Asian-Aust. J. Anim. Sci.
Vol. 23, No. 11 : 1469 - 1475
November 2010

www.ajas.info

Effects of Feeding Methods of Total Mixed Ration on Behavior Patterns of Growing Hanwoo Steers

Sangmoo Lee[1], Youngil Kim, Youngkyoon Oh[2] and Wansup Kwak*

Department of Animal Science, College of Natural Sciences, Konkuk University, Chung-Ju, Chung-Buk, 380-701, Korea

ABSTRACT : A study was conducted to investigate the effects of methods of feeding a total mixed ration (TMR) on behavior patterns of growing Hanwoo steers. A total of 15 growing steers (13 months old) were assigned to the control (fed roughage and concentrate mix separately), TMR1 (fed restricted TMR), and TMR2 (fed TMR *ad libitum*) groups. Individual behaviors of steers were observed for 48 hours. Compared with the control, feeding restricted TMR (TMR1) resulted in short eating time, long ruminating time, short chewing time, high frequencies of defecation, urination, and drinking of water, great numbers of boluses and chews, long ruminating time per bolus, low feed value index, high eating and chewing efficiencies ($p<0.05$). Compared with feeding restricted TMR (TMR1), feeding TMR *ad libitum* (TMR2) resulted in 1.2 kg more daily feed DM intake, long eating and chewing times, short resting time, great frequencies of defecation, urination and drinking of water, more numbers of boluses and chews, long ruminating time per bolus, low feed value index, low eating and high ruminating efficiencies ($p<0.05$) and similar chewing efficiency ($p>0.05$). Considering all these results, the wet TMR feeding system induced generally more desirable eating and ruminating behaviors of growing Hanwoo steers, but made the barn floor wetter due to more defecation and urination. (**Key Words :** Behavior, Rumination, Total Mixed Ration, Beef Cattle, Hanwoo)

INTRODUCTION

The eating behavior of ruminants, such as feed intake, ruminating time and number of chews, varies by feed type and physical characteristics and absolutely affects the digestive physiology of the ruminant. Moreover, it is used as an indicator of the physical and chemical characteristics of roughage (Lee et al., 2004b; Lee et al., 2008). Particularly, the physical shape and feeding ratio of roughage affect the eating and ruminating time (Gill et al., 1969; Castle et al., 1979) and considerably change the buffering capacity in the rumen by affecting the secretion of saliva (Bartley, 1976).

Chewing during rumination separates the liquid component from the rest of the feed and increases the surface area of the feed to facilitate the enzymatic activity of microorganisms in the rumen by masticating the ingested feed and destroying its structure (Reid et al., 1962; Pond et al., 1984). A recent study by Lee et al. (2008) on the concentrate mix-rice straw feeding system showed that ruminating time, number of boluses and chewing movements, and feed value index (FVI) were slightly lower when small particles of spent mushroom substrates were fed compared with long particles of rice straw, but that the eating, ruminating and chewing efficiencies were higher than when only rice straw was fed. Thus, the type, quality, and shape of feed had various influences on the expression of chewing activities (Jeon et al., 1997), and the understanding of the pattern and procedure of chewing activities during eating or ruminating of ruminants can provide important data in order to more effectively grow and fatten beef cattle with cheap by-product feeds and TMR.

Recently, an increasing number of stockbreeders of Hanwoo steers have been switching from the conventional concentrate mix-rice straw feeding system to the TMR feeding system, in which roughage and concentrate mix are mixed together rather than fed separately. Feeding TMR allows stockbreeders to save on feed cost by using a variety of agricultural by-products and farm-grown forage. It also improves livestock productivity. The TMR feeding system,

* Corresponding Author : Wansup Kwak. Tel: +82-43-8403521, Fax: +82-43-8518675, E-mail: wsk@kku.ac.kr
[1] Department of Animal Science, Kyungpook National University, Sang-Ju, Kyungbuk, 742-711, Republic of Korea.
[2] National Institute of Animal Science, RDA, Kyungkido, Korea.
Received March 16, 2010; Accepted July 12, 2010

however, results in severe selective eating because it provides concentrates and roughage simultaneously, and stockbreeders tend to cut roughage thin and short because long roughage tends to separate from the concentrates and to increase the volume of the diet. Roughage that is shorter than the acceptable length can cause reduced saliva production in the mouth due to the decreased physical properties, leading to decreased productivity due to semi-clinical and clinical acidosis and foot rot caused by reduced ruminal pH (Ki et al., 2003). In particular, if the particle size of the feed is small, it may become smaller after it is swallowed. Thus, it will rapidly leave the rumen, increasing the dry matter intake and its passage rate to the lower digestive tract (Jaster and Murphy, 1983; Weston and Kennedy, 1984; Martz and Belyea, 1986), whereas the rate of roughage digestion decreases because the retention time for microbial digestion in the rumen is shortened (Uden, 1987; Ki et al., 2003). Nevertheless, there is limited scientific understanding of the effects of TMR feeding methods on the eating and behavioral patterns of growing Hanwoo steers.

This study was conducted to investigate the effect of TMR feeding methods (restricted or *ad libitum*) on the general eating bahaviors and defecating and urinating activities of growing Hanwoo steers.

MATERIALS AND METHODS

Animals and treatment

Five growing steers of average age 13 months and average body weight 316-346 kg were assigned to each treatment group. The control group was fed 4.7 kg/d concentrate mix (a normal commercial formulated feed for growing Hanwoo steers) on a restricted basis and had free access to rice straw and timothy hay; the TMR1 group was fed 13 kg wet TMR per day on a restricted basis; and the TMR2 group was fed wet TMR *ad libitum*. The expected feed DM intake was designed to be identical at 2.4% of body weight for the control and TMR1 groups, respectively, and was 2.6% of body weight for the TMR2 group. The steers were fed at about 7 am and 7 pm (twice daily), and they had free access to water and mineral blocks. All the steers had been accustomed to their treatment diets and housing environment for more than 4 months before this experiment.

Ingredient and chemical composition of the experimental feeds and diets

Chemical composition of the experimental feeds : The rice straw was sun-dried, containing 90.3% dry matter (DM), 3.8% crude protein (CP), 1.2% ether extract (EE), 70.9% neutral detergent fiber (NDF), 44.9% acid detergent fiber (ADF), 26.0% hemicellulose, 13.3% non-fibrous carbohydrate, and 10.8% crude ash on a DM basis. The timothy hay contained 88.9% DM, 12.2% CP, 1.5% EE, 70.6% NDF, 39.7% ADF, 30.9% hemicellulose, 7.9% non-fibrous carbohydrate, and 7.8% crude ash. The commercial concentrate mix contained 88.0% DM, 14.7% CP, 3.0% EE, 34.7% NDF, 20.6% ADF, 14.1% hemicellulose, 38.4% non-fibrous carbohydrate, and 9.1% crude ash.

Composition of concentrate mix and TMR fed to steers : The commercial concentrate mix contained 28.0% corn grain, 14.0% coconut meal, 13.2% wheat bran, 10.0% wheat grain, 7.0% palm meal, 6.1% rapeseed meal, 6.0% cane molasses, 5.0% corn gluten feed, 5.0% wet distillers grain, 1.7% wheat flour, 1.4% tapioca pellets, 0.2% NaCl, 0.1% vitamin premix, 0.1% mineral premix, and 2.3% other additives on a dry matter basis. The TMR contained 35.3% corn gluten feed, 28.4% tall fescue, 16.3% corn grain, 5.9% alfalfa bale, 3.5% citrus juice pulp, 2.9% whole cottonseeds, 2.4% cane molasses, 1.7% wheat bran, 1.7% barley bran, 1.4% palm meal, 0.2% vitamin premix, 0.2% mineral premix, and 0.1% NaCl on a dry matter basis.

The chemical composition of diets fed to steers is presented in Table 1. The control diet composed of concentrate mix, rice straw and timothy hay contained 12.5% CP and 48.4% NDF. The roughage and concentrate ratio of the control diet was 38.2:61.8 on a dry matter basis. The TMR fed restricted (TMR1) or *ad libitum* (TMR2) contained 41.2% moisture, 12.5% CP, and 48.4% NDF. The roughage and concentrate ratio of TMR was 34.3:65.7. The roughage ratio of TMR was 3.9% less than that of the control diet.

Particle size of the experimental feed : The particle sizes of the experimental feed were measured using a Penn State particle separator (PSPS), according to the method employed by Kononoff and Heinrichs (2003). The PSPS consisted of three sieves (1.18, 8, and 19 mm) that could separate feed into four different types depending on the particle size.

For the physical effectiveness factor, the proportion of the particle size above 8 mm was considered $pef_{8.0}$ according to the method employed by Lammers et al.

Table 1. Chemical composition of the diets fed to steers[1]

Items	Control	TMR
	---------------- % ----------------	
Dry matter	88.5	58.8
Crude protein	12.5	11.5
Ether extract	2.4	2.6
Crude ash	9.1	8.5
Neutral detergent fiber	48.4	48.4
Acid detergent fiber	28.6	33.7
Hemicellulose	19.8	14.7
Nonfibrous carbohydrate	27.5	29.0

[1] On a dry matter basis.

Table 2. Particle size distribution of feeds and diets

Items	Rice straw	Timothy hay	Concentrate mix	Control[1] diet	TMR
PSD[2]% DM retained on sieves					
Above 19.0 mm	97.8	56.3	-	27.5	14.7
8.0-19.0 mm	1.2	16.2	84.8	56.5	18.4
1.18-8.0 mm	0.9	17.3	14.7	13.3	46.0
Below 1.18 mm	0.2	10.2	0.5	2.8	21.0

[1] The control diet consisted of rice straw, timothy hay and concentrate mix. [2] PSD = Particle size distribution.

(1996), and the proportion of the particle size above 1.18 mm was considered $pef_{1.18}$ according to the method employed by Kononoff et al. (2003). The $peNDF_{8.0}$ and $peNDF_{1.18}$ were calculated by multiplying the NDF% by $pef_{8.0}$ and $pef_{1.18}$, respectively.

Behavior observation methods and analysis

Thirty-well trained inspectors were recruited to observe two steers per inspector on a two-hour shift. The behavior of individual steers was observed with the naked eye for 48 h (2 d) at 1-min intervals, and was recorded on a plotting paper. Feed intake was calculated by determining the difference between the supplied and the remaining amount of feed, and the remaining feed was retrieved and measured before the meal time the next morning. The eating/ruminating/resting time, the number of boluses, and the frequency of defecation and urination were observed with the naked eye and were recorded. The chewing time was calculated by adding the eating and ruminating times, and the feed value index was calculated based on the chewing time per unit dry matter intake (Balch, 1971). The eating, ruminating, and chewing efficiencies were calculated by dividing the voluntary DM intake by the eating, ruminating, and chewing time, respectively.

Feed samples were analyzed for DM, CP, NDF, ADF, EE, and crude ash according to the methods of AOAC (2000).

Statistical analysis

For statistical analysis of the results, analysis of variance was performed using the General Linear Model procedure of Statistical Analysis System (SAS, 2002), and the significance for each treatment group was tested at the 5% and 1% significance levels using Duncan's multiple-range test.

RESULTS AND DISCUSSION

Particle sizes of feeds and diets

The particle sizes of rice straw, timothy hay, concentrate mix, control diet and TMR used for this experiment are presented in Table 2. The proportion of the particle size above 8 mm was 2.5 times higher for the control diet and the proportion below 8 mm was 4.2 times higher for TMR.

Daily feed intake

The daily feed intake per treatment group is presented in Table 3. The feed DM intake was 7.6 kg for the control, 7.9 kg for TMR1 (with restricted TMR), and 9.1 kg for TMR2 (with TMR *ad libitum*). The feed intake per 100 kg body weight, which was designed to be identical for the control and TMR1, was 2.4 kg for the control, 2.4 kg for TMR1 and 2.6 kg for TMR2. The TMR2 group showed a higher feed intake than the TMR1 group because of their free access to the TMR. Compared with the control group, the increased intake was partly attributed to the fact that the particle size of TMR2 was smaller than that of the control, that the TMR maintained pH homeostasis in the rumen (Nocek et al., 1986) and increased the intake and bodily utilization of dry matter due to such homeostasis (Harrison et al., 1989;

Table 3. Daily intake of growing Hanwoo steers fed different diets[1]

Items	Control	TMR1	TMR2
	kg/d		
Concentrate mix	4.7±0.0	-	-
Rice straw	1.1±0.3	-	-
Timothy hay	1.8±0.1	-	-
TMR	-	7.9±0.1	9.1±1.7
Total feed DM intake	7.6±0.3[a]	7.9±0.1[a]	9.1±1.7[b]
Intake/body weight, 100 kg	2.4±0.1[a]	2.4±0.0[a]	2.6±0.3[b]
Feed NDF intake	3.7±0.2[a]	3.8±0.1[a]	4.4±0.4[b]

[1] On a dry matter basis. [a, b] Means within the same row with different superscripts are significantly different (p<0.05).

Kellems et al., 1991), and that the small particle size of the feed induced an increased dry matter intake (Kato et al., 1989; Jeon et al., 2001).

Eating, ruminating, resting and excreting behaviors

The effect of TMR feeding on the eating, ruminating, and resting behaviors of growing Hanwoo steers is presented in Table 4. The eating time was longest in the control group (365.5 min/d) and shortest in the TMR1 group (245.8 m/d), and the eating times of the TMR1 and TMR2 groups were shorter than for the control group ($p<0.01$). Lee et al. (2008) reported that eating time was longer in Hanwoo steers that were fed rice straw with long particles than in those that were fed short particles of spent mushroom substrates. Kim et al. (1994) showed that the eating time significantly decreased in Korean native cattle that were fed 3-cm-long rice straw compared with those fed 9- and 15-cm-long rice straw. Besides, Jeon et al. (1997) demonstrated that the eating time was twofold longer in Korean native cattle that were fed rice straw as a roughage source than in those fed wild oats and bagasse. Based on these results, it is considered that the shorter eating time in the TMR group in this study can be attributed to the smaller particle size.

The entire ruminating time was longer in the TMR2 group than in the control group ($p<0.05$). Beauchemin and Buchanan (1989) and Woodford et al. (1986) reported that the higher the NDF content, the longer the ruminating time. In this study, NDF intake was greater in TMR2 than in the control, and it is believed that this was what caused the longer ruminating time. In addition, the time spent ruminating while standing was longer than that spent while seated. The TMR1 group, which had the shortest eating time, showed the longest resting time, and the control group showed the shortest resting time ($p<0.05$). The chewing time (eating time+ruminating time) was in the following order: control>TMR2>TMR1 ($p<0.05$). For comparison of the TMR groups, the chewing time for TMR1 was shorter than that for TMR2, which can be attributed to the higher feed intake on TMR2.

For frequency of defecation (Table 4), the TMR groups showed a much higher frequency than the control group ($p<0.01$). Ryu et al. (1998) reported that the frequency of defecation of Korean native cattle that were fed rice straw *ad libitum* and restricted from concentrate mix was 9.8/d for seven-month-old steers, 10/d for 11-month-old steers, and 8.2/d for 15-month-old steers. Lee et al. (2008) reported that the frequency was 11.5/d in 13-month-old steers. Compared with these results, the control steers in this study showed a similar frequency of defecation, whereas TMR1 and TMR2 steers showed more frequent defecation.

For frequency of urination, there was no significant difference ($p>0.05$) between the control and TMR1, whereas urination was more frequent in TMR2 (16.0/d) compared with the control and TMR1 ($p<0.01$). The more frequent defecation and urination in TMR1 and TMR2 than in the control can be attributed to more feed intake and the wet property of the TMR, which contained 42.2% moisture (Table 2). In particular, during the experiment, the pen floors of TMR1 and TMR2 treatments were considerably wetter than that of the control. This was considered to have been due to the increased frequency of defecation and urination of the TMR groups compared with the control.

Considering the aforementioned causes, the time that the Hanwoo steers spent ruminating and resting while standing increased appreciably in the TMR groups compared with the control group because the increased frequency of defecation and urination made the floors apparently much wetter.

Table 4. Chewing, ruminating, resting, and excreting behaviors of growing Hanwoo steers fed different diets[1]

Items	Control	TMR1	TMR2
Eating time (min/d)	365.5 ± 31.3^{A}	245.8 ± 21.9^{C}	315.2 ± 9.7^{B}
Ruminating time (min/d)	357.7 ± 21.0^{b}	391.6 ± 14.5^{a}	403.4 ± 24.9^{a}
Standing	42.6 ± 14.2^{b}	120.1 ± 18.6^{a}	105.6 ± 59.9^{a}
Sitting	315.1 ± 12.7	291.5 ± 20.5	297.8 ± 39.2
Resting time (min/d)	716.8 ± 57.6^{b}	802.6 ± 39.0^{a}	721.4 ± 16.8^{b}
Standing	307.8 ± 42.9^{b}	420.8 ± 29.4^{a}	355.6 ± 56.5^{ab}
Sitting	409.0 ± 69.7	381.8 ± 31.2	365.8 ± 53.7
Total time (min/d)	1,440.0	1,440.0	1,440.0
Chewing time (min/d)[2]	723.3 ± 57.6^{a}	637.5 ± 9.9^{b}	718.6 ± 28.8^{a}
Defecating frequency (no./d)	11.8 ± 2.8^{B}	16.5 ± 1.8^{A}	17.6 ± 2.1^{A}
Urinating frequency (no./d)	11.0 ± 2.1^{B}	12.5 ± 1.7^{B}	16.0 ± 1.2^{A}
Drinking frequency (no./d)	7.8 ± 1.9	9.6 ± 2.3	10.8 ± 2.0

[1] Means of 5 observations. [2] Chewing time = ruminating time+eating time.
[A,B,C] Means within the same row with different superscripts are significantly different ($p<0.01$).
[a,b,c] Means within the same row with different superscripts are significantly different ($p<0.05$).

Table 5. Numbers of boluses, numbers of total chews, ruminating time per bolus, and FVIs of growing Hanwoo steers fed different diets[1]

Items	Control	TMR1	TMR2
No. of boluses	328.0±15.4[B]	386.4±41.2[A]	423.5±30.7[A]
No. of total chews	16,301±383[B]	20,478±2,054[A]	21,386±1,628[A]
Ruminating time/bolus (s)	65.4±5.0	60.8±2.3	57.2±3.31
No. of chews/bolus	49.7±1.2	53.0±2.8	50.5±0.7
Boluses/min	0.92±0.07[b]	0.99±0.04[ab]	1.05±0.02[a]
FVI[2] (min/kg, DM)	95.2±7.6[A]	80.7±1.3[B]	79.0±3.2[B]

[1] Means of 5 observations. [2] FVI = Feed value index (chewing time/feed intake, 1 kg).
[a,b,c] Means within the same row with different superscripts are significantly different ($p<0.05$).
[A,B,C] Means within the same row with different superscripts are significantly different ($p<0.01$).

Bolus, chewing and feed value index

The effects of TMR feeding on the number of boluses and chews and on the feed value index are shown in Table 5. The number of boluses during rumination was 328.0 in the control, 386.4 in TMR1, and 423.5 in TMR2, with TMR1 and TMR2 showing significantly higher bolus numbers than the control ($p<0.01$). There was no significant difference, however, between the bolus numbers of TMR1 and TMR2 ($p>0.05$). Lee et al. (2004a) and Jeon et al. (1997) reported that the shorter the cutting length (particle size) of the roughage, the lower the number of boluses. In the present study, however, although the particle sizes in TMR1 and TMR2 were small on average, the numbers of boluses were greater than in the control possibly because of the increased feed intake volume and the higher NDF intake, as reported also by Luginbuhl et al. (1989) and Beauchemin (1991).

The total numbers of chews were in the order of TMR2>TMR1>control, which were proportionate to the numbers of boluses ($p<0.01$). The ruminating time per bolus was longest in the control (65.4 s) and shortest in TMR2 (57.2 s), with no significant difference between the two groups. However, Kim et al. (1994) reported, that when 3-, 9-, and 15-cm-long rice straws were fed, the chewing time increased with the length of the rice straw. No significant difference in the number of chews per bolus (chewing rate) was shown between the groups, although the TMR groups showed slightly greater number of chews than the control. The results of the present study are consistent with those reported by Okine and Mathison (1991) and Luginbuhl et al. (1989), in which the number of chews per bolus increased with the increase in NDF intake.

The number of boluses per minute was in the order of TMR2 (1.05)>TMR1 (0.99)>control (0.92), with no significant difference between TMR1 and TMR2, but with a significant difference between the control and TMR groups ($p<0.05$). The feed value index was 95.2 for the control, which was higher than for TMR1 and TMR2 (80.7 and 79.0, respectively) ($p<0.01$). Lee et al. (2008) reported that Hanwoo cattle which were allowed free access to rice straw or were fed 0.82 and 1.64 kg spent mushroom substrates with a small particle size showed FVIs of 92.8, 74.9, and 72.3, respectively. These results support the fact that eating time was longer in the control than in the TMR groups, as shown in Table 4, because most of the roughage sources in the control were longer and closer to the original form than those in the TMR groups.

Eating rate, ruminating efficiency and chewing efficiency

The effects of TMR feeding methods on eating rate, ruminating efficiency and chewing efficiency are presented in Table 6. The eating rate per hour was highest in TMR1 and lowest in the control ($p<0.01$). Kim et al. (1994) reported that the shorter the length of the feed, the higher the eating rate, although the difference was not significant. Jeon et al. (1997) reported that eating rate was higher with roughage of a smaller particle size. The results of the present study are consistent with these two studies. In the present study, the eating rate per ruminating hour (ruminating efficiency) was high in TMR2 and, although

Table 6. Eating rate, ruminating efficiency, and chewing efficiency of growing Hanwoo steers fed different diets[1]

Items	Control	TMR1	TMR2
Eating rate[2]	1,247.9±103.2[C]	1,926.8±190.0[A]	1,733.3±52.7[B]
Ruminating efficiency[3]	1,275.2±106.8[ab]	1,211.7±69.7[b]	1,354.2±87.3[a]
Chewing efficiency[4]	630.2±46.8[B]	743.2±11.7[A]	759.6±31.7[A]

[1] Means of 5 observations. [2] Voluntary DM intake (g/d)/eating time (h/d).
[3] Voluntary DM intake (g/d)/ruminating time (h/d). [4] Voluntary DM intake (g/d)/chewing time (h/d).
[A,B,C] Means within the same row with different superscripts are significantly different ($p<0.01$).
[a,b,c] Means within the same row with different superscripts are significantly different ($p<0.05$).

not significantly different from the control, it was different from TMR1 ($p<0.05$). Lee et al. (2008) reported that ruminating efficiency varied by feed characteristics, age, and health status, and Balch (1971) reported that ruminating efficiency was a key factor in deciding the physical characteristics of the feed.

The results in terms of eating rate per chewing hour (chewing efficiency) were in the order of TMR2 (759.6 g)> TMR1 (743.2 g)>control (630.2 g), with no significant difference between TMR1 and TMR2 but with a significant difference between the TMR groups and the control ($p<0.01$). Campling et al. (1966), Shaver et al. (1986), Woodford et al. (1986), and Ryu et al. (1998) reported that crushed and chopped feeds with a small particle size reduced the eating time compared with feeds in original form. Considering this, increased chewing efficiency in the TMR groups can be attributed to the increased eating rate and the decreased eating time. As such, the increase in feed DM intake by TMR feeding can also be explained by the improved eating and chewing efficiency.

In overall conclusion, compared with feeding the control diet, feeding restricted TMR (TMR1) resulted in short eating time, long ruminating time, short chewing time, great frequencies of defecation, urination, and drinking of water, great numbers of boluses and chews, long ruminating time per bolus, low feed value index, and high eating and chewing efficiencies ($p<0.05$).

Compared with feeding restricted TMR (TMR1), feeding TMR *ad libitum* (TMR2) resulted in 1.2 kg more daily feed DM intake, long eating, ruminating and chewing times, short resting time, great frequencies of defecation, urination and drinking of water, great numbers of boluses and chews, long ruminating time per bolus, low feed value index, low eating rate, and high ruminating efficiency ($p<0.05$) and similar chewing efficiency ($p>0.05$).

Considering all these results, feeding TMR *ad libitum* was found to be most effective for improving the eating rate, chewing efficiency, and ruminating activities (the number of boluses and chews, and the ruminating time). However, TMR feeding in either way showed an undesirable effect on the barn floor environment caused by more frequent defecation and urination.

IMPLICATIONS

Compared with the conventional concentrate mix-rice straw feeding system, feeding TMR restricted or *ad libitum* showed an increased wet feed intake followed by increased ruminating or chewing time, greater numbers of boluses (18-29% greater) and chews (26-31% greater), and increased eating, ruminating or chewing efficiency. These phenomena can improve the ruminal environment for enhanced animal productivity. However, it should be noted that all these outcomes can vary more or less depending on the ingredient and chemical composition of TMR, such as the quantity and quality of dietary fiber particularly.

In addition, the wet TMR feeding system made the barn floor wetter, resulting in a long time spent standing while ruminating or resting. This stress can have a negative effect on animal production. Therefore, more frequent floor cleaning is required for a better housing environment and animal performance.

ACKNOWLEDGMENTS

This study was funded by Sang-Ju Livestock Cooperatives as a part of Sang-Ju New Activity Movement project. The authors are grateful to Mr. J. H. Lee and his colleagues including undergraduate students recruited from Kyungpook University and Konkuk University for their dedicated animal behavior observations. Special thanks go to Mr. H. D. Jo, Mr. Whang and all other officials in Sang-Ju Livestock Cooperative and Mr. S. H. Kim in Sang-Ju city hall.

REFERENCES

AOAC. 2000. Official methods of analysis, 17th ed. Association of Official Analytical Chemists. Washington, DC, USA.

Balch, C. C. 1971. Proposal to use time spent chewing as an index of the extent to which diets for ruminants possess the physical property of fibrous characteristic of roughages. Br. J. Nutr. 26:383-392.

Bartley, E. E. 1976. Bovine saliva: production and function of buffers in ruminant physiology and metabolism. Church and Dwight Co., Inc., New York. USA.

Beauchemin, K. A. 1991. Effects of dietary neutral fiber concentration and alfalfa hay quality on chewing, rumen function, and milk production of dairy cows. J. Dairy Sci. 74:3140-3151.

Beauchemin, K. A. and S. Buchanan. 1989. Effects of dietary neutral fiber concentration and supplementary long hay on chewing activities and milk production of dairy cows. J. Dairy Sci. 72:2288-2300.

Campling, R. C., M. Freer and C. C. Balch. 1966. Factors affecting the voluntary intake of food by cows. Br. J. Nutr. 17:263-272.

Castle, M. E., W. C. Retter and J. N. Watson. 1979. Silage and milk production: comparisons between three silages of different chop lengths. Grass Forage Science 34:293-301.

Gill, S. S., H. R. Conrad and J. W. Hibbs. 1969. Relative rate of *in vitro* cellulose disappearance as a possible estimator of digestible dry matter intake. J. Dairy Sci. 52:1687-1690.

Harrison, J. H., R. E. Riley and K. A. Long. 1989. Effect of type and amount of buffer addition to grass silage-based total mixed ration on milk production and composition. J. Dairy Sci. 72:1824-1825.

Jaster, E. H. and M. R. Murphy. 1983. Effects of varying particle size of forage on digestion and chewing behavior of dairy heifers. J. Dairy Sci. 66:810.

Jeon, B. T., S. H. Moon, Y. J. Kwon and W. S. Kwak. 2001. Effect of supplementary level of fermented broiler litter on the dry matter intake, digestibility and nitrogen balance in female spotted deer (*Cervus Nippon*). Korean J. Anim. Sci. 43(5)730-731.

Jeon, B. T., I. H. Park, S. M. Lee, K. H. Kim, J. S. Kim and J. C. Son. 1997. The effect of different fiber sources on chewing behavior of Korean native cattle. Korean J. Anim. Sci. 39(4):385-388.

Kato, K., Y. Kajima, M. Odashima, L. S. Lee, K. T. Nam, H. Chiga, Y. Shoji, M. Otha and Y. Sasaki. 1989. Feed passage and digestibility in Japanese deer and sheep. Research report of Kawatabi experimental station 5:59-62.

Kellems, R., O. R. Jones, D. Andrus and M. V. Wallentine. 1991. Effect of moisture in total mixed rations on feed consumption and milk production and composition in Holstein cows. J. Dairy Sci. 74:929-932.

Ki, K. S., H. S. Kim, H. Y. Jeong, H. J. Lee, B. S. Ahn, J. S. Kim, S. W. Kwang, Y. K. Kim and J. K. Ha. 2003. The survey of particle of total mixed ration in Korea. Korean J. Anim. Sci. Technol. 5(5):813-818.

Kim, C. M., B. S. Lee and T. Y. Chung. 1994. Influence of cutting length of ammoniated barley straw on the eating and ruminating behavior of Korean native cattle. Korean J. Anim. Sci. 36(5)487-493.

Kononoff, P. J. and A. J. Heinrichs. 2003. The effect of reducing alfalfa haylage particle size on cows in early lactation. J. Dairy Sci. 86:1445-1457.

Lammers, B. P., D. R. Buckmaster and A. J. Heinrichs. 1996. A simple method for the analysis of particle sizes of forage and total mixed rations. J. Dairy Sci. 79:922-928.

Lee, S. M., J. H. Hwang, Y. B. Yoon, W. S. Kwak, Y. I. Kim, S. H. Moon and B. T. Jeon. 2008. Effects of spent mushroom substrates addition on eating behavior of growing Hanwoo. Korean J. Grassl. Forage Sci. 28(2):107-118.

Lee, W. S., B. S. Lee, S. C. Lee, S. S. Lee, S. Y. Lee, D. Y. Lee and J. K. Ha. 2004a. Effects of rice straw and rice hull supplement on rumination and chewing behavior in Hanwoo steers. Korean J. Anim. Sci. 46(1):49-54.

Lee, W. S., B. S. Lee, Y. K. Oh, S. W. Kang, S. S. Lee and J. K. Ha. 2004b. Effects of concentrate to roughage ratios on duration and frequencies of rumination and chewing in Hanwoo steers. Korean J. Anim. Sci. 46(1):55-60.

Luginbuhl, J. M., K. R. Pond, J. C. Burns and J. C. Russ. 1989. Eating and ruminating behavior of steers fed bermudagrass hay at four levels. J. Anim. Sci. 67:3410-3418.

Martz, F. A. and R. L. Belyea. 1986. Role of particle size and forage quality in digestion and passage by cattle and sheep. J. Dairy Sci. 69:1996-2008.

Nocek, J. E., R. E. Steele and D. G. Braund. 1986. Performance of dairy cows fed forage and grain separately versus a total mixed ration. J. Dairy Sci. 69:2140-2147.

Okine, E. K. and G. W. Mathison. 1991. Effects of feed intake on particle distribution, passage of digesta, and extent of digestion in the gastrointestinal tract of cattle. J. Anim. Sci. 69:3435-3445.

Pond, K. R., W. C. Ellis and D. E. Akin. 1984. Ingestive mastication and fragmentation. J. Anim. Sci. 58:1567-1574.

Reid, C. S. W., J. W. Lyttleton and J. L. Mangan. 1962. Bloat in cattle. Part XXIV. A method of measuring the effectiveness of chewing in the release of plant cell contents from ingested feed. N.Z. J. Agric. Res. 5:237-248.

Ryu, Y. W., Y. D. Ko and S. M. Lee. 1998. Effects of feeding rice straw silage made with apple pomace, sesame oil meal and cage layer excreta on growth rate, eating behavior and economical efficiency in Korean native cattle. Korean J. Anim. Sci. 40(3):240-242.

SAS. 2002. SAS/STAT software for PC. Release 9.1, SAS Institute Inc. Cary, NC, USA.

Shaver, R. D., A. J. Nytes, L. D. Satter and N. A. Jorgensen. 1986. Influence of feed intake, forage physical form on digestion and passage of pre-bloom alfalfa hay in dairy cows. J. Dairy Sci. 69:1545-1559.

Uden, P. 1987. The effect of grinding and pelleting hay on digestibility, fermentation rate, digesta passage and rumen and faecal particle size in cows. Anim. Feed Sci. Technol. 19:145-157.

Weston, R. H. and P. M. Kennedy. 1984. Various aspects of reticulorumen digestive function in relation to diet and digesta particle size. In: Proc. Techniques in Particle Size Analysis of Feed and Digesta in Ruminants (Ed. P. M. Kennedy). pp 1-17. Can. Soc. Anim. Sci., Edmonton, AB, Canada.

Woodford, J. A., N. A. Jorgensen and G. P. Barrington. 1986. Impact of dietary fiber and physical form on performance of lactating dairy cows. J. Dairy Sci. 69:1035-1047.