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Effects of altering total mixed ration conservation method when feeding dry-rolled versus steam-flaked hulled rice on lactation and digestion in dairy cows

M. Miyaji*[1] and K. Nonaka†
*Hokkaido Agricultural Research Center, National Agriculture and Food Research Organization (NARO), Sapporo, Hokkaido, 062-8555, Japan
†Institute of Livestock and Grassland Science, NARO, Nasushiobara, Tochigi, 329-2793, Japan

ABSTRACT

We evaluated the effects of different methods of conserving the total mixed ration (TMR) and processing hulled rice (*Oryza sativa* L.) on intake, digestion, ruminal fermentation, lactation performance, and nitrogen utilization in dairy cows. Eight multiparous Holstein cows (126 ± 19 d in milk) were used in a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of dietary treatments. The experimental diets used fresh TMR and ensiled TMR containing either dry-rolled (DR) hulled rice or steam-flaked (SF) hulled rice. The fresh TMR was prepared every morning. The ensiled TMR was prepared by baling fresh TMR and then sealing it with a bale wrapper; this was stored outdoors at 10 to 30°C for >4 mo. The method of grain processing did not affect the dry matter (DM) intake. The DM intake tended to be greater for ensiled TMR than for fresh TMR. Apparent total-tract DM digestibility and milk yield were increased by feeding ensiled TMR instead of fresh TMR and by replacing DR with SF. An interaction effect between the TMR conservation method and the grain processing method was detected for DM digestibility and milk yield; replacing DR with SF increased the DM digestibility and milk yield in cows fed fresh TMR, but this did not affect the cows fed ensiled TMR. The milk fat and lactose contents did not differ among dietary treatments. The milk protein concentration was higher for the cows fed SF processed hulled rice than those fed DR, but it was not influenced by the TMR conservation method. The ruminal total volatile fatty acid concentration was higher for the cows fed ensiled TMR compared with those fed fresh TMR, but it was not affected by the grain processing method. The molar proportion of acetate was decreased and propionate was increased by feeding ensiled TMR instead of fresh TMR and by replacing DR with SF. The concentrations of rumen ammonia N and plasma urea N were higher for the cows fed ensiled TMR than fresh TMR and were lower for SF than DR. Feeding ensiled TMR instead of fresh TMR increased the cows' urinary N excretion and decreased the retention N. Replacing DR with SF decreased the urinary N excretion, increased the milk N secretion, and then improved the nitrogen efficiency. These results show that feeding ensiled TMR instead of fresh TMR has an adverse effect on N utilization, but it increases digestion and milk production. Replacing DR with SF also increases digestion, milk yield, and milk protein content, and the improvement of milk yield by replacing DR with SF was prominent in the cows fed fresh TMR.

Key words: ensiled total mixed ration, milk production, nitrogen balance, nutrient digestibility, processing method

INTRODUCTION

The practice of using ensiled TMR instead of fresh TMR as a dairy cow diet is increasing in Japan, along with an increase in the number of TMR centers, which are organizations that produce ensiled TMR and deliver it to neighboring dairy farmers. Ensiled TMR, which is prepared by ensiling fresh TMR, has several advantages such as the supply of homogeneous feed over time to cows, labor savings during the preparation of TMR, the opportunity to include wet food by-product, and improved aerobic stability (Nishino et al., 2003; Wang and Nishino, 2008; Xu et al., 2007, 2010). Because of these advantages, the practice of using ensiled TMR is increasing not only in Japan, but also in China and Israel (Weinberg et al., 2011; Yuan et al., 2015). Cao et al. (2010) reported that ensiled TMR increased nutrient digestibility and the digestible energy content compared with fresh TMR. It is thus possible that increasing nutrient digestibility by feeding ensiled TMR instead of fresh TMR could improve dairy cow lactation performance.

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[1]Corresponding author: mmiyaji@affrc.go.jp

However, the ruminal degradation characteristics of TMR are changed by ensiling. The rapidly degradable fraction and effective ruminal degradability of CP and starch increase during storage (Miyaji et al., 2017b). Miyaji et al. (2017a) suggested that increasing the rumen-digestible CP in diets could increase the excess N not used for microbial protein synthesis and increase the urinary N loss, because rumen-digestible CP that is not synthesized into microbial protein is absorbed from the rumen, converted to urea in the liver, and recycled to the gastrointestinal tract or excreted in urine (McDonald et al., 1995; Recktenwald et al., 2014; Mutsvangwa et al., 2016). In addition, some researchers have reported that increasing the rumen-digestible starch in the diets of cows resulted in depressions of DMI and decreased productivity among the cows (Oba and Allen, 2003; Miyaji et al., 2014). Thus, these adverse effects of feeding ensiled TMR on DMI and N utilization could occur.

Rice grain (*Oryza sativa* L.) is produced in many of the world's regions and may be an option as a dietary starch source in the future. The cultivation of rice, rather than of corn, barley, and wheat, is appropriate for the humid climates of East Asia, including Japan. Although the production of rice is increasing because of technology, the consumption has been reduced due to a population decrease and the westernization of food culture in some regions. Especially in Japan, hulled rice has recently begun to be used in dairy cow diets, and the cultivation area of rice grain for feed has been increasing.

The use of grain starch varies with the grain processing method (Dehghan-Banadaky et al., 2007). The dry-roll (**DR**) and steam-flake (**SF**) methods are the common techniques used to process grain as cold and hot physical processing methods, respectively. The SF process, which uses moisture, heat, and pressure, increases the gelatinization of starch granules (Dehghan-Banadaky et al., 2007) and thus increases the digestibility of starch (Svihus et al., 2005). Zinn et al. (1996) and Plascencia et al. (1998) reported that ruminal starch digestibility was higher for SF than for DR processing. In rice grain, the processing method has a large effect on ruminal degradation, and SF treatment is the effective method to digest starch; the effective ruminal degradability of starch is higher for SF than for cold physical processing methods such as DR and ground (Miyaji et al., 2010). Increasing the fermentable starch in the diet decreases urinary N losses and enhances milk production by increasing the ruminal microbial protein synthesis (Theurer et al., 1999; Krause et al., 2002; Miyaji et al., 2014). Thus, the SF processing of hulled rice could improve starch utilization, and then feeding SF-processed hulled rice instead of DR-processed hulled rice could improve dairy cow lactation performance and N utilization.

The objective of present study was to determine the effect of cold and hot physical processing methods for hulled rice on DMI, milk production, nutrient digestibility, N balance, ruminal fermentation characteristics, and blood metabolites in dairy cows fed fresh or ensiled TMR. Our hypothesis was that the TMR conservation method and grain processing method would influence nutrient digestibility, lactation performance, and N utilization. We expected that greater rumen-digestible starch from ensiled TMR or SF-processed hulled rice would increase milk production and nutrient digestion and improve N utilization compared with fresh TMR or DR-processed hulled rice. Alternatively, we speculated that increasing the rumen-digestible CP due to TMR ensiling could increase the urinary N loss.

MATERIALS AND METHODS

Cows, Diets, and Management

All animal studies were conducted in accordance with the animal care and use guidelines of the NARO Institute of Livestock and Grassland Science of Japan. Eight multiparous Holstein cows (3.1 ± 0.6 parity, 640 ± 26 kg of BW, 126 ± 19 DIM; ±SD) were randomly assigned to a replicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of dietary treatments. The experimental period was 21 d, with 14 d for treatment adaptation and 7 d for data collection. Treatments were the conservation method of TMR (fresh vs. ensiled TMR) and the processing method of grain (DR vs. SF). The experimental diets contained either DR or SF hulled rice at 33.5% of dietary DM and were supplemented with rye silage, beet pulp, soybean meal, vitamin mix, and mineral mix (Table 1). The DR grains were prepared by passing whole hulled rice through rollers without steaming. The SF grains were prepared by steaming whole hulled rice under atmospheric pressure at 100°C for 30 min in a chamber before passing through rollers. The particle size distribution of processed grains was measured by sieving using a sieve shaker (AS200; Retsch GmbH, Haan, Germany). Sieves with 5.60-, 4.00-, 2.00-, 1.40-, 1.00-, 0.50-, 0.25-, and 0.125-mm openings were used. The percentages of DR particles retained on each sieve were 0.0, 16.8, 44.8, 19.0, 13.8, 4.2, 0.5, 0.5, and 0.4%, and those of SF were 32.4, 38.3, 24.9, 2.5, 0.9, 0.6, 0.3, 0.2, and 0.0%, on sieves with openings of 5.60, 4.00, 2.00, 1.40, 1.00, 0.50, 0.25, and 0.125 mm and on a pan, respectively. The densities of grains were measured in triplicate by weighing a standard volume