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Effects of Combination of Rice Straw with Alfalfa Pellet on Milk Productivity and Chewing Activity in Lactating Dairy Cows

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ABSTRACT: An experiment was conducted to determine the effects of diets containing coarse-texture rice straw and small particle size alfalfa pellets as a part of total mixed ration (TMR) on milk productivity and chewing activity in lactating dairy cows. Sixteen multiparous Holstein dairy cows (670±21 kg body weight) in mid-lactation (194.1±13.6 days in milk) were randomly assigned to TMR containing 50% of timothy hay (TH) or TMR containing 20% of rice straw and 30% of alfalfa pellet mixture (RSAP). Geometric mean lengths of TH and RSAP were found to be 5.8 and 3.6, respectively. Dry matter intake, milk yield and milk composition were measured. Moreover, eating and ruminating times were recorded continuously using infrared digital camcorders. Milk yield and milk composition were not detected to have significant differences between TH and RSAP. Dry matter intake (DMI) did not significantly differ for cows fed with TH or RSAP. Although particle size of TH was larger than RSAP, eating, ruminating and total chewing time (min/d or min/kg of DMI) on TH and RSAP were similar. Taken together, our results suggest that using a proper amount of coarse-texture rice straw with high value nutritive alfalfa pellets may stimulate chewing activity in dairy cows without decreasing milk yield and composition even though the quantity of rice straw was 40% of TH. (**Key Words:** Alfalfa Pellet, Chewing Activity, Dairy Cattle, Milk Productivity, Rice Straw, Timothy)

INTRODUCTION

Rice is the staple food in East and Southeast Asian countries, and it produces the largest amount of crop residues, called rice straw, that are used as a main feed for ruminants (Van Soest, 2006). Feed cost for dairies are continuously increasing because of commodity supply and pressure of land use (Bradford and Mullins, 2012). Rice straw is relatively cheaper than other roughage sources, but has low nutritive values with high fiber, silica and lignin contents and low dry matter digestibility (Wanapat et al., 2009). Silica and lignin contents in rice straw showed a negative correlation to hydrolysis performance (Jin and Chen, 2006), and negatively affects digestibility of forages (Van Soest and Jones, 1968; Smith et al., 1971; Agbagla-Dohnani et al., 2012). However, the indigestible and coarse-texture characteristics of rice straw stimulate chewing activity thus preventing metabolic disorders such as subacute ruminal acidosis. Balch (1971) also reported that eating, ruminating and total chewing time of the straw was longer than other hay, silage and concentrate.

In current high-producing dairy feeding systems, concerns to reconcile feeding energy-dense diets with adequate amounts of dietary physically effective fiber have been growing (Zebeli et al., 2011). In addition, in our previous study, a diet containing 15% rice straw (dry matter [DM] basis) as a sole source of roughage was as effective as the diet containing 50% timothy hay (TH, DM basis) with regard to total chewing and ruminating time in goats (unpublished).

Alfalfa pellet is a roughage source having high protein and digestibility, however, particle size of alfalfa pellets is too small to stimulate chewing activity. Khafipour et al. (2009) reported that replacement of 16% of the DM of alfalfa hay with alfalfa pellets induced subacute ruminal acidosis.

Based on these view points, we hypothesized that total mixed ration (TMR) based on rice straw and high protein

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alfalfa pellets would enhance chewing time leading to increased rumination. Thus, we evaluated the effect of the diet containing rice straw and alfalfa pellets as a roughage source against commonly used roughage source (TH) on milk production and chewing activity in mid-lactating dairy cows.

MATERIALS AND METHODS

Animals were cared for and handled in accordance with Konkuk University Animal Care and Use committee guidelines (Seoul, Korea).

Animals and management

Sixteen multiparous Holstein dairy cows (670±21 kg body weight) in mid-lactation (194.1±13.6 days in milk) were used for this experiment. Animals were kept in the pen, which was installed with individual feeding gates (American Calan, Inc., North-wood, NH, USA) and moved to milking parlors for milking twice daily at 05:00 and 17:00 h. Cows were fed a TMR twice daily at 09:00 and 16:00 h *ad libitum*. Animals had unlimited access to fresh water and mineral block. Feed offered and orts were measured daily during the experimental period to calculate feed intake.

Experimental design and sample collection

The experiment was conducted as a randomized complete block design with two treatments in two blocks. Experimental diets offered were TMR with 50% concentrate (based on corn and soybean meal) and 50% of TH or 20% of rice straw and 30% of alfalfa pellet mixture (RSAP) (Table 1). Animals were blocked by milk yield, parity number and days in milk, and were randomly assigned to one of the two experimental diets before the preliminary period. During the 33 d experimental periods, animals were offered one of the two TMR, and dry matter intake (DMI) and milk yield were measured daily from d 19 to d 33. Milk samples were collected at morning and afternoon of d 19, d 26, and d 33 for analysis of milk composition.

Feed and milk analyses

Samples of TMR were analyzed for dry matter, crude fiber, ether extract and ash by AOAC (1995) procedure. Neutral detergent fiber was analyzed according to Van Soest et al. (1991) and heat stable α-amylase (Sigma, St. Louis, MO, USA) was used during analysis. Particle size distribution of TMR was measured using the Penn State Particle Separator (PSPS; 19-, 8-, and 1.18-mm sieves) as described by Kononoff et al. (2003a), and all feed samples were sieved in triplicate. Geometric mean length (X_{gm}) and standard deviation (S_{gm}) were calculated as outlined by ASAE (2001) (S424) (Table 2).

Milk samples were stored at 4°C and preserved with Broad Spectrum Microtabs II (Advanced Instruments, Inc., Norwood, MA, USA), and sent to the Korea Animal Improvement Association Milk Testing Laboratory (An-

Table 1. Ingredients and chemical composition of experimental diet (DM basis)

Item	Diets[1]	
	TH	RSAP
Ingredients (% DM)		
Corn, cracked	27.96	33.12
Soybean meal	20.90	16.32
Timothy, hay	50.00	-
Rice straw	-	20.00
Alfalfa, pelleted (8 mm, 15% CP)	-	30.00
Limestone	0.56	-
Salt	0.29	0.28
Vitamin-mineral premix[2]	0.29	0.28
Chemical composition (% of DM)		
DM	59.18	60.69
CP	15.80	15.80
NDF	39.33	38.84
NDF from forages	31.93	31.24
ADF	22.47	23.60
EE	2.62	2.49
Ash	4.81	8.50

DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; EE, ether extract; TMR, total mixed ration.
[1] TH = TMR containing 50% of timothy hay, RSAP = TMR containing 20% of rice straw and 30% of alfalfa pellet.
[2] Contained 3,250 K IU/kg vitamin A, 500 K IU/kg vitamin D, 2,500 IU/kg vitamin K, 200 mg/kg vitamin B_1, 200 mg/kg vitamin B_2, 250 μg/kg vitamin B_{12}, 3,500 mg/kg niacin, 9,000 mg/kg choline chloride, 48,000 mg/kg methionine, 10,200 mg/kg glycine, 100 mg/kg β-carotene, 254 g/kg calcium, 38 g/kg phosphorus, 4,000 mg/kg manganese, 9,050 mg/kg zinc, 4,500 mg/kg iron, 200 mg/kg iodine, 45 mg/kg cobalt, 11,000 mg/kg magnesium, 2,300 mg/kg copper, 92 mg/kg selenium.

Table 2. Particle size distribution for timothy base TMR and rice straw base TMR as measured by the Penn State Particle Separator

Item	Diets[1]	
	TH	RSAP
% DM retained		
>19 mm	18.68	9.04
19 mm to 8 mm	21.73	19.39
8 mm to 1.18 mm	48.19	46.12
<1.18 mm	11.39	25.45
Xgm (mm)[2]	5.80	3.60
Sgm (mm)[3]	3.36	3.20

TMR, total mixed ration; DM, dry matter.
[1] TH = TMR containing 50% of timothy hay, RSAP = TMR containing 20% of rice straw and 30% of alfalfa pellet.
[2] Xgm = Geometric mean length as calculated by the ASAE (2001).
[3] Sgm = Standard deviation as calculated by ASAE (2001).

sung, Korea) for milk fat, milk protein, lactose and solid not fat analysis by using an infrared analyzer (Foss electric, Hillerød, Denmark).

Chewing activity

Chewing activity was recorded continuously using previously installed infrared digital recording camcorders (Digite, Seoul, Korea) without blind spot. Total chewing, eating and ruminating times were observed during 24 hours in the last five days of the experimental period. Data were expressed as daily eating, ruminating, or total chewing time by calculating the sum of eating and ruminating time during 24 hours. Chewing activity per kg DMI was calculated by dividing total minutes by DMI.

Statistical analyses

Data were analyzed as a completely randomized block design using MIXED procedure of SAS version 9.2 (SAS Institute, 2008). The statistical model included the fixed effect of diet and the random effect of block. The estimation method used was the restrictive maximum likelihood and the degrees of freedom method used was Kenward-Rogers. Comparison test was determined using PDIFF option and significance was declared at $p \leq 0.05$. A trend was considered to exist if $0.05 < p \leq 0.10$. All means presented are least squares means.

RESULTS AND DISCUSSION

Intake, milk production, and milk composition

Dry matter intake, milk yield and milk composition are summarized in Table 3. The DMI did not significantly differ for cows fed TH or RSAP, but tended ($p \leq 0.10$) to increase in RSAP. Milk yield, 4% fat corrected milk (FCM) and milk compositions were similar between the groups.

Usually, increasing the dietary forage to concentrate ratio reduces DMI due to filling effect of forages (Moorby et al., 2006; Yang and Beauchemin, 2007). But just as in this study, DMI was not affected when forage particle size was increased (Krause et al., 2002; Beauchemin et al. 2003; Kononoff and Heinrichs, 2003a; Yang and Beauchemin, 2009). In the case of early lactating dairy cows, DMI was increased by reducing forage particle size (Kononoff and Heinrichs, 2003b). The non-significant differences in DMI also reflected in similar milk yield, 4% FCM and milk composition in cows fed with TH or RSAP. These results are similar to some studies where reducing forage particle size did not affect milk yield and composition (Beauchemin et al., 2003; Kononoff and Heinrichs, 2003b; Rustomo et al., 2006; Yang and Beauchemin, 2009; Kammes and Allen, 2012), but are in contrast to others reporting a linearly reducing milk yield and milk fat when alfalfa hay was gradually replaced with the alfalfa pellet (Khafipour et al., 2009). However, in the current study, we compared two diets using different roughage sources but having similar nutritional value meeting the requirement of lactating cows. This suggests that a proper combination of rice straw and alfalfa pellets can replace TH without decreasing of milk yield and composition.

Chewing activity

Time and time per kg DMI for eating, ruminating and total chewing are presented in Table 4. No significant differences on eating, ruminating and total chewing time (min/d or min/kg of DMI) were detected. Although there were no measurements of ruminal parameters, visible signs of metabolic disorders and difference of chewing activities were not detected in the cows.

Chewing activities of cows were affected by body size (Bae et al., 1983), breed (Welch et al., 1970), fasting (Welch and Smith, 1968), forage intake (Welch and Smith, 1969a), forage quality (Welch and Smith, 1969b), forage maturity (Lippke, 1980), particle size (Yang and Beauchemin, 2009) and fibrousness characteristics (Balch, 1971). In the current study, body size, breed, fasting and feed intake were controlled in homogeneous conditions, but there were

Table 3. Dry matter intake, milk production and composition of cows fed experimental diets

Item	Diets[1]		SEM	p-value
	TH	RSAP		
Dry matter intake (kg/d)	24.34	26.04	0.67	0.0967
Milk yield (kg/d)	24.85	25.35	2.12	0.5840
4% FCM (kg/d)	26.62	26.04	2.64	0.6327
Milk fat (%)	4.50	4.18	0.24	0.3743
Milk protein (%)	3.43	3.25	0.09	0.1744
Lactose (%)	4.56	4.64	0.06	0.3687
Solid not fat (%)	8.62	8.52	0.10	0.5089

SEM, standard error of the mean; FCM, fat corrected milk; TMR, total mixed ration.

[1] TH = TMR containing 50% of timothy hay, RSAP = TMR containing 20% of rice straw and 30% of alfalfa pellet.

Table 4. Chewing activity of cows fed experimental diets

Item	Diets[1]		SEM	p-value
	TH	RSAP		
Min/24 h				
Eating	335.67	309.17	18.50	0.3351
Ruminating	439.00	485.66	30.52	0.2528
Total chewing time	774.17	791.83	36.07	0.7363
Min/kg DMI				
Eating	13.21	12.17	0.73	0.3375
Ruminating	17.28	19.12	1.20	0.2545
Total chewing time	30.49	31.19	1.42	0.7373

SEM, standard error of the mean; DMI, dry matter intake; TMR, total mixed ration.

[1] TH = TMR containing 50% of timothy hay, RSAP = TMR containing 20% of rice straw and 30% of alfalfa pellet.

forage quality, particle size and fibrous characteristics differences between TH and RSAP. However, significant differences were not detected in chewing characteristics, even though there were particle size differences between TH and RSAP. This re-validates our previous findings (unpublished) where effect of a diet containing a small amount of rice straw was not different to a diet containing large amount of TH with regard to total chewing and ruminating time in goats.

As rice straw was used after threshing the rice grain, it obviously possessed a low degradation rate of nutritive components, starch, protein and lipid, and was highly lignified due to late harvesting time compared to other forage sources which are grown primarily as feedstuff for animals. In addition, rice straw contains more silica than other cereal straws (Van Soest, 2006). Silica content in rice straw is an important factor in structural strength and digestibility (Van Soest and Jones, 1968; Smith et al., 1971; Bae et al., 1997; Agbagla-Dohnani et al., 2012), but the relationships between silica content and degradability of morphological fractions are still unclear (Ghasemi et al., 2013).

Balch (1971) reported straw showed longer eating, ruminating and total chewing time than other hay, silage and concentrate. Woodford and Murphy (1988) observed a significant reduction of the time spent ruminating and chewing, ruminal fluid outflow and pH when alfalfa hay was gradually replaced with alfalfa pellets. Khafipour et al. (2009) reported that replacing of 16% of DM of alfalfa hay with alfalfa pellets increased lipopolysaccharide in rumen fluid inducing subacute ruminal acidosis. However, both studies (Woodford and Murphy, 1988; Khafipour et al., 2009) were conducted comparing alfalfa with alfalfa pellets, whereas, in the current study, we used different roughage sources having different physical characteristics. Thus, although alfalfa pellets, which has a small particle size, have less effect on chewing stimulation, coarse-textured rice straw with alfalfa pellets stimulates chewing activity in dairy cows even though the quantity of rice straw was 40% of the TH.

CONCLUSION

Rice straw has low digestibility and nutritive values, on the other hand, it has coarse-texture and cheaper price than other roughage sources in East and Southeast Asian countries. In current dairy feeding systems, rice straw is not widely used in high-producing dairy animals due to its low nutritive values. The results suggested that using a combination of the proper amount of rice straw and other high nutritive roughage such as alfalfa pellets in a TMR can very well replace the other high nutritive and expensive roughage sources without adversely affecting milk production and chewing activity of mid-lactating dairy cattle.

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