.4-5.1)

Values are means ± standard deviations with the range in values given in parenthesis
Source: Kahanika et al (1984)

TABLE 9. CHEMICAL COMPOSITION (% OF DRY MATTER) AND *IN VITRO* ORGANIC MATTER DIGESTIBILITY (IVOMD, %) OF INTERNODES SHEATHS AND BLADES OF RICE STRAW

	Internodes		Sheaths		Blades	
	mean	range	mean	range	mean	range
Crude protein	2.7	1.7-6.4	3.5	2.0-6.9	4.6	3.2-8.6
Total ash	15	11-20	20	14-25	18	12-25
Residual ash	8	6-13	14	6-20	14	8-20
Neutral detergent fibre	81	77-85	82	77-86	76	71-81
Acid detergent fibre	60	55-64	57	54-62	51	47-56
Hemicellulose	21	13-28	25	21-31	25	20-29
Cellulose	47	38-51	39	33-49	31	27-35
Lignin	5	4-6	4	4-6	6	4-8
IVOMD	42	34-54	45	39-55	44	31-59

Source: Devendra, et al. (1986)

Cell contents are estimated as neutral detergent solubles according to Van Soest (1967). They consist of soluble protein, non-protein nitrogen compounds, sugars, starch lipids and minerals, within individual internodes and leaf sheaths, the upper portions have also been shown to contain less soluble carbohydrates and total cell contents. Since the proportion of cell contents is positively related to organic matter digestibility, the lower *in vitro* digestibility of the upper portion of grass internodes (compared with lower portions) reported by Pritchard et al.(1963) was probably due to

TABLE 10. CHEMICAL COMPOSITION (% DRY MATTER) AND *IN VITRO* ORGANIC MATTER DIGESTIBILITY (IVOMD, %) OF RICE STRAW FOLLOWING VARYING LEVELS OF NITROGEN FERTILIZER APPLICATION

Fertilizer level (N kg/ha)	Composition of straw								
	Crude protein	Total ash	Neutral detergent fibre	Acid detergent fibre	Hemi-cellulose	Cellulose	Lignin	Silica	IVOMD
50	3.4	21	72	50	22	31	7	11	39
100	4.4*	22	71	49	22	31	7	8	36
150	3.7	19	72	49	23	32	8	8	40
[1] Means of three varieties of rice,									
B. Roxas et al. (1985)[2]									
0 Wet season	5.6	20	67	–	–	31	6	16	48
30	6.2	21	67	–	–	28	6	17	48
60	6.2	22	66	–	–	29	6	17	48
120	6.9	21	65		–	29	6	17	48
0 Dry season	6.1	18	68	–	–	33	5	15	44
30	6.0	18	67	–	–	32	5	15	44
60	6.6	18	68		–	32	6	15	42
120	6.9	19	66	–	–	31	6	16	46
[2] Means of four varieties of rice									

Source: Sannasgala et al (1985)

the lower NDS content.

Blacklow and Incoll (1981) reported that during the reproductive stage of winter wheat, there is a general decline in the mass and proportion of soluble substances such as carbohydrates and protein in the stem. This is attributed to the translocation to the developing grain of photosynthates accumulated in the culm prior to anthesis (Gallagher et al., 1975), and/or those accumulated in the internodes during the 28 days after anthesis (Blacklow and Incoll, 1981).

(5) Within cell wall, what are the differences?

The cell wall is a complex unit and forms the structural elements of the plant. It consists mainly of structural carbohydrates. The proportion of cell wall is estimated by neutral detergent fiber(NDF). The principal components of cell walls are cellulose, hemicellulose, lignin, residual ash, pectins and minerals.

Different types of cells may have walls of different chemical composition, and digestibility. The presence of lignin and/or interactions between lignin and other cell wall components appear to limit the extent of cell wall break down.(Minson, 1976; Morrison, 1979). Lignin does not appear to be utilized to any significant degree by ruminants (Kelford, 1958; Theender, 1982 and Hartley 1982).

B. Environmental factors affecting cereal straw quality.

Much of the variation in the characteristics of cereal straw may be caused by the environment in which the plants grow. For normal growth, a plant needs specific conditions to meet its requirements at different stages of development. There is some opportunity for differentiation associated with the availability of soil nutrients, the supply of water, the ambient temperature and temperature range, the intensity and daily duration of light and the incidence of diseases.

(1) Soil nutrients

The nutrient status of the soil can influence the extent of accumulation and translocation of plant nutrients. These factors may cause changes in chemical composition and digestibility. The means by which the effects are expressed are, firstly, by change in the proportions of main morphological fractions of plants (i.e. leaf blades, leaf sheathes and stem internodes) and, secondly, by variation in chemical composition within each of these main fractions.

In this context, nitrogen seems to be one of the limiting factors. Evidence for this is the growth response to N-fertilizer application (Minson, 1980) and the response to soil N build-up from legume-grass swards (Jones et al., 1967). Wilson (1982) has pointed out the variable responses that have been obtained to nitrogen fertilizer application on the digestibility of grass. Increased digestibility may be obtained from the stimulation of new growth with a high protein content and a low cell wall content.

Recently, several measurements have been made on rice straw fertilized with varying levels of nitrogen (table 10).

The crude protein contents differed ($P < 0.01$) being 3.4% at the lower level of nitrogen application 4.4% at the intermediate level and 3.7% at the highest level. But in these data the only pronounced effect was the nitrogen fertilizer application increased markedly the nitrogen of the straw analysed by Roxas (1985). There were no changes in the proportion of cell contents and cell wall and consequently no marked or consistent effects on IVOMD occurred in either experiment.

(2) Water stress

Bardy (1973) and Christie (1975) found that water stress could cause accelerated leaf sencence (wheat straw) and suggested that it also induced early maturity in plants. Both result in increased cell wall content and a decline in the proportion of cell contents. Aspinall et al.(1964) found that there was always a tendency for soil water stress to reduce stem internode elongation of barley straw and grain numbers when such stress occurs between stamen initiation and anthesis. stress after anthesis is found to cause a severe reduction in grain size. Under condition of irrigation, the rate of reanslocation of set sugar to the grain (wheat) could be high (Cooper, 1980). Straws from such a crop are likely to be low in cell contents.

(3) Temperature

In general, the effect of increasing temperature, in the case of both tropical and temperate grasses, is to reduce their digestibility. Dirven and Denum (1977) attributed the decrease in digestibility to more rapid growth of the plant, particularly of stem, resulting in a lower proportion of soluble carbohydrates and a corresponding increase in the cell wall content at different stages of growth. Decreases in cell wall digestibility have been reported (Deinum and Dirven, 1976; Moir et al., 1977), attributed to apparently greater lignification (Ford et al., 1979). In cereals, high temperatures are known to hasten anthesis, reduce the maturation period and grain weight (Spiertz,1974; Kolderup, 1979) as a result of increased carbon evaporation (Wardlaw et al., 1980) and a reduction in net photosynthesis (Marcellose and Single, 1972). The consequence of this is the mobilization of accumulated nutrients from the vegetative parts to the developing grain (Spiertz, 1974; Wardlew et al., 1980). This again will tend to result in residues of poor quality.

(4) Light Intensity and Day-length

The effect of growing grasses under low light intensities has been shown to decrease their digestibility. Usually the decreases have been small (1-5 percentage units) but Wong (1978) reduced digesbibility by 10-12 units by growing panicum maximum under conditions of 60 or 40 percent shade for 2 to 4 months. Such decreases are apparently caused by a reduction in the proportion of soluble carbohydrates in the plant (Smith, 1973), increases in cell wall components (Burton et al., 1959) and a decrease in the proportion of mesophyll in relation to epidermis (Evans, 1964). The extent to which such changes may occur in rice grown under normal conditions in different regions is not known. Aitken (1966) reported that, in some ryegrass species, flower initiation and development could be hastened by long days. Higher light intensity tends to increase the digestibility of forages (Van Soest, 1978) perhaps due to its role in photosynthetic activity.

(5) Diseases and Pests

Diseases and pests can be have a tremendous effect on plant grouth. A common effect is that photosgnthetic activities are reduced which leads to low sugar and starch production. Khush, Q. S. (1977) and Khush, Q. S. and Kumar, I. (1986) reported that diseases, such as bacterial blight, blast, sheath blight, sheeth rot and stem rot, and insects such as leaf and plant hoppers and stem borers usually attack the leaves, then proliferate and consume the whole soft vegetative parts leaving the stem which is often also badly eaten. Since the cell contents are a target for many diseases and pests, it is presumed that, in many instances, the result will be a deduction in the proportion of cell contents, and hence a reduction in digestibility.

C. Management factors associated with grain harvest, threshing and straw storage.

The effects of management can be grouped under the general heading of environment. However they are under human control and therefore, offer some mechanism that can be modified with relative ease, to maximize straw quality. Because of wide differences in the nutritive value of different fractions of mature plants, various methods of harvesting and processing might result in products of varying quality.

(1) Harvesting method

Since the proportion of cell wall components varies with time, the time for harvest is of paramount importance in relation to final straw quality.

The nutritive value may also be associated with different harvesting methods. For example, in some parts of Asia only the panicles are removed at grain harvest and any straw conserved is the result of subsequent straw collection. In most areas, however, part of the stem and the top leaves are harvested with the panicle. In this case the conserved straw is that retained after threshing. Obviously variation in final straw quality may interact with height of cutting because this varies substantially also.

Hart and Wanapat (1985) found rice stubble to be of higher digestibility (48 vs 42%) than rice straw. In general, however, it is more usual for the top of plants to be more digestible than the bottom. Therefore, different cutting heights may subsequently lead to straws of different qualities. The cutting height is significant in that the chemical composition and digestibility of the straw change from the top of the plant to the bottom. Where the plant has senesced it may be expected that the upper parts of the plant would be more digestible than the lower parts, as occurs in normal dryland farming conditions. However, in many rice growing areas the irrigation procedures adopted allow the plant to remain vegetatively active even though the grain is mature and in these situations, the lower parts of plant may be more digestible than the upper parts. For example, Kent (1986) has found bottom internodes of rice plants at grain maturity to have IVOMD values of 70% or more while the IVOMD of top internodes was about 50%.

(2) *Threshing method*

The method of threshing may also influence straw quality. Different procedures may result in the removal of varying proportions of leaf and stem from the fraction which is retained for feeding to animals. Hilmersen et al. (1984) have suggested that machine-threshed straw may be a better feed than manually-threshed material as the straw surface may be fractured and this may render it softer for animals to eat, and increase the surface area for microbial attack, in effect being synonymous with physical pretreatments. Wanapat (1985), however, found no difference in the intake and digestibility of machine and hand-threshed straw.

(3) Storage

Subsequent to grain harvest, the conditions under which the straw is stored may affect its quality. The degree of protection from the environment appears to determine the extent of storage associated losses in quality. Under good storage conditions the general experience is that little deterioration in nutritive value occurs. However, under temperate conditions, wheat and oat stubbles left unharvested for several months declined in *in vitro* digestibility by 0.15 units/day (Round and Jacka, 1976). Devendra (1982) reproted a preliminary investigation of the effects of storage conditions on the chemical composition of straw. The three conditions investigated were fully exposed straw, partially exposed straw and straw kept under shelter. Exposure to the weather decreased crude protein content from 5.6 to 3.4% Ca from 0.31 to 0.21%, P from 0.11 to 0.02% but did not affect total ash or Mg content. Pearce (1986) reported following grain harvest, wheat stubble *in situ* changes little in digestibility for at least several weeks provided that the weather remains fine. However, heavy rain may leach out the cell contents resulting in a lowering of the digestibility (Pearce et al., 1979). Similar effects would be expected under conditions of inadequate protection from moisture when cut straw is stored. In addition, mouldiness may reduce the acceptability of the material to animals. Shaif (1984) obtained reduced intake and digestibility by sheep fed stored straw compared with fresh material. All these data indicate that post-harvest handling and storage of straw can have important effects on final straw quality.

(4) Method of feeding to animals

The cereal straw is usually fed in an unchaffed, or long form. In this case, the animals can select from the diet offered. For example, animals generally prefer leaf rather than stem. In some areas, however, such as India, the straw may be chaffed hence reducing selection and wastage. On the other hand, many Asian farms offer some forage, concentrate and additives with rice straw to stall-fed ruminants. Devendra (1984) reported that small quantities of roadside grasses (green forage) can improve the utilization of straw diets through increases in intake and digestion. While concentrate supplements are generally fed to milk producing or dairy replacement animals. Concentrate supplements, such as rice bran, coconut cake, cassava chips, can provide limiting nutrients in balanced amounts or for specific purposes.

3. The possible ways for improving the nutritive value of cereal straw without pretreatment.

There is ample evidence to show that considerable variation exists for the chemical composition and digestibility of straw in the germplasm collections of cereal crops. This variability could presumably be exploited to improve the nutritional value of straw of these cereals.

The possible ways of improving the nutritive value of cereal straw without pretreatment may be achieved by selecting and breeding better cereal straw, by controlling environmental factors, by controlling management practices and by appropriate supplementation strategies to alleviate deficiences of essential nutrients.

A. Improving nutritive value of cereal straw through selection and breeding.

(1) Breeding and selection of high quality cereal varieties.

It is possible to improve nutritive value of cereal straw through selecting and breeding. The variation in chemical composition and digestibility of straw in the germplasm collections of cereal crops could presumably be exploited to improve the nutritional value of the straw. White et al., (1981) found that differences in straw digestibility among cultivators of winter and spring wheats, barley and oats were greater than the differences between crops and, in addition, cultivators with higher straw digestibility did not have lower grain yields and were not more susceptible to lodging. Differences in the vitro digestibility of rice straw grown at particular sites within countries have been shown to differ by as little as 2 percentage units and as much as 18 percentage units. Studies such as these indicate that it may be possible to select for straw-quality within a cereal species. In some species, improvement can be effected by selecting for leafiness, since leaves have both a higher cell wall digestibility and high proportion of cell contents, than stem. But a greater understanding of the overall mechanisms that determine digestibility must be achieved first. For instance the variations due to environment may be large and mask and genetic differences that occur. Further if significant interactions occur between environment and genotype the ranking of varieties in terms of straw quality, may vary across environments. At present very few data exist to answer these questions. Selection for improving these components can also possible be done on phenotypic basis as in the case of brown midrib-3 (bm 3) gene which is known to lower the lignin content by a margin of 30-40% in maize (Sheldrick, 1979; Keith, 1979 and Ryadchikov et al., 1981).

The silica content in leaf and culms is reported to be correlated (Yein, 1981) and high silica content is known to increase lodging resistance. However, positive correlation with digestibility as observed by Roxes et al.(1984) does not seem to pose any problem with digestibility of high yielding dwarf rice varieties.

The plants high in nitrogen do not necessarily transfer all of the nitrogen to the grains. The straw in such cases would possibly be rich in N and protein.

Cereal crop breeders are also selecting for higher biomass production to increases yield which in turn would also increase the yield of straw. The effect of this on straw quality is unknown.

To improve the grain yield and grain quality further, breeders also select for plants having higher photo synthetic rates and late leaf senescencae. The varieties having late leaf senescence may have more carbohydrates and thus provide a more nutritious diet for ruminants.

Improved varieties are lodging resistant and are highly responsive to nitrogenous fertilizers. Therefore use of fertilizers has increased many fold with the introduction of high yielding varieties. Crop biomass have a higher protein content from fertilized than unfertilized plots. On the basis the nutritional value of straw produced in modern agriculture is perhaps better than the straw produced in traditional agriculture. But, it is not always so, since in increase in the absolute value is not necessarily increase the nutritive value.

(2) Innovative breeding results in better quality straw.

Preliminary observations indicate that there is heterosis for protein content in grain and straw of hybrid varieties of rice and wheat. Thus these innovative breeding approaches may result in the availability of better quality straw.

(3) Breeding and selecting cereal varieties of short growth duration.

With the development of short duration and photoperiod insensitive varieties of rice, many areas are now growing two or three crops of rice per year. The straw of these rice varieties is stored for shorter periods of time and therefore is probably more palatable and of higher quality than the straw from long term storage (Khush et al., 1986).

(4) Breeding and selecting disease and insect resistant varieties.

Plant breeders are striving to improve cereal crop yields by breeding disease and insect resistant varieties. The disease not only reduces the grain yield but also lowers the quality of the straw. Feeding of diseased or infected straw may also be harmful to the animals as well as being less palatable. Rice varieties with multiple disease and insect resistance have been bred by incorporating resistance genes into a single variety. (Khush, 1977).

B. Improving nutritive value of cereal straw through controlling environment factors.

(1) Control soil type

It is possible by controlling soil mositure to create suitable conditions for cereal crops to grow, producing abundant grain and perhaps maximising the quality of the straw. Patel and Shah (1967) observed that straw from irrigated wheat had a highr proportion or crude fibre compared with that from non-irrigated crops. Purser (1982) observed that cereal straws grown in the high rainfall district of Western Australia were less digestible than those in drier areas. McManus (1981) attributed this to less water passing through the plant causing less accumulation of mineral matter.

The fertilizer type and amounts applied have to be controlled to obtain higher quality cereal straw. Induced early maturity and translocation of soluble carbohydrates and protein to the maturing grain in low-N-crops were reported by Blacklow and Incell (1981). Calcium has also been implicated in the lignification of plant tissues. Wilman et al. (1977) observed that fertilizing with N is profitable only during the early stage of pasture growth but as the plant matures it causes more rapid death of leaves.

(2) Control sowing period

The most appropriate sowing time can be determined so that the cereal crops can grow and mature in a suitable climate to achieve high quality cereal straw. Raxas et al. (1985) reported that wet season straws generally had a higher *in vitro* digestibility than dry season straw, but organic matter and NDF content were lower.

(3) Light incidence

The amount of incident light is a function of light intensity and day-length. This can be controlled under experimental conditions. Reduction in the level of soluble carbohydrates in pastures occurs at night (Smith, 1973) and increases during the afternoon (Wilson and Mannetje, 1978). It was also noted by Wilson and Mannetje (1978) that the level of total non-structural carbohydrates in Buffel and Green Panic leaves were highest in spring, largely due to an increase in starch, and lowest in late summer and autumn. Hence vegetative parts harvested at night and in summer-autumn are expected to have less cell content. In contrast to the above adverse effects, higher light intensity tends to increase the digestibility of forage (Van Soest, 1978) perhaps due to its role in photosynthetic activity.

(4) Control disease and insects

khush (1986) reported that higher quality cereal straw could be chieved by controlling disease and insects. Diseases like bacterial blight, blast, sheath blight, sheath rot and stem rot, and insects such as leaf and planthoppers and stem borers not only reduce the grain yield but also lower the quality of the straw. To ensure that the cereal straws are not damaged from these diseases and insects it would necessary to use insecticides and fungicides.

C. Improving nutritive value of cereal straw through management practices.

(1) Harvest time

The quality of cereal straw can be optimised by harvesting the grain and straw at the most appropriate time. The best harvesting time is obviously that where yield of grain is optimised, and also when higher quality straw can be achieved. Different cereal crops have different growth periods, times of development, and harvesting time, so different cereal crops have different appropriate harvest time with different verieties and different area.

(2) Suitable height of cutting

It has been shown that different plant parts have different nutritive values. There may also be trends in digestibility from the top to the bottom of the plant. It would be of great advantage to determine the reasons for the graduation in digestibility to allow cutting heights to be made to optimise the digestibility of the collected and stored straw.

(3) Correct storage method

The correct storage method of straw can ensure that losses in quality do not occur. Pearce (1979) reported that rain-damaged cereal straw has lower quality than undamaged straw. The straws that had suffered rain damage had *in vitro* organic matter digestibility from 25 to 34%, compared with 30 to 49% for the undamaged straw. It is likely that leaching of water soluble carbohydrates was the major effect of the rain damage, but under prolonged showery conditions, microbial and fungal action may also depress the concentration of fermentable constituents. To optimise the feeding value of cereal straw it is preferable to store them under cover, and keep them in a dry condition.

(4) Correct threshing method

There are two main methods of threshing, namely manual threshing and machine threshing. The machine-threshing straw may be better feed than manually threshed material. Because this process reduces the straw to short lengths and the straw surface may be fractured and this may render it softer for animals to eat. In addition, threshing cereal crops as quickly as possible after harvesting will avoid damage from rain and high temperature.

D. Improving efficiency of use of absorbed nutrients.

Ruminants fed cereal straw as a high proportion of their diet lose weight and the major reason for this is a low voluntary intake. Contributing factors are low digestibility and a limited supply of protein, minerals and vitamins in the straw. Both the level of intake and the digestibility of cereal straw may be increased by providing supplementary nutrients. The methods of practical supplementation are:

(1) Supplementation of cereal straw with non-protein nitrogen

Urea and molasses supplementation of low quality roughages has been found to reduce weight losses in cattle (Beames, 1959) and sheep (Coombe, 1959). These effects are due to increases in the intake and digestion of the basal diet in response to the provision of rumen degradable nitrogen (Redman et al., 1980; Egan and Doyle, 1985). Other sources of non-protein nitrogen, such a biuret, have been shown to be as effective as urea in reducing or preventing weight losses in grazing cattle (Winks et al., 1979). As regards a slow release nitrogen supplement, Erust et al. (1976) reported that biuret improved the intake of cereal straw and liveweight performance of stears.

Further, uric acid, a component of poultry litter (Jacobs and Leibholz, 1977), and lactosyl urea (Merry et al., 1982a, 1982b) which are more slowly degraded in the rumen provide RDN (rumen degradable nitrogen) which may be more efficiently used for microbial protein synthesis than urea.

In some circumstances, it is importance to provide a source of readily available energy, such as molasses, to ensure efficient use of urea due to its rapid degradation. Also, when the sulphur content of the basal diet is low, supplements of this element can also improve the efficiency of use of urea-nitrogen (Siebert and Kennedy, 1972). The requirement for sulphur is related to its use in the synthesis of sulphur containing amino acids by the microbial population. As with other low quality feeds, non-protein supplementation increases the intake and/or digestion of cereal straw resulting in improved animal performance.

(2) *Supplementation of cereal straw with concentrates.*

The traditional approach to overcoming the low intake of fibrous feed and the consequent low supply of nutrients to ruminants has been to dilute these feed with large quantities of grain and protein. By-products from concentrates which are used as supplements are often classified as energy or protein feeds bases on their chemical composition. These feedstuffs as protein supplements may also provide useful amounts of energy.

Agro-industrial by-product, such as copra cake, palm kernel cake, soyabean cake, groundnut cake are valuable sources of protein. If these feeds are used as supplements for ruminants, they can increase the utilization of the cereal straw leading to improvements in animal performance.

Creek et al. (1983) reported that increasing the level of an energy protein-mineral supplement from 1 to 7 kg DM/day decreased the intake of rice straw by cattle. The supplement increased diet digestibility apparently through the provision of RDN and/or minerals required by the microbial population of reticulo-rumen, and possibly also contributed to increased production through the provision of specific nutrients, amino acids and/or minerals, which improved the efficiency of absorbed nutrients at the tissue level.

(3) Supplementation of cereal straw with forage

Ranjhan (1983) recommended that feeding straw mixed with green fodders, whether these are grasses or legumes, in the ratios of 3:1 or 1:1 should meet the requirements of ruminants for maintenance and growth, respectively. Preston and Leng (1984) have suggested that green forage, preferably legume, be given at up to maximum of about 0.7% (DM basis) of liveweight or about 25% of diet. Supplements of leucaena had little effect on diet digestibility even when they comprised a significant proportion of the diet (Devendra, 1983; Moran et al., 1983). Vearasilp (1981) reported that when high quality leucaena or gliricidia leaf was included at between 10 and 12% of dietary dry matter of a rice straw-based diet liveweight losses by sheep were small over a 45-day period.

Some forage supplements particularly the leaves of cassava, gliricidia, leucaena and sesbania provide protein to the animals.

(4) *Supplementation of other crop residues.*

Materials such as sugarcane tops, maize stovers and residues from leguminous crops, such as groundnut and coupea vines, are potentially valuable feeds. These resources should be considered when developing year round feeding strategies for particular area. Cheva-Isarakul (1982) reported that peanut hay, if harvested by cutting the tops prior to uprooting the peanuts, and sweet corn stalks are as good as or better than rice straw as a feed for ruminants when properly conserved.

Consideration needs to be given to the feeding value of these feeds, if they are of higher quality than rice straw they should be used in preference to, or with, rice straw as the basal diet for ruminants. Some of these feeds contain more nitrogen or minerals than rice straw and could all eleviate the need for supplements.

Preston and Leng (1984) have suggested the following priorities for supplementing poor quality roughage: firstly, the fermentable nitrogen content of the diet should be raised to a minimum of 30g/kg DOM; secondly, green forage should be provided up to a minimum of about 0.7% of liveweight (25% of the diet); and thirdly, oilseed meal or an animal by-product should be given in amounts not to exceed 25% of the total dietary dry matter.

4. Conclusion

On the basis of results accumulated over the last decade or so it has been shown that considerable variation exists for chemical composition and digestibility of straw in the germplasm collection of cereal crops. This variability could presumable be exploited to improve the nutritional value of straw of these cereals.

There is evidence that variation might be due to the genetic make up of different varieties, that it may be affected by environmental conditions determining the pattern of growth, and that the nature of straw made avaiable for feeding to animals may be affected by procedures associated with grain harvest, threshing and storage of the straw. It is therefore necessary to attempt to control these factors during the growth and development of the crop, and associated processes of collection, storage and feeding of the cereal straw. Thus improvement in the nutritive value of cereal straw would be attained without pretreatment.

With the availability of accumulated knowledge, new approaches to improved utilization of the feed resources, and real opportunities for application of what is already known have set the stage for aparticularly challenging task for the future.

It is hoped that animal nutritionists will cooperate with plant breeders to collect and breed new cereal crop varieties which have high grain and straw yields as well as nutritional quality of both the grain and straw in cereal crops by manipulating the genetic variation.

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