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Effects of Crude Protein Levels in Total Mixed Rations on Growth Performance and Meat Quality in Growing Korean Black Goats

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ABSTRACT : This study was carried out to investigate effects of crude protein (CP) levels in total mixed rations (TMR) on growth performance and meat quality in growing Korean black goats. Thirty-six 6-month-old growing black male goats (initial body weight = 17.95±0.13 kg) were used. The goats were randomly divided into four treatments and 9 animals were allotted to each treatment. In terms of treatments, CP levels in TMR were 14, 16, 18, and 20% of dry matter (DM) and all diets were isocaloric (2.4 Mcal ME/kg DM). The experiment lasted for 20 weeks with a 15-day adaptation period. After the end of the trial, five goats from each treatment were slaughtered to measure carcass characteristics and meat quality. Average daily gain (ADG) significantly ($p<0.05$) increased as dietary CP levels increased, but the highest ADG was found on the 18% CP treatment. The higher CP levels in TMR significantly ($p<0.05$) decreased feed conversion ratio, but the lowest ratio was on the 18% CP treatment, suggesting a higher bioavailability of nutrients by balanced energy and protein levels on this treatment. There was no significant difference in dressing percentage among treatments, but there was a tendency for levels more than 16% CP in TMR to have a comparatively higher dressing percentage than the 14% treatment. The percentages of meat, fat and bone were not significantly influenced by dietary CP levels. Dietary CP levels did not influence chemical composition of goat meat. Furthermore, there was no significant difference among treatments in any of the sensory parameters except for tenderness. Tenderness was similar for 18 and 20% treatments, which were significantly ($p<0.05$) higher than the 14% treatment. The results from this study suggested that an adequate CP level in TMR for achieving optimal growth performance and meat quality of growing Korean black goats might be 18% of DM, and that dietary CP level above 18% seemed not to further increase growth performance and meat quality. (**Key Words** : Crude Protein, Total Mixed Rations, Growth Performance, Meat Quality, Goats)

INTRODUCTION

The population of 370,000 Korean black goats in Korea was kept on 27,000 farms in 2007 (MAF, 2008). The production pattern of black goats in Korea is becoming a multi-faceted, intensive feeding system as consumption of meat for food increases, while previously, goat meat consumption pattern was mostly for medicine cooked in a double boiler, and a small-size, free-range farming system using farm byproducts was predominant. For this reason, moving out of an experience-dependent feeding system, a scientific and systematic feeding management for black goat production is increasingly required.

Song et al. (1998) reported in growth study that average daily gain (ADG) of black goats was just 60 g and they demonstrated that an extensive feeding management was a reason for the low growth performance. However, in recent studies aimed at determining optimal feed protein (Choi et al., 2005) and energy levels (Choi et al., 2007) for Korean black goats, growth could be built up to 83.9 and 77 g of ADG, respectively, suggesting that optimal nutrient provision required for growth and body weight gain of Korean black goats could achieve the best performance for meat production.

In particular, protein is an essential nutrient for animal growth and development, and thus a sufficient protein supply is a crucial factor for normal growth. Previous studies on optimal protein levels in feeds of goats reported that 14% (Prieto et al., 2000), 16% (Titi et al., 2000) and 20.3% (Shahjalal et al., 2000) were optimum protein levels for fattening, and 14 to 16% in concentrates and above 15%

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in total mixed rations were optimal protein levels in the fattening of Korean black goats (Choi et al., 2005) and early pregnant black goats (Hwangbo et al., 2007), respectively.

It has been well known that total mixed rations (TMR) improve nutrient utilization due to balanced intakes for roughage and concentrates leading to stabilization of ruminal fermentation (Nocek et al., 1985). Taking this into account, in order to maximize Korean black goat growth performance and ruminal fermentation, the determination of optimal protein levels in a TMR feeding system is indispensable. However, even protein levels of concentrates have not been clearly defined, which might result in the low productivity of Korean black goats (Choi et al., 2005).

Therefore, the objectives of this study were to investigate effects of crude protein (CP) levels in TMR on the growth performance and meat quality of growing Korean black goats.

MATERIAL AND METHODS

Experimental animals and site

Thirty-six growing Korean black male goats (approximately 6-months-old; 17.95±0.13 kg of initial body weight) were used and 9 animals were allotted to each treatment. The experiment was conducted at the Animal Genetic Resources Station, the National Institute of Animal Science, Namwon, Korea from May 14th until October 10th, 2007.

Experimental diets and feeding management

The CP levels in TMR used in this experiment were 14, 16, 18 and 20% of dry matter (DM) and energy level was isocaloric at 2.4 Mcal ME/kg DM in all treatments. The ingredients and chemical composition of experimental diets are shown in Table 1. The TMR was prepared using wet brewers grain, corn gluten feed, sugarcane molasses, fescue straw, alfalfa hay, corn, and a vitamin mineral supplement at a defined ratio of treatments on a DM basis. The moisture content of all TMR was kept to around 30% to induce favorable fermentation. The manufactured TMR was packed in polyethylene bags until fed to goats. TMR used in this experiment was provided to each treatment at 1.5% of body weight (BW) and the amount of TMR was gradually increased by adaptation from 15 days prior to the initiation of the trial. After starting the experiment, TMR at 3.0% of BW was equally divided into two parts and was provided twice a day at 09:00 and 16:00. The animals were assigned to each group of nine goats and placed in each group with three replications kept in pens (2×2 m) with free-choice access to fresh water. The body weights were measured at an interval of 30 days prior to feeding and from the initiation until the end of the trial. Feed intake was calculated as the difference between the amount of feed offered and feed refusal, and the feed refusal was obtained and weighed in the morning of the next day.

Carcass, meat and diet analyses

Five animals from each treatment were slaughtered with a scalded process at the meat processing laboratory, animal product processing division, the National Institute of Animal Science and chilled at 5°C for 24 h prior to boning. For carcass measurement, carcass weight, dressed meat

Table 1. Ingredients and chemical composition of experimental diets

Item	Treatments (CP %)			
	14	16	18	20
Ingredients (% of dry matter)				
Wet brewers grains	31.17	31.17	31.17	31.17
Corn gluten feed	12.18	23.50	26.40	26.20
Molasses, sugarcane	5.00	5.00	5.00	5.00
Fescue straw	15.00	15.00	15.00	15.00
Alfalfa hay	5.00	5.00	3.00	3.00
Corn	29.00	16.70	11.80	6.80
Soybean meal	-	-	-	3.50
Sesame meal	-	1.10	5.20	7.00
Limestone	2.30	2.20	2.10	2.00
Salt	0.10	0.08	0.08	0.08
Vitamin premix	0.25	0.25	0.25	0.25
Chemical composition (% of dry matter)				
Dry matter (%)	66.73	67.88	68.33	68.27
Crude protein (%)	14.13	16.09	18.15	20.02
Crude fat (%)	1.67	1.64	1.99	2.11
Acid detergent fiber (%)	20.15	22.86	24.63	25.24
Neutral detergent fiber (%)	45.63	48.14	50.22	50.65
Crude ash (%)	6.41	7.03	7.27	7.37
Non-fibrous carbohydrate (%)	32.16	27.10	22.37	19.85

Table 2. Effects of crude protein levels in total mixed rations on body weight gain and dry matter intake in Korean black goats

Item	Treatments (CP %)				SEM[1]
	14	16	18	20	
Initial body weight (kg)	18.08	18.00	17.78	17.95	1.56
Final body weight (kg)	32.09	32.70	33.25	32.67	1.47
Total gain (kg)	14.02[b]	14.70[b]	15.48[a]	14.72[b]	0.36
ADG (g/d)	94.07[b]	98.66[b]	103.86[a]	98.80[b]	2.43
TDMI (g/d)	669.18	650.30	643.69	645.76	15.43
CPI (g/d)	94.59[d]	104.61[c]	116.82[b]	129.34[a]	2.60
Feed conversion ratio	7.11[a]	6.59[b]	6.20[c]	6.54[b]	0.13

ADG = Average daily gain. TDMI = Total dry matter intake. CPI = Crude protein intake.

[1] Standard error of the mean.

[a, b, c, d] Values with different superscripts within same row are significantly different ($p<0.05$).

weight, bone and fat weights were weighed with an electronic scale. Nine samples of m. *longissimus* and sirloin from three animals with 3 replications of each treatment were prepared and used for measurements of proximate chemical composition and Warner-Bratzler shear force, respectively. The proximate chemical composition of feed and m. *longissimus* samples was analyzed by AOAC (1990), and cooking loss and Warner-Bratzler shear force (Warner-Bratzler shear meter, G-R Elec. Mfg. Co. USA) were measured. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents in the diet were determined based on the methods of Van Soest et al. (1991). Non-fibrous carbohydrate content was calculated by subtracting crude protein, crude fat, crude ash, and NDF from DM. Panel tests for sensory evaluation were performed on juiciness, tenderness and flavor by ten testers chosen randomly with a 6 score range for acceptability.

Statistical analyses

The data were analyzed using the GLM procedure (SAS, 2000). Duncan's multiple range tests ($p = 0.05$) were used to determine statistical differences between treatment means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Body weight gain and feed intake

The effects of CP level in TMR on BW gain and DM intake of Korean black goats are presented in Table 2. The average daily gain (ADG) range of all treatments was 94.1 to 103.9 g during the experimental period and the 18% CP treatment had significantly ($p<0.05$) higher ADG compared with other treatments. Daily total DM intake ranged from 643.7 to 669.2 g and daily CP intake significantly ($p<0.05$) increased with increasing dietary CP level. Feed conversion ratio was 7.11, 6.59, 6.20 and 6.54 for 14, 16, 18 and 20% treatments of dietary CP, respectively. The lower CP levels in TMR significantly ($p<0.05$) increased feed conversion ratio, which was lowest in the 18% treatment suggesting a higher bioavailability of nutrients by balanced energy and protein levels on this treatment.

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 CP level in feed increased (Hart et al., 1993; Jia et al., 1995; Choi et al., 2005). In the present study, the results showed that ADG increased as dietary CP levels increased from 14 to 18%, similarly to previous studies. Average daily gain, however, significantly decreased as CP level in TMR increased from 18% to 20%. Since the higher dietary CP utilization in goats is closely related to energy provision, when energy provision is deficient, dietary CP utilization for animal growth decreases (Titi et al., 2000). Furthermore, dietary CP utilization varies with breed, feed type and growth phase (Negesse et al., 2001). Osuagwuh and Akinsoyinu (1990) found that 17% protein level showed the highest nitrogen absorption, but more than 17% protein level decreased nitrogen absorption in West African dwarf goats. In the present study, lower ADG in the 20% treatment compared to 18% treatment may have resulted from insufficient energy provision due to a high level of protein in the diet.

In general, it is well known that feed intake increases as dietary CP level increases (Huston et al., 1988; Cheema et al., 1991). In contrast, the present study showed that there was no significant difference in total DM intake among treatments. The results from this study were similar to those from Ahn and Moon (1985) and Choi et al. (2005), who reported no significant differences in feed intake when sheep were fed diets with different CP levels which ranged from 9 to 13% and when Korean black goats consumed diets containing 12 to 18% CP, respectively. These feed intake results might be attributable to not only dietary CP content but also to several different factors such as feed palatability.

Goats at 30 kg BW need 92 g of total protein to meet the nutrient requirement for maintenance and minor activity (intensive management, 25% increase), and 100 g of ADG (NRC, 1981). In the present study, total protein required for 100g of ADG was met, and goats in 16 and 18% treatments

Table 3. Effects of crude protein levels in total mixed rations on carcass characteristics and chemical composition of muscles in Korean black goats

Item	Treatments (CP %)				SEM[1]
	14	16	18	20	
Carcass					
Slaughter weight (kg)	31.67	31.33	31.33	31.00	1.00
Cold carcass weight (kg)	16.33	16.97	17.03	16.77	0.87
Dressing percentage (%)	51.59	54.18	54.36	54.10	1.86
Meat percentage (%)	58.08	58.49	59.62	58.37	1.28
Fat percentage (%)	4.78	4.05	3.86	4.03	1.03
Bone percentage (%)	18.91	18.62	18.12	18.28	0.84
Chemical composition					
Moisture (%)	74.30	74.57	74.75	74.79	0.91
Crude protein (%)	22.22	22.42	22.52	21.73	0.80
Crude fat (%)	1.41	1.43	1.65	1.54	0.19
Crude ash (%)	1.04	1.00	1.01	0.95	0.06

[1] Standard error of the mean.

were fed 24.8 and 37.3 g more protein, respectively, than the requirement. Choi et al. (2007) reported that the optimal energy requirement for Korean black goats at 15% CP in feed was 3.0 Mcal ME/kg DM. However, in the present study, 2.4 Mcal ME/kg DM provision to black goats might be somewhat limiting to synchronize with dietary protein in the rumen, and thus it might have led to the lower protein availability.

Carcass characteristics and chemical composition

The effects of CP level in TMR on carcass characteristics and chemical composition of Korean black goat meats are presented in Table 3.

The dressing percentages on the 16 to 20% treatments represented 54.1 to 54.4% of slaughter weight, which tended to be higher than 51.6% on the 14% treatment. There were no significant differences among treatments in the percentages of meat, fat and bone, representing 58.1 to 59.6, 3.9 to 4.8 and 18.1 to 18.9%, respectively, of the carcass. The dressing percentages of Korean black goats from previous studies were 48.6 to 51.4% in animals of 27 kg BW for different dietary energy levels (Choi et al., 2007), 45.1 to 46.2% in goats of 17 kg BW for browse feeding (Choi et al., 2003) and 45.2 to 46.8% in goat wethers of 20.2 kg BW (Choi et al., 2000). The dressing percentage in the present study ranged from 51.6 to 54.4%, indicating a higher tendency compared to previous studies described above. Since dressing percentage is closely related to BW at slaughter and, furthermore, dressing percentage increases as BW at slaughter increases (Marinova et al., 2001; Mourad et al., 2001), the higher dressing percentage tendency in the present study may have resulted from the higher BW compared to previous studies.

Similar BW at slaughter in the present study possibly showed no significant differences on dressing percentages among treatments since dressing percentages have a closer association with BW at slaughter than dietary CP levels (Mtenga and Kitaly, 1990; Atti et al., 2004).

There were no significant differences in bone percentages, ranging from 18.1 to 18.9%. In general, since the bone formation is completed earlier than other tissues in growing animals (Colomer-Rocher et al., 1992), it is conceivable that, in the present study, there were no differences in bone percentage among treatments due to the likelihood of completion of bone formation before this growth trial. Although there were no significant differences in the meat percentage among treatments, as dietary CP levels increased meat percentage tended to increase up to the 18% CP level. However, 20% treatment tended to decrease meat percentage compared with 18% treatment. This trend was similar to the results of Atti et al. (2004) who reported that in Tunisian male goat kids a, medium level of dietary CP produced more muscle than low dietary CP level, but high protein diets had less muscle compared with medium protein diets. In this regard, Atti et al. (2004) demonstrated that nitrogen was more efficiently used in the medium than in the high protein diet. In the present study, it is concluded that goats fed the 18% CP diet more efficiently utilized nitrogen than goats fed 20% CP.

The content of moisture, crude protein, crude fat and crude ash accounted for 74.3 to 74.8%, 21.7 to 22.5%, 1.4 to 1.7 and 0.95 to 1.04%, respectively, with no significant differences among treatments. In previous studies on proximate chemical composition of Korean black goat meat, the average percentages of moisture, crude protein, crude fat and crude ash were 73.5, 21.4, 3.4 and 1.2%, respectively, in the trial with different energy levels (Choi et al., 2007) and 76.6, 20.0, 1.2 and 1.1%, respectively, in the browse feeding study (Choi et al., 2003). Furthermore, Choi et al. (2005) found that the average percentages of moisture, crude protein, crude fat and crude ash in Korean black goat meat were 75.1 to 76.9, 20.5 to 21.2, 1.0 to 1.1 and 1.3 to 2.6%, respectively, when goats were fed diets with different dietary CP levels ranged from 14 to 18%. The results in

Table 4. Effects of crude protein levels in total mixed rations on physical property and sensory evaluation of Korean black goat meat

Item	Treatments (CP %)				SEM[1]
	14	16	18	20	
Shear force (kg/cm^2)	3.18	3.13	2.98	3.00	0.22
Cooking loss (%)	27.14	26.01	25.80	26.67	3.81
Water holding capacity (%)	54.82	55.35	57.03	55.67	3.27
Juiciness[2]	4.13	4.23	4.33	4.23	0.21
Tenderness[3]	4.27[b]	4.50[ab]	4.80[a]	4.63[a]	0.15
Flavor[4]	3.33	3.50	3.60	3.73	0.31

[1] Standard error of the mean.

[2, 3, 4] Sensory scores were assessed on 6 point scale based on 1-extremely dry, tough and weak for juiciness, tenderness and flavor, respectively, 6-extremely juicy, tender and strong for juiciness, tenderness and flavor, respectively.

[a, b] Values with different superscripts within same row are significantly different ($p<0.05$).

chemical composition for Korean black goat meat in the present study were similar to previous ones. Choi et al. (2005) also reported that there were no significant differences in proximate chemical composition of Korean black goat meat in the feeding trial of diets with different dietary CP level, which was similar to results of this study.

Table 4 presents the effects of CP level in TMR on physical property and sensory evaluation of Korean black goat meat. The shear force, cooking loss and water holding capacity were 2.98 to 3.18 kg/cm^2, 25.8 to 27.1% and 54.8 to 54.0%, respectively. Although no significant differences among treatments were found in shear force, cooking loss and water holding capacity, the 18% CP treatment showed tendency for lower shear force and cooking loss, and tendency for higher water holding capacity compared with other treatments.

From sensory evaluation, the juiciness and flavor scored 4.1 to 4.3 and 3.3 to 3.7, respectively, without statistical differences among treatments, while tenderness in treatments above 18% CP was significantly ($p<0.05$) higher than for 14% treatment. The present study showed that shear force, the index for mechanical tenderness of meat, tended to be lower with increasing levels of dietary CP. The shear force is closely related to intramuscular fat content (Berry, 1993) and it is lowered as intramuscular fat content increases (Hodgson et al., 1992), which was similar to the present study (Table 3). It has been reported that as intramuscular fat content increased, cooking loss decreased (Palanska and Nosal, 1991) and water holding capacity increased (Kim et al., 2002). The lower cooking loss and higher water holding capacity in the 18% CP treatment of the present study might be caused by the higher content of fat (Table 3). In this regard, tendency for higher fat content for the 18% treatment might be associated with dietary protein level. Since it is well known that adipocytes are proliferated and differentiated by the expression of several lipogenic enzymes and specific hormones like insulin which are protein constituents (Wu et al., 1999; Lundgren et al., 2004; Yamada et al., 2009), fat content in the muscle was likely to be regulated by dietary protein level. Likewise, Yan et al. (2008) reported that, in trials of lambs fed different dietary protein levels, a higher dietary protein increased their pelvic fat weight, fat thickness of the 10th rib, *longissimus* muscle area, and deposition rate of intramuscular fat, but some studies with other species have reported results which differ from this logic (De Smet et al., 2000; Teye et al., 2006). De Smet et al. (2000) reported that, in a Belgian blue bull feeding trial, dietary CP levels did not influence fat content in muscles. Contrary to our expectation, Teye et al. (2006) indicated that low protein diets increased intramuscular fat content, tenderness and juiciness more than high protein diets in pigs. Therefore, various results in response to dietary CP level conflict with the view that dietary CP stimulates the proliferation and differentiation of adipose cells, and thus further research is needed.

Tenderness is the most critical index of sensory evaluation (Platter et al., 2003), because it is the most important factor affecting meat taste (Savell et al., 1989). Park et al. (2002) reported that sensory evaluation including tenderness, juiciness and flavor had a negative correlation with shear force in Korean native cattle. In the present study, no difference in tenderness between the 18 and 20% CP treatments suggests that the 18% protein level is optimal.

The results from this study suggested that an adequate CP level in TMR for achieving optimal growth performance and meat quality of growing Korean black goats might be 18% of DM, and that dietary CP level above 18% seemed not to further increase growth performance and meat quality.

REFERENCES

Ahn, B. H. and Y. H. Moon. 1985. Effect of dietary protein and calcium levels on nutrition in sheep I. Effect of dietary protein and calcium levels on digestibility, nitrogen balance and some mineral retention in sheep. Kor. J. Anim. Sci. 27:507-514.

AOAC. 1990. Official methods of analyses. 15th ed. Association of Official Analytical Chemists. Arlington, VA.

Atti, N., H. Rouissi and M. Mahouachi. 2004. The effect of dietary crude protein level on growth, carcass and meat composition of male goat kids in Tunisia. Small Rumin. Res. 54:89-97.

Berry, B. W. 1993. Tenderness of beef loin steaks as influences by marbling level, removal of subcutaneous fat and cooking

method. J. Anim. Sci. 71:2412-2419.
Cheema, A. U., M. L. Galyean, J. S. Caton and A. S. Freeman. 1991. Influence of protein levels and naloxone on intake, nitrogen metabolism and digestion kinetics in lambs fed oat hay or barley straw. Small Rumin. Res. 5:35-46.
Choi, S. H., B. Y. Park, Y. M. Cho, C. Y. Choi, E. G. Kwon, Y. K. Kim and S. N. Hur. 2003. Effects of feeding browses on growth and meat quality of Korean native goats. J. Anim. Sci. Technol. (Kor.) 45:819-824.
Choi, S. H., S. Hwangbo, S. W. Kim, Y. K. Kim, B. D. Sang, J. H. Myung, S. N. Hur and I. H. Jo. 2007. Effects of dietary energy level on growth and meat quality of Korean native goats. J. Anim. Sci. Technol. (Kor.) 49:509-514.
Choi, S. H., S. W. Kim, B. Y. Park, B. D. Sang, Y. K. Kim, J. H. Myung and S. N. Hur. 2005. Effects of dietary crude protein level on growth and meat quality of Korean native goats. J. Anim. Sci. Technol. (Kor.) 45:783-788.
Choi, S. H., Y. M. Cho, M. J. Kim, H. S. Chai, J. W. Lee and Y. K. Kim. 2000. Effects of castration and searing of musk gland on growth performance and meat quality of Korean native goats. J. Anim. Sci. Technol. (Kor.) 42:891-896.
Colomer-Rocher, F., A. H. Kirton, G. J. K. Mercer and D. M. Duganzich. 1992. Carcass composition of New Zealand Saanen goats slaughtered at different weights. Small Rumin. Res. 7:161-173.
De Smet, S., E. C. Webb, E. Claeys, L. Uytterhaegen and D. I. Demeyer. 2000. Effect of dietary energy and protein levels on fatty acid composition of intramuscular fat in double-muscled Belgian Blue bulls. Meat Sci. 56:73-79.
Hart, S. P., T. Sahlu and J. M. Fernandez. 1993. Efficiency of utilization of high and low quality forage by three goat breeds. Small Rumin. Res. 10:293-301.
Hodgson, R. R., K. E. Belk, J. W. Savell, H. R. Cross and F. L. Williams. 1992. Development of a quantitative quality grading system for mature cow carcasses. J. Anim. Sci. 70:1840-1847.
Huston, J. E., G. S. Engdahl and K. W. Bales. 1988. Intake and digestibility in sheep and goats fed three forages with different levels of supplemental protein. Small Rumin. Res. 1:81-92.
Hwangbo, S., S. H. Choi, S. H. Lee, S. W. Kim, Y. K. Kim, B. D. Sang and I. H. Jo. 2007. Effects of crude protein levels in total mixed rations on dry matter intake, digestibility and nitrogen balance in early pregnant Korean black goats. J. Kor. Grassl. Sci. 27:93-100.
Jia, Z. H., T. Sahlu, J. M. Femandez, S. P. Hart and T. H. Teh. 1995. Effects of dietary protein level on performance of Angora and cashmere-producing Spanish goats. Small Rumin. Res. 16: 113-119.
Kim, J. H., B. Y. Park, Y. M. Yoo, S. H. Cho, Y. K. Kim, J. M. Lee, H. J. Yun and K. N. Kim. 2002. Characteristics of carcass meat yields of fattening pigs by production step. J. Anim. Sci. Technol (Kor.) 44:793-800.
Lundgren, M., J. Buren, T. Ruge, T. Myrnas and J. W. Eriksson. 2004. Glucocorticoids down-regulate glucose uptake capacity and insulin-signaling proteins in omentals but not subcutaneous human adipocytes. J. Clin. Endocrinol. Metab. 89:2989-2997.
Marinova, P., Y. Banskalieva, S. Alexandrov, V. Tzvetkova and H. Stanchev. 2001. Carcass composition and meat quality of kids fed sunflower oil supplemented diet. Small Rumin. Res. 42:217-225.
Ministry of Agriculture and Forestry. 2008. Statistical yearbook of agriculture, forestry and fisheries.
Mourad, M., G. Gbanamou and L. B. Balde. 2001. Carcass characteristics of West African dwarf goats under extensive system. Small Rumin. Res. 42:81-85.
Mtenga, L. A. and A. J. Kitaly. 1990. Growth performance and carcass characteristics of Tanzanian goats fed *Chloris gayana* Hay with different levels of protein supplement. Small Rumin. Res. 3:1-8.
Negesse, T., M. Rodehutscord and E. Pfeffer. 2001. The effect of dietary crude protein level on intake, growth, protein retention and utilization of growing male Saanen kids. Small Rumin. Res. 39:243-251.
Nocek, J. E., R. L. Steele and D. G. Braund. 1985. Effect of mixed ration nutrient density on milk of cows transferred from high production group. J. Dairy Sci. 68:133-139.
NRC. 1981. Nutrient requirements of goats, national academy of sciences - national research council, Washington DC.
Osuagwuh, A. I. A. and A. O. Akinsoyinu. 1990. Efficiency of nitrogen utilization by pregnant West African dwarf goats fed various levels of crude protein in the diet. Small Rumin. Res. 3:363-371.
Palanska, O. and V. Nosal. 1991. Meat quality of bulls and heifers of commercial crossbreeds of the improved Slovak Spotted cattle with the Limousine breed Vedecke Prace Vyskumneho Ustavu Zivocisnej Vyroby Nite (CSFR) 24:59.
Park, G. B., S. S. Moon, Y. D. Ko, J. K. Ha, J. G. Lee, H. H. Chang and S. T. Joo. 2002. Influence of slaughter weight and sex on yield and quality grades of Hanwoo (Korean native cattle) carcasses. J. Anim. Sci. 80:129-136.
Platter, W. J., J. D. Tatum, K. E. Belk, P. L. Chapman, J. A. Scanga and G. C. Smith. 2003. Relationships of consumer sensory ratings, marbling score, and shear force value to consumer acceptance of beef strip loin steaks. J. Amin. Sci. 81:2741-2750.
Prieto, I., A. L. Goetsch, V. Banskalieva, M. Camerton, R. Puchala, T. Sahlu, L. J. Dawson and S. W. Coleman. 2000. Effects of dietary protein concentration on postweaning growth of Boer crossbred and Spanish goat wethers. J. Anim. Sci. 78:2275-2281.
SAS. 2000. User's Guide: Statistics, Version 8e. SAS Inst., Inc. Cary, NC.
Savell, J. W., H. R. Cross, J. J. Francis, J. W. Wise, D. S. Hale, D. L. Wilkes and G. C. Smith. 1989. National consumer retail beef study: Interaction of trim level, price and grade on consumer acceptance of beef steaks and roasts. J. Food Qual. 12:251-274.
Shahjalal, M., M. A. A. Bishwas, A. M. M. Tareque and H. Dohi. 2000. Growth and carcass characteristics of goats given diets varying protein concentration and feeding level. Asian-Aust. J. Anim. Sci. 13:613-618.
Song, H. B., I. H. Jo, M. J. Jun, Y. K. Park, K. C. Hong, N. C. Park, J. C. Do and H. S. Lim. 1998. Study on the increasing method of income in the goat farmers. Ministry of Agriculture and Forestry.
Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach (2nd Ed.). McGraw-Hill Bok Co., New York.
Teye, G. A., P. R. Sheard, F. M. Whittington, G. R. Nute, A.

Stewart and J. D. Wood. 2006. Influence of dietary oils and protein level on pork quality. 1. Effects on muscle fatty acid composition, carcass, meat and eating quality. Meat Sci. 73:157-165.

Titi, H. H., M. J. Tabbaa, M. G. Amasheh, F. Barakeh and B. Daqamseh. 2000. Comparative performance of Awassi lambs and Black goat kids on different crude protein levels in Jordan. Small Rumin. Res. 37:131-135.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wu, Z., E. D. Rozen, R. Burn, S. Hauser, G. Adelmant, A. E. Troy, C. McKeon, G. J. Darlington and B. M. Spiegelman. 1999. Cross-regulation of C/EBPα and PPARγ controls the transcriptional pathway of adipogenesis and insulin sensitivity. Mol. Cell 3:151-158.

Yamada, T., S.-I. Kawakami and N. Nakanishi. 2009. Expression of adipogenic transcription factors in adipose tissue of fattening *Wagyu* and Holstein steers. Meat Sci. 81:86-92.

Yan, X., W. Zhang, J. Cheng, R. Wang, D. O. Kleemann, X. Zhu and Z. Jia. 2008. Effects of chromium yeast on performance, insulin activity, and lipid metabolism in lambs fed different dietary protein levels. Asian-Aust. J. Anim. Sci. 21:853-860.