NUTRITIVE VALUE OF STRAW, WITH SPECIAL REFERENCE TO WET-SEASON RICE STRAW AS RELATED TO VARIETY AND LOCATION OF GROWTH IN EAST-JAVA, INDONESIA

Soebarinoto[1], Siti Chuzaemi[1], Hermanto[1], Hartutik[1], J. van Bruchem[2] and E.R. Ørskov[3]

SUMMARY

Variation in nutritive quality between morphological components is less for rice straw than for wheat straw. Wheat straw stems have a lower quality than stems of rice straw, while leaves and leaf sheaths of wheat are of better quality than of rice. Variation in voluntary organic matter intake, and in vivo *and* in sacco *organic matter digestibility was studied with straw of 10 rice varieties grown in two locations (highland and lowland) in two years in Indonesia. Variation in nutritive quality was observed between varieties. Variation in DOMI was higher than* in vivo *OMD.* In sacco *degradation parameters were poor predictors of* in vivo *OMD and DOMI. Grain yield of the rice varieties studied was positively correlated with DOMI.*

INTRODUCTION

Fibrous crop residues and agricultural by-products do play an essential role in the seasonal feed-plan of integrated smallholder crop-livestock farming systems in the tropics. The nutritive value of such low quality fibrous feeds for ruminants is affected by stage of maturity at harvest, the method of grain harvesting and the post harvest storage conditions. Variations in cutting height, growing conditions and harvesting and threshing procedures can result in large differences in the nature of leaf and stem material collected at the threshing site (Egan, 1987). Next to metabolizability and the efficiency of utilization of the absorbed nutrients, the nutritive value of fibrous feeds is largely determined by voluntary intake. Chemical characteristics are relatively poor predictors of the intake of digestible organic matter and thus of the fibrous feed's nutritive potential (Ørskov *et al.*, 1989). They found that in barley and wheat straws, whether or not treated with anhydrous ammonia, covering an *in vivo* digestibility range of 343-596 g/kg, *in vitro* digestibility and *in sacco* degradation characteristics were closely associated to feed intake and animal performance. After a comparison of wheat and rice straw, this paper discusses various aspects of the nutritive value of wet season rice straws with special reference to recent results obtained in Indonesia.

[1] Faculty of Animal Husbandry, Brawijaya University, Jalan Mayjen Haryono 161, Malang, Jatim, Indonesia

[2] Department Tropical Animal Production, Agricultural University Wageningen, PO Box 338, the Netherlands

[3] Rowett Research Institute, Greenburn Road, Bucksburn, Aberdeen AB2 9SB, Great Britain

CHARACTERISTICS OF WHEAT AND RICE STRAWS

The morphological variation of cereal straws varies considerably (Doyle *et al.*, 1987). As a proportion of the whole plant, excluding grain, wheat stem can range from 33% to 53% and rice stem from 22% to 34%. In addition to a genetically induced variation, it is obvious that these values are affected by harvesting height and growing conditions. Contrary to wheat straw (stem 24-36%, sheath 45-63% and leaf 58-77%), the variation *in vitro* organic matter digestibility (IVOMD) amongst plant parts showed to be less in rice straw (stem 43-75%, sheath 38-56% and leaf 45-60%). The grinding energy needed for physical reduction showed a comparable picture. Average values were 213, 122 and 81 J/g for wheat straw stem, sheath and leaf, respectively, whereas for rice straw values of 168, 147 and 133 J/g were reported. From these observations the conclusion seems valid that both physical and fermentative degradation of wheat straw stem is inferior to stems of rice straw, but that with sheaths and leaves the opposite seems the case. In rice straw stems, however, the energy needed for physical reduction remains high relative to its digestibility. Accordingly, relatively to OMD, eating rate of rice straw was lower as compared to wheat straw.

Time of harvesting may also significantly affect the straw's nutritive value. Pearce *et al.* (1988) clearly showed in wheat straw that initially after flowering the straw's neutral detergent solubles increased as caused by a production of photosynthates in excess of requirements for grain development. Thus the gradual decrease in OMD starting 20 - 30 days prior to flowering was temporarily equalized. However, a further decrease in OMD was observed soon after grain maturity, associated with a decrease in neutral detergent solubles. Thus in view of the straw's nutritive value, the timing of harvesting is presumably of an utmost importance, since the level of storage carbohydrates, fructans in wheat and starch in rice, retained in straw are critical to the straw's feeding value because of their high digestibility.

VOLUNTARY INTAKE OF WHEAT AND RICE STRAW

The intake of rice straw is influenced by various factors, amongst others by physical and chemical characteristics, palatability and degradability, differences in feeding conditions such as the amounts offered and the frequency and form of feeding, and finally the physiological state of the animal.

Whether with rice straw with a comparatively lower variation in digestibility between plant parts, selection for different plant parts plays a less important role as compared to wheat straw, is not quite clear. According to Doyle *et al.* (1987), for whole plant material, relatively to *in vivo* OMD, OMI, eating rate and IVOMD were lower with rice straw as compared to wheat straw.

The latter authors also pointed out that the intake of straw may be related to the previous nutritional history of the animals. Animals in good condition may be able to recycle more nutrients into the reticulo-rumen and thereby increasing microbial growth in the reticulo-rumen, and consequently intake.

NUTRITIVE VALUE OF RICE STRAWS IN INDONESIA

In East-Java, 10 rice varieties (Table 1) were planted at two locations: Mojosari (lowland, regosol, 28 m above sea level) and Malang (highland, alluvial soil, 435 m above sea level). First transplanting (I) was done in early March 1988 in the wet season. Harvesting was in May-June at the onset of the dry season. This wet-season planting (II) was repeated in 1989. Intake and *in vivo* digestibility of the rice straws were tested with young fat-tailed sheep with a body weight of 20 - 25 kg. Rice straw was

Table 1 *In vivo* organic matter digestibility (g/kg) of 10 rice straw varieties, grown at 2 locations (lowland: Mojosari; highland: Malang) in the wet season of 1988 and 1989

Variety	Mojosari		Malang		Mean[1]
	1988	1989	1988	1989	
A. IR 36	461	476	390	463	448
B. Batang Pane	457	495	471	471	474
C. IR 54	414	471	422	398	426
D. IR 64	457	486	457	440	460
E. Citandui	454	468	422	454	450
F. Progo	483	449	486	477	474
G. Cisadane	367	514	469	525	469
H. Krueng Aceh	473	458	531	497	490
I. Kapuas	464	502	487	530	496
J. Tuntang	468	529	468	489	489
Mean[2]	450	485	460	474	468

Note: - least significant differences (LSD), P <0.05: 1) 46.2; 2) 29.2

Table 2 Voluntary intake of digestible organic matter (g/kg MW) of 10 rice straw varieties, grown at 2 locations (lowland: Mojosari; highland: Malang) in the wet season of 1988 and 1989

Variety	Mojosari		Malang		Mean[1]
	1988	1989	1988	1989	
A. IR 36	18.0	17.2	10.4	17.1	15.7
B. Batang Pane	18.3	18.1	16.5	18.8	17.9
C. IR 54	11.5	15.7	13.8	13.2	13.6
D. IR 64	11.8	17.7	12.2	16.5	14.6
E. Citandui	14.8	16.1	13.9	15.6	15.1
F. Progo	13.5	15.3	16.9	18.3	16.0
G. Cisadane	12.7	18.6	13.7	18.0	15.8
H. Krueng Aceh	19.2	14.8	17.5	16.0	16.9
I. Kapuas	16.5	19.1	18.9	22.8	19.3
J. Tuntang	16.1	20.5	18.8	21.5	19.2
Mean[2]	15.2	17.3	15.3	17.8	16.5

Note: - least significant differences (LSD), P < 0.05: 1) 2.96; 2) 1.87

offered at a level of 10 - 20 % excess and was supplemented with about 18 g DM/kg MW of concentrates containing about 20 % crude protein. The season I *in vivo* digestibility trials were run in the period December 1988 till June 1989; of the season II rice straws in the period December 1989 till April 1990. Tables 1 and 2 show the rice straw's organic matter digestibility (OMD) and voluntary intake of digestible organic matter (DOMI), respectively.

Voluntary intake of rice straw OM was slightly positively related to the straw's OMD ($R^2 = 0.16$, $P < 0.01$). Hence the variation in DOMI with a coefficient variation (CV) of 17.2 % exceeded that of OMD (CV = 8.1 %).

DIGESTIBILITY OF RICE STRAW

The *in vivo* digestibility of rice straw is highly variable. In such highly fibrous material only a minor part of the OM is water soluble. In addition to this it seems that the fractional rate of passage of the liquid phase from the reticulo-rumen is low. A pilot experiment with sheep fed on urea- ammonia treated rice straw as a basal feed in Indonesia revealed 6.1 %/h for the liquid phase (Co-EDTA). Hence digestion occurs almost quantitatively by fermentation, predominantly in the reticulo-rumen. A minor part, generally less than 10% of the fermentation products emerge from the hind gut. Digestion in the small intestine is almost limited to the microbial biomass synthesized in the reticulo-rumen, of which the true protein digestibility approximates 85% (Storm *et al.*, 1983; Van Bruchem *et al.*, 1989).

The extent to which the feed is degraded in the reticulo-rumen depends on its water soluble part, which presumably is degraded almost quantitatively by the rumen microbes, and the water insoluble part. This water insoluble part in turn can be divided into a part which is truly resistent to microbial degradation and a potentially degradable part. Of the latter part the extent of degradation is related to a lag phase related to rate of attachment of the microbes as well as subsequently the rate of colonization, the *in situ* fractional rate of degradation and the residence time in the reticulo-rumen. In turn the residence time is determined by the rate of physical degradation of large into small particles and the subsequent passage of the latter to the omasum.

In temperate cereal straws a close relationship was found between *in sacco* OM degradation characteristics and *in vivo* digestibility. These biological measures were found to be superior to chemical analyses. This can easily be understood based on the above theoretical considerations. However, in rice straw the picture thus far obtained is less clear. In Table 3, the rice straw's *in sacco* degradation characteristics, determined in sheep according to Mehrez and Ørskov (1977), are presented.

The multiple regression of IDOM versus S, D, t′ and kd gave results as presented in Table 4.

Table 3 Effect of variety and location of growth (lowland, L; highland, H) on *in sacco* OM degradation of wet-season rice straw (mean of seasons I and II)

Variety	S[1]		D[2]		R[3]		t′[4]		kd[5]	
	L	H	L	H	L	H	L	H	L	H
A. IR 36	189	186	481	408	330	406	5.5	8.1	2.7	3.3
B. Batang Pane	210	168	463	416	328	417	6.1	5.7	3.1	3.0
C. IR 54	200	163	401	363	399	474	6.5	7.0	2.7	2.4
D. IR 64	198	162	378	381	424	457	6.3	5.5	3.3	3.1
E. Citandui	177	180	402	290	422	530	6.5	6.5	3.1	3.4
F. Progo	192	163	405	345	403	493	5.2	6.0	3.1	3.1
G. Cisadane	200	157	380	390	420	453	6.4	6.0	3.0	2.4
H. Krueng Aceh	215	178	400	437	385	386	6.2	4.7	3.7	3.0
I. Kapuas	208	183	425	439	367	379	5.8	6.6	2.9	3.3
J. Tuntang	186	195	487	378	327	427	4.2	7.6	2.8	3.0
Mean	198	173	422	385	380	442	5.9	6.4	3.0	3.0

Notes: 1) S: water soluble part (g/kg), estimated as (a) in the exponential equation: $a + b * (1 - \exp(-c * (t-t')))$; least significant difference (LSD, $P < 0.05$) 9.6
2) D: water insoluble but potentially degradable part (g/kg), estimated as (b); LSD ($P < 0.05$) 14.1
3) R: truly undegradable part (g/kg), equivalent to 1000 - (a + b); LSD ($P < 0.05$) 7.6
4) t′: lag phase (h); LSD ($P < 0.05$) 3.29
5) kd: fractional rate of degradation of D, estimated as c (%/h); LSD ($P < 0.05$) 1.38

Figure 1 Observed DOMI values versus DOMI values fitted from the multiple regression analysis vs. S, D, t′ and kd

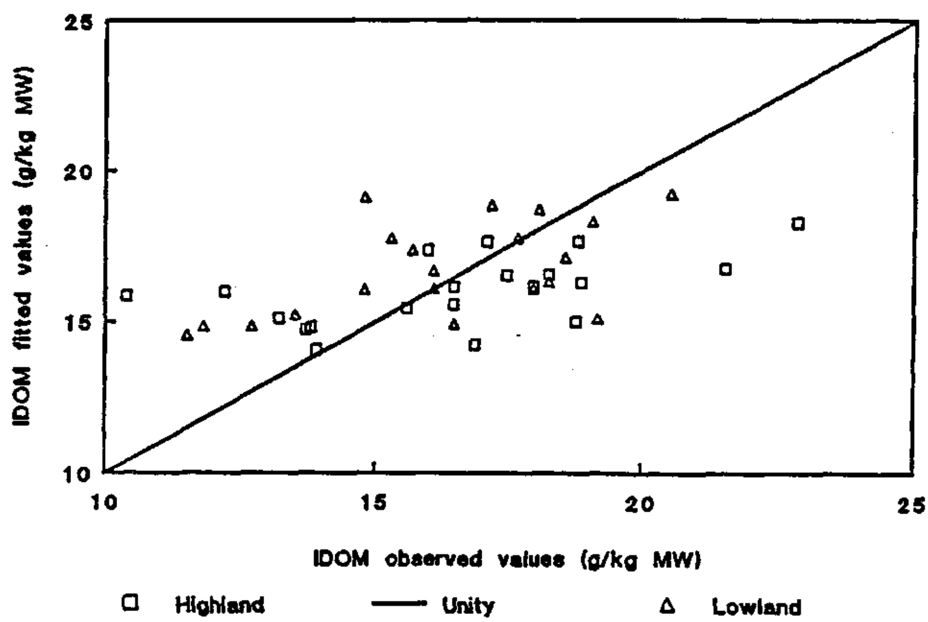
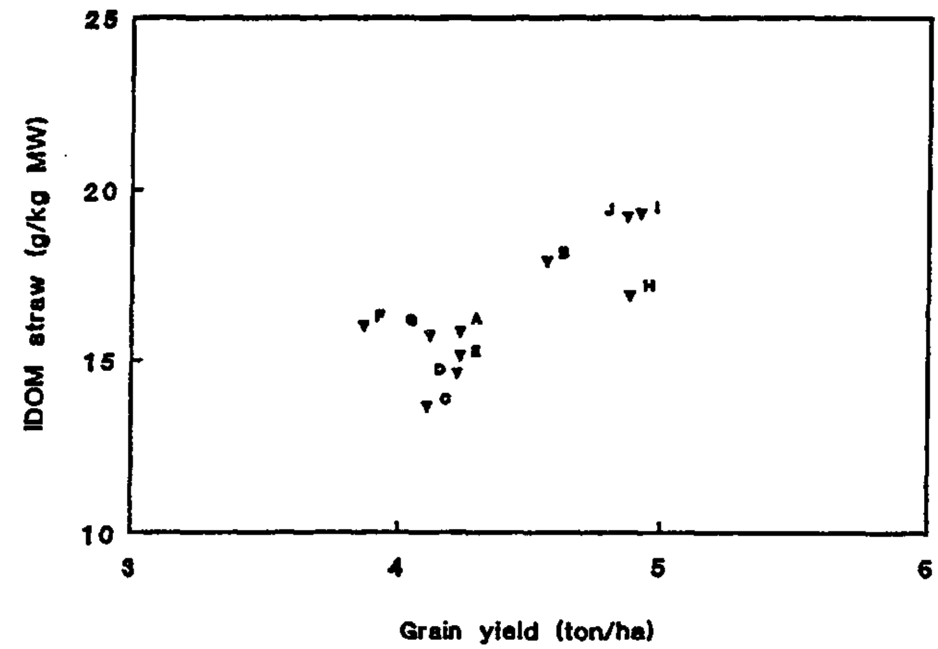


Table 4 Prediction of DOMI from OM *in sacco* degradation characteristics

Factors	Equations	R2
S	20.1 - 0.20*S	0.072
D	8.6 + 0.19*D	0.211
S + D	10.1 - 0.05*S + 0.18*D	0.215
t'	16.9 - 0.09*t'	0.002
S + D + t'	9.3 - 0.05*S + 0.19*D + 0.09*t'	0.217
kd	12.1 + 1.44*kd	0.084
S + D + t' + kd	5.7 + 0.01*S + 0.18*D - 0.03*t' + 1.16*kd	0.262

Figure 2 Nutritive value (DOMI) of rice straw as related to grain yield. Mean of two wet-season crops and two attitudes (letters indicate varieties, see Table 1)



In Figure 1, the fitted DOMI values as derived from this multiple regression analysis are plotted versus the observed DOMI values, showing a somewhat less clear cut relationship as compared to the temperate cereal straws (Ørskov *et al.*, 1989). In line with the differences in truly undegradable OM residue (R) between lowland and highland (see Table 3), 48-h OMD was lowest for highland rice straws. Somewhat surprisingly, this difference was not reflected in the *in vivo* OMD (see Table 1).

It thus seems that further research is needed to elucidate why in rice straw the *in sacco* OM degradation characteristics are such poor predictors of *in vivo* OM digestibility. Since the rice straws were offered in excess, perhaps part of this absent relationship could be explained by selection. Generally, however, the rice straw residues did not exceed 20% of the quantity supplied, so that these residues can hardly be expected to account for this. It would also be possible that due to differences in physical characteristics the rates of physical degradation of large into small particles differ. Finally, the rate of passage to the omasum may differ, due to the consistency of the reticulo-ruminal contents and the shape and/or functional specific gravity of the small particles. Possibly, in experiments with Cr-mordanted rice straw particles such differences could be identified.

RELATION BETWEEN GRAIN YIELD AND STRAW QUALITY

Identifying the most suitable rice variety is first of all related to its grain yield. The straw's quantity and quality have to be regarded as a second priority. This is elaborated in this workshop in the paper by De Wit *et al.* (1993). Hence, it is worthwhile to investigate the relation between straw quality, straw quantity and grain yield. Figure 2 is a pictorial presentation of this relationship as derived from the data obtained in Indonesia, showing that as averaged over both altitudes and seasons the straw's nutritive value fortunately seemed positively related to grain yield. This possibly could be explained on the basis of a variation in photosynthetic capacity, and the fact that harvesting took place at a stage that the straw was still greenish, and the excess of photosynthates produced were as yet not completely stored in the grain. These observations are not in line with those of Erickson *et al.* (1982), who observed in barley a poor relationship between grain yield and straw quality.

CONCLUSIONS

Significant differences between *in vivo* OMD, DOMI and *in sacco* degradation parameters were found for straw from 10 rice varieties grown in Indonesia. Variation in DOMI was higher for DOMI than for *in vivo* OMD. *In sacco* degradation characteristics could only explain 26.2% of variation in DOMI. No significant effects of location of growth (highland or lowland) on *in vivo* determined quality parameters were found, but *in sacco* degradability was significantly better for straw of rice cultivated in highland than for rice grown in lowland. A positive relation was observed between grain yield and DOMI for the ten rice varieties studied.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support provided by the Commission of European Communities.

REFERENCES

Doyle, P.T., Pearce, G.R., Djajanegara, A., 1987.Intake and digestion of cereal straws, pp. 59-62. In: Proceedings of the 4th Animal Science Congress of the Asian-Australian Association of Animal Production Societies. The Organising Committee, 4th AAAP Congress.

De Wit, J., Dhaka, J.P., Subba Rao, A., 1993. Relevance of breeding and management for more or better straw in different farming systems. These proceedings.

Egan, A.R., 1987. The utilization of fibrous crop residues as feed for ruminants, pp. 58. In: Proceedings of the 4th Animal Science Congress of the Asian-Australian Association of Animal Production Societies. The Organising Committee, 4th AAAP Congress.

Erickson, D.O., Meyer, D.W., Foster, A.E., 1982. The effect of genotypes on the feed value of barley straws. J. Anim. Sci. 5: 1015-1026.

Mehrez, A.Z., Ørskov, E.R., 1977. A study of the artificial fibre bag technique for determining the digestibility of feeds in the rumen. J. Agric. Sci. Cambridge 88: 645-650.

Ørskov, E.R., Kay, M., Reid, G.W., 1989. Prediction of intake of straw and performance by cattle from chemical analysis, biological measurements and degradation characteristics, pp. 155-162. In: M. Chenost and P. Reiniger (eds.): Evaluation of straws in ruminant feeding. Elsevier Science Publishers Ltd, Essex IG11 8JU, England.

Pearce, G.R., Lee, J.A., Simpson, R.J., Doyle, P.T., 1988. Sources of variation in the nutritive value of wheat and rice straws, pp. 195-233. In: J.D. Reed, B.S. Capper, P.J.H. Neate (eds.): Plant breeding and the nutritive value of crop residues. ILCA, Addis Ababa, Ethiopia.

Storm, E., Brown, D.S., Ørskov, E.R., 1983. The nutritive value of rumen micro-organisms in ruminants. 3. The digestion of microbial amino and nucleic acids in and losses of endogenous nitrogen from the small intestine of sheep. British Journal of Nutrition 50: 479-485.

Van Bruchem, J., Bongers, L.J.G.M., Bangma, G.A., Van Adrichem, P.W.M., 1989. Apparent and true digestibility of proteins in and losses of endogenous proteins from the small intestine in sheep as related to dry matter intake and digestibility. Livestock Production Science 23: 317-327.