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EFFECTS OF DIETARY CRUDE PROTEIN LEVELS ON INTAKE, DIGESTIBILITY, AND CRUDE PROTEIN BALANCE OF GROWING KOREAN NATIVE GOATS (*CAPRA HIRCUS COREANAE*)

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ABSTRACT

This study was conducted to determine the adequate dietary CP level for growing wethers by investigating the effect of dietary CP level on dry matter intake, apparent digestibility, and protein balance inKorean native goats. Each growing wether was fed three diets that were formulated to contain low (13%, T1), medium (15%, T2), and high (18%, T3) levels of CP based on dry matter. Dietary protein levels affected the apparent digestibility of CP, CP intake (CPI), urinary CP, digestible CP, and CP efficiency ($p<0.05$). The apparent CP digestibility increased linearly as dietary CP increased (T1=73.03%, T2=76.49%, T3=80.66%; $p<0.05$). The CPI and digestible CP for T3 (129.92g/d, 104.93g/d) were also higher ($p<0.05$) than those for T1 (90.39g/d, 65.68g/d), in addition, urinary emission for T3 (55.23g/d) was higher ($p<0.05$) than that for T2 (27.11g/d). CP utilization efficiency for T2 (49.11%) and T3 (44.42%) were both higher ($p<0.05$) than that for T1 (26.14%). A strong linear relationship existed between CPI and digestible CP ($p<0.001$, $r^2=0.988$). The results from this study suggest that an adequate CP level for achieving optimal growth performance of growing Korean native goats is 15% of dietary intake.

Key words: Crude protein level, Digestibility, Maintenance, Crude protein requirement, Korea native goat.

INTRODUCTION

The economic importance of goats in providing animal protein in developing countries has been extensively reviewed. In Korea, consumption of goat meat has increased recently because it is a good source of desirable fatty acids, with goats accumulating higher amounts of polyunsaturated fatty acids than other ruminants (Mahgoup *et al*., 2002). In addition, the main feed resources are natural pastures or poor-quality grasses (Choi *et al*., 2005). Goats are well adapted to a harsh environment and limited feed, and they utilize marginal land to produce high-protein products. However, few studies have investigated the effects of diet composition on goat carcass characteristics, and there are no references values for the protein requirements of growing Korea native goats (*Capra hircus coreanae*).

Dietary CP is an important determinant of growth rates and the efficiency of protein deposition in young animals. A low ratio of dietary CP to DM (dry matter) impairs weight gain, whereas high ratios lead to inefficient use of dietary protein for growth (Edozien and Switzer, 1987). A high ratio also leads to environmental pollution due to ammonia emissions from the degradation of urea in excreta, and optimum levels of dietary protein need to be defined to avoid unnecessary loss of nitrogen (Tegene Negesse *et al.*, 2001).

The CP requirement for maintenance has been demonstrated to be 3.13g/kg $BW^{0.75}$/d for goats *(Plural saanen goat)* (Silva Sobrinho, 1989) and 3.57g/kg $BW^{0.75}$/d for 8- to 12-month-old Thai indigenous goats (Chobtang *et al*., 2009). The digestible CP requirement for maintenance was calculated to be 2.82g/kg $BW^{0.75}$/d for goats *(Capra hircus)* (NRC, 1981) and 1.65 g/kg$W^{0.75}$/d for adult Thai native goats (Cheva-Isarakul *et al*., 1991). The metabolizable protein requirement for maintenance of growing goats was 3.07g/kg $BW^{0.75}$/d (Luo *et al*., 2004). Chobtang *et al*. (2009) fed Thai indigenous goats diets containing 8%, 10%, 12%, and 14% CP (% of DM) to evaluate the influence of dietary CP levels on nutrient digestibility and growth performance. They found that increasing levels of CP content in TMR not only improved CP intake (CPI) but also enhanced CP digestibility and promoted growth performance of the goats. Ki *et al.* (2009) fed growing dairy goats dietary treatments containing 11%, 12%, and 13% CP, respectively, to investigate the influence of CP and total digestible nutrition (TDN) level on DMI, apparent digestibility, nitrogen, and energy balance. They found that high CP and energy TMR were better than low CP TMR for high intake, digestibility, nitrogen, and energy utilization. Osuagwuh and Akinsoyinu (1990) found that a 17% protein level yielded the highest nitrogen absorption but higher levels decreased nitrogen absorptionin pregnant West African dwarf goats (*Fouta djallon*). Although some research has evaluated the dietary CP level for various species of goats, studies targeting Korean native goats, which have a different genetic background and are adapted to different environmental conditions, have not been conducted. Thus, this study was conducted to investigate the effect of dietary CP level on the bioavailability like as intake, apparent digestibility, and CP balance (CPB) and to define the optimal dietary CP level and CP requirement for maintenance in Korea native goats.

MATERIALS AND METHODS

Animals and diets: All animal care protocols were approved by the Konkuk University Institutional Animal Care and Use Committee (KU14109-1). The experiment was conducted at a goat farm in South Korea, located at 37°14′16″ N, 127°22′31″E and at an average altitude of 80 m. The experiment was carried out using six 5-month-old male goats whose mean body weight was 23.2±3.5 kg. During the experiment, the animals were kept in individual metabolism cages (1 × 1.6 × 1.5m) that permitted separate collection of feces and urine. The cages were similar to those designed by Cowan *et al*. (1969). The animals were allocated to a 3 × 3 Latin square (six animals, three diets), so each goat consumed all three diets. Each of six goats had a 14-day adaptation period and a 7-day sample collection period. Feed ingredients and chemical compositions of the three diets are presented in Table 1. Goats were fed diets which differed in CP concentrations: 13.3% (low CP, T1), 15.8% (medium CP, T2), and 18.9% (high CP, T3) based on DM, respectively. Feed based on the standard diet for nutrient requirements of goats by the National Research Council (1981), was restricted to achieve an ADG of 100g and was offered twice per day (at 09:00 and 18:00h). Water was constantly available.

Sampling procedures: To estimate the percentage of nitrogen in body weight, the animals were weighed at the beginning and end of every trial period. Feed samples were collected once weekly, and orts were collected daily with; DM determinations done on a weekly basis. Feed offered and orts were measured and recorded daily during the last 7 days of the period to calculate feed intake. Urine and fecal samples were collected daily during the 7-days sampling periods.Urine was collected into a jar containing 15mL of 4N H_2SO_4. After the urine was weighed, 2% of the urine volume was sub-sampled, refrigerated, and bulked. A hundred grams (or 100 mL) of fecal and urine samples in each treatment during the collection period was thoroughly mixed. These samples were dried in a forced-air oven at 60°C, ground to pass through a 1-mm screen (Thomas Scientific Model4, Swedesboro, NJ, USA), and stored for further analysis.

Analytical techniques: Daily feed and orts samples were frozen and analyzed for DM, OM, CP, and ADF. Daily fecal samples were dried in a 60°C dry oven and analyzed for DM, OM, CP, and ADF as above. The nitrogen content of urine was also determined.

Table 1. Feed composition and chemical composition of the experimental diets.

Items	T1	T2	T3
Ingredient (%, as fed)			
Corn gluten meal	2.19	6.46	12.34
Wheat bran	54.71	50.44	44.56
Timothy hay	40	40	40
Limestone	3	3	3
Vitamin mineral premix	0.1	0.1	0.1
Total	100	100	100
Chemical composition (%, DM)			
Dry matter	88.30 ± 0.12	87.30 ± 0.66	87.80 ± 0.14
Crude protein	13.30 ± 0.03	15.76 ± 0.20	18.91 ± 0.10
Ether extract	2.97 ± 0.05	2.55 ± 0.34	2.20 ± 0.02
Crude fiber	21.41 ± 0.83	21.79 ± 0.74	21.52 ± 0.12
Ash	6.17 ± 0.05	5.69 ± 0.68	6.08 ± 0.40
Neutral detergent fiber**	53.04 ± 0.70	51.55 ± 1.00	49.59 ± 1.50
Acid detergent fiber	24.69 ± 0.60	24.76 ± 0.77	25.06 ± 0.93
Total digestible nutrients	66.1	66.0	66.3

*T1, low protein (13% CP); T2, medium protein (15% CP); T3, high protein (18% CP); ** Total digestible nutrients used the standard of NRC (2007)

Statistical analysis: A randomized complete block ANOVA was used to compare CPB data (CPI, urinary CP, fecal CP, and retained CP) with apparent digestibility characteristics among treatments for each trial (SAS, 2008). Treatment means were compared by the new multiple range test of Duncan to identify differences between means. Significant differences were declared if $p<0.05$.

To estimate the CP maintenance requirement for Korean native goats, the relationship between CPB (g/kg $BW^{0.75}$/d) and CPI (CPI, g/kg $BW^{0.75}$/d) was evaluated by performing coefficient correlation and regression analysis. The statistical model was $Y = a + bX$, where Y was CPB (g/kg $BW^{0.75}$/d) and X was CPI (g/kg $BW^{0.75}$/d), while a was the y-intercept and b was the slope of the equation.

RESULTS AND DISCUSSION

Intake, daily gain, feed conversion ratio, and apparent digestibility of nutrients: Average daily gain (ADG), DMI, and the feed conversion ratio of Korean native goat are presented in Table 2. ADG for T2 (181.77g/d) was higher than ADG for T1 and T3 (130.36g/d, 181.77g/d); however, there were no differences ($p>0.05$) between the three groups. DMI was not significantly different among the three groups either, but for T2 it was lower (651.88g/d) than in the other groups (T1=679.61 g/d, T3=687.03g/d, $p>0.05$). Protein is an essential nutrient for animal growth and plays an important role in muscle growth and animal development (Mtenga and Kitaly, 1990), and earlier studies reported that ADG increased as the CP level in feed increased (Jia *et al*., 1995; Choi *et al*., 2005). However, in the present study, dietary CP levels did not affect intake or daily gain. Prieto *et al*.(2000) suggested that adequate protein levels for growth are up to 14%, and similar findings have been reported in studies using Awassi lambs and Black goat kids (Titi *et al*., 2000). In addition, Yurtman *et al*. (2002) carried out a study with 15%, 17.7%, and 21.4% CP diets in Turkgeldi lambs and found that lambs fed 15% CP had higher daily BW gain and DMI than the other groups.

The feed conversation ratios were 5.90, 5.73, and 6.94 for T1, T2, and T3 treatments, respectively; however, the values did not differ statistically. This result differs from the study of Kim and Ko (1995), who reported that the feed conversation ratios of whole crop corn silage containing 7.66% CP and of whole crop corn ensiled with 30% cage layer manure containing 14.86% CP (DM basis) were 8.47 and 5.98, respectively, in Korean native goats. The difference between the two treatments in the study was significant ($p<0.05$). Dietary CP utilization varies with breed, feed type, and growth phase (Negesse *et al*., 2001). Nevertheless, we found no significant difference in the current study. The feed conversation ratio of T2 (15.8% CP) was lower than that of T3 (18.9% CP), which implied the bioavailability for 15.8% CP might be greater than at a higherCP levelin Korean native goats.

The apparent nutrient digestibility of dietary CP treatments in Korean native goats is presented in Table 3. Dietary CP levels did not affect the apparent digestibility of DM, ether extract, crude fiber, ash, NDF, and ADF in treated diets. However, the apparent CP digestibility increased linearly as dietary CP increased (T1=73.03%, T2=76.49%, T3=80.66%; $p<0.05$). This result was consistent with the report of Pralomkarn *et al.*(1995), who found that goats fed an ad libitum diet(54.2 g/$BW^{0.75}$/d, DMI) had a CP digestibility of 80.8%, and the CP digestibility was significantly decreased when the goats were fed with a lower amount offeed or CP. Also, to estimatethe CP requirement for maintenance, Yang *et al*. (2014) fed diets with a CP content of 7%, 12%, and 17%, respectively, to 2-year-old female Korean spotted deer. With regard to apparent CP digestibility, they discovered that significantly different values of 42.6%, 58.3%, and 68.7% with increasing CP level ($p<0.05$). Kim *et al*. (2006) fed Hanwoo (*Bos Taurus coreanae*) steers with feed that contained CP levels of 9.8%, 14%, and 18.9%, respectively, to investigate CP requirement for maintenance; they reported that apparent CP digestibility increased gradually (34.8%, 51.5%, and 62.5%) along with CP level increase ($p<0.05$).The results of the current study are consistent with the previous research, and dietary CP level appears to directly influence apparent CP digestibility.

Dietary CP level and protein requirement for maintenance: Increased CPI, digestible CP, urinary excretion, and CP utilization efficiency in the present study were observed when the goats were fed a higher protein diet. The CPI increased linearly as the dietary CP increased.CPI for T3 (T3=129.92g/d) was higher ($p<0.05$) than that for T1 (90.39g/d). This increase in CPI resulted in a linear increase in digestible CP and urinary CP. The digestible CP for T3 (104.93g/d) was higher ($p<0.05$) than that for T1 (65.68g/d). Urinary emission for T3 (55.23g/d) was higher ($p<0.05$) than that for T2 (27.11g/d), suggesting that excess CP uptake by the body was mainly excreted through the urine. Under a high CP feeding regimen, excess CP absorbed by the body was shown to be lost mainly through the urine in growing beef cattle (Griffiths, 1984) and sheep (Wanapat *et al*., 1982). CP utilization efficiency (retained CP/CPI)for T2 (49.11%) and T3 (44.42) were higher ($p<0.05$) than that for T1 (26.14%), but the difference between T2 and T3 was not significant. Although there was no significant difference in the CP utilization efficiency between T2 and T3, the CP level of T2 was higher than that of T3. This outcome demonstrated that CP bioavailability for T3 was lower than that of T2. Therefore, the dietary CP level which maximizes internal accumulation and minimizes loss of CP in growing Korean native goats was estimated to be approximately 15% (the CP level of T2).

Table 2. Effects of dietary crude protein level on body weight and feed intake of growing Korean native goats.

Item	Treatment, CP(%)*		
	T1	T2	T3
Initial body weight (kg)	24.65 ± 4.90	23.49 ± 3.76	25.25 ± 4.54
Final body weight (kg)	26.33± 6.12	25.94± 4.25	26.05± 5.25
Average daily gain (ADG, g/d)	130.36 ± 106.2	181.77 ± 125.5	133.13 ± 51.7
Dry matter intake (DMI, g/d)	679.61 ± 204.27	651.88 ± 173.95	687.03 ± 154.08
Feed conversion ratio			
DMI/ADG (g/g)	5.90 ± 2.62	5.73 ± 4.40	6.94 ± 5.09

*T1, low protein (13% CP); T2, medium protein (15% CP); T3, high protein (18% CP).

Table 3. Apparent nutrient digestibility in growing Korean native goats fed at different dietary crude protein contents.

Item	Treatment, CP(%)*		
	T1	T2	T3
	------------------------- % DM -------------------------		
DM**	71.14 ± 2.28	70.15 ± 1.85	70.43 ± 3.23
CP	73.03 ± 2.84[c]	76.49 ± 1.94[b]	80.66 ± 1.48[a]
EE	74.07 ± 11.80	78.52 ± 8.84	73.37 ± 3.64
CF	59.17 ± 6.36	57.32 ± 5.26	57.53 ± 4.53
Ash	45.14 ± 7.95	44.18 ± 5.17	44.09 ± 9.13
NDF	66.12 ± 2.94	62.73 ± 2.73	61.01 ± 4.97
ADF	55.50 ± 6.92	53.95 ± 5.12	53.52 ± 5.78

*T1, low protein (13% CP); T2, medium protein (15% CP); T3, high protein (18% CP).
**DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fiber; Ash, crude ash; NDF, neutral detergent fiber; ADF, acid detergent fiber.
[a, b, c] Means with a different superscript in the same row are different.

Table 4. CP balance in growing Korean native goats fed dietary at different crude protein contents.

Item	Treatment, CP(%)**		
	T1	T2	T3
	---------------------------- g/d ----------------------------		
Crude protein intake(CPI)	90.39 ± 27.17[b]	102.34 ± 27.41[ab]	129.92 ± 29.14[a]
Emission			
Fecal	24.71 ± 8.87	23.96 ± 5.73	24.99 ± 5.43
Urinary	36.62 ± 19.43[ab]	27.11 ± 12.77[b]	55.23 ± 26.62[a]
Digestible CP	65.68 ± 18.72[b]	78.77 ± 22.10[ab]	104.93 ± 24.09[a]
Retained CP	29.05 ± 19.25	51.66 ± 25.26	49.71 ± 18.39
% CP utilization efficiency (RCP/CPI)	26.14 ± 12.52[b]	49.11 ± 14.60[a]	44.42 ± 13.11[a]

*T1, low protein (13% CP); T2, medium protein (15% CP); T3, high protein (18% CP).
[a, b, c] Means with a different superscript in thesame row are different.

The regression model between digestible or absorbed CP (DCP, g/kg $BW^{0.75}$/d) and CPI (g/kg $BW^{0.75}$/d) to estimate the metabolic fecal CP is shown in Figure 1. The estimated regression equation was

$$Y = -0.6580+0.8423X,\ p<0.001,\ r^2 = 0.9878$$

where Y is the digestible CP, and X is the CPI. The metabolic fecal CP level was calculated to be 0.66 g/kg $BW^{0.75}$/d by extrapolating the line to zero CPI. A strong linear relationship existed between CPI and DCP (r^2=0.9878), which means that more CP was digested and absorbed as the amount ingested increased. However, the r^2 of the regression model between CPB(g/kg $BW^{0.75}$/d) and CPI (g/kg $BW^{0.75}$/d) declined to 0.4642 (Figure 2), indicating that the CPB dispersion for the CPI was large. Therefore, the utilization efficiency of digested and absorbed CP in the body was unstable because the urinary CP excretion of T3 was the highest.In addition, the regression r^2 between CPB (g/kg $BW^{0.75}$/d) and CPI (g/kg $BW^{0.75}$/d) of the T2 (15% CP) was as high as 0.8362 (see Figure 3). These results demonstratethat the main treatment in which absorbed CP was used disproportionately in the body was T3 (18% CP). Thus feeding18% dietary CP could increase the digestion or absorption of CP, but itseemed to be ineffective with regard to the bioavailability of CP because the level of urinary excretion was high. Therefore, the optimal dietary CP level is estimated to be around 15% in Korean native goats. Meanwhile, the regression equation of CPB (g/kg $BW^{0.75}$/d) according to CPI(g/kg $BW^{0.75}$/d) suggested by analyzing T2 data was as follows:

$$Y = -2.5469 + 0.7873X,\ p<0.05,\ r^2 = 0.8362$$

where Y is CPB, and X is CPI. The X-interceptof equation was 3.23; therefore, Korea native goats need 3.23g/kg $BW^{0.75}$/d of CP to maintain their body weight.The CP requirement of Korean native goats for maintenance in the present study was lower than the 3.57g/kg$BW^{0.75}$/dreported for Thai indigenous goats (Chobtang *et al*., 2009), 4.17g/kg $BW^{0.75}$/d for Korean spotted deer (Yang *et al*., 2014), 5.56g/kg $BW^{0.75}$/d for Korean beef steers (Kim *et al*., 2006), 5.83g/kg $BW^{0.75}$/d for beef cows (Susmel *et al*., 1993), 5.83g/kg $BW^{0.75}$/d for Indian goats (Mandal *et al*., 2005), and 7.8 and 7.2 g/kg $BW^{0.75}$/d for wool and hair lambs (Silva, 1996), while it was higher than the 3.13g/kg $BW^{0.75}$/d for goats (Silva Sobrinho, 1989). In addition, the digestible CP requirement for maintenance was 2.82g/kg $BW^{0.75}$/d for goats (NRC, 1981) and 1.65 g/kg $BW^{0.75}$/d for adult Thai native goats (Cheva-Isarakul *et al*., 1991). Nutrient requirements could be affected by genotype, environmental condition, dietary situation, and calculation method (NRC, 1981; AFRC, 1998; Mandal *et al*., 2005). Therefore, to get more precise information on proper dietary CP level and CP requirement for maintenance of goats, additional analyses should be conducted using different types of animals, various regions and climates, different types of protein feed source and intake, a variety of measuring methods, and so forth, and results of such research should be compared.

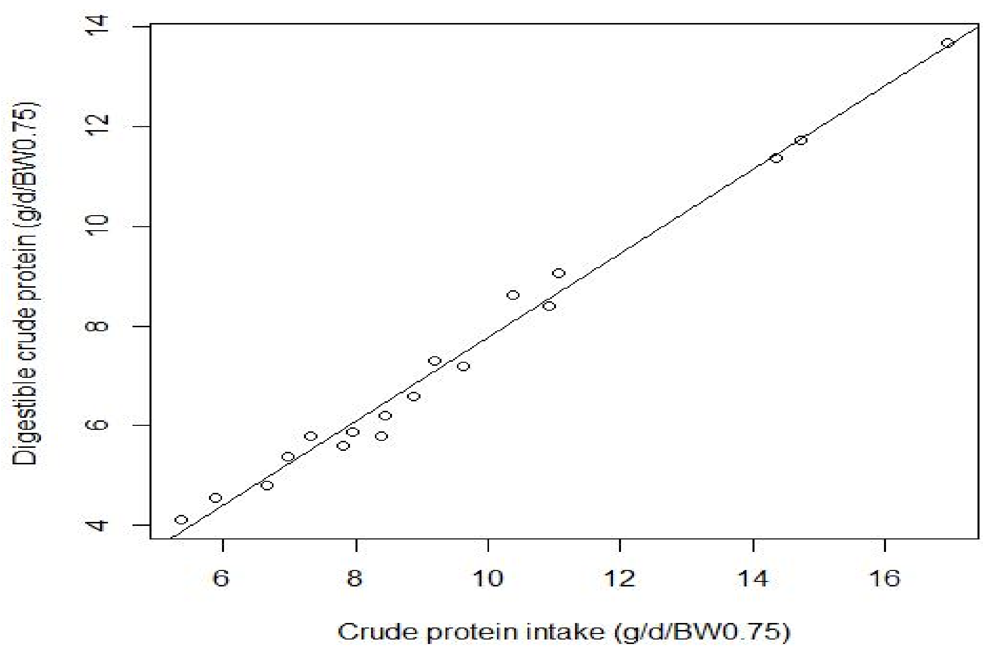

Figure 1. Simple linear regression equation between crude protein intake (g/kg $BW^{0.75}$/d) and digestible crude protein (g/kg $BW^{0.75}$/d) in growing Korean native goats.

CP balance = −0.6580 + 0.8423 x CPI ($p<0.001, r^2= 0.9878$).

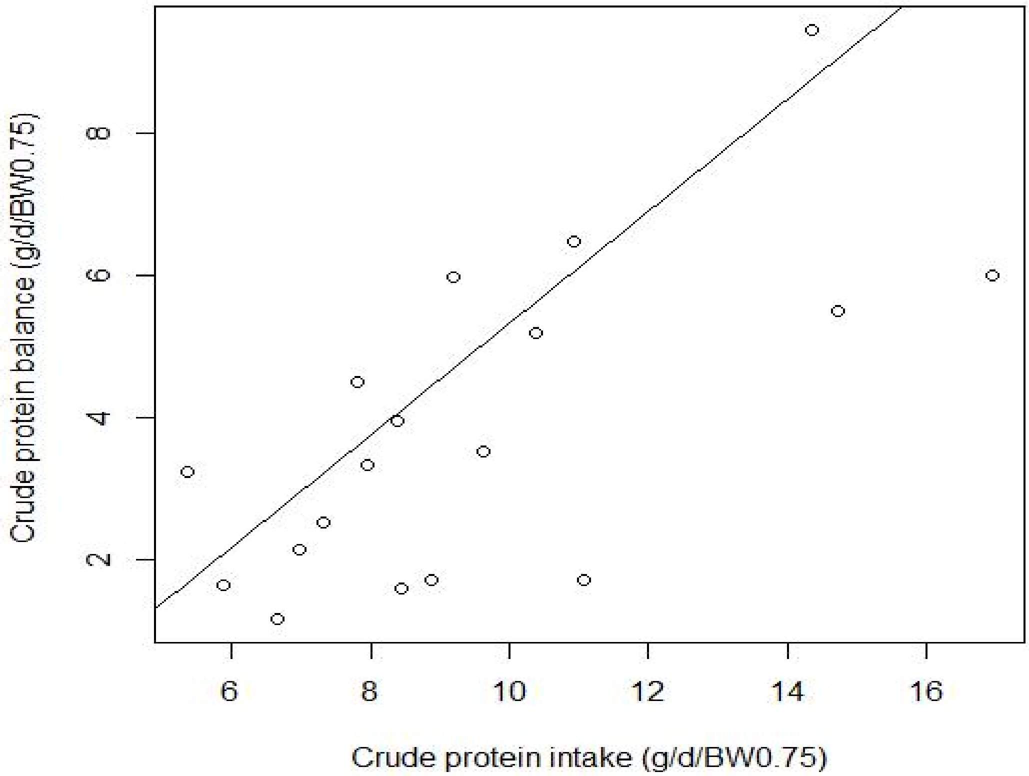

Figure 2. Simple linear regression equation between crude protein intake (g/kg BW$^{0.75}$/d) and crude protein balance (g/kg BW$^{0.75}$/d) in growing Korean native goats.

CP balance = −0.6943 + 0.4804 x CPI ($p<0.01$, $r^2= 0.4642$).

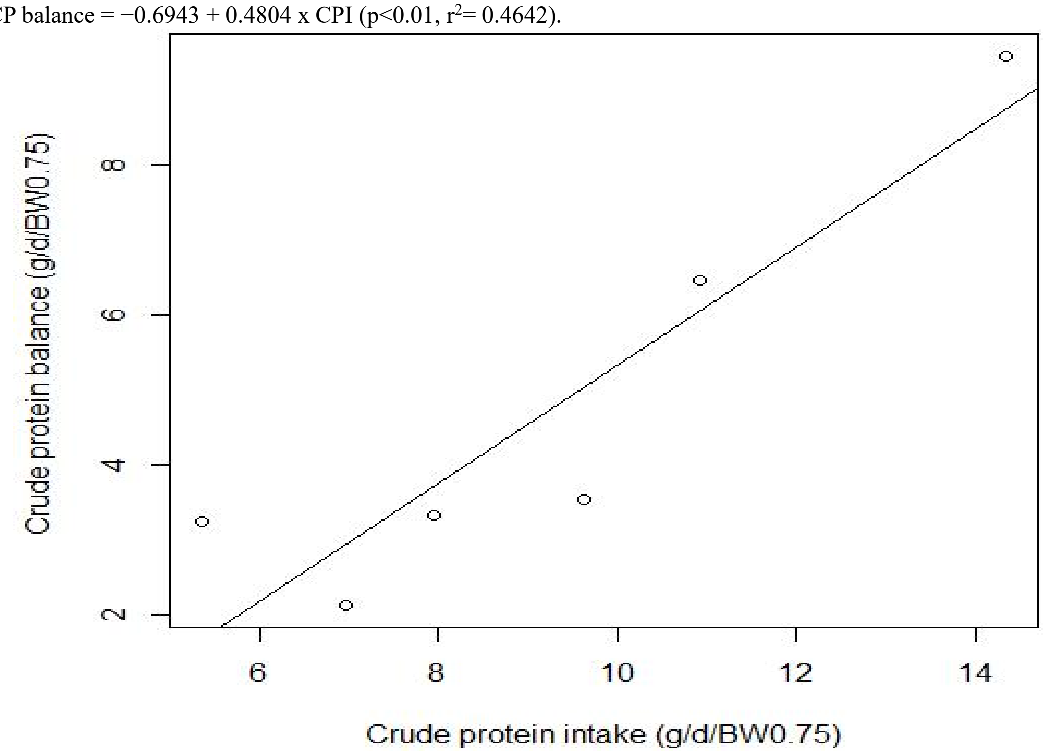

Figure 3. Simple linear regression equation between crude protein intake (g/kg BW$^{0.75}$/d) and crude protein

balance (g/kg BW$^{0.75}$/d) with the dietary crude protein level of 15% in growing Korean native goats.

CP balance = −2.5469 + 0.7873 x CPI ($p<0.05, r^2= 0.8362$).

Conclusion: The results of this study indicate that an increase in the dietary CP level fed to Korean native goats increased CP intake, apparent CP digestibility, and digestible CP within a normal range. However, excessive CP intake led to the loss of CP through urine and could eventually reduce the bioavailability of CP. Accordingly, this research determined that a proper level of dietary CP was important for efficient maintenance and growth of goats. In the present study, a dietary CP level of around 15% appeared to be suitable for Korean native goats. Meanwhile, the dietary CP requirement of Korean native goats for maintenance was 3.23g/kg BW$^{0.75}$/d.

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