Effect of Variety and Stage of Maturity on Nutritive Value of Whole Crop Rice Silage for Ruminants: *In situ* Dry Matter and Nitrogen Degradability and Estimation of Metabolizable Energy and Metabolizable Protein

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ABSTRACT : The effect of eight varieties of whole crop rice silage (WCRS) harvested at four stages of maturity were investigated for *in situ* DM and N degradability, ME and MP yield and content in an 8×4 factorial experiment. The varieties were Akichikara, Fukuhibiki, Habataki, Hamasari, Hokuriku 168, Kusanami, Tamakei 96 and Yumetoiro. Hamasari and Kusanami were forage varieties while all others were grain varieties. Forages were harvested on 10, 22, 34 and 45 days after flowering, ensiled and kept in airtight condition. Between 45 and 49 days after ensiling, silages opened, chopped and milled green to pass through 4 mm screen. Samples were incubated in the rumen of two Holstein steers for 0, 3, 6, 9, 12, 24, 48, 72 and 96 h over eight 4 d periods. Bags at 0 h were washed in a washing machine. Variety affected DM ($p<0.001$; except 'a+b', $p<0.01$) and N ($p<0.001$) degradability characteristics of WCRS. Stages of maturity also affected DM ($p<0.001$; except 'a+b', $p<0.05$; 'c', $p<0.08$) and N ($p<0.01$; except 'c', $p<0.05$) degradability characteristics of WCRS. Interactions between variety and stages of maturity occurred in all DM ($p<0.001$) and N ($p<0.001$) degradability characteristics except ($p>0.05$) for DM 'b', DM 'c', DM 'a+b' and N 'c'. Effective DM degradability was higher in grain varieties than forage varieties and degradability increased with maturity. N availability decreased only slightly with maturity. Variety was the key factor for N degradability characteristics of WCRS since variety accounted for most of the total variation for degradability characteristics. Both ME and MP content and yield were higher ($p<0.001$) in grain varieties, and they increased ($p<0.001$) with the maturity. The results clearly demonstrated that the grain type varieties contained higher ME and MP content than forage varieties, and increase in maturity increases both ME and MP content of WCRS. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 11 : 1541-1552)***

Key Words : Whole Crop Rice, Variety, Maturity, *In situ* Degradability, Metabolizable Energy, Metabolizable Protein

INTRODUCTION

Buxton (1996) reported that maturity is the most important factor influencing forage quality. A number of workers (Yahara et al., 1981; Hara et al., 1986; Nakui et al., 1988) reported that the increase in maturity also increases dry matter (DM) intake, DM and organic matter (OM) digestibility, but decreases crude protein (CP) and fiber digestibility of whole crop rice silage (WCRS) by both sheep and cattle. In contrast, many workers reported that the DM or OM digestibility (*in vitro* or *in vivo*), or degradability decreases with the increase in maturity in whole crops such as sorghum (Snyman and Joubert, 1996), corn (Bal et al., 1997; Firdous and Gilani, 1998) and wheat (Adesogan, 1996), and in grasses (Burn et al., 1997; Mbwile and Uden, 1997; Vieira et al., 1997) and grass silages (Rinne et al., 1997). Therefore, in contrast to other crops, WCR may not need to compromise yield with nutritive value (Crovetto et al., 1998) with the increase in maturity. However, CP digestibility (*in vivo*) of WCRS decreased with the increase in maturity (Hara et al., 1986; Nakui et al., 1988), which was similar to other forages (Mitchell et al., 1997). All studies with WCRS used only one variety at different stages of maturity *in vivo*. These studies, therefore, did not describe the differences in nutritive value of WCRS due to variety at different stages of maturity as well as their interactions. Moreover, information on rate of degradability is important because digestion rates determine the amount of nutrients to be supplied to the animals. Allen (1996) reported that the differences in ruminal degradation of forage components affect energy intake, absorbed nitrogen or metabolizable protein and subsequent production. There is, however, no information in the literature on ruminal degradation characteristics of WCRS. To formulate an effective ration for dairy and beef animals, it is important not only to know the degradation characteristics of WCRS, but also important to know which variety at which stage of maturity is suitable for these animals.

Diet formulation also requires information on metabolizable energy (ME) and metabolizable protein (MP) content of feeds (AFRC, 1993). Therefore, accurate diet formulation based on WCRS needs information on the ME and MP content of different varieties at different stages of maturity. The present study will therefore investigate the effect of variety and stages of maturity on *in situ*

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degradability of DM and N as well as ME and MP content of WCRS.

MATERIALS AND METHODS

Agronomy, variety and sample preparation

A detailed description of sample preparation was presented in Islam et al. (2004a; 2001). Differences among varieties, maturities, and proportion of head and straw in each variety can also be seen in Islam et al. (2004a). In short, eight varieties of rice (Akichikara, Fukuhibiki, Habataki, Hamasari, Hokuriku 168, Kusanami, Tamakei 96 and Yumetoiro) were grown under identical condition at Saitama, Japan in 1997, and harvested in 1998. Two of the varieties, Hamasari and Kusanami are regarded as 'feed' (i.e. forage) type rice while others are 'grain' types. All varieties were harvested at four stages of maturity; 10 (MS1), 22 (MS2), 34 (MS3) and 45 (MS4) days after flowering and ensiled. Silages were opened between 45 and 49 days after ensiling, chopped by a machine (Yamamoto P-156, Japan) and stored at -18°C until further processing.

All samples from each variety at each maturity stages were ground green through a 4 mm screen (Retsch, Germany).

In situ degradation

In situ degradation procedure followed was principally the same as described by Hoffman et al. (1993). Each variety at each stages of maturity was incubated over eight 4 d (96 h) periods. One variety with all four maturity stages was incubated in each period. Two steers fitted with rumen cannulae (648 kg, SD 25; 3.5 years old) were used to incubate sample. Nylon bags (polyester made bags; 10×20 cm; pore size 45 μm; T-NO. Tetron Screen, NBC Industries, Tokyo) were filled with fresh sample (ca. 5 g on DM basis). Bags were placed in a polyester mesh bag secured to the ruminal cannula via a nylon cord. At each time point, bags were incubated in the steers in a reverse order for 0, 3, 6, 9, 12, 24, 48, 72 and 96 h. The advantage of incubation in a reverse order enable to bring out all bags at the same time after incubation which minimizes error because all bags were washed at the same time (von Keyserlingk et al., 1996). A standard forage, alfalfa, was also incubated in the rumen of those two steers for 12, 24 and 48 h and DM degradability was determined to investigate the effect of period. Bags at 0 h were included in all cases but not incubated in the rumen. After removal of the bags from rumen, the polyester mesh bags including all nylon bags were immersed in ice water (for 10 min) to stop microbial activity. The polyester bag, including the nylon bags was rinsed with cold water to remove particulate material. The bags were then removed from the polyester bags and placed in a domestic washing machine (Hitachi PS-555, Japan). The machine 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.

Animals, feeding and feed analysis

The Holstein steers fitted with rumen cannula fed a diet consisting of 10 kg of alfalfa hay offered once in a day. They were also fed on mineral block and water *ad libitum*. N content of WCRS was determined from fresh sample while N content of *in situ* residues of WCRS was determined from dried sample. All analysis was done in duplicates.

Data fitting

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. These values were fitted to the model developed by Ørskov and McDonald (1979) as $p=a+b\ (1-e^{-ct})$, where, p=disappearance (%) of DM and N from the bags at time t, a=proportion of immediately soluble DM or N, b= proportion of degradable fraction which 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. Data were fitted by SAS (1988).

Effective degradability (ED) or availability of DM and N was calculated by fractional rate of passage of the particulate matter in the rumen at 5% per h (ED5) by the model of McDonald (1981) as $ED=a+(bc/(c+kp))$, where, a, b, c are described as above and k=passage rates.

ME and MP estimation

The ME (MJ kg^{-1} DM) was estimated according to Terada et al. (1988) and total digestible nutrients (TDN, %DM) was estimated according to Abe et al. (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).

The fermentable metabolizable energy (FME, MJ kg^{-1} DM), ME from fats and oils (MEF, MJ kg^{-1} DM), ME from fermentation of acids (MEA, MJ kg^{-1} DM) were estimated according to AFRC (1993). However, the values of fat and oils, and organic acid content of whole crop rice given in

Table 1. Effect of variety and stages of maturity on DM degradability characteristics of whole crop rice (% or as stated)

Variety (V)	Maturity (M)[1]	48 h DM loss	Washing loss	b	(a+b)	c (h^{-1})	ED5
Akichikara	MS1	54.6	31.7	26.3	56.6	0.058	44.4
	MS2	58.9	41.7	20.1	60.9	0.050	50.6
	MS3	58.1	43.7	17.2	61.2	0.046	52.1
	MS4	57.4	49.4	10.2	59.5	0.044	54.0
Fukuhibiki	MS1	61.3	33.1	36.6	67.7	0.036	46.4
	MS2	66.5	46.9	26.5	72.0	0.030	55.4
	MS3	64.2	45.7	24.3	70.2	0.034	55.7
	MS4	64.0	46.3	21.4	68.3	0.036	55.8
Habataki	MS1	65.4	41.1	28.2	67.3	0.061	54.4
	MS2	69.7	51.0	21.0	72.3	0.047	61.4
	MS3	63.2	37.9	29.3	67.5	0.067	54.8
	MS4	63.6	46.1	20.9	66.2	0.062	56.6
Hokuriku 168	MS1	52.9	22.1	35.7	59.8	0.039	39.6
	MS2	56.0	34.4	29.9	66.3	0.024	46.0
	MS3	54.2	44.1	35.5	81.8	0.008	51.0
	MS4	59.5	46.7	30.8	79.0	0.017	53.3
Tamakei 96	MS1	61.6	29.8	39.1	67.7	0.049	47.8
	MS2	63.6	39.7	30.2	69.2	0.036	51.6
	MS3	63.6	46.1	24.6	70.3	0.030	54.9
	MS4	57.3	44.3	15.1	60.3	0.045	52.2
Yumetoiro	MS1	60.3	33.8	32.5	65.3	0.041	47.5
	MS2	66.1	46.2	22.4	68.3	0.040	55.7
	MS3	65.0	42.5	25.2	69.5	0.041	55.7
	MS4	67.4	59.1	9.5	69.0	0.037	63.4
Hamasari	MS1	56.1	29.0	37.7	65.3	0.034	42.8
	MS2	59.1	37.4	30.3	67.5	0.029	48.3
	MS3	58.1	41.3	25.1	66.1	0.029	50.3
	MS4	59.4	41.6	19.9	61.8	0.039	50.7
Kusanami	MS1	54.7	30.0	32.9	62.1	0.035	42.2
	MS2	58.4	40.7	29.1	68.9	0.025	48.6
	MS3	60.4	42.9	25.6	68.0	0.038	52.6
	MS4	56.3	41.6	27.4	68.9	0.019	49.0
Grain	MS1	59.4	31.9	33.1	64.1	0.047	46.7
	MS2	63.5	43.3	25.0	68.2	0.038	53.5
	MS3	61.4	43.3	26.0	70.1	0.038	54.0
	MS4	61.5	48.7	18.0	67.1	0.040	55.9
Forage	MS1	55.4	29.5	35.3	63.7	0.035	42.5
	MS2	58.8	39.1	29.7	68.2	0.027	48.5
	MS3	59.3	42.1	25.4	67.1	0.034	51.5
	MS4	57.9	41.6	23.7	65.4	0.029	49.9
Overall	Grain	61.4	41.8	25.5	67.3	0.041	52.5
Overall	Forage	57.8	38.1	28.5	66.1	0.031	48.1
Overall	Mean	60.5	40.9	26.3	67.0	0.038	51.4
	SED	1.08	1.32	1.42	1.11	0.003	0.93
	R^2	0.92	0.99	0.82	0.69	0.76	0.98
	V	72***	16***	32***	42**	74***	42***
	M	11***	61***	49***	15*	NS	43***
	S	*	NS	NS	NS	NS	NS
	V×M	16**	23***	NS	NS	NS	15***

[1] MS1, MS2, MS3 and MS4 are maturity stages at harvest means harvesting on 10, 22, 34 and 45 days after flowering respectively; ED5 is effective degradability at the passage rate of 5% per h; S=effect of steer. R^2 is the proportion of variation accounted for by the model.

this series (Islam et al., 2004a) were used in calculation.

For protein (g kg^{-1} DM), quickly degradable protein (QDP), slowly degradable protein (SDP), rumen degradable protein (RDP), effective rumen degradable protein (ERDP), undegradable protein (UDP), digestible undegradable protein (DUP), microbial crude protein (MCP), digestible microbial true protein (DMTP) and metabolizable protein (MP) were also calculated according to AFRC (1993) from the *in situ* nitrogen degradability data of this paper, and CP content and ADIN of whole crop rice given in this series

Table 2. Means of main effect of variety and stages of maturity on *in situ* DM degradability characteristics of whole crop rice (% or as stated)

	n	48 h DM loss	Washing loss	b	c (h^{-1})	(a+b)	ED5
Variety							
Akichikara	8	57.2^{de}	41.6^{d}	18.5^{d}	0.049^{ab}	59.6^{c}	50.3^{e}
Fukuhibiki	8	64.0^{a}	43.0^{c}	27.2^{bc}	0.034^{de}	69.5^{ab}	53.3^{c}
Habataki	8	65.5^{a}	44.0^{b}	24.8^{bc}	0.059^{a}	68.3^{ab}	56.8^{a}
Hokuriku 168	8	55.6^{d}	36.8^{g}	33.0^{a}	0.022^{e}	71.7^{a}	47.5^{f}
Tamakei 96	8	61.5^{b}	40.0^{e}	27.3^{bc}	0.040^{bc}	66.9^{ab}	51.6^{d}
Yumetoiro	8	64.7^{a}	45.4^{a}	22.4^{de}	0.040^{bc}	68.0^{ab}	55.6^{b}
Hamasari	8	58.2^{c}	37.3^{g}	28.3^{ab}	0.033^{de}	65.2^{b}	48.0^{f}
Kusanami	8	57.5^{c}	38.8^{f}	28.8^{ab}	0.029^{de}	67.0^{ab}	48.1^{f}
Grain	48	61.4	41.8	25.5	0.0475	67.3	52.5
Forage	16	57.8	38.1	28.5	0.031	66.1	48.1
Maturity stages[1]							
MS1	16	58.3^{c}	31.3^{d}	33.6^{a}	0.044	64.0^{b}	45.7^{d}
MS2	16	62.3^{a}	42.3^{c}	26.2^{b}	0.035	68.2^{a}	52.2^{c}
MS3	16	60.8^{b}	43.0^{b}	25.9^{b}	0.037	69.3^{a}	53.4^{b}
MS4	16	60.6^{b}	46.9^{a}	19.4^{c}	0.038	66.6^{ab}	54.4^{a}

[1] MS1, MS2, MS3, MS4, and ED5 as described in Table 1.

[a, b, c, d, e, f, g] Values with different superscripts in a column within the same subclass differ (p<0.001 to 0.01).

(Islam et al., 2004a). For FME content, 3 times maintenance level of feeding was used and hence all parameters (e.g. MCP, DMTP, MP) related to FME are applied to dairy cows only.

ME yield (MJ ha^{-1}) was calculated from its ME content and DM yield. Similarly, MP (kg DM ha^{-1}) content was calculated from MP content and DM yield.

Statistical analysis

Data on variety and stages of maturity was analyzed by SAS using general linear model procedure (SAS, 1988) in an 8×4 factorial experiment with reps, which includes 8 varieties at 4 maturity stages. The statistical model was as follows:

$$Y_{ijk} = \mu+V_i+M_j+S_k+(V\times M)_{ij}+E_{ijk}$$

Where, Y_{ijk}=dependent variable, μ=population mean, V_i=average effect of variety i, M_j=average effect of maturity stage j, S_k=average effect of steer k; $(V\times M)_{ij}$= average effect of interaction of variety i and maturity j, and E_{ijk}=residual error, assumed to be normally, identically and independently distributed. All means were tested by least square difference (SAS, 1988).

RESULTS

DM degradability

Variety affected (p<0.001) 48 h DM loss, washing loss ('a'), all *in situ* parameters ('a+b', p<0.01) and ED at all passage rates. Stage of maturity also affected (p<0.001) the 48 h DM loss, washing loss, *in situ* degradability characteristics ('a+b', p<0.05; 'c', p<0.08) and ED at all passage rates. Interactions between variety and maturity existed (p<0.001) for washing loss, and ED, but there were no interactions (p>0.05) on 'b', 'a+b' and 'c'. Steers did not affect (p>0.05) the *in situ* degradability parameters (p>0.05) except for 48 h DM loss (p<0.05). Washing loss increased, but in contrast 'b' decreased with the increase in maturity. Rate of degradation generally decreased with the increase in maturity. Potential degradability increased from MS1 to MS3, but remain similar or decreased slightly at MS4 compared to MS3. ED increased with the increase in maturity (Table 1).

DM solubility at 0 h was higher (p<0.001) in 'grain' varieties than 'forage' varieties with the exception of a grain variety, Hokuriku 168 of which DM loss was the lowest. Moreover, 'c' was higher in grain varieties but in contrast, 'b' fraction was higher (p<0.001) in forage varieties. The 'a+b' was highest (p<0.001) in Hokuriku (71.7%) and the lowest in Akichikara (59.6%). ED was higher (p<0.001) in grain varieties than forage varieties at all passage rates (Table 2).

DM solubility at 0 h increased (p<0.001), but 'b' fraction decreased (p<0.001) with the increase in maturity. The 'c' decreased (p<0.001) from MS1 to MS3, but 'c' at MS4 did not differ (p>0.05) with the rate at other stages of maturity. In contrast, 'a+b' increased (p<0.001) from MS1 to MS3, but 'a+b' at MS4 did not differ (p>0.05) with other stages of maturity. However, ED increased (p<0.001) with the increase in maturity at all passage rates (Table 2).

N degradability

Variety affected (p<0.001) on 48 h N loss, washing loss, *in situ* degradability characteristics and availability of N. Maturity similarly affected (p<0.001) 48 h loss, washing loss, *in situ* degradability characteristics ('c'; p<0.05) and availability. Interactions between variety and stages of

Table 3. Effect of variety and stages of maturity on *in situ* N degradability characteristics of whole crop rice (% DM or as stated)

Variety (V)	Maturity (M)[1]	48 h N loss	N	Washing loss	b	c (h^{-1})	(a+b)	ED5
Akichikara	MS1	89.3	1.15	77.4	10.4	0.100	88.2	84.7
	MS2	85.6	0.80	73.9	9.8	0.083	83.8	80.1
	MS3	82.6	0.76	70.9	11.0	0.081	81.8	77.5
	MS4	83.6	0.83	76.8	5.6	0.104	83.1	81.2
Fukuhibiki	MS1	87.2	1.16	76.4	11.0	0.079	86.5	82.2
	MS2	87.1	0.93	78.9	8.4	0.054	87.3	83.2
	MS3	84.4	0.89	73.3	11.6	0.061	85.3	80.1
	MS4	85.0	0.87	72.2	12.4	0.075	85.0	80.0
Habataki	MS1	91.0	1.11	80.9	10.1	0.118	90.8	87.8
	MS2	89.2	0.89	79.3	9.5	0.115	88.9	86.1
	MS3	86.5	0.95	65.7	20.6	0.113	86.3	79.9
	MS4	86.3	0.91	72.9	12.3	0.103	85.4	81.4
Hokuriku 168	MS1	84.4	1.67	64.7	20.7	0.061	84.9	75.6
	MS2	80.8	1.30	65.0	14.0	0.066	79.4	73.2
	MS3	78.9	1.08	61.3	16.0	0.046	77.6	69.3
	MS4	70.1	0.95	53.3	14.5	0.085	69.4	63.9
Tamakei 96	MS1	91.5	1.53	80.8	10.9	0.076	91.6	87.3
	MS2	90.3	1.23	79.7	11.1	0.052	90.6	85.1
	MS3	86.2	1.04	74.0	12.3	0.053	86.9	80.9
	MS4	81.4	1.13	73.1	7.7	0.044	81.3	77.2
Yumetoiro	MS1	88.5	1.04	73.8	15.2	0.085	88.3	82.6
	MS2	87.8	0.89	75.7	13.1	0.054	88.3	82.0
	MS3	87.3	0.91	70.5	18.8	0.052	89.0	79.7
	MS4	88.7	1.16	82.6	6.9	0.070	88.0	85.1
Hamasari	MS1	90.7	1.50	80.7	10.4	0.060	91.0	86.2
	MS2	90.1	1.30	83.3	6.8	0.067	90.0	87.0
	MS3	89.3	1.30	82.8	6.8	0.059	89.8	86.6
	MS4	87.6	1.31	79.5	7.5	0.073	87.4	84.4
Kusanami	MS1	83.4	0.92	68.2	15.4	0.072	83.7	77.3
	MS2	82.1	0.72	66.0	15.9	0.046	83.3	75.0
	MS3	81.7	0.67	69.0	14.7	0.049	83.9	76.1
	MS4	79.7	0.64	67.0	13.2	0.054	80.7	74.2
Grain	MS1	88.7	1.3	75.7	13.1	0.087	88.4	83.4
	MS2	86.8	1.0	75.4	11.0	0.071	86.4	81.6
	MS3	84.3	0.9	69.3	15.1	0.068	84.5	77.9
	MS4	82.5	1.0	71.8	9.9	0.080	82.0	78.1
Forage	MS1	87.1	1.2	74.5	12.9	0.066	87.4	81.8
	MS2	86.1	1.0	74.7	11.4	0.057	86.7	81.0
	MS3	85.5	1.0	75.9	10.8	0.054	86.9	81.4
	MS4	83.7	1.0	73.3	10.4	0.064	84.1	79.3
Overall	Grain	85.6	1.05	73.0	12.2	0.076	85.3	80.3
Overall	Forage	85.6	1.05	74.6	11.3	0.060	86.2	80.9
Overall	Mean	85.5	1.05	73.4	12.0	0.072	85.5	80.4
	SED	1.11	0.06	1.24	0.69	0.004	0.81	0.97
	R^2	0.97		0.99	0.98	0.78	0.99	0.99
	V	62***		72***	50***	74***	62***	74***
	M	22***		8***	17***	10*	20***	12***
	S	NS		**	NS	NS	NS	NS
	V×M	16***		20***	33***	NS	17***	13***

[1] MS1, MS2, MS3, MS4, ED5, S and R^2 are as described in Table 1.

maturity occurred (p<0.001) in all above parameters.

Solubility at 0 h was the highest (p<0.001) in Hamasari (forage variety) despite its lowest DM solubility. In contrast, N solubility of Kusanami (forage variety) and Hokuriku (grain variety) was low, which was similar in pattern to DM solubility. Hamasari, on the other hand, contained the lowest (p<0.001) but Hokuriku contained the highest 'b' fraction. Rate of degradation was the highest (p<0.001) in Habataki. Potential degradability and availability (at all passage rate) was the highest (p<0.001) in Hamasari and lowest in Hokuriku (Table 4).

N solubility and 'c' decreased (p<0.001) from MS1 to MS3, but increased slightly at MS4. Slowly degradable fraction (b) was, however, the highest (p<0.001) at MS3

Table 4. Means of main effect of variety and stages of maturity on *in situ* N degradability of whole crop rice (% DM or as stated)

	n	N	48 h N loss	Washing loss	b	c (h^{-1})	(a+b)	ED5
Variety								
Akichikara	8	0.88^{d}	85.3^{c}	74.7^{dc}	9.2^{e}	0.092^{b}	84.3^{e}	80.9^{d}
Fukuhibiki	8	0.96^{c}	85.9^{c}	75.2^{dc}	10.9^{d}	0.067^{c}	86.0^{d}	81.4^{d}
Habataki	8	0.96^{c}	88.2^{ab}	74.7^{d}	13.1^{c}	0.112^{a}	87.9^{bc}	83.8^{b}
Hokuriku 168	8	1.25^{b}	78.5^{e}	61.1^{f}	16.3^{a}	0.064^{c}	77.8^{g}	70.5^{f}
Tamakei 96	8	1.23^{b}	87.3^{b}	76.9^{b}	10.5^{d}	0.056^{c}	87.6^{c}	82.6^{c}
Yumetoiro	8	1.00^{c}	88.1^{b}	75.7^{c}	13.5^{c}	0.065^{c}	88.4^{b}	82.3^{c}
Hamasari	8	1.35^{a}	89.4^{a}	81.6^{a}	7.9^{f}	0.065^{c}	89.5^{a}	86.0^{a}
Kusanami	8	0.74^{e}	81.7^{d}	67.5^{e}	14.8^{b}	0.055^{c}	82.9^{f}	75.7^{e}
Grain	48	1.05	85.6	73.0	12.2	0.076	85.3	80.3
Forage	16	1.05	85.6	74.6	11.3	0.060	86.2	80.9
Maturity[1]								
MS1	16	1.26^{a}	88.2^{a}	75.4^{a}	13.0^{b}	0.081^{a}	88.1^{a}	83.0^{a}
MS2	16	1.01^{b}	86.6^{b}	75.2^{a}	11.1^{c}	0.067^{b}	86.5^{b}	81.5^{b}
MS3	16	0.95^{c}	84.6^{c}	70.9^{c}	14.0^{a}	0.064^{b}	85.1^{c}	78.8^{c}
MS4	16	0.97^{bc}	82.8^{d}	72.2^{b}	10.0^{d}	0.076^{ab}	82.6^{d}	78.4^{d}

[1] MS1, MS2, MS3, MS4 and ED5 as described in Table 1.

[a, b, c, d, e, f, g] Values with different superscripts in a column within the same subclass differ (p<0.001 to 0.05).

and lowest at MS4. Potential degradability and availability at all passage rates decreased (p<0.001) with the increase in maturity (Table 4).

Metabolizable energy and metabolizable protein

Both variety and stages of maturity affected (p<0.001) the FME, ME, TDN and ME yield. These parameters increased, but MEF and MEA decreased with the increase in maturity in all varieties (Table 5). There were no interactions (p>0.05) between variety and maturity on those parameters. The FME, ME, TDN and ME yield of grain varieties were higher (p<0.001) than forage varieties (Table 6).

All QDP, SDP, RDP, ERDP, UDP, DUP, MCP, DMTP, MP and MP yield differed (p<0.001) due to the variety and stages of maturity. There were no interactions (p>0.05) between variety and maturity on these parameters (Table 7). The ERDP, MCP, MP and MP yield was generally higher in grain varieties than forage varieties, and these parameters increased with maturity (Table 8).

DISCUSSION

DM degradability

Buxton (1996) reported that maturity stage is the most important factor influencing forage quality. The results of this study suggest that both variety and maturity are equally important in determining quality of WCRS because they accounted for by similar proportion of variation on effective DM degradability, but variety accounted for by most of the variation for effective N degradability (Tables 1 and 3). Therefore, both selection of variety and harvesting at a suitable maturity are equally important.

The rapidly degradable DM increased (12-17%), but slowly degradable DM decreased (8-14%) in most varieties with the increase in maturity. In contrast, Hoffman et al. (1993) reported that both rapidly and slowly degradable DM fractions of most grasses and legumes decreased with the increase in maturity. Despite these contrasting results, the range of slowly and rapidly degradable DM fractions of WCRS was in agreement with the ranges reported by Hoffman et al. (1993). The range of rapidly degradable DM fraction was also in agreement with the ranges of corn silage (44-57%) and grass silages (28-59%) reported by von Keyserlingk et al. (1996), while the range of slowly degradable DM fraction (31-42% and 13-58%, respectively) reported by them contrasts with WCRS. However, it is worth to mention that unlike the present study, von Keyserlingk et al. (1996) did not described the variety and maturity status of forages they studied. In the present study, the contrasting characteristics of both slowly and rapidly degradable fraction may be explained by the differences in botanical fractions of varieties at different maturity stages. Grain varieties contained a higher proportion of head than straw compared to forage varieties, which might lead to higher rapidly and lower slowly degradable fraction in the former varieties than the latter. It is also worth to mention that both rapidly and slowly degradable DM were mostly similar in all varieties at MS1, while rapidly degradable fraction increased, slowly degradable fraction on the other hand decreased with the increase in maturity. This phenomenon also likely to be due to the fact that, while proportion of head increased, proportions of straw on the other hand decreased with the increase in maturity.

The rate of degradation of DM was generally higher in grain varieties than forage varieties presumably because the rate of degradation of DM of head was higher than leaf or stem, which might lead to higher rate of degradation of grain type varieties. In general, rate of DM degradation at MS1 was higher than other stages of maturity (Table 1). The rate of DM degradation of varieties at different maturities did not follow any trend, which disagreed with the data of Hoffman et al. (1993) where rate of degradation of forages generally decreased with the maturity. The range of rate of DM degradation of grasses (Hoffman et al., 1993) and hybrid maize (Verbič et al., 1995) was in agreement with the range of rate of degradation of WCRS in the present study. Ovenell-Roy et al. (1998) on the other hand reported a much higher rate of degradation (9-15%) for barley cultivars.

Table 5. Effect of variety and stages of maturity on energy characteristics of whole crop rice (MJ kg^{-1} DM or as stated)

Variety (V)	Maturity stages (M)[1]	MEF	MEA	TDN (%)	FME	ME	ME yield (MJ ha^{-1})
Akichikara	MS1	0.75	1.30	55.6	3.99	6.04	58,584
	MS2	0.93	1.05	59.2	5.03	7.00	74,360
	MS3	0.66	0.34	62.5	7.53	8.54	107,098
	MS4	0.75	0.63	62.4	7.01	8.40	104,344
Fukuhibiki	MS1	0.65	1.10	49.5	2.80	4.55	35,927
	MS2	0.80	0.74	56.0	4.83	6.37	68,246
	MS3	0.58	0.37	60.7	7.20	8.16	98,469
	MS4	0.58	0.26	60.6	7.43	8.26	100,014
Habataki	MS1	0.67	1.39	51.6	2.69	4.75	53,779
	MS2	0.73	0.69	63.7	6.90	8.31	104,970
	MS3	0.75	0.45	63.9	7.49	8.69	119,621
	MS4	0.60	0.48	65.4	8.30	9.38	148,182
Hokuriku	MS1	0.68	0.86	55.8	4.43	5.97	61,974
	MS2	0.79	0.58	53.5	4.24	5.61	62,869
	MS3	0.63	0.51	58.2	6.26	7.40	92,451
	MS4	0.72	0.52	59.5	6.48	7.72	100,058
Tamakei	MS1	0.72	1.44	54.6	3.36	5.52	53,202
	MS2	0.83	0.77	52.6	3.57	5.16	62,240
	MS3	0.61	0.51	56.6	5.70	6.81	83,432
	MS4	0.54	0.02	56.3	5.93	6.48	85,680
Yumetoiro	MS1	0.68	1.25	51.2	2.57	4.50	53,583
	MS2	0.73	0.66	57.8	5.21	6.60	81,473
	MS3	0.63	0.39	60.8	6.85	7.87	126,578
	MS4	0.43	0.07	60.0	7.07	7.57	122,116
Hamasari	MS1	0.75	1.03	48.5	2.26	4.04	43,204
	MS2	0.84	0.61	53.7	4.23	5.67	68,858
	MS3	0.76	0.78	55.6	4.79	6.33	90,853
	MS4	0.67	0.30	55.4	5.27	6.24	92,210
Kusanami	MS1	0.66	1.29	49.4	2.58	4.52	51,552
	MS2	0.87	0.68	53.6	3.89	5.45	70,211
	MS3	0.79	0.69	55.8	4.48	5.95	87,439
	MS4	0.67	0.18	56.6	5.69	6.53	105,654
Grain	MS1	0.69	1.22	53.1	3.31	5.22	52,842
	MS2	0.80	0.75	57.1	4.96	6.51	75,693
	MS3	0.64	0.43	60.5	6.84	7.91	104,608
	MS4	0.60	0.33	60.7	7.04	7.97	110,066
Forage	MS1	0.71	1.16	49.0	2.42	4.28	47,378
	MS2	0.86	0.65	53.7	4.06	5.56	69,535
	MS3	0.78	0.74	55.7	4.64	6.14	89,146
	MS4	0.67	0.24	56.0	5.48	6.39	98,932
Overall	Grain	0.69	0.68	57.8	5.54	6.90	85,802
Overall	Forage	0.75	0.70	53.6	4.15	5.59	76,248
Overall	Mean	0.70	0.69	56.8	5.19	6.57	83,413
	SED	0.993	0.990	0.77	0.999	0.999	4,715
	R^2	0.02	0.07	0.998	0.30	0.25	0.906
	V	25***	4***	35***	20***	30***	21***
	M	50***	80***	49***	69***	56***	79***
	R	NS	NS	NS	NS	NS	-
	V×M	25***	17***	16***	11***	14***	-

[1] MS1, MS2, MS3, MS4, ED5, S and R^2 are as described in Table 1.

Table 6. Main effect means of variety and stages of maturity on metabolizable energy characteristics (MJ kg^{-1} DM or as stated) of whole crop rice

	n	MEF	MEA	FME	ME	TDN (%)	ME yield (kg ha^{-1})
Variety							
Akichikara	8	0.77^{a}	0.83^{a}	5.89^{b}	7.49^{b}	59.9^{b}	$86{,}097^{bc}$
Fukuhibiki	8	0.65^{f}	0.62^{f}	5.56^{c}	6.83^{c}	56.7^{d}	$75{,}664^{cd}$
Habataki	8	0.69^{d}	0.75^{b}	6.34^{a}	7.78^{a}	61.1^{a}	$106{,}638^{a}$
Hokuriku 168	8	0.70^{c}	0.62^{g}	5.35^{d}	6.67^{d}	56.7^{d}	$79{,}338^{cd}$
Tamakei 96	8	0.67^{e}	0.69^{d}	4.64^{e}	5.99^{e}	55.0^{e}	$71{,}139^{d}$
Yumetoiro	8	0.62^{g}	0.59^{h}	5.42^{d}	6.63^{d}	57.4^{c}	$95{,}938^{ab}$
Hamasari	8	0.75^{b}	0.68^{e}	4.13^{f}	5.57^{f}	53.3^{g}	$73{,}781^{cd}$
Kusanami	8	0.75^{b}	0.71^{c}	4.16^{f}	5.61^{f}	53.8^{f}	$78{,}714^{cd}$
Grain	48	0.69	0.68	5.53	6.90	57.8	85,802
Forage	16	0.75	0.70	4.15	5.59	53.6	76,248
Maturity stages[1]							
MS1	16	0.69^{b}	1.21^{a}	3.08^{d}	4.98^{d}	52.0^{d}	$51{,}476^{c}$
MS2	16	0.81^{a}	0.72^{b}	4.73^{c}	6.27^{c}	56.3^{c}	$74{,}153^{b}$
MS3	16	0.68^{c}	0.51^{c}	6.28^{b}	7.47^{b}	59.3^{b}	$100{,}743^{a}$
MS4	16	0.62^{d}	0.31^{d}	6.64^{a}	7.57^{a}	59.5^{a}	$107{,}282^{a}$

[1] MS1, MS2, MS3 and MS4 as described in Table 1.

[a, b, c, d, e, f, g] Values with different superscripts in a column within the same subclass differ ($p<0.001$).

Availability of DM at all passage rates was higher for grain type varieties (except Hokuriku) compared to forage type. As stated earlier, grain type varieties contained a higher proportion of grain than straw (Islam et al., 2004a). Furthermore, ED of head was higher than leaf or stem (Islam et al., 2004b; accepted Manuscript ED 402) which may lead to higher availability of grain type varieties than forage type. Increased availability of DM with the increase in maturity also likely to be due to the fact that proportion of grain increased with the maturity.

N degradability

Variety is the key factor affects N degradability of WCRS as it accounted for by 50-84% of the total variation in contrast to 8-20% of the total variation accounted for by maturity (Table 3). On average 73% of the N in WCRS solubilized immediately. In contrast to DM solubility, which was the lowest, rapidly degradable N of Hamasari was the highest. However, N solubility of another forage variety, Kusanami and grain variety, Hokuriku was lower than other varieties, similar to the pattern of DM solubility. The reason for high N solubility of Hamasari and low N solubility of Kusanami or Hokuriku was not clear and cannot be explained by the proportion of botanical fractions. N solubility rather may be associated with the internal structure of each of botanical fraction (Ramanzin et al., 1986; Verbiĉ et al., 1995). The rapidly soluble N content of WCRS was twice than those reported by von Keyserlingk et al. (1996) for corn and grass silages, and much higher than other silages, grasses and legumes (AFRC, 1993; Hoffman et al., 1993). In contrast, the slowly degradable fraction of WCRS was much lower than those reported for different forages and silages (AFRC, 1993; Hoffman et al., 1993; von Keyserlingk et al., 1996).

The rate of N degradation was similar to the rate of degradation of grasses (Hoffman et al., 1993), but was lower than corn and grass silages (von Keyserlingk et al., 1996). In fact, rate of degradation of N of leaf and stem of WCRS was too low (Islam et al., 2004b; accepted Manuscript ED 402) may be due to the ash content of the former and association of fiber content in the latter which might lead to lower rate of degradation of WCRS. Generally, the grain varieties have higher rate of degradation than forage varieties may be due to fact that rate of N degradation of head was higher than leaf or stem (Islam et al., 2004b; accepted Manuscript ED 402).

Like rapidly soluble N, availability of N was high for Hamasari and low for Kusanami and Hokuriku. Availability of ruminal N of WCRS was higher than those reported for forages and silages (AFRC, 1993; Hoffman et al., 1993; von Keyserlingk et al., 1996). This may be due to the higher ruminal solubility of N from WCRS compared to other forages. Availability of N generally decreased at all passage rates with the increase in maturity was in agreement with Hoffman et al. (1993), but the magnitude of decrease in WCRS was not as sharp as reported by those workers.

In situ residues were not corrected for microbial contamination in the present study. While several workers reported that the microbial contamination might affect results (Mathers and Aitchison, 1981; Varvikko and Lindberg, 1985; Waters and Givens, 1992), Hoffman et al. (1993) reported no significant bacterial contamination in forages. Moreover, since all samples were treated similarly in the present study, effect of microbial contamination, if any, is likely to be similar in all cases and hence nullified each others effect (von Keyserlingk et al., 1996).

Metabolizable energy and metabolizable protein

The higher ME and TDN of grain type varieties than forage types may be due to their (grain varieties) higher proportions of head than straw. The increase in both ME and TDN content with the increase in maturity also likely to be due to the fact that the proportion of head also increased with the maturity. In addition to the lower proportion of head, the lower FME and ME of forage varieties was in fact

Table 7. Effect of variety and stages of maturity on rumen degradable and metabolizable protein (g kg^{-1} DM or as stated) of whole crop rice

Variety (V)	Maturity (M)[1]	QDP	SDP	RDP	ERDP	UDP	DUP	MCP	DMTP	MP	MP yield (kg DM ha^{-1})
Akichikara	MS1	67.8	5.0	72.8	59.3	14.3	4.4	43.5	27.7	32.1	312
	MS2	61.4	4.1	65.5	53.2	17.4	8.1	54.8	34.9	43.0	456
	MS3	55.1	4.2	59.3	48.3	18.4	9.0	82.1	52.3	61.4	766
	MS4	62.4	2.4	64.9	52.4	15.6	6.5	76.4	48.7	55.3	683
Fukuhibiki	MS1	70.0	5.1	75.1	61.1	17.7	6.3	30.5	19.5	25.7	203
	MS2	65.7	2.8	68.5	55.3	14.8	4.9	52.6	33.6	38.5	410
	MS3	57.9	4.0	61.9	50.3	16.7	6.7	78.5	50.0	56.7	681
	MS4	57.6	4.8	62.3	50.8	17.1	6.8	80.9	51.6	58.4	702
Habataki	MS1	81.1	6.0	87.1	70.9	13.3	2.6	29.3	18.7	21.3	241
	MS2	71.5	5.0	76.5	62.2	13.5	2.8	75.2	47.9	50.8	637
	MS3	55.7	10.2	65.9	54.7	18.9	7.0	81.6	52.0	59.1	808
	MS4	65.7	6.2	72.0	58.8	18.0	5.0	90.4	57.6	62.6	983
Hokuriku	MS1	56.3	7.8	64.2	52.9	23.5	14.4	48.2	30.7	45.1	469
	MS2	55.3	5.3	60.6	49.5	24.1	14.6	46.1	29.4	44.0	492
	MS3	45.8	4.4	50.1	41.0	24.2	12.8	68.2	43.5	56.3	699
	MS4	41.3	5.5	46.8	38.6	28.4	17.0	70.6	45.0	62.0	799
Tamakei	MS1	71.8	4.7	76.5	62.1	12.4	3.3	36.6	23.3	26.6	257
	MS2	67.9	3.7	71.6	58.0	13.8	5.4	38.9	24.8	30.1	362
	MS3	57.9	3.8	61.6	50.1	15.9	6.6	62.1	39.6	46.2	562
	MS4	67.8	2.5	70.3	56.8	21.8	6.0	64.6	41.2	47.2	619
Yumetoiro	MS1	66.3	7.1	73.4	60.1	17.3	7.1	28.0	17.9	25.0	297
	MS2	62.5	4.4	66.9	54.4	16.3	7.0	56.8	36.2	43.2	531
	MS3	58.9	6.2	65.0	53.3	18.8	9.8	74.7	47.6	57.4	916
	MS4	78.3	3.0	81.3	65.7	15.2	0.6	77.0	49.1	49.7	752
Hamasari	MS1	65.2	3.6	68.8	55.7	12.1	1.7	24.6	15.7	17.4	186
	MS2	60.0	2.2	62.2	50.2	10.0	1.2	46.1	29.4	30.6	371
	MS3	56.3	1.9	58.2	46.9	9.6	1.5	52.2	33.3	34.8	496
	MS4	57.7	2.6	60.2	48.7	11.9	3.2	57.4	36.6	39.8	585
Kusanami	MS1	51.2	5.4	56.6	46.4	18.3	8.5	28.1	17.9	26.4	302
	MS2	49.3	4.2	53.5	43.6	19.6	10.5	42.4	27.0	37.5	482
	MS3	49.4	3.8	53.2	43.3	18.2	8.8	48.8	31.1	39.9	581
	MS4	46.4	3.6	50.0	40.7	18.8	9.6	61.9	39.5	49.1	789
Grain	MS1	68.9	6.0	74.9	61.1	16.4	6.4	36.0	23.0	29.3	297
	MS2	64.1	4.2	68.3	55.4	16.7	7.1	54.1	34.5	41.6	481
	MS3	55.2	5.5	60.6	49.6	18.8	8.7	74.5	47.5	56.2	739
	MS4	62.2	4.1	66.3	53.9	19.4	7.0	76.7	48.9	55.9	756
Forage	MS1	58.2	4.5	62.7	51.1	15.2	5.1	26.4	16.8	21.9	244
	MS2	54.7	3.2	57.9	46.9	14.8	5.9	44.3	28.2	34.1	427
	MS3	52.9	2.9	55.7	45.1	13.9	5.2	50.5	32.2	37.4	539
	MS4	52.1	3.1	55.1	44.7	15.4	6.4	59.7	38.1	44.5	687
Overall	Grain	62.6	4.9	67.5	55.0	17.8	7.3	60.3	38.5	45.7	568
Overall	Forage	54.4	3.4	57.8	46.9	14.8	5.6	45.2	28.8	34.4	474
Overall	Mean	60.54	4.55	65.08	52.98	17.07	6.87	56.5	36.0	42.9	545
	SED	1.62	0.31	1.63	1.32	0.74	0.71	3.30	2.11	2.30	37.8
	R^2	0.997	0.964	0.997	0.996	0.993	0.993	0.999	0.999	0.999	0.905
	V	59***	53***	62***	63***	78***	81***	20***	20***	26***	17**
	M	21***	17***	24***	25***	5***	2***	69***	69***	63***	83***
	R	NS	NS	NS	NS	NS	NS	NS	NS	NS	-
	V×M	20***	30***	14***	13***	17***	16***	12***	12***	11***	-

[1] MS1, MS2, MS3, MS4, ED5, S and R^2 are as described in Table 1.

Table 8. Means of main effect of variety and stages of maturity on rumen degradable and metabolizable protein (g kg^{-1} DM or as stated) of whole crop rice

	n	QDP	SDP	RDP	ERDP	UDP	DUP	MCP	DMTP	MP	MP yield (kg DM ha^{-1})
Variety											
Akichikara	8	61.7^{d}	3.94^{de}	65.6^{e}	53.3^{e}	16.4^{cd}	7.02^{c}	64.2^{b}	40.9^{b}	47.9^{b}	555^{abcd}
Fukuhibiki	8	62.8^{c}	4.14^{de}	66.9^{d}	54.4^{d}	16.6^{c}	6.17^{d}	60.6^{c}	38.7^{c}	44.8^{c}	499^{cde}
Habataki	8	68.5^{a}	6.87^{a}	75.4^{a}	61.7^{a}	15.9^{e}	4.36^{f}	69.1^{a}	44.1^{a}	48.4^{b}	667^{a}
Hokuriku 168	8	49.7^{f}	5.75^{b}	55.4^{g}	45.5^{g}	25.1^{a}	14.70^{a}	58.3^{d}	37.2^{d}	51.9^{a}	615^{abc}
Tamakei 96	8	66.3^{b}	3.67^{e}	70.0^{c}	56.7^{c}	16.0^{de}	5.31^{e}	50.5^{e}	32.2^{e}	37.5^{f}	450de
Yumetoiro	8	66.5^{b}	5.17^{c}	71.7^{b}	58.4^{b}	16.9^{c}	6.12^{d}	59.1^{d}	37.7^{d}	43.8^{d}	624^{ab}
Hamasari	8	59.8^{e}	2.57^{f}	62.4^{f}	50.4^{f}	10.9^{f}	1.91^{g}	45.1^{f}	28.7^{f}	30.6^{g}	410^{e}
Kusanami	8	49.1^{f}	4.26^{d}	53.3^{h}	43.5^{h}	18.7^{b}	9.35^{b}	45.3^{f}	28.9^{f}	38.2^{e}	539^{bcd}
Grain	48	62.6	4.93	67.5	55.0	17.8	7.28	60.3	38.5	45.7	568
Forage	16	54.4	3.41	57.8	46.9	14.8	5.63	45.2	28.8	34.4	474
Maturity stages[1]											
MS1	16	66.2^{a}	5.59^{a}	71.8^{a}	58.6^{a}	16.1^{c}	6.03^{c}	33.6^{d}	21.4^{d}	27.5^{d}	284^{c}
MS2	16	61.7^{b}	3.96^{c}	65.6^{b}	53.3^{b}	16.2^{c}	6.83^{b}	51.6^{c}	32.9^{c}	39.7^{c}	468^{b}
MS3	16	54.6^{d}	4.81^{b}	59.4^{d}	48.5^{d}	17.6^{b}	7.77^{a}	68.5^{b}	43.7^{b}	51.4^{b}	689^{a}
MS4	16	59.7^{c}	3.82^{c}	63.5^{c}	51.5^{c}	18.3^{a}	6.83^{b}	72.4^{a}	46.2^{a}	53.0^{a}	739^{a}

[1] MS1, MS2, MS3 and MS4 as described in Table 1.

[a, b, c, d, e, f, g] Values with different superscripts in a column within the same subclass differ ($p<0.001$).

reflected in their lower fermentation quality (Islam et al., 2004a) and poor DM degradability characteristics compared to grain varieties. However, both FME and ME of all WCRS used in this study were lower than those of WCC reported by AFRC (1993) may be partly because of the poor fermentation quality and hence deduction of energy from acids. The fact that WCRS used in this study was high in moisture content, which might lead to poor fermentation quality. The increase in ME content of WCRS with the increase in maturity contrasts with many studies using whole crop wheat (Crovetto et al., 1998; Adesogan, 1996) and alfalfa forage (Belyea et al., 1999) who reported that the ME and net energy content respectively decreased. This result is very important because nutritive value of WCRS does not need to compromize with yield with the increase in maturity as suggested by some workers (Adesogan, 1996; Crovetto et al., 1998). Moreover, increase in maturity decreases organic cell wall, ADF, ADL (Islam et al., 2004a), hemicellulose, cellulose (Yahara et al., 1981) and silica (Nakui et al., 1988) but increases water soluble carbohydrate (Yahara et al., 1981), nitrogen free extract and starch (Hara et al., 1986; Fukume et al., 1979). ME yield was optimized at physiological mature stage in WCRS which was usually 2 to 3 times higher than harvesting at 10 days after flowering (i.e. MS1). These improvements in quality and quantity of WCRS with maturity may help in improving farm economy to a greater extent.

The higher QDP of grain varieties is the reflection of higher CP and higher solubility of CP of grain varieties than forage varieties. The lower MCP and MP in forage varieties were due largely to the lower FME and partly because of the lower N content of forage varieties than grain varieties. The ERDP and UDP of WCRS at the same outflow rate was similar to winter forages, but was much lower than that of spring and some of the summer and autumn forages reported by Wales et al. (1999). However, UDP of WCRS was similar to the cereal silages reported by AFRC (1993), although ERDP of WCRS was lower than those reported by AFRC (1993).

In contributing to MCP or MP, N content or rumen degradability of protein of WCRS had a lesser effect than that of FME. Generally, an increase in maturity also increased FME, which ultimately contributed to higher MCP or MP. However, it can be seen that the MCP content of some varieties was higher than ERDP (Tables 7 and 8) suggesting that the MCP yield of these varieties may be increased with the additional supply of nitrogen sources such as urea.

AFRC (1993; p62) reported that a 600 kg cow losing 0.5 kg per d and giving 30 kg milk with 4.06% fat and 3.29% protein per litre fed on (DM per d) grass silage (10.5 kg) and compound feed (7.0 kg) requires (per d) 205 MJ ME and 1.625 g MP. A diet formulated using Habataki MS4 (9.34 MJ ME, Table 5; 62.6 g MP, Table 7) at the rate of 10.5 kg DM d^{-1} may supply 98.5 MJ ME and 657 g MP which is 48 and 40% respectively of the total requirement. A diet formulated using Habataki MS1 may provide two-third of ME and only one third of the MP supplied by Habataki at MS4, which emphasizes the importance of maturity in improving nutritive value of WCRS.

CONCLUSIONS

Both DM and N availability, ME and MP content and their yield in grain varieties were higher than forage varieties. Availability of DM and N, ME and MP content and their yield also increased consistently with the increase in maturity. These results therefore clearly suggest that grain varieties at physiological mature stage optimize both yield and nutritive value of WCRS. Therefore, both grain and forage varieties at different maturity stages should be tested using animals before using grain varieties because of the problems related to the excretion of grain with the increase in maturity.

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