

## Estimation of Nutritive Value of Whole Crop Rice Silage and Its Effect on Milk Production Performance by Dairy Cows

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**ABSTRACT** : The nutritive value and utilization of whole crop rice silage (WCRS), Hamasari, at yellow mature stage was determined by three studies. In first study, chemical composition, *in vivo* digestibility and metabolizable energy (ME) content of WCRS was determined by Holstein steers. WCRS contains 6.23% CP, its digestibility is 48.4% and estimated TDN is 56.4%. Its ME content was 1.91 Mcal/kg DM. Gross energy (GE) retention (% of GE intake) in steers is only 22.7% most of which was lost through feces (44.7% of GE intake). It takes 81 minutes to chew a kg of WCRS by steers. In another study, the effect of Hamasari at yellow mature stage at three stages of lactation (early, mid and late lactation) and two levels of concentrate (40 or 60%) on voluntary intake, ME content and ME intake, milk yield and composition using lactating Holstein dairy cows were investigated. Total intake increased with the concentrate level in early and mid lactation, but was similar irrespective of concentrate level in late lactation. WCRS intake was higher with 40% concentrate level than with 60% concentrate. ME intake by cows increased with the concentrate level and WCRS in early lactating cows with 40% concentrate can support only 90% of the ME requirement. Milk production in accordance with ME intake increased with the increase in concentrate level in early and mid lactating cows but was similar in late lactating cows irrespective of concentrate level. Fat and protein percent of milk in mid and late lactating cows were higher with for 60% concentrate than 40%, but reverse was in early lactating cows. Solids-not-fat was higher with for 60% concentrate than 40% concentrate. Finally *in situ* degradability of botanical fractions such as leaf, stem, head and whole WCRS, Hamasari at yellow mature stage was incubated from 0 to 96 h in Holstein steers to determine DM and N degradability characteristics of botanical fractions and whole WCRS. Both DM and N solubility, rate of degradation and effective degradability of leaf of silage was lower, but slowly degradable fraction was higher compared to stem and head. Solubility of DM and N of stem was higher than other fractions. The 48 h degradability, effective degradability and rate of degradation of leaf were always lower than stem or head. In conclusion, voluntary intake of silage ranged from 5 to 12 kg/d and was higher with low levels of concentrate, but milk yield was higher with high levels of concentrate. Fat corrected milk yield ranged from 19 to 37 kg per day. For consistency of milk, early lactating cows should not be allowed more than 40% whole crop rice silage in the diet, but late lactating cows may be allowed 60% whole crop rice silage. (*Asian-Aust. J. Anim. Sci.* 2004. Vol 17, No. 10 : 1383-1389)

**Key Words** : Whole Crop Rice, Lactation Stage, Concentrate Level, Intake, Digestibility, Milk Yield

### INTRODUCTION

Rice (*Oryza sativa* L. *Japonica*) is the staple food for human in Japan and in many other Asian countries. Climatic conditions of Japan where there is heavy rain in rainy season, but hot and humid weather in summer are favorable to grow rice. In fact, rice cultivation started in Japan since time immemorial and plays an integral part in the socio-economy and culture of Japan, where other cereal crops are still and will probably remain secondary to rice.

During the last decade (except in 1993), production of rice was either similar or higher than the consumption in Japan (MAFF, 1994). In this situation although it appeared that Japan does not need to grow excess rice any more, it is in fact very important to grow rice at least for two environmental and economic reasons. Firstly, rice is recycling water in the paddy fields and thereby maintaining

a balance of ground and surface water, which is very important to make the environment sustainable. While Japan is importing a huge amount of animal feed including forages, the challenge is to use these potential cultivable lands to reduce dependency on the import of animal feed. Forage crops such as corn can also be planted in these set aside paddy fields, but production of whole crop rice (WCR) as feed is considered to be a better strategy because of the reasons mentioned above.

Secondly, at present about one-third of the paddy fields remain set aside, which is a potential loss of economy and the environment. Presently 14% of the total digestible nutrient requirements of dairy cattle come from imported forages, which would be higher if other species of animals are taken into consideration. Growing whole crop rice (WCR) as feed in these set aside land (10-13 ton DM/ha) would be a step forward self sufficiency in feed (Nakui et al., 1988). However, there is little information on the nutritive value of WCR for dairy cows. Information on nutritive value particularly voluntary intake, digestibility of whole WCR and their botanical fractions (Islam et al., 2003; Islam et al., 2004), subsequent milk yields and milk

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**Table 1.** Diet composition and nutritive value of concentrate

Ingredients/chemical composition	Concentrate level (% DM or otherwise stated)
Flaked corn	70.25
Soybean meal	26.45
CaHPO <sub>4</sub>	0.17
CaCO <sub>3</sub>	1.82
Vitamin mixture	0.50
Salt	0.83
Total	100.00
ME, Mcal/kg DM*	3.39
CP (%DM)	20.95

\* Estimated according to Abe (1988).

compositions are key to formulate a diet for cows which will be used by the farmers. More specifically, farmers need information on the ratio of forage like WCR to concentrate (Sanh et al., 2002) to use at different lactation stages for dairy cows.

The objectives of the present experiment were therefore to investigate chemical composition, *in situ* degradability, *in vivo* digestibility, voluntary intake, feeding behavior, and milk production and composition by lactating dairy cows fed on whole crop rice silage.

## MATERIALS AND METHODS

### Whole crop rice

The variety, Hamasari used in this experiment was developed by breeders as a forage type rice characterized by long stem and less grain. It was grown at Saitama Prefecture, Japan and harvested in 1997, 30 days after flowering at yellow mature stage. Crop was harvested by a commercial harvester and wilted for two days. The wilted forage was then round baled and stored for five months. After opening, crops were chopped to about 2-3 cm length to feed animals.

A portion of silage was fractionated botanically into leaf (leaf blade), stem (leaf sheath plus stem) and head. These fractions were processed for *in situ* trial.

### Chemical composition and pH

Samples were milled through 1 mm screen and analyzed in duplicates for DM, ash, crude protein (CP), ether extract (EE) (AOAC, 1984); Oa, Ob, organic cell wall (OCW), organic cell content (OCC), CP in OCC and nitrogen-cell wall free extract (NCWFE) (Abe et al., 1979; Abe, 1988). Gross energy (GE) content was determined by bomb calorimeter. The pH of WCRS was determined on samples obtained after filtration (Horiba, ex-20, Kyoto, Japan) where 25 g of sample was mixed with water, which was then filtrated through a layer of cheesecloth to determine pH. The pH of rumen fluid was determined on fluids after collecting from the rumen using a pump-operated pipe with nozzle at the end of the pipe, which inserted to the rumen

through mouth and oesophagus, collected to a conical flask and then filtrated through a cheese cloth to determine pH as above. All analysis was done in duplicates.

### Steer trial

Four Holstein steers of about 18 months of age with a mean body weight (BW) of 346.9 kg (SD 54.9) were used in the trial. The trial was lasted for 21 days with 14 days preliminary period and 7 days data collection period. A group of two steers (first group) were placed individually in the digestion stall. Simultaneously, the rest two steers were placed individually in the closed circuit respiration chamber to monitor the gas release (methane) and to determine metabolizable energy content for two days and then returned to the digestion stall. Feces and urine were collected for the last 7 days from all four steers. Meanwhile, all steers were monitored for behavioral indices such as chewing, rumination, standing time over 24 h from day 20 of the trial. On the last day of the trial, ruminal fluid was collected at 0900 h and 1130 h to determine pH.

The data included digestibility of nutrients, feeding behavior, gross and metabolizable energy content at maintenance level of feeding. Steers were fed on whole crop rice silage (WCRS) at a maintenance level of feeding (MAFF, 1994). Since Hamasari at yellow mature stage contains only 6.23% crude protein (CP), 2% urea (2 g urea in 100 g DM of WCRS) was fed to every steer. Moreover, the diet was also supplemented with common salt (0.25% of DM intake) and vitamin mixture (42.4 IU/kg BW). The animals had free access to water. Urea was mixed with salt and vitamin before feeding. Whole crop rice silage was fed to the steers twice a day, half in the morning (0900 h) and half in the afternoon (1600 h). However, urea, salt and vitamin mixtures were fed only once in the morning. Animals were weighed at the beginning and every weekend thereafter to adjust the amount of feeding.

### Dairy cow trial

Eight lactating primiparous Holstein dairy cows were used. They were divided into three groups according to their stage of lactation (days, d), which consists of four early lactating (88 d, SD 28), two mid lactating (222 d, SD 13) and two late lactating (278 d, SD 10) cows. The range of live body weight (kg) was between 496 and 649. In each lactating group, one cow received 40% whereas the other one received 60% of the concentrate mixture of total DM intake except that in early lactating group where two cows received 60% concentrate. All cows were fed chopped (2-3 cm length) whole crop rice silage *ad libitum*. Whole crop rice was prepared using the variety, Hamasari, at yellow mature stage that was mowed, harvested and wilted for a day and then round baled (about 200 kg). The concentrate mixture fed consisted of flaked corn, soybean meal, minerals and vitamins (Table 1). Silages and concentrates

were fed individually to each cow but offered to cows twice a day, at 0900 h and 1800 h in two equal parts by weight. Immediately after finishing concentrates, silage was offered to the cows. Orts were collected before morning feeding, weighed, mixed thoroughly and sampled everyday. Feed intake was measured by the difference between amount offered and refused. Animals were weighed before commencing and on the finishing day of the experiment before morning feeding and at the same time of the day. Animals were housed individually in an air-conditioned house with concrete floor. A soft rubbery mat was placed in the lying paddock for the comfort of animals. For ME estimation of WCRS in lactating dairy cows at different stage, they were placed in closed circuit respiration chamber for two days to monitor the different gas release. Data on feed intake, Orts and milk production were measured for 21 days. The silage offered was sampled for DM determination once per week.

Milking was done by milking machine twice a day at 0900 h and 1800 h. About 200 ml of milk samples was collected and analyzed for composition (Milko-Scan, 133B, N. Foss Electric, Denmark). Each cow was monitored for eating, ruminating and standing time in every five minutes for 24 h.

### *In situ* trial

The botanical fractions and whole sample of WCRS

**Table 2.** Nutritive value of whole crop rice silage

Components	% DM or otherwise stated
Chemical composition (% DM or as stated)	
DM (%)	48.12
Crude ash	10.05
CP	6.23
EE	1.64
Nitrogen cell wall-free- extract	7.57
Organic cell wall	66.94
Oa	22.38
Ob	44.56
Ruminal pH (steer)	
Before feeding (0900 h)	6.84
After feeding (1130 h)	6.93
Dry matter digestibility (%)	48.4
Gross energy (GE, Mcal/kg DM)	3.87
Gross energy loss (% of GE intake)	
Feces	44.7
Urine	1.8
Methane	4.6
Heat production	26.4
GE retention (% of GE intake)	22.7
ME (Mcal/kg DM)	1.91
Estimated ME, Mcal/kg DM*	1.52
TDN (%)*	56.38
Feeding behavior (steer)	
Eating (min/kg DM intake)	34
Ruminating (min/kg DM intake)	47
Chewing (min/kg DM intake)	81

\* Estimated according to Abe (1988).

were subjected to *in situ* dry matter (DM) and nitrogen (N) trial. The percent of leaf, stem (leaf sheath inclusive) and head in WCRS used was 28, 48 and 24% respectively. *In situ* DM and N degradability of all samples were determined using two Holstein steers (648 kg body weight, 3.5 years old) fed on alfalfa hay. Samples were grounded green to pass through 4 mm screen. All samples were incubated for 0, 3, 6, 9, 12, 18, 24, 48, 72 and 96 h in a reverse order and removed at a common time in order to minimize the variation in time that the bags were exposed to air after incubation and enabled simultaneous washing of all bags. Zero (0) h bags were included in all cases but not incubated in the rumen. A machine (Hitachi PS-555, Japan) washed the bags (including 0 h bags) for 10 min and agitates for 3 min prior to drain water. After removing the bags from washing machine, bags were washed again by hand with cold tap water until the water became clear. All bags were dried at 60°C for 48 h in a forced draft air oven. N content of WCR was determined from fresh sample while N content of *in situ* residues was determined from dried sample. All analysis was done in duplicates.

The disappearance of DM and N at each individual incubation time was calculated as the difference between the feed and the portion remaining after incubation in the rumen. Data were fitted to the model developed by Ørskov and McDonald (1979) as  $p=a+b(1-e^{-ct})$ , where, p=% DM or %N (in DM) disappeared from the bags at time t, a=amount of immediately soluble DM or N also called y-intercept, b=amount of degradable fraction which in time will degrade at a fractional rate c (% per h). Solubility of DM and N was determined similarly by washing of 0 h bags, which was subjected only to washing procedure.

Effective degradability (ED) or availability of DM and N was calculated by fractional rate of passage of the particulate matter in the rumen at 2 (ED2), 5 (ED5) and 8 (ED8) % per h (AFRC, 1993) by the model of McDonald (1981) as  $ED=a+(bc/(c+kp))$ , where, a, b, c are described as above and k=passage rates. Data were analyzed for one-way analysis of variances (SAS, 1988).

### ME and TDN estimation

The ME (MJ kg<sup>-1</sup> DM) was estimated according to Terada et al. (1988) and total digestible nutrients (TDN, % DM) was estimated according to Abe (1988) as follows:

$$ME = -1.312 + 0.0603 \times CP + 0.05 \times Oa + 0.0215 \times Ob + 0.0505 \times NCWFE$$

$$TDN = 54.18 + 0.287 \times (OCC + Oa) - 0.183 \times Ob$$

The chemical composition was assayed based on enzymatic analysis of Abe et al. (1979).

### Statistical analysis

Data on *in situ* degradability of dry matter and nitrogen of botanical fractions of WCRS was analyzed for variances using SAS (1988).

## RESULTS

### Nutritive value of whole crop rice silage

The WCRS at yellow mature stage contained low CP (6.23%), high organic cell wall (OCW, 66.94%), low nitrogen-cell-wall-free extract (NCWFE, 7.57%), low DM digestibility (48.4%) and low metabolizable energy (ME, 1.91 Mcal/kg DM). The calculated ME content (1.52 Mcal/kg DM; Abe, 1988) of WCRS was lower than the measured ME content (1.91 Mcal/kg DM). About half of the gross energy (44.7%) intake of WCRS was lost through feces and only about one-fourth of the GE intake was retained (22.7%). Rumen pH increased slightly after feeding WCRS. It took about half an hour to eat a kg (DM) of WCRS by steers (Table 2).

### Milk production and milk composition of cows fed on WCRS

Table 3 shows intake, feeding behavior, milk production and milk composition of cows. Intake of silage was higher in mid and late lactating cows fed on 40% concentrate than 60% concentrate, but intake was similar in early lactation irrespective of concentrate level. In contrast to silage intake, ME intake was higher with 60% concentrate than 40% level in early and mid lactation, but the effect of concentrate level on ME intake in late lactation was narrower than in early or mid lactation. However, ME intake followed the trend of milk yield and fat-corrected-milk (FCM) production. Dairy cows took 35 minutes to 47 minutes to chew a kg of WCRS.

Both milk yield and FCM production was higher in early and mid lactating dairy cows with 60% concentrate, but similar to ME intake there was little effect of concentrate on milk production in late lactating cows. However, eating and rumination time in early lactating cows were similar irrespective of the concentrate level, but in mid and late lactating cows fed with 40% concentrate spent longer time for eating and rumination than with 60% concentrate. Fat and protein % in milk in early lactation with 40% concentrate was higher than with 60%, but in middle and late lactation 40% concentrate yielded lower fat and protein % than 60% concentrate. Solids-not-fat was always higher with high levels of concentrate.

### DM degradability of botanical fractions and whole crop of wilted rice silage

DM solubility due to washing loss, 'b' fraction, 'c', 'a+b' and ED2 of different botanical fractions differed ( $p < 0.05$ ); 'a', ED5 and ED8 also differed ( $p < 0.01$  or  $< 0.001$ ) (Table 4).

DM degradability at 0 h was similar ( $p > 0.05$ ) for stem and head, which were higher than leaf. Conversely, 'b' fraction was similar ( $p > 0.05$ ) in stem and head, which were lower than leaf. Rate of degradation was the highest for head and lowest for leaf. In contrast, 'a+b' was the highest for leaf and lowest for head. However, effective degradability of DM was the highest and lowest for head and leaf respectively (Table 4).

### N degradability of botanical fractions and whole crop wilted rice silage

Botanical fractions differed for washing loss, *in situ* 'a', 'b', and ED8 to a greater extent ( $p < 0.001$ ), and to a lesser extent for ED5 ( $p < 0.01$ ) followed by 'c' and ED2 ( $p < 0.05$ ).

**Table 3.** Voluntary intake, milk production and milk composition, eating and rumination time by lactating Holstein dairy cows fed on whole crop rice silage

Parameters/lactation stage	Early		Middle		Late		SD
	40	60	40	60	40	60	
Concentrate level (%)	40	60	40	60	40	60	
Number of cows	2	2	1	1	1	1	
WCRS intake (kg DM/d)	8.1	8.4	12.2	9.1	8.8	5.0	3.02
Concentrate intake	6.7	15.2	8.5	12.1	6.3	9.5	3.77
Total intake (kg DM/d)	14.8	23.6	20.7	21.2	15.1	14.5	6.20
ME intake (Mcal/kg DM/d)	38.3	64.2	47.3	55.4	33.9	39.5	12.22
ME intake (Mcal/d)	36.3	66.8	51.4	58.8	36.2	40.8	13.61
ME intake (% of requirement)	90.8	102.6	116.3	121.2	95.7	106.5	11.24
Feeding behavior							
Eating (Min/kg DM intake)	12.2	12.5	18.1	13.4	11.4	17.8	3.83
Rumination (Min/kg DM intake)	22.6	24.1	29.2	21.1	22.8	25.1	3.74
Chewing (min/kg DM intake)	34.8	36.6	47.2	34.6	43.0	34.2	5.82
Milk yield (kg/d)	22.7	41.6	25.4	27.1	16.7	17.4	9.78
4% fat-corrected-milk yield (kg/d)	21.3	37.1	22.5	26.1	19.4	19.7	7.43
Milk composition (%)							
Fat	4.61	3.27	3.23	3.76	4.90	5.07	0.85
Protein	3.48	3.02	2.73	3.48	3.64	4.12	0.51
Solids-not-fat	8.76	8.78	7.82	8.91	9.74	9.87	0.66

**Table 4.** Proportion of botanical fractions, *in situ* DM and N degradability of botanical fractions and whole crop of whole crop rice silage

Parameters (% or as stated)	Botanical fractions			SD	Whole
	Leaf	Leaf sheath+stem	Head		
Proportion (%DM)	28.3	47.4	24.3	11.1	100.0
DM degradability					
48 h degradability	53.1 <sup>b</sup>	59.9 <sup>ab</sup>	58.5 <sup>ab</sup>	3.5	63.0
Washing loss	15.5 <sup>b</sup>	25.2 <sup>a</sup>	21.9 <sup>a</sup>	4.5	24.3
a	13.7 <sup>c</sup>	23.6 <sup>a</sup>	18.8 <sup>b</sup>	4.5	22.9
b	61.2 <sup>a</sup>	39.8 <sup>b</sup>	43.3 <sup>b</sup>	10.4	41.1
c, h <sup>-1</sup>	0.021 <sup>c</sup>	0.044 <sup>bc</sup>	0.083 <sup>a</sup>	0.028	0.073
(a+b)	74.9 <sup>a</sup>	63.4 <sup>ab</sup>	62.2 <sup>b</sup>	6.3	64.0
ED2	44.4 <sup>c</sup>	50.6 <sup>b</sup>	53.7 <sup>ab</sup>	4.4	54.8
ED5	31.3 <sup>c</sup>	42.0 <sup>b</sup>	45.8 <sup>a</sup>	6.8	46.9
ED8	26.1 <sup>d</sup>	37.5 <sup>c</sup>	40.8 <sup>b</sup>	7.0	42.2
N degradability					
48 h degradability	71.3 <sup>b</sup>	80.0 <sup>a</sup>	82.5 <sup>a</sup>	5.5	83.5
Washing loss	30.6 <sup>c</sup>	58.6 <sup>a</sup>	45.2 <sup>b</sup>	12.6	45.4
a	27.6 <sup>c</sup>	58.9 <sup>a</sup>	45.4 <sup>b</sup>	14.1	44.7
b	59.5 <sup>a</sup>	27.2 <sup>c</sup>	39.3 <sup>b</sup>	14.6	39.3
c, h <sup>-1</sup>	0.024 <sup>c</sup>	0.030 <sup>c</sup>	0.111 <sup>a</sup>	0.044	0.087
(a+b)	87.1 <sup>a</sup>	86.1 <sup>a</sup>	84.7 <sup>a</sup>	1.2	84.0
ED2	59.2 <sup>b</sup>	74.6 <sup>a</sup>	78.7 <sup>a</sup>	9.3	76.6
ED5	46.4 <sup>b</sup>	68.7 <sup>a</sup>	72.5 <sup>a</sup>	12.7	69.6
ED8	41.0 <sup>b</sup>	66.0 <sup>a</sup>	68.2 <sup>a</sup>	13.5	65.1

ED2, ED5 and ED8 represent effective degradability at an outflow rate of 2, 5 and 8% per h respectively.

<sup>a, b, c</sup> values with different superscripts of botanical fractions in the same row differ ( $p < 0.001$  to  $p < 0.05$ ).

Potential degradability however, did not differ ( $p > 0.05$ ) between botanical fractions (Table 4).

Similar to DM solubility, N solubility (washing loss or 'a') was the highest for stem and lowest for leaf, which was reverse in case of 'b'. Rate of degradation was higher for head, and lower but similar between leaf and stem. Effective degradability of N was lower from leaf at all passage rates, which was lower than for stem or head. However, effective degradability of stem and head was similar (Table 4).

## DISCUSSION

Hamasari is a forage variety of rice characterized by long stem, high leaf and low grain. This has been reflected in its lowest proportion of head (24%). The CP content of WCRS was similar to that of whole crop barley (6.4%) and whole crop corn (6.9%), but was lower than whole crop wheat (7.1%) as reported by AFRC (1993). The ME content of WCRS was much lower than those cereals (9.1 to 11.3 MJ/kg DM; AFRC, 1993). Although this suggests that WCRS is low quality forage, our observation suggests that this may not be the case if grain varieties of WCRS are taken into consideration compared to forage varieties like the Hamasari used in the present study. The reason for lower ME content of WCRS may be explained by the botanical composition of whole crop cereals. Adamson and Reeve (1992) reported that a change in proportion of grain

to straw ratio from 50:50 to 60:40 represents an increase in ME content of 0.8 MJ/kg DM. The fact that the proportion of head (i.e. grain plus rachis) of WCRS used in this study was only 24% (Table 4). However, Yoshida et al. (1987) found that Hamasari at yellow mature stage contains about twice (47%) more proportion of head in than in the present study. This huge difference in proportion of head between these studies might be due to the fact that a large proportion of grain might have been lost during wilting in the present study whereas Yoshida et al. (1987) did not wilt. This low proportion of head of Hamasari used in this study might have been attributed to its low ME content. It is also important that the grain varieties of WCR contain 51 to 60% head (Yahara et al., 1981; Hara et al., 1986; Nakui et al., 1988), which is much higher than the forage varieties like Hamasari used in this study. It is therefore likely that the grain varieties of WCR would contain more nutritive value than forage varieties. However, further study is needed to look for the actual causes of low nutritive value of WCRS.

Ørskov et al. (1988) reported that the 48 h DM degradability could be equated to the DM digestibility *in vivo*. However, it can be seen that the 48 h DM degradability of whole WCRS was much higher (63%, Table 4) than *in vivo* DM digestibility (48%, Table 1). This flaw in DM digestibility between methods partly may be because different animals were used in two methods although in both methods Holstein steers were used. The

fact that *in situ* degradability was determined in older and heavier animals compared to the animals in *in vivo* study (see materials and methods section). Several workers (Jeffry, 1976; Minson and Ratcliffe, 1982) reported that the animals with heavier live-weight have higher digestibility than lighter animals. Moreover, alfalfa hay was used as diet of the animals in *in situ* study, which also explains the difference in digestibility, by two methods. However, it can also be seen that most of the gross energy intake is lost through feces (Table 1). This suggests a great deal of energy component particularly grain which is rich in energy likely to be lost through feces. Hara et al. (1986) reported that the excretion of grain *in vivo* increases with the increase in maturity might also resulted in lower digestibility than *in situ* method. These factors suggest that in formulating a diet of one group of animals using the data of other group may have underestimate or overestimate in practical situation and hence these need to be considered carefully during formulation of a diet.

Although potential degradability of leaf was the highest and head the lowest, availability of leaf DM at all passage rates was the lowest. The lowest rate of degradation of leaf is unlikely due to the fiber content since despite higher fiber content of stem, rate of DM degradation of stem was higher than leaf. The lower rate of degradation of leaf DM, therefore is likely to be due to its (leaf) higher content of ash and silica. Similarly, lower DM solubility of leaf may also be due to its higher ash content. Effective degradability of N from leaf was also the lowest despite similar potential degradability of leaf, stem or head. As explained, the higher ash or silica content of leaf (Yahara et al., 1981) likely to impede solubility of leaf N and hence may make leaf N unavailable in the rumen. Evidently, the 48 h degradability, effective degradability and rate of degradation of both DM and N of leaf were always lowest. Yahara et al. (1981) reported that while *in vitro* DM digestibility of leaf and stem of WCR ranged from only 46 to 49%, the same was 76% for head. These results are in contrast with many other types of forage where leaves are more digestible or degradable than other fractions. This suggests that unlike other forages, it is not the leaf but the proportion of head, which need to be increased in WCRS. In other words, grain varieties of WCRS should be used in the diet of cattle rather than forage varieties like the Hamasari used in the present study.

With the level of concentrates in the diet, consequent forage or roughage intake was reduced in dairy cows (Vérité et al., 1997) and in goats (Hossain, 1993). The result presented in the present experiment was in accordance with the literature. Decreased total DM intake with lower level of concentrates (40%) compared to high (60%) particularly in early and mid lactation may be explained by their lower level of concentrate supply, although it was associated with

higher amount of silage intake. It is likely the fact that passage rate of silage is lower than that of concentrates where the former increased the gut fill for longer time than the latter may be the reason for lower intake of the former. Poppi et al. (1981a,b) reported that the feeds with lower passage rate limits intake.

The data suggests that 40% concentrate in early lactation may not support milk production in early lactating cows as it can meet only 91% of total ME required for milk production. However, in mid and late lactating cows 40% concentrate seems to be sufficient since this level of concentrate can meet the ME requirements of these lactation stages. The longer time for eating, ruminating and chewing with 40% concentrate than 60% level in mid and late lactating cows may be due to the increased silage intake in the former level. Because silage intake in early lactation with both levels of concentrate was similar and hence the feeding behavior was also similar. The intake of whole crop rice silage (Hamasari, yellow mature stage) by Holstein cows offered from 40 to 60% concentrate ranged from 5 to 12 kg DM/day with FCM production from 19 to 37 kg/day. The results also suggest to include not more than 40% whole crop rice silage in early lactation for sustainable milk production, but may include up to 60% whole crop rice silage in late lactating cows without any detrimental effect on milk yield and quality.

## CONCLUSIONS

It may be concluded that to optimize nutritive value of WCRS, the proportion of head needs to be increased since head of WCRS is more nutritious than leaf or stem. One strategy could be the use of grain varieties of WCRS, which contains higher proportion of head than forage varieties of WCRS. In addition, forage breeders may incorporate head rather than other fractions in their breeding program to improve quality of WCR. Early lactating dairy cows given 40% concentrate of the total diet should not be offered WCRS until and unless its nutritive value increased in the way mentioned above or by manipulating in other ways. However, WCRS can be offered in early lactation with heavy concentrate support (60% of the total diet). Mid and late lactating dairy cows can be given *ad libitum* WCRS for sustained milk production.

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## REFERENCES

- Abe, A. 1988. Feed analysis based on carbohydrates and its application to the nutritive value of feeds. Memoirs of National Institute of Animal Industry, No. 2, National Institute of Animal Industry, Ministry of Agriculture, Forestry and Fisheries, Tsukuba, Japan.
- Abe, A., S. Horii and K. Kameoka. 1979. Application of enzymatic analysis with gluco-amylase, pronase and cellulase to various feeds for cattle. *J. Anim. Sci.* 48:1483-1490.
- Adamson, A. H. and A. Reeve. 1992. Nutritional evaluation of whole crop wheat. Chalcombe Publications, Canturbury, UK.
- AFRC. 1993. Energy and Protein Requirements of Ruminants. An advisory manual prepared by the AFRC Technical Committee on Responses to Nutrients. Compiled by G. Alderman, in collaboration with B.R. Cottrill. CAB International, Wallingford, UK.
- AOAC. 1984. Official Methods of Analysis, Centennial Edition. Association of Official Analytical Chemist, Washington DC.
- Hara, S., I. Egawa, S. Itoh, K. Deoka, T. Bando and M. Okamoto. 1986. Feeding value of whole crop silage at various growth stages from rice plant in Hokkaido. *Bull. Hokkaido National Agric. Exp. Stn.* 15:19-27 (in Japanese).
- Hossain, M. M. 1993. Effect of amount of straw offered or amount of concentrate fed on growth and on intake and selection of straw. Ph.D. thesis, Department of Agriculture, The University of Reading, UK.
- Islam, M. R., C. K. Saha, N. R. Sarker, M. A. Jalil and M. Hasanuzzaman. 2003. Effect of variety on proportion of botanical fractions and nutritive value of different napier (*Pennisetum purpureum*) grasses and relationship between botanical fractions and nutritive value. *Asian-Aust. J. Anim. Sci.* 16(6):837-842.
- Islam, M. R., M. Ishida, S. Ando, T. Nishida, N. Yoshida and M. Arakawa. 2004. Effect of variety and stages of maturity on nutritive value of whole crop rice: Yield, botanical fractions, fermentability and chemical composition. *Asian-Aust. J. Anim. Sci.* 17(2):183-192.
- Jeffry, H. 1976. Effect of liveweight of caged sheep and the amount of feed on offer on estimates of digestibility and *ad libitum* intake. *Aust. J. Exp. Agric. Anim. Husb.* 16:656-660.
- MAFF. 1994. Ministry of Agriculture, Forestry and Fisheries, MAFF Research Council Secretariat, Japanese Feeding Standard for Cattle, Central Association of Livestock Industry, Tokyo, Japan.
- McDonald, I. M. 1981. A revised model for the estimation of protein degradability in rumen. *J. Agric. Sci. (Camb.)*. 96:251-252.
- Minson, D. J. and D. Ratcliffe. 1982. Effect of liveweight of caged sheep on the digestibility of grasses fed *ad libitum*. *Aust. J. Exp. Agric. Anim. Husb.* 22:159-162.
- Nakui, T., S. Masaki, T. Aihara, N. Yahara and S. Takai. 1988. The making of rice whole crop silage and an evaluation of its value as forage for ruminants. *Bull. Tohoku Natl. Agric. Exp. Stn.* 78:161-174.
- Ørskov, E. R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *J. Agric. Sci. (Camb.)*. 92:499-503.
- Ørskov, E. R., G. W. Reid and M. Kay. 1988. Prediction of intake by cattle for degradation characteristics of roughages. *Anim. Prod.* 46:29-34.
- Poppi, D. P., D. J. Minson and J. H. Ternouth. 1981a. Studies of cattle and sheep eating leaf and stem fractions of grasses. 1. The voluntary intake, digestibility and retention time in the reticulo-rumen. *Aust. J. Agric. Res.* 32:109-121.
- Poppi, D. P., D. J. Minson and J. H. Ternouth. 1981b. Studies of cattle and sheep eating leaf and stem fractions of grasses. 2. The retention time of large particles in the rumen. *Aust. J. Agric. Res.* 32:122-137.
- Sanh, M. V., H. Wiktorsson and L. V. Ly. 2002. Effects of natural grass forage to concentrate ratios and feeding principles on milk production and performance of crossbred lactating cows. *Asian-Aust. J. Anim. Sci.* 15(5):650-657.
- SAS. 1988. Statistical Analysis System. SAS Procedures Guide, Release 6.03 Edition, SAS Institute Inc., Cary, NC.
- Terada, F., S. Serizawa, R. Tano, K. Iwasaki and A. Abe. 1988. Prediction of metabolizable energy contents of the diets for cattle from chemical composition or digestible nutrients. *Jpn. J. Zootech. Sci.* 59:490-495.
- Vérité, R., P. Faverdin and J. Agabriel. 1997. Developments in the INRA feeding systems for dairy cows. In: *Recent Advances in Animal Nutrition* (Ed. P. C. Garnsworthy and J. Wiseman), Nottingham University Press, UK, pp. 153-166.
- Yahara, N., S. Takai and T. Numakawa. 1981. Studies on utilization of rice plant as whole crop silage. *Bull. Tohoku Natl. Agric. Exp. Stn.* 63:151-159 (in Japanese).
- Yoshida, N., M. Tomita, Y. Takemasa and T. Takahashi. 1987. Forage paddy rice for whole crop utilization. I. The storability affected by different conservation method. *J. Japanese Grassland. Sci.* 33:109-115 (in Japanese).
- Yoshida, N., M. Tomita, Y. Takemasa and T. Takahashi. 1987. Studies on the utilization of whole crop rice silage. III. Feed value of rice plants breeding for forage at different growth stages. *Bull. Saitama Prefec. Livestock. Exp. Stn.* 35:32-37 (in Japanese).