

# Effects of physically effective neutral detergent fiber content on dry matter intake, digestibility, and chewing activity in Korean native goats (*Capra hircus coreanae*) fed with total mixed ration

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**Objective:** This experiment was to determine proper physical traits in the diet for goats by investigating the effects of physically effective neutral detergent fiber (peNDF) content on dry matter intake (DMI), digestibility, and chewing activity in black goats fed with total mixed ration (TMR).

**Methods:** Six growing wethers of Korean native black goats (*Capra hircus coreanae*) aged 8 months and weighing between 26.9 kg and 27.1 kg (27.03±5.05 kg) were used in this experiment. Three diets of varying peNDF content were obtained by original TMR (T1), 12,000 rpm grinding (T2), and 15,500 rpm grinding (T3) of the same TMR diet. The peNDF<sub>1.18</sub> content of the experimental diets was 23.85%, 21.71%, and 16.22% for T1, T2, and T3, respectively.

**Results:** Average daily gain (ADG) was higher in T2 group compared to those of the control and T3 groups, but ADG and DMI were not affected by the dietary particle size and peNDF content. Also, there was no difference between apparent nutrient digestibility of dry matter, crude fiber, ether extract, neutral detergent fiber, and acid detergent fiber. Although there was no significant difference, rumination and total chewing time were associated with decreased peNDF content.

**Conclusion:** The feeding of peNDF-based TMR showed no impact on apparent nutrient digestibility and nitrogen balance. Further studies are required with a wider range of dietary peNDF level and particle size to better identify the effect of dietary peNDF and particle size on chewing activity and performance in goats.

**Keywords:** Black Goat; Chewing Activity; Digestibility; Dry Matter Intake; Physically Effective Neutral Detergent Fiber (peNDF)

## INTRODUCTION

A demand for goat meat has increased in both developing and developed countries, resulting in a rising number of livestock producers raising goats. However, there has been little research on goats and goat products compared to other ruminants such as cattle, and sheep, even though goats have been significantly rolled into food and in economic security over the world [1]. Goats have been traditionally raised for meat production in Korea and this has increased over the last decade due to a rising demand for goat meat, being a healthier option as well as the migration of Chinese people in Korea. Korean native goat (KNG, *Capra hircus coreanae*) is the main breed for goat meat production in Korea and most of them are predominantly black [2]. However, this species is low in productivity as well as in average daily gain (ADG) with about 50 to 70 g/d [3] compared to other breeds such as a boar (about ADG of 124 g) for meat production [4]. This is mainly due to a lack of breed improvement and improper feeding management. Therefore, it is necessary to improve the productivity of KNG for the sustainability of the goat industry.

Currently with the widespread use of total mixed ration (TMR) in ruminants, including beef cattle, deer, and goat as well as in dairy cows, it is important to provide proper fiber content and its physical traits in TMR [5]. Generally, ruminants require adequate amounts of coarse textured feeds to avoid metabolic disorders [6]. To attain better performance without any metabolic disorders, animals need adequate dry matter intake (DMI) and proper fiber content in their rations. Thus, it is essential to accurately estimate the portion of dietary fiber required by ruminants as forages and roughage are lower in internal availability and available energy than grains. It is also desirable to reduce fiber to a minimum level in the diet for high-performance [7]. However, there is limited information on the physical traits of dietary fiber and the appropriate amount required in goats, especially in KNG.

Hence, this experiment was aimed to determine the proper physical traits in the diet of goats by investigating the effects of physical effective neutral detergent fiber content on DMI, digestibility, and chewing activity in black goats fed with TMR.

## MATERIALS AND METHODS

### Animals and diets

Six growing wethers of KNG aged 8 months and weighing between 26.9 kg and 27.1 kg ( $27.03 \pm 0.51$  kg) were used in the experiment, which had a replicated  $3 \times 3$  Latin square design for balancing carryover effects. The wethers were housed in individual metabolic cages and were fed TMR twice a day at 08:00 and 18:00 h. All animal-based procedures were approved by the Institutional Animal Care and Use Committee at Konkuk University (KU11058).

Each wether was offered one of the three diets based on the same chemical formula but differing in physically effective neutral detergent fiber (peNDF) content which was grouped as T1, T2, and T3. The three diets with different peNDF content levels were obtained by original TMR (T1), 12,000 rpm grinding (T2), and 15,500 rpm grinding (T3) of the same TMR diet. The mixing duration was 30 seconds for both treatment groups (T2 and T3). The experimental TMR diets were produced by the commercial formula for fattening goats recommended by the Institute of Bio Feed (Seoul, Korea) and were offered to each wether at approximately 2.0% of body weight (BW) on a dry matter (DM) basis. Ingredients of diets are shown in the Table 1. Animals had free access to fresh water and mineral blocks at all times. Each trial period consisted of 14-d of adaption to diets and 7-d of experimental measurements.

The offered feeds and refusals were measured and recorded daily during the last 7-d to calculate feed intake and apparent nutrient digestibility. Feed samples were collected once every week, and refusals were collected daily where DMI was determined. The collected samples were dried in an oven at  $65^\circ\text{C}$  for 48-h and ground through a 1-mm mesh screen (Model 4, Thomas Scientific, Swedesboro, NJ, USA) for analysis of chemical com-

**Table 1.** Ingredient composition of experimental diet

Ingredient composition	Measurement (% of dry matter)
Perennial ryegrass	6.0
Annual ryegrass	3.0
Alfalfa hay	2.0
Klein grass	1.0
Corn, flaked	15.0
Wheat meal	26.5
Soybean meal	15.0
Corn gluten meal	8.0
Coconut meal	9.1
Lupin, flaked	2.0
Whole cottonseed	2.0
Molasses	5.0
Yeast culture	2.0
Limestone	2.5
Salt	0.6
Mineral	0.3

position. Particle size distribution of the TMR was determined using a Penn State Particle Separator [8] containing three sieves (19, 8, and 1.18 mm) and a pan. The peNDF content of TMR was calculated by multiplying neutral detergent fiber (NDF) content of the TMR by  $pef_{1.18}$  [9]. The proportion of sample DM collected in a  $\geq 1.18$  mm sieve is commonly used as the physical effectiveness factor in the equation [10].

### Apparent digestibility, chewing activity, and chemical analysis

Apparent digestibility was determined by total fecal collection. Fecal samples were collected four times daily at a 6-h interval. Each collected sample was mixed and divided into three sub-samples. One of the sub-samples was pooled by wether within the given period, dried at  $65^\circ\text{C}$  and ground before chemical analysis and determination of digestion coefficient. Chewing activities of each wether were monitored continuously for 48-h where six digital video cameras (SDC-435, Samsung, Seoul, Korea) and two multiplexers (PDR-XM3004, Egpis, Goyang, Korea) were used. The cameras were carefully arranged such that there were no blind spots.

Samples of feed, feces, and urine were collected during the last 7-d to calculate nitrogen balance. The  $\text{H}_2\text{SO}_4$  (3 N) of 20 mL was daily added to prevent volatilization of ammonia in urine. All samples were analyzed for chemical composition using the standard methods of AOAC [11] and analyzed for NDF and acid detergent fiber (ADF) by Goering and Van Soest [12].

### Statistical analysis

The data were analyzed using the general linear model procedure of SAS (Version 9.2, SAS Institute, Cary, NC, USA). The model for statistical analysis was as follow:  $Y_{ijkm} = \mu + S_i + P_{j(i)} + T_m + G_{k(i)} + \epsilon_{ijkm}$ , where  $Y_{ijkm}$  = dependent variable;  $\mu$  is the mean,  $S_i$  is the fixed effect of square  $i$ ,  $P_{j(i)}$  is the fixed effect of period,  $T_m$  is

the fixed effect of dietary treatments,  $G_{k(i)}$  is random effect of goat within square, and  $\epsilon_{ijmk}$  is random error. The differences between means were identified using Tukey's multiple range test and statistical significance was defined as  $p < 0.05$ .

## RESULTS

### Chemical composition, particle-size distribution, and peNDF content of TMR

The chemical compositions of the experimental TMR diet are shown in Table 2. The chemical compositions are similar to T1, T2, and T3, as the same diets were used in this study. Different particle size variables and peNDF contents are given in Table 3. The peNDF values of TMR decreased linearly with increasing grinding intensity. The peNDF<sub>1.18</sub> contents of experimental diets were 23.85%, 21.71%, and 16.22% for T1, T2, and T3 ( $p < 0.05$ ),

**Table 2.** Chemical composition of the experimental TMR feed with different physically effective NDF contents

Chemical composition	Content of peNDF <sup>1)</sup>		
	T1	T2	T3
DM (%)	87.13 ± 0.17	87.42 ± 0.28	86.87 ± 0.24
CP (% DM)	16.11 ± 0.22	16.86 ± 0.17	16.65 ± 0.13
EE (% DM)	7.26 ± 0.12	7.41 ± 0.04	7.95 ± 0.22
CF (% DM)	10.12 ± 0.10	10.58 ± 0.12	10.20 ± 0.09
Ash (% DM)	8.32 ± 0.20	8.76 ± 0.37	8.02 ± 0.24
NDF (% DM)	41.77 ± 0.30	41.20 ± 0.64	41.28 ± 0.14
ADF (% DM)	24.79 ± 1.43	24.37 ± 0.41	24.66 ± 0.35

TMR, total mixed ration; peNDF, physically effective neutral detergent fiber; DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fiber; Ash, crude ash; NDF, neutral detergent fiber; ADF, acid detergent fiber.

<sup>1)</sup> T1, original TMR; T2, 12,000 rpm grinding; T3, 15,500 rpm grinding.

Mean ± standard error.

**Table 3.** Particle size distribution and peNDF content of the experimental TMR feeds with different peNDF contents

Items	Content of peNDF <sup>1)</sup>		
	T1	T2	T3
Particle size distribution <sup>2)</sup>	----- % -----		
19 mm	1.62 ± 0.18 <sup>Da</sup>	0.00 ± 0.00 <sup>Cb</sup>	0.00 ± 0.00 <sup>Cb</sup>
8 mm	9.99 ± 0.34 <sup>Ca</sup>	3.70 ± 0.13 <sup>Bb</sup>	0.50 ± 0.25 <sup>Cc</sup>
1.18 mm	45.45 ± 0.97 <sup>Aa</sup>	48.97 ± 1.73 <sup>Aa</sup>	38.82 ± 0.98 <sup>Bb</sup>
Pan	42.93 ± 0.54 <sup>Bc</sup>	47.33 ± 1.40 <sup>Ab</sup>	60.68 ± 0.91 <sup>Aa</sup>
peNDF			
pef <sub>1.18 mm</sub>	0.571 ± 0.13	0.527 ± 0.20	0.393 ± 0.60
NDF (% DM)	41.77 ± 0.30	41.20 ± 0.64	41.28 ± 0.14
peNDF <sub>1.18 mm</sub> (% DM)	23.85 ± 0.12 <sup>a</sup>	21.71 ± 0.24 <sup>b</sup>	16.22 ± 0.04 <sup>c</sup>

peNDF, physically effective neutral detergent fiber; TMR, total mixed ration; DM, dry matter; NDF, neutral detergent fiber.

<sup>1)</sup> T1, original TMR; T2, 12,000 rpm grinding; T3, 15,500 rpm grinding.

<sup>2)</sup> Retained ratio using Penn State Particle Separator.

<sup>A,B,C,D</sup> Means with different superscript in the same column are different ( $p < 0.05$ ).

<sup>a,b,c</sup> means with different superscript in the same row are different ( $p < 0.05$ ).

Mean ± standard error.

respectively.

### Feed intake and growth performance

Data regarding DMI and ADG are presented in Table 4. The DMI of T1 group was higher than those of other groups. Although DMI decreased by reducing dietary peNDF content, there was no significant difference between groups. The ADG of T2 group was higher compared to those of control and T3 groups. Likewise, ADG had no significant differences among the three diet groups.

### Digestibility, nitrogen balance, and chewing activity

Despite of differences in peNDF content, no differences were observed in the digestibilities of DM, crude fiber, crude protein, NDF, and ADF among the treatments (Table 5). The digestibility of NDF increased with reducing the peNDF content of the diet, but there was no significant difference between the groups. Although there was no difference in digestibility between the groups, it did tend to increase in T3 groups than in others. The nitrogen balance was not affected by dietary peNDF content (Table 6). Although nitrogen absorption tended to increase in T3, there was no significant difference between groups. Also, the peNDF content did not affect ( $p > 0.05$ ) chewing activity of wethers (Table 7).

**Table 4.** Body weight, average daily gain and total dry matter intake in Korean native goats fed TMR feeds with different peNDF contents

Items	Content of peNDF <sup>1)</sup>		
	T1	T2	T3
Initial body weight (kg)	26.93 ± 1.60	26.98 ± 2.17	27.18 ± 2.42
Average daily gain (ADG, g/d)	42.86 ± 50.16	51.19 ± 48.61	44.76 ± 14.90
Dry matter intake (DMI, g/d)	594.44 ± 41.18	577.53 ± 48.61	557.27 ± 44.57
Feed conversion ratio			
DMI/ADG (g/g)	13.87	11.28	12.45

TMR, total mixed ration; peNDF, physically effective neutral detergent fiber.

<sup>1)</sup> T1, original TMR; T2, 12,000 rpm grinding; T3, 15,500 rpm grinding.

Mean ± standard error.

**Table 5.** Apparent nutrient digestibility in Korean native goats fed the TMR feeds with different peNDF contents

Items	Content of peNDF <sup>1)</sup>		
	T1	T2	T3
	----- % DM -----		
DM	75.54 ± 0.66	75.25 ± 0.91	77.41 ± 0.68
CP	68.25 ± 0.87	69.18 ± 1.09	69.44 ± 0.92
EE	89.01 ± 0.30	87.02 ± 1.00	89.91 ± 0.31
CF	63.88 ± 1.00	61.17 ± 1.37	65.10 ± 1.05
Ash	36.31 ± 1.76	32.78 ± 2.36	33.25 ± 2.02
NDF	50.76 ± 1.36	47.27 ± 1.85	53.05 ± 1.42
ADF	49.74 ± 1.38	43.34 ± 1.99	47.78 ± 1.58

TMR, total mixed ration; peNDF, physically effective neutral detergent fiber; DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fiber; Ash, crude ash; NDF, neutral detergent fiber; ADF, acid detergent fiber.

<sup>1)</sup> T1, original TMR; T2, 12,000 rpm grinding; T3, 15,500 rpm grinding.

Mean ± standard error.

**Table 6.** Nitrogen balance of Korean native goats fed the TMR feed with different peNDF contents

Items	Content of peNDF <sup>1)</sup>		
	T1	T2	T3
	----- g/d -----		
Nitrogen intake (NI)	12.80 ± 0.95	13.62 ± 1.21	14.08 ± 1.21
Fecal nitrogen	2.77 ± 0.26	2.47 ± 0.22	2.83 ± 0.38
Digestible nitrogen	10.03 ± 0.69	11.15 ± 1.14	11.25 ± 0.87
Urinary nitrogen	5.01 ± 0.46	5.61 ± 0.92	5.34 ± 0.73
Retained nitrogen (RN)	5.03 ± 0.41	5.54 ± 1.24	5.91 ± 0.55
RN/NI (%)	39.36 ± 1.73	39.41 ± 6.81	42.67 ± 3.78

TMR, total mixed ration; peNDF, physically effective neutral detergent fiber.

<sup>1)</sup> T1, original TMR; T2, 12,000 rpm grinding; T3, 15,500 rpm grinding.

Mean ± standard error.

**Table 7.** Chewing activity of Korean native goats fed the TMR feeds with different peNDF contents

Items	Content of peNDF <sup>1)</sup>		
	T1	T2	T3
	----- Min. -----		
Eating time	121.20 ± 42.84	132.33 ± 29.98	82.17 ± 3.72
Rumination time	176.00 ± 21.96	152.33 ± 43.6	167.83 ± 25.15
Total chewing time	297.20 ± 43.06	248.70 ± 58.53	250.00 ± 23.27

TMR, total mixed ration; peNDF, physically effective neutral detergent fiber.

<sup>1)</sup> T1, original TMR; T2, 12,000 rpm grinding; T3, 15,500 rpm grinding.

Mean ± standard error.

Time spent on eating was higher in T2 than in T1, but there was no significant difference ( $p > 0.05$ ). Ruminating and total chewing activities were associated with the peNDF content, but there were no significant differences ( $p > 0.05$ ).

## DISCUSSION

In general, the physical effect of diets for ruminants is one of the most important factors that makes growth performance or digestibility. Several researchers have taken the time to note that diets particle size or length had an impact on the physiology of digestion in ruminants [7]. Basically, ruminants will select a diet of better quality [13]. In the current study, DMI was not affected by dietary peNDF. This result is consistent with previous studies [14-17]. DMI were 21.1, 21.0, 20.0 kg/d (high, medium, and low) which were no differences [15] and reducing dietary particle size resulted in a small increase (19.4 [high concentrate short chop] to 20.1 [high concentrate long chop] kg/d) in feed intake [14]. In all of these studies, distribution divided two screens into the top (19 mm) and middle (8 mm). In contrast, it has been reported that steers are preferred to feed the low peNDF content and thereby increase intake (8.7 kg/d to 11.1 kg/d) [5]. The DMI decreased (7.4 kg/d [fed the short barley silage] to 6.3 kg/d [fed the long barley silage]) with increasing dietary peNDF [18]. Studies in heifers [5] and steers [18] were conducted further detail distri-

bution which was divided into 1.18 mm. Although the effects of peNDF on DMI were different according to an experimental animal in the previous studies, DMI was similar between groups in this study. This was assumed that restricted feed supply by 2% of BW for all wethers was to ensure similar DMI. This procedure used in the present study was based on the experiment of Li et al [17], who studied the effect of peNDF on rumen fermentation in the dairy goat. Li et al [17] suggests that this procedure can eliminate the confounding effects of dissimilar nutrient intake among treatments. However, peNDF of diets have not been as effective as expected in this study. In the current study, the reduced dietary peNDF had no impact on chewing activity and digestibility. The peNDF values (16.2% to 23.8%) of the diets offered in the present study were lower than those (range of 18.7% to 24.3%) reported by Li et al [17] because a higher proportion of alfalfa hay (43.7%) was used in that study. Furthermore, Yang and Beauchemin [19] summarized that feed intake is influenced by digestion rate and passage rate of feeds through the rumen. It is possible to assume that although there were significant differences in peNDF contents among the groups, passing rate has no difference with same DMI of low level (2% of BW). When low-peNDF diets are fed to lactating dairy cows, there may be a relationship between retention time and digestion efficacy [19]. In contrast, retention time has no difference when goats eat the same quantity of good quality forage [20]. Also, the retention time of feed particles tends to be shorter for goats (28-h) than other ruminants (cattle 36-h, sheep 34-h) [21]. Also, goats can eat diets of the higher surface area of absorptive mucosa than in grass and roughage eaters [20]. In addition, the level of intake and the characteristics of digestion depend closely on the feeding behavior of goats [20]. Dairy cows may select long feed particles to maintain ruminal pH in the normal range [15]. Goats are able to control the chewing activity of ruminal frequency to maintain in the ruminal pH normal range [22]. In the current study, however, dietary peNDF did not affect chewing activity. This result is a contrast to other ruminants [16,5,17]. For example, reducing peNDF increased rumen total volatile fatty acids and decreased chewing time [23]. In fact, Li et al [23] used a proportion of particles on the 19 mm (range of 3.5% to 17.8%) and 8 mm (range of 21.1% to 39.7%) Penn State Particle Separator (PSPS) screens. In the present study, a lack of the effectiveness of dietary peNDF on chewing activity was likely due to the proportion of 19 mm (range of 0% to 1.6%) and 8 mm (range of 0.5% to 10.0%). Goats are likely to be better digesting diets regardless of particle size differences. Morand-Fehr [20] suggests that the total tract of goats is very similar to those of other ruminants. However, it is possible that BW or total tract size of goats varies greatly from other ruminants. Therefore, this might be due to relatively small ruminant digestion characteristics [20]. Although it was not significantly dietary of physical characteristics in the current study, peNDF of diets are important when the goats fed to TMR.

## CONCLUSION

The feeding of peNDF-based TMR shows no impact on daily gain and chewing activity of black goats. Furthermore, the effect of peNDF did not affect the apparent nutrient digestibility. These results indicate that goats have the ability to digest diets regardless of particle size differences. There are no studies that investigate the effect of dietary peNDF measured using the PSPS for goats. Also, there is limited information for expected particle size distribution for goats. In conclusion, further studies are required with a wider range of dietary peNDF level and particle size to better identify the effect of dietary peNDF and particle size on chewing activity and performance in goat.

## CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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