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Effects of conservation method and crushing method of rice grain on rumen fermentation and nutrient digestibility in steers

Makoto Miyaji*, Hidehiko Inoue, Tetsuo Kawaide, Masanori Tohno, Yuko Kamiya, Kazuhisa Nonaka

Institute of Livestock and Grassland Science, NARO, Nasushiobara, Tochigi, 329-2793, Japan

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ABSTRACT

We evaluated the effects of different methods for conserving and crushing rice grain on rumen fermentation characteristics and whole-tract apparent digestibility in steers. The preparation of dietary treatments followed a 2 × 2 factorial design with conservation method (drying *vs.* ensiling) and crushing method (using an impeller crusher *vs.* a double–roller crusher) of rice grain as main effects. Rice grain was crushed by the impeller crusher (volume weight: 490.4 g/L, mean particle size: 1382 μm) or the double–roller crusher (volume weight: 373.9 g/L, mean particle size: 2043 μm). Dried rice was prepared by drying to adjust the moisture to 100 g kg^{-1}. Ensiled rice was prepared by sealing crushed rice with the addition of water and lactic acid bacteria to adjust the moisture to 300 g kg^{-1}, and stored for 4 months. Eight ruminally cannulated steers (366 ± 32.2 kg initial body weight [BW]) were randomly assigned to a replicated 4 × 4 Latin square design. The experimental diets contained 434 g kg^{-1} grass silage, 96 g kg^{-1} soybean meal and 470 g kg^{-1} treated rice grain (dry matter [DM] basis). Steers were offered experimental diets at 1.55 kg DM/100 kg of BW/day. The conservation method had a large impact on the ruminal fermentation and nutrient digestibility. The ruminal fermentation characteristics and nutrient digestibility (except for starch digestibility) were not affected by the crushing method. No significant interactions were observed between the conservation and crushing methods of rice grain for all fermentation and digestion measurements. The ruminal pH was lower ($P < 0.01$) and the lactic acid and total volatile fatty acid concentrations were higher ($P < 0.01$ and $P = 0.02$, respectively) for the steers fed ensiled rice than those fed dried rice. The proportions of acetate, propionate and butyrate were not affected by ensiling treatment. The whole-tract apparent digestibility of organic matter, crude protein and starch were increased ($P = 0.04$, $P < 0.01$ and $P < 0.01$, respectively) and the digestibility of neutral detergent fiber and acid detergent fiber were decreased ($P = 0.046$ and $P = 0.03$, respectively) by replacing dried rice with ensiled rice. The starch digestibility was higher ($P < 0.01$) for steers fed rice crushed by the impeller crusher compared to the double-roller crusher. These results show that the feeding of ensiled instead of dried rice increases the likelihood of decreasing fiber digestibility because it reduces ruminal pH, but it improves organic matter, crude protein and starch digestion, and thus an ensiling process can be a strategy to improve the nutrient value of rice grain.

Abbreviations: ADFom, acid detergent fiber expressed exclusive of residual ash; aNDFom, neutral detergent fiber assayed with a heat stable amylase, sodium sulfite and expressed exclusive of residual ash; BW, body weight; CP, crude protein; DM, dry matter; DMI, dry matter intake; EE, ether extract; ERD, effective ruminal degradability; OM, organic matter; VFA, volatile fatty acid

* Corresponding author.
E-mail address: mmiyaji@affrc.go.jp (M. Miyaji).

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1. Introduction

Rice grain is widely produced around the world, and is increasingly being used as a dietary source for dairy and beef cattle and other livestock animals. The production of rice grain as a feedstuff has also been rising in Japan in recent years. Rice will decay over the long term if stored at a moisture content over 140 g kg^{-1} (Fleurat-Lessard, 2004), but harvested rice has an approximate moisture content of 200–250 g kg^{-1} (Nagato et al., 1964). Thus costly artificial-drying processes are needed when using dry grain rice as a feedstuff. On the other hand, ensiled rice grain prepared by sealing crushed rice with the addition of water and lactic acid bacteria could be a cheaper and promising alternative for the preservation of rice grain (Inoue et al., 2013a,b).

The process of ensiling grain generally changes the ruminal degradation characteristics; i.e., it increases the rumen digestible fraction (Krause et al., 2002; Hoffman et al., 2011; Miyaji et al., 2017). In addition, the use of dietary starch sources with different rumen-degradation properties can affect the nutrient digestion (Ferraretto et al., 2013), ruminal fermentation (Silveria et al., 2007) and nitrogen (N) utilization (Gozho and Mutsvangwa, 2008). Several research groups have reported that increasing ruminal starch digestibility due to replacing starch source resulted in fiber digestibility depression (Ferraretto et al., 2013; Miyaji et al., 2014) due to a lowering of ruminal pH (Harmison et al., 1997). Thus, the process of ensiling rice grain could increase ruminal fermentable starch, and the feeding of ensiled rice could have adverse effects on ruminal fermentation and fiber digestion. However, Aguerre et al. (2015) reported that the nutritive value of ground sorghum grain was increased by using an ensiling treatment rather than a dry one. Krause et al. (2002) and Ferraretto et al. (2013) also found that feeding ensiled corn grain instead of dry corn grain increased the starch digestibility. Therefore, ensiling treatment of rice grain could improve the nutrient digestibility. However, little research has been conducted to evaluate the effects of feeding ensiled rice grain on rumen fermentation and nutrient digestion.

Rice grain should be crushed before ensiling storage in order to prepare ensiled rice appropriately (Inoue et al., 2013a,b). In Japan, two types of portable rice–crushing machines have been developed and made available: an impeller–type crusher that crushes by impact force and a double roller–type crusher that crushes by shearing force (Shigeta et al., 2008). These different approaches to crushing would have major effects on the particle size, volume weight and other physical characteristics of the crushed rice, and could potentially impact the nutrient digestibility as well.

Our hypothesis in the present study was that (1) an ensiling treatment of rice grain will increase the ruminal digested starch content compared with a drying treatment, and (2) these differences in the availability of ruminal fermentable starch between the conservation methods could result in differences in the digestion and N balance. We also hypothesized that a rice–crushing method may alter the digestion and ruminal fermentation. Our objective in the present study, therefore, was to evaluate the effect of the conservation method (drying or ensiling) and the crushing method (using an impeller crusher or a double–roller crusher) for rice grain on *in situ* ruminal degradation characteristics and *in vivo* nutrient digestibility, rumen fermentation characteristics and N balance in steers.

2. Materials and methods

The method of feeding management used in this study was approved by the Animal Care and Use Guidelines of the NARO Institute of Livestock and Grassland Science of Japan.

2.1. Preparation of diets

The preparation of dietary treatments followed a 2 × 2 factorial design with the conservation method (drying *vs*. ensiling) and the crushing method (using the impeller crusher *vs*. the double–roller crusher) of rice grain as main effects. Mature rice was either crushed by an impeller crusher (SH-2; Otake Ltd, Ooharu, Japan) or by double–roller crusher (DHC4000; Delica Co., Matsumoto, Japan). The volume weights of crushed rice using the impeller and double–roller crushers were 490.4 and 373.9 g/L, respectively.

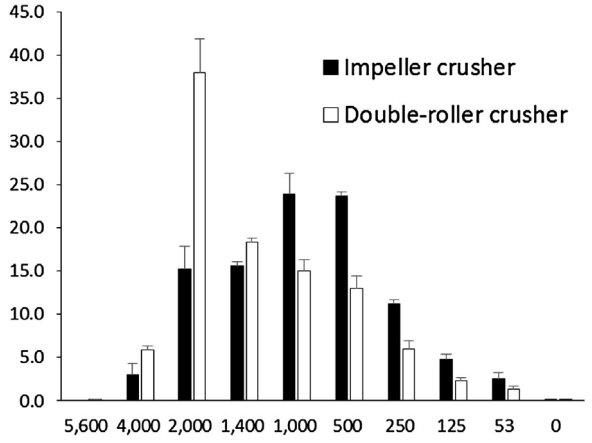

Fig. 1. Particle size distribution (percentage of retained particles on sieves) of crushed rice grain. Data are presented as the mean and standard error of each treatment.