J. Dairy Sci. 97:952–960
http://dx.doi.org/10.3168/jds.2013-7046

Effect of substituting brown rice for corn on lactation and digestion in dairy cows fed diets with a high proportion of grain

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ABSTRACT

The effects of the substitution of brown rice (*Oryza sativa* L.; BR) for corn (*Zea mays* L.) in ensiled total mixed ration (TMR) that had a high proportion of grain on feed intake, lactation performance, ruminal fermentation, digestion, and N utilization were evaluated. Nine multiparous Holstein cows (51 ± 9 d in milk) were used in a replicated 3 × 3 Latin square design with 3 dietary treatments: a diet containing 0, 20, or 40% steam-flaked BR and 40, 20, or 0% steam-flaked corn (dry matter basis). Cows were fed ad libitum an ensiled TMR consisting of 40.7% alfalfa silage, 11.8% grass silage, 7.1% soybean meal, and 40.0% steam-flaked grain (dry matter basis). The ensiled TMR was prepared by baling fresh TMR, and then sealed by a bale wrapper and stored outdoors at 5 to 30°C for over 6 mo. Dry matter intake and milk yield were lower for cows fed 40% BR than for cows fed 40% corn. The ruminal pH and total volatile fatty acid concentrations were not affected by dietary treatment. The ruminal ammonia-N concentration decreased as the percentage of BR in the diets was elevated. The proportion of acetate decreased, and that of propionate and butyrate increased with the increasing levels of BR. Plasma urea-N concentrations was lower and glucose and insulin concentrations were higher for cows fed 40% BR than for cows fed 40% corn. The whole-tract apparent digestibility of dry matter, organic matter, and starch increased, and the digestibility of neutral detergent fiber and acid detergent fiber decreased with the increasing BR level in the diet, with no dietary effect on crude protein digestion. As a proportion of N intake, the urinary N excretion was lower and the retention of N was higher for cows fed 40% BR than for cows fed 40% corn, with no dietary effect observed on N secretion in milk and fecal N excretion. These results show that substituting BR for corn decreases urinary N losses and improves N utilization, but causes adverse effects on milk production when cows are fed high-grain diets at 40% of dietary dry matter.

Key words: brown rice, dairy cow, ensiled total mixed ration, nitrogen balance

INTRODUCTION

Corn grain is used as the main dietary starch source in dairy farming. In Japan, however, brown rice grain (**BR**) has recently begun to be used in dairy cow diets as a partial substitute for corn grain due to high prices of imported corn grain, and the cultivation area of rice grain for feed has been increasing (MAFF, 2013a). Japan's National Agriculture and Food Research Organization (NARO, 2009) reported that the digestible and metabolizable energy of BR are 4.2 and 3.7 Mcal/kg and that those of corn grain are 4.1 and 3.6 Mcal/kg, respectively. Miyaji et al. (2012) reported the concentrations of CP, NDF, ADF, and starch as 7.5, 7.7, 2.8, and 67.4% for steam-flaked corn and 7.5, 5.3, 1.6, and 70.9% for steam-flaked BR (DM basis), respectively. Based on these similar energy and nutrient contents between corn grain and BR, BR is a potentially suitable replacement for corn grain in dairy cow diets.

The characteristics of ruminal starch degradation vary with the cereal grain sources (Huntington, 1997), and BR starch is digested in the rumen more rapidly than corn grain starch (Miyaji et al., 2012). In dairy cows, these differences in ruminal digestion characteristics due to the dietary starch source have a large impact on DMI (McCarthy et al., 1989), digestion (Harmison et al., 1997), milk fat concentration (Grummer, 1988), and N utilization (Krause et al., 2002; Cabrita et al., 2006; Gozho and Mutsvangwa, 2008). Miyaji et al. (2012, 2013) reported that the replacement of corn with BR had little effect on DMI, milk yield, and composition when cows were fed diets that contained 30.9 to 31.2% grain (DM basis). On the other hand, Oba and Allen (2003) reported that replacing the starch source that has a lower ruminal digestibility with one that has a greater ruminal digestibility resulted in DMI depressions and decreased the productivity of cows fed diets containing a high percentage of grain. Thus, increasing the ruminal starch digestibility by substituting BR for

Received May 20, 2013.
Accepted November 2, 2013.
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corn could cause adverse effects on the production of lactating cows fed diets containing a high proportion of grain. However, little research has been conducted to evaluate the effects of the substitution of BR for corn on the digestion and lactation performance of dairy cows when cows are fed diets with a high proportion of grain.

We hypothesized that differences in the ruminally digested starch content between corn and BR would result in differences in the productivity, ruminal fermentation, and N utilization when cows were fed diets with a high proportion of grain. Therefore, the objective of the present study was to evaluate the effect of substituting steam-flaked BR for steam-flaked corn on DMI, milk production, ruminal fermentation, blood metabolites, nutrient digestibility, and N balance in cows fed diets containing grain at 40% of dietary DM. Additionally, the practice of using ensiled TMR as dairy cow diets is increasing in Japan by increasing the number of TMR centers (MAFF, 2013b). The ensiled TMR has some advantages, such as the supply of homogeneous feed over time to cows, the labor savings during preparation of TMR, the opportunity to include wet food by-product, and the improvement in aerobic stability (Nishino et al., 2003; Wang and Nishino, 2008; Xu et al., 2007, 2010). Thus, in the present study, the experimental diet was fed as an ensiled TMR.

MATERIALS AND METHODS

All animal studies were conducted in accordance with the animal care and use guidelines of the National Agriculture and Food Research Organization (NARO) Institute of Livestock and Grassland Science of Japan (Nasushiobara, Japan).

Cows, Diets, and Management

Nine multiparous Holstein cows (3.0 ± 1.1 parity, 578 ± 68 kg of BW, 51 ± 9 DIM) were used in a replicated 3 × 3 Latin square design with 3 dietary treatments. The experimental period was 21 d, with 14 d for treatment adaptation and 7 d for data collection. The diets were formulated with 52.5% forage in combinations of alfalfa silage and grass silage, and 47.5% concentrate in combinations of steam-flaked cereal grain, soybean meal, minerals, and vitamins (DM basis). The dietary treatments were a diet containing 40.0% steam-flaked corn, 40.0% steam-flaked BR, or an equal mixture of steam-flaked corn and BR (Table 1). Both cereal grains were steamed under similar conditions (100°C for 20–30 min) and flaked. The densities of grains were measured in triplicate by weighing a standard volume (2 L) of processed grains. The volume weights of the processed corn and BR were 52.7 and 59.3 kg/100 L, respectively. The processing index of corn and BR, which was expressed volume weight after processing as a proportion of volume weight before processing, was 73.7 and 77.2, respectively. All experimental diets were formulated to meet or exceed the Japanese Feeding Standard for Dairy Cattle (NARO, 2006). The diets were fed as ensiled TMR. The ensiled TMR was prepared by baling fresh TMR using a round baler for chopped material (TSB1000; IHI STAR Machinery Corp., Chitose, Japan). The TMR was then sealed by a bale wrapper and stored outdoors at 5 to 30°C after preparation for over 6 mo. Throughout the experiment, the cows were housed in individual tie-stalls and had free access to fresh water. The cows were offered the diets for ad libitum intake (10% refusals) twice daily (0900 and 1900 h) and were milked in their stalls twice daily (0830 and 1830 h).

Data and Sample Collection

During d 15 to 20 of each period, the amount of feed offered and orts were weighed and recorded daily. Representative samples of ensiled TMR and orts were collected daily during d 15 to 20 of each period. The ensiled TMR sample was stored at −30°C for later

Table 1. Ingredient proportions, chemical composition, and fermentation characteristics of experimental ensiled TMR

	Corn:rice		
Item	40:0	20:20	0:40
Ingredient, % of DM			
Alfalfa silage	40.7	40.7	40.7
Grass silage	11.8	11.8	11.8
Steam-flaked brown rice	0.0	20.0	40.0
Steam-flaked corn	40.0	20.0	0.0
Soybean meal	7.1	7.1	7.1
Dicalcium phosphate	0.1	0.1	0.1
Mineral mix[1]	0.2	0.2	0.2
Vitamin mix[2]	0.2	0.2	0.2
Chemical composition			
DM, %	49.2	49.6	49.4
OM, % of DM	92.8	92.9	92.8
CP, % of DM	18.5	18.5	18.6
Ether extract, % of DM	4.2	3.6	3.2
NDF, % of DM	33.6	31.8	31.1
ADF, % of DM	25.4	25.3	25.2
Starch, % of DM	25.4	26.5	27.6
Fermentation profile			
pH	3.90	3.78	3.72
Lactic acid, % of DM	8.70	9.36	9.63
Acetic acid, % of DM	2.08	1.91	1.96
Propionic acid, % of DM	0.11	0.09	0.10
Butyric acid, % of DM	0.06	0.07	0.06
Volatile basic N, % of DM	0.13	0.12	0.12

[1]Contained 220 g of Ca/kg, 110 g of P/kg, and 100 g of Mg/kg.

[2]Contained 5,000,000 IU of vitamin A/kg, 600,000 IU of vitamin D_3/kg, and 20,000 mg of DL-α-tocopherol acetate/kg.