A Study on the Seasonal Comparison of Dry Matter Intake, Digestibility, Nitrogen Balance and Feeding Behavior in Spotted Deer (*Cervus nippon*) Fed Forest By-products Silage and Corn Silage*

S. H. Moon, B. T. Jeon, S. K. Kang, S. H. Sung and R. J. Hudson**[1]

Korea Nokyoung Research Center, Konkuk University, Danwol 322, Chungju, 380-701, Korea

ABSTRACT : The purpose of this experiment was to assess seasonal variation of feed utilization by feed sources and to obtain information on the use of feed resources by comparing seasonal changes of dry matter intake, digestibility, nitrogen balance and feeding behavior in spotted deer (*Cervus nippon*) fed forest by-product silage (FBS) and corn silage (CS). Dry matter intake (DMI) of FBS was higher than that of CS in both winter and summer. While DMI of both diets was higher in summer, this was not significant at the 5% level. In contrast to DMI, digestible dry matter intake (DDMI) was higher for CS than for FBS in both seasons, but the difference was not significant. Digestibility of dry matter and crude protein was significantly higher ($p<0.01$) for CS than for FBS, whereas digestibility of crude fiber was significantly higher ($p<0.01$) for FBS than for CS in both seasons. Seasonal digestibility of dry matter and crude fiber for FBS was significantly greater ($p<0.01$) in summer than in winter: In summer, seasonal digestibility was 57.2% for dry matter and 55.5% for crude fiber, and in winter, 50.8% for dry matter and 30.7% for crude fiber. On the other hand, seasonal digestibility of crude protein was higher ($p<0.01$) in winter (42.1%) than in summer (32.3%). No significant difference ($p>0.05$) was found between the two seasons and diets for nitrogen intake (NI), 18.7 g/d in summer and 19.4 g/d in winter for FBS, 17.7 g/d in summer and 17.7 g/d in winter for CS. Fecal nitrogen was higher ($p<0.01$) for FBS than for CS and varied little seasonally. There was significant difference ($p<0.01$) between two seasons in urinary nitrogen, which was little difference between two diets. Retained nitrogen (RN) was different significantly ($p<0.01$) between two diets in both seasons, but there was little difference between seasons. Deer usually spent longer time on eating FBS than eating CS. Eating FBS took 221 min in summer and 187 min in winter, whereas eating CS took 113 min in summer and 109 min in winter. Deer spent less time on eating food in winter than in summer. Time spent on rumination was longer for FBS than for CS: for FBS, 504 min in summer and 456 min in winter, for CS, 423 min in summer and 279 min in winter. Time varied seasonally with both diets. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 1 : 80-85)***

Key Words : Deer, Digestibility, Dry Matter Intake, Nitrogen Balance, Feeding Behavior, Seasonality

INTRODUCTION

Deer have been morphophysiologically classified as ruminants which readily browse, shrubs, forbs and grasses (Hofmann, 1988; Henke et al., 1988; Jeon et al., 1995). Jeon et al. (2000) reported that forest by-product consists of about 80-90% shrubs and browses such as oak tree, lacquer tree, hazel tree, arrowroot, azalea and sedge, which were widely available to deer. They also reported that forest by-product was highly economical as a roughage source for deer in competition with imported feed such as oak leaf hay and alfalfa bale. However, deer show marked seasonality in feed intake (Suttie et al., 1983; Barry et al., 1991; Moon et al., 2000), the volume of rumen, feed passage rate (Kato et al., 1989) and forming ammonia in rumen (Freudenberger et al., 1994) with lower value in winter and higher value in summer. Therefore, it is necessary to conduct research on feeding management considering the unique digestive physiology of deer.

The purpose of this experiment is to assess seasonal variation on feed utilization by feed sources and to obtain information on the use of feed resources by comparing seasonal changes of dry matter intake, digestibility, nitrogen balance and feeding behavior in spotted deer (*Cervus nippon*), which were fed forest by-product silage and corn silage.

MATERIALS AND METHODS

Feeding trials were conducted at the HANA Deer Research Institute, Chungju, from Jan. 2001 to Aug. 2001. Two years old 4 male spotted deer (*Cervus nippon*) weighing avg. 44.5 kg at the beginning of experiment were held individually in metabolism cages with visual contact with neighboring animals. The metabolism cages were designed to allow separate collection of urine and feces. Feeding trials were conducted in winter (Jan. 2001, average environmental temperature of 1°C) and summer (Aug. 2001, average environmental temperature of 28°C) to estimate seasonal changes of intake, digestibility, nitrogen balance and feeding behavior. Trials consisted of a 10 day adjustment period and a 7 day collection period. A 2×2

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** Corresponding Author: Sang H. Moon. Tel: +82-43-840-3527, Fax: +82-43-851-8216, E-mail : moon0204@kku.ac.kr

[1] Renewable Resources, University of Alberta, Edmonton, Canada T6G 2P5.

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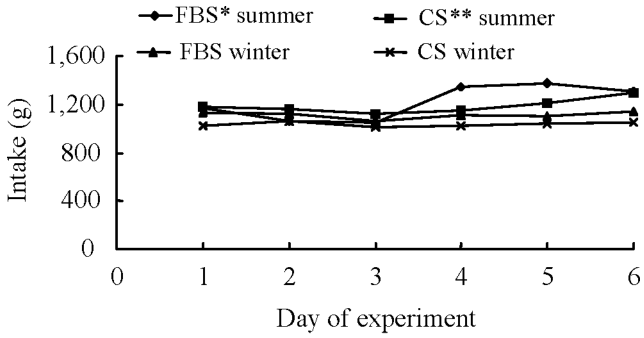

Figure 1. Daily changes of dry matter intake during experimental period in spotted deer fed experimental diets. * FBS: forest by-product silage, ** CS: corn silage.

Latin square design was used to balance carryover effects. The behavioral pattern of experimental animals during a 24 h period was recorded by using a video camera on the last day of collection period. Behavior was recorded in terms of its patterns, eating, ruminating and resting.

Throughout the experiment, forest by-product silage (FBS) and corn silage (CS) were offered *ad libitum* to each deer, and those were fed along with a commercial concentrate at 1% of body weight. Forest by-product silage contained fresh leaves (about 60.3% dry matter) and stems (about 39.7% dry matter) of trees, shrubs and wild grasses collected from a reforestation area in August 2000. The fresh material was ensiled after being chopped into 3.1±2.9 cm length. Forest by-product silage mainly consisted of oak tree (*Quercus aliena*), lacquer tree (*Rhus verniciflua*), hazel tree (*Corylus heterophylla*), arrowroot (*Puerario thunbergiana*), azalea (*Rhododendron mucronulatum*), sedge (*Carex disticha*) and others. It had a fermentative quality of 4.23-4.61 pH and 7.1-6.7% lactic acid on a dry matter (DM) basis. Corn silage was harvested at the yellow stage and ensiled after being chopped into pieces with 2.9±2.5 cm length. Corn silage had a fermentative quality of 3.97-4.11 pH and 8.5-9.1% lactic acid (DM basis). The experimental diet was offered to each deer at about 3.0% of body weight on a DM basis and fed twice daily at 09:00 and at 18:00 h. Feed refusals, excreted feces and urine were collected twice daily prior to the next feeding period. In order to prevent the volatilization of ammonia in the urinary nitrogen, 20 ml of H_2SO_4 (3 N) was added to the urine collection container for each collection. The deer had access to water and a commercial mineralized salt throughout the experimental period. Deer were weighed pre- and post-collection periods.

Voluntary feed intake of each animal was estimated daily. Apparent digestibility was determined by the total fecal collection method. Samples of feed offered (all), refusals (all), feces (all) and urine (300 ml) were refrigerated or immediately oven-dried. Dried and ground samples were passed through a 1 mm sieve and analyzed for chemical composition using the standard methods of AOAC (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to Georing and Van Soest (1970). pH of experimental diets were determined by using a Micro Processor pH meter (HI 9321W, HANNA Instruments). Lactic acid concentration in the each silage was estimated using a spectrophotometer after enzymatic dehydration using an Enzymatic Bioanalysis Kit (Boehringer Mannheim).

Recorded video footage was analysed for the eating, ruminating and chewing behavior of the deer. The data was analysed according to a one-way analysis or varience, using a general linear model and Tukey's Multiple Range test (SAS, 1989). Results are presented as means and their associated define error term.

RESULTS AND DISCUSSION

Figure 1 shows seasonal daily dry matter intake (DMI) of spotted deer fed FBS and CS. Although there was slight difference between treatments, daily intake was relatively stable at approximately 3% of body weight on a DM basis. Previous research has shown that DMI is around 2.0% in winter increasing to 2.3% in summer for adult spotted deer (Moon et al., 2000). When FBS was fed to deer intake was

Table 1. Dry Matter Intake (DMI), digestible dry Matter Intake (DDMI) and digestibility of nutrients in spotted deer fed experimental diets (mean±SE).

Item	Summer		Winter	
	FBS*	CS**	FBS	CS
DMI (g/day)	1,269.7±265.2^{aA}	1,110.9±212.8^{aA}	1,130.6±67.4^{aA}	1,040.6±104.6^{aA}
DDMI (g/day)	744.1±266.7^{aA}	790.6±174.2^{aA}	574.4±87.7^{aB}	620.4±107.1^{aA}
DMI (g/kgW$^{0.75}$/day)	77.2±15.6^{aA}	69.7±10.0^{aA}	66.3±8.2^{aB}	61.1±5.7^{bB}
Digestibility				
Dry matter (%)	57.3±8.9^{bA}	63.9±7.1^{aA}	50.8±8.0^{bB}	59.4±6.7^{aA}
Crude protein (%)	32.4±3.8^{bB}	48.7±9.9^{aA}	42.2±10.1^{bA}	50.2±9.1^{aA}
Crude fiber (%)	55.5±6.6^{aA}	40.2±13.0^{bA}	30.7±21.4^{aB}	26.1±16.2^{bB}

$^{a, b}$ Means (n=16) with different superscripts in the same row (diets) are significantly different ($p<0.01$).
$^{A, B}$ Means (n=16) with different superscripts in the seasonal row are significantly different ($p<0.01$).
* FBS: forest by-product silage, ** CS: corn silage.

Table 2. Chemical composition of experimental diets

Diet	Chemical composition*								
	DM	CP	EE	CF	Ash	ADF	NDF	pH	LA
Summer	% in DM								
FBS**	52.8	6.4	2.1	48.3	4.9	57.7	74.6	4.23	7.1
CS***	37.4	7.2	2.1	20.4	4.7	26.1	58.6	3.97	8.5
Concentrate	89.0	18.7	4.0	18.6	2.3	11.7	36.7		
Winter									
FBS	47.7	6.3	2.2	49.8	4.5	58.2	76.6	4.61	6.7
CS	27.3	6.0	2.1	26.2	4.8	34.4	58.8	4.11	9.1
Concentrate	88.9	19.0	4.9	16.1	3.3	10.3	35.8		

* DM: dry matter, CP: crude protein, EE: ether extract, CF: crude fiber, Ash: crude ash, ADF: acid detergent fiber, NDF: neutral detergent fiber, LA: lactic acid (% DM). ** FBS: forest by-product silage, *** CS: corn silage.

around 2.5% of body weight (Jeon et al., 2002, 2003). Kim et al. (1996) reported high level (around 2.1% DM basis) of DMI in spotted deer fed on corn silage (CS). Therefore, there was no adverse affect on palatability in spotted deer fed on FBS or CS.

Seasonal DMI and digestibility of spotted deer fed on FBS and CS are reported in Table 1. Dry matter intake of FBS was higher ($p>0.05$) than that of CS in winter and summer. Season had no effect on DMI (Table 1). Previous research has indicated that deer show a marked seasonal effect on intakes, with higher intakes reported during summer (Suttiie et al., 1983; Domingue et al., 1991; Barry et al., 1991; Moon et al., 2000). The reduction in DMI during winter has been largely attributed to physiological adaptation of energy conservation under low environmental temperature (Worden and Pekins, 1995).

Many researchers have reported that there are pronounced seasonal changes in metabolic rate, which are associated with significant annual changes in voluntary feed intake (Silver et al., 1969; Blaxter and Boyne, 1982; Argo and Smith, 1983; Renecker and Hudson, 1986). The seasonal cycle of voluntary DMI in deer is associated with the seasonal cycle of body growth and protein and energy metabolism (Mitchell et al., 1976; Moen, 1978; Barry et al., 1991).

In contrast to DMI, digestible dry matter intake (DDMI) was higher in deer fed CS compared to deer fed FBS in both summer and winter (Table 2), but the difference was not significant. Digestible dry matter intake of FBS ($p<0.001$) was higher in summer than in winter and DDMI of CS was not seasonal difference. Forbes and Jackson (1971) reported that DM content is one of the main factors affecting feed intake in ruminants. Pelletier et al. (1976) also reported that high moisture content in silage was a factor disturbing DMI in ruminants. In this experiment, FBS had higher level of DM content than CS (Table 2) and this was mainly due to high level of DMI in FBS. However, because of higher DM digestibility for CS in both seasons, DDMI of FBS was lower than that of CS.

Dry matter intake expressed by metabolic body weight (BMW, $kgW^{0.75}$) of FBS was only significantly higher than CS in winter ($p<0.05$). Intake of both FBS and CS was greater during the summer period compared to winter ($p<0.05$) that is in agreement with results presented by Semiadi et al. (1993) and Moon et al. (2000). This seasonal affect of DMI on body weight may be due to the same mechanisms that govern DMI. Intake of both FBS and CS, when expressed on a metabolic body weight basis, was similar to those presented in the literature (Kim, 1994; Moon et al., 2000).

Digestibility of both DM and crude protein was significantly higher ($p<0.01$) in the deer fed CS compared to FBS, whereas the digestibility of crude fiber was significantly higher ($p<0.01$) for FBS than for CS (Table 2). Except for digestibility of crude fiber, there was no significant effect of season in the deer fed CS. Seasonal digestibility of DM and crude fiber for FBS was significantly greater in summer than in winter ($p<0.01$). The digestibility of crude protein was higher ($p<0.01$) in winter (42.1%) than in summer (32.3%).

Deer had higher palatability for browses and shrubs than for forages, but internal availability of nutrients was greater in corn and rye silage than in oak leaf hay (Kim et al., 1996). Because FBS had high content of fiber including much stem, it was assumed that digestibility of DM and crude protein was lower for FBS than for CS in both seasons. However, higher digestibility of crude fiber for FBS in both seasons was mainly due to longer retention time in the rumen even if FBS had more stem part than CS.

Odashima et al. (1991) reported lower DM digestibility in winter than in summer, due mainly to faster passage rate of feed fractions. It is generally accepted that digestibility in ruminants is largely influenced by feed intake, therefore, as feed intake increases, digestibility decreases (Brown, 1966). Despite low DMI, the results of this experiment show a lower digestibility in winter than in summer. This may be attributed to a faster passage rate and shorter retention time of feed in the reticulo-rumen during winter compared to summer.

Sasaki et al. (1987) suggested that a faster passage rate of feed particles during winter was related to variation in digestion ability caused by the changes in the endocrine and

Table 3. Nitrogen balance in spotted deer fed experimental diets (mean±SE)

Item	Summer		Winter	
	FBS*	CS**	FBS	CS
Nitrogen balance				
Nitrogen intake (NI, g/day)	18.7±2.8^{aA}	17.7±2.8^{aA}	19.5±1.1^{aA}	17.7±2.0^{aA}
Fecal nitrogen (g/day)	12.4±1.9^{aA}	9.1±2.0^{bA}	11.2±1.9^{aA}	9.1±1.4^{bA}
Digestible nitrogen (g/day)	6.3±3.4^{bA}	8.7±2.2^{aA}	8.2±2.1^{bA}	9.3±2.2^{aA}
Urinary nitrogen (g/day)	4.6±2.0^{aB}	4.2±1.6^{bB}	7.2±2.2^{aA}	6.6±2.2^{aA}
Retained nitrogen (RN, g/day)	1.7±2.9^{bA}	4.4±2.4^{aA}	1.0±2.1^{bA}	2.7±1.5^{aA}
RN/NI (%)	7.6±14.2^{bA}	27.3±11.9^{aA}	5.3±11.2^{bA}	14.9±8.6^{aA}

$^{a, b}$ Means (n=16) with different superscripts in the same row (diets) are significantly different (p<0.01).
$^{A, B}$ Means (n=16) with different superscripts in the seasonal row are significantly different (p<0.01).
* FBS: forest by-product silage, ** CS: corn silage.

Table 4. Time spent on eating and ruminating and chewing behavior during rumination in spotted deer fed experimental diets (mean±SE)

Item	Summer		Winter	
	FBS*	CS**	FBS	CS
Voluntary DM intake (g/day)				
Eating (min)	1,040±202.5^{aA}	987±112.4^{aA}	873±200.1^{aA}	858±175.9^{aA}
Ruminating (min)	221±45.1^{aA}	113±37.2^{aA}	187±89.2^{aA}	109±72.3^{aA}
Chewing behavior	504±102.1^{aA}	423±125.7^{aA}	456±98.4^{aA}	279±138.2^{bA}
Chewing time per bolus (sec)	50.2±6.5^{aA}	43.2±6.4^{bA}	52.2±9.4^{aA}	43.1±11.1^{bA}
Number of chews per bolus (No.)	55.3±6.4^{aA}	40.6±5.0^{bA}	56.9±10.0^{aA}	43.6±9.2^{bA}
No. of chews per minute (No.)	66.0±4.7^{aA}	56.3±6.4^{bA}	65.4±6.1^{aA}	60.7±5.8^{bA}

$^{a, b}$ Means (n=16) with different superscripts in the same row (diets) are significantly different (p<0.01).
$^{A, B}$ Means (n=16) with different superscripts in the seasonal row are significantly different (p<0.05).
* FBS: forest by-product silage, ** CS: corn silage.

autonomic nervous system. This in turn is caused by the decline of photoperiod and decreased environmental temperature. This implies a close relationship between food intake and digestibility and the seasonal metabolism of deer. A short retention time in winter led to low digestibility of dry matter and fiber, but encouraged dietary protein to pass through the rumen without degradation (Kay et al., 1980). Therefore, this resulted in higher digestibility of crude protein in winter than in summer.

Data relating to the nitrogen balance are presented in Table 3. No significant difference (p>0.05) was found between seasons and diets for nitrogen intake (NI), for both FBS and CS. Fecal nitrogen was higher (p<0.01) for FBS than for CS, but showed no seasonal variation. There was significant difference (p<0.01) in terms of the urinary nitrogen for both diets and seasons. Retained nitrogen (RN) differed significantly (p<0.01) between diets in both seasons, but there was little difference between the two seasons.

Estimation of the utilization efficiency of dietary nitrogen is important for predicting the nitrogen requirement of deer. It has been observed that nitrogen balance in deer was greatly influenced by seasonality (Domingue et al., 1991; Freudenberger et al., 1994). Nitrogen intake, recycled nitrogen, and fecal and urinary nitrogen excretion are related to feed nitrogen content (Robbins et al., 1974; Mould and Robbins, 1981; Freudenberger et al., 1994). In this experiment, there was similar nitrogen content and DMI for both the FBS and CS diets, and thus dietary nitrogen intakes were similar for both diets and seasons.

Similar results were also found by Domingue et al. (1991) and Freudenberger et al. (1994). It has been suggested that the increase in nitrogen retention during summer was due to increased rumen capacity and ammonia concentration by prolonged bacterial fermentation. Increased recycling of nitrogen in the rumen may also contribute to increased nitrogen retention (Feudenberger et al., 1994) as rumination time increases (Table 4), which causes in turn more excretion of saliva in summer. The differences between diets seem to be mainly attributable to difference in nitrogen digestibility between FBS and CS.

The deer spent a longer time eating the FBS diet compared to the CS diet. Less time was spent eating during winter compared to summer. Rumination was also longer on the FBS diet, and there was significant difference (p<0.05) in winter and was not significant in summer. In the deer fed CS, rumination time was not significantly affected by seasons, with decreased rumination time during winter.

The deer spent similar amount of time on eating and rumination during the 12 h between noon and night for both diets and seasons. There were significant differences in chewing time per bolus, the number of chews per bolus, and the number of chews per minute between diets (p<0.05).

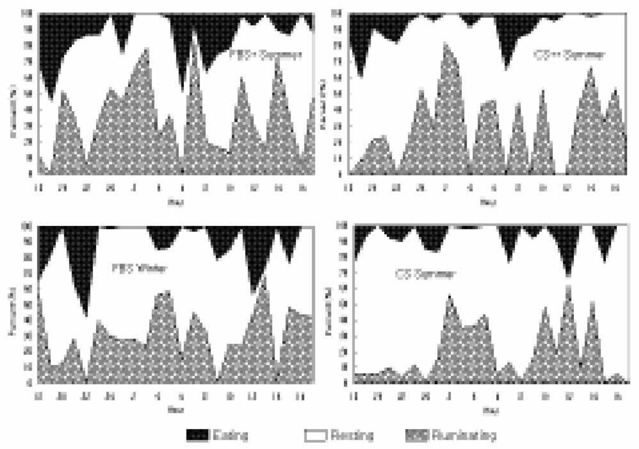

Figure 2. Diurnal patterns of seasonal feeding behavior in spotted deer fed experimental diets. * FBS: forest by-product silage, **CS: corn silage.

However, there was no seasonal effects (Table 4). Also deer exhibited similar patterns of relatively short and frequent periods of eating and rumination in both experimental diets and seasons (Figure 2).

Time spent eating in shorter in deer compared to other ruminants, however, rumination time tends to be similar (Leaver, 1982; Renecker, 1987; Jeon and Kim, 1992; Moon et al., 2000). The time spent eating and ruminating are influenced by amount of feed consumed or its physical treatment (Welch and Smith, 1969). Although eating and ruminating times in this study reflected seasonal differences in DMI, the eating time reported in this experiment was shorter than those of other ruminants. This may mean that deer have a larger bite size or faster feeding rate than other ruminants (Moon et al., 2000). There was little seasonal difference for chewing time and the number of chews per bolus in deer, but there was dietary difference. This may indicate an influence of the quality and physical form of the feed on rumination in deer.

The major role of rumination is in reducing the particle size to allow its passage from the reticulo-rumen (Pearce and Moir, 1964). Luginbuhl et al. (1989) reported that ingestion of greater proportions of coarse particles was compensated for by increased comminution during rumination. Moon et al. (1995) and Jeon et al. (1997) reported that ruminating behavior was largely affected by physical form and quality of feed. Therefore, it is thought that the larger the particle size and the poorer the quality of diet will increase ruminating behavior in deer as with other ruminants.

Therefore, a conclusion can be made that because the differences of DMI, DDMI and digestibility in this experiment were mainly due to seasonality of deer, FBS and CS are probably acceptable as a feed resource for deer.

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