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Whole crop rice silage: Predictions of yield and content of metabolizable energy, metabolizable protein and other nutrients for dairy cows from crop maturity and botanical fractions at harvest

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ABSTRACT

The study investigated the suitability of stage of maturity and botanical fractions of whole crop rice (WCR) to predict yield and nutritive value of ensiled WCR for dairy cows. Eight varieties of WCR (*i.e.*, Akichikara, Fukuhibiki, Habataki, Hamasari, Hokuriku 168, Kusanami, Tamakei 96, Yumetoiro) were harvested at four stages of maturity (*i.e.*, 10, 22, 34, 45 days after flowering [DAF]) and ensiled. Dry matter (DM) yield at each harvest was determined. Silage samples were fractionated into four botanical fractions being: leaf blade, leaf sheath, stem and head. Silage samples were also analyzed for chemical composition, fermentation characteristics, *in situ* DM and N disappearance. Metabolizable energy (ME) and metabolizable protein (MP) content of samples were estimated according to Terada et al. (1988) and AFRC (1993), respectively. Relationships between maturity or proportions of botanical fractions and contents of WCR silage in terms of DM, ME and MP, and their yields, were estimated by correlation and regression analysis. Stage of maturity was positively related ($P<0.001$) to ME content ($R^2 = 0.46$; $y = 4.53 + 0.08X$) and MP content ($R^2 = 0.56$; $y = 22.26 + 0.76X$), and DM yield ($R^2 = 0.63$; $y = 9.21 + 0.12X$), ME yield ($R^2 = 0.68$, $y = 36931 + 1708X$) and MP yield ($R^2 = 0.72$, $y = 161.0 + 14.15X$) of WCR. Proportion of leaf was negatively related to yields and nutritive value of ensiled WCR, whilst proportion of head was positively related ($P<0.05$ to <0.001). Proportion of head was best related to the ME content ($R^2 = 0.72$; $y = 3.26 + 0.009X$), MP content ($R^2 = 0.72$; $y = 12.31 + 0.079X$), and DM yield ($R^2 = 0.41$; $y = 9.02 + 0.009X$), ME yield ($R^2 = 0.76$, $y = 19494 + 165.5X$), and MP yield ($R^2 = 0.75$, $y = 34.37 + 1.32X$) of WCR. Results suggest that to optimize yield and nutritive value, WCR should be ensiled within 40 DAF and the proportion of head should be equal to or more than 500 g per kg DM of WCR silage. Stage of maturity and proportion of head of WCR predict yields of DM, ME and MP of WCR, and their contents, in WCR silage with acceptable accuracy. However, these relationships need to be validated using large data sets and *in vivo* studies.

Abbreviations: ADIN, acid detergent insoluble N; DAF, days after flowering; DMD, disappearance of DM; EE, ether extract; ME, metabolizable energy; MP, metabolizable protein; ND, disappearance of N; NFCW, N free cell wall; Oa, soluble organic cell wall; Ob, insoluble organic cell wall; OCC, organic cell content; OCW, organic cell wall; WCC, whole crop cereal; WCR, whole crop rice.

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1. Introduction

Diet formulation based on AFRC (1993) requires information on both the metabolizable energy (ME) and metabolizable protein (MP) contents of feedstuffs. Accurate estimation of ME requires an *in vivo* balance and metabolism studies (AFRC, 1993). However, such studies are very expensive, time consuming, labour intensive, require a large amount of feed and laboratory analysis, and hence are not suitable for routine analysis. In addition, many laboratories are not equipped with facilities for such studies. Therefore, a number of prediction equations, based on routinely used analytical techniques (*i.e.*, chemical composition and *in vitro* digestibility), are commonly used to estimate the ME content of forages (Adesogan et al., 1999, 1998; Terada et al., 1988; AFRC, 1993). However, little information is available as to how the proportions of botanical fractions are related to nutritive value of whole crop cereals (WCC), particularly whole crop rice (WCR). The ability to accurately predict the ME and MP of WCR silage, and other forages, from physical characteristics such as maturity or botanical fractions at harvest would be useful for farmers and extension workers as it would obviate the need to undertake expensive chemical analyses.

Differences in proportions of botanical fractions of forages influence chemical composition, ruminal *in situ* disappearance (Islam et al., 2004a,b, 2003a), digestibility, intake and consequently animal production (Ramanzin et al., 1986; Capper et al., 1986). Ramanzin et al. (1986) estimated that the leaf to stem ratio accounted for 20% of the variation of ruminal *in situ* dry matter (DM) disappearance of barley straw while Capper et al. (1986) estimated that the leaf to stem ratio accounted for 40% of the variation of its feed intake by sheep. Adamson and Reeve (1992) reported that a change in the grain to straw ratio in WCC from 50:50 to 60:40 represents an increase in ME of 0.8 MJ/kg DM. However, these researchers did not include WCR in their investigation.

Many reports have also shown that the stage of maturity of plants affects botanical fractions, chemical composition, fermentation characteristics (Islam et al., 2004b), degradability characteristics (Islam et al., 2004a, 2001), intake and digestibility (Yahara et al., 1981; Hara et al., 1986), ME (Crovetto et al., 1998) as well as the net energy (Belyea et al., 1999) content of forages. Plant characteristics such as botanical fractions or plant maturity may be used as a low cost tool in order to estimate the nutritive value of forages, provided that good relationships exist between plant characteristics and nutritive value indicators.

The objective of this study was to investigate the potential of stage of maturity of WCR at harvest and botanical fractions of WCR silage in order to predict the ME and MP content of WCR silage and to estimate the yield of WCR, for practical use.

2. Materials and methods

2.1. Samples

Thirty two samples of WCR and WCR silage were used, with each sample being the mean of four replications. Eight varieties of rice (*i.e.*, Akichikara, Fukuhibiki, Habataki, Hamasari, Hokuriku 168, Kusanami, Tamakei 96, Yumetoiro) were sown under similar agronomic and management conditions in Saitama Prefecture (Japan) and each variety was harvested four stages of maturity (*i.e.*, 10, 22, 34, 45 days after flowering (DAF)). 'Days of flowering' was defined as the time when half of the crops in the field had bloomed. Dry matter yield was calculated for each sample. Before harvest, plant height (cm), stem length (cm), head length (cm) and number of head/m^2 were measured from each plot. Each treatment of WCR was grown in a plot of 4 m × 4 m with three replications. Crops were harvested manually using a sickle approximately 10 cm above the ground, and ensiled in poly bags after vacuuming out the inside air without wilting, chopping or additives. This method was chosen in order to mimic production of round bale silage, which is a common way of making WCR silage in Japan (Islam et al., 2004c). Ensiled material was stored between 45 and 49 days. After opening, five 300 g fresh silage samples from each variety and each stage of maturity were fractionated into leaf blade, leaf sheath, stem or head.

All fractions were dried (*i.e.*, 60 °C for 48 h) and proportions of botanical fractions were calculated on a DM basis. The 'leaf' fraction consisted of the leaf blade plus leaf sheath, and the 'straw' fraction consisted of leaf plus stem. The 'head' fraction consisted of the rachis and grain. The head to straw ratio was calculated, and the biomass yield at harvest (before ensiling) was calculated on a DM basis (t DM/ha). Nutritive value estimates and proportions of botanical fractions were estimated on the ensiled material, but estimates of yield were based on the DM yield at harvest before ensiling.

After sampling for botanical fractionation, all fresh silage samples were mechanically chopped (Yamamoto P-156, Japan) to an average length of 2 cm. A portion of the chopped sample was dried at 60 °C for 48 h and ground using a hammer mill with a 1 mm sieve for chemical analysis. Another portion of fresh chopped silage was stored at −20 °C for ruminal *in situ* DM and N disappearance determination.

2.2. Chemical composition and fermentation characteristics of silage samples

Samples were analyzed in duplicate for DM by drying at 60 °C for 48 h and ash at 550 °C for 6 h, crude protein (CP; 977.02; AOAC, 1990), crude fat (EE) (920.39; AOAC, 1990); acid detergent fibre (ADFom; 973.18; AOAC, 1990), soluble OCW (Oa), insoluble OCW (Ob), organic cell content (OCC), CP in OCC and N free cell wall (NFCW) (Abe, 1988; Abe et al., 1979), neutral detergent fibre (aNDFom), lignin (sa) and acid detergent insoluble N (ADIN) (Van Soest et al., 1991). The organic acid