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ARTICLE

Effects of Different Levels of Concentrate in the Diet on Physicochemical Traits of Korean Native Black Goat Meats

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Abstract

The effects of feeding of diets based on roughage supplemented with concentrate on the carcass and meat quality attributes of Korean black goats were investigated. The 40 male goats at 5 mon age were divided into four treatment groups; T1 (1.5%), T2 (2.0%), T3 (2.5%) and T4 (*ad libitum*) feeding of concentrate with *ad libitum* rice straw. Forty bucks at the end of the feeding were fasted for 12 h before slaughter and were then slaughtered. For carcass measurement, cold buck carcasses were examined after 24 h of chilling at 5°C. The carcasses were chilled in refrigerator at 2±2°C for 24 h, then the *longissimus dorsi* muscle was removed from the carcasses. The samples were separately vacuum packaged, frozen and stored at -20°C for up to 1 mon, prior to physicochemical evaluations. Carcass yields were greatly affected by rate of concentrate feeding. T4 showed the heaviest live and carcass weights and the highest dressing and fat percentages ($p<0.05$). The moisture contents were lower in T4 compared with other treatments, while the crude protein and fat contents were higher ($p<0.05$). monounsaturated fatty acid in T4 was significantly higher than others, which showed the highest percentages of oleic acid (C18:1). For the sensory test, T4 was tenderer and produced better flavor scores than others. Increasing the level of concentrate in the diet resulted in an improvement in growth performance, and carcass and physicochemical characteristics of goat meats.

Keywords: Korean native black goat, concentrate level, physicochemical traits, fatty acid composition

Introduction

The 599 breeds (including 512 native species) and 789 million goats are being raised throughout the world and have been a notable source of food since ancient times. Especially, goat meats have been popular with the greatest production and consumption in Asia and Africa (Kannan *et al*., 2001). Korean native goats have been raised as a domestic stock in Korea about 2,000 years ago. The statistics show that 43,000 farm households have raised 476,000 head of black goat in Korea (Ministry of Agriculture, Food and Rural Affairs, 2012). The consumption of Korean black goats, which has traditionally been known as a health food, has increased significantly during recent years because of the increased consumer demand for livestock products. They are recognized as healthy foods, especially, for pregnant women, patients recovering form diseases, and frail children (Kim *et al*., 1993). Typical types in consuming methods of Korean black goats include broil or soups/stews and extraction of the juice with spices (Kim *et al*., 1993). They are superior in nutritional aspects to other meat sources commonly consumed. Korean black goat meats are a rich source consisting of lower cholesterol and fat contents and higher contents of calcium and iron as compared to beef and pork (Kim *et al.,* 1993). They are also beneficial to health since it helps control blood cholesterol levels (Young *et al*., 2005). Also, goat is a good source of lean meat with desirable fatty acids, since it deposit relatively higher proportion of polyunsaturated fatty acids compared to other ruminants (Mushi *et al.,* 2009).

In Korea, the common goat farming system is multiple farming in which large areas of plant resources are available for grazing within fences. And the goats returned to barns where their diet was supplemented with concentrates and this system allows more utilization of grass within the forest (Son, 1999). In order to meet the growing demand for goat meat, goat-raising operations became larger and more specialized (Choe *et al*., 2012). The carcass composition and meat quality in goats were greatly influenced by feed, age, sex, body weight, growth,

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physiological conditions and physical activity (Marinova *et al.,* 2001). Growing animals from concentrate-fed lambs could have higher average daily gain, dressing percentage and better carcass quality than those on pasture (Priolo *et al*., 2002). Moreover, adjusting energy levels in a diet in order to produce high quality goat carcasses could be beneficial to goat producers, especially if they satisfy consumer desire by altering carcass composition and the quality of meat (Abdullah and Musallam, 2007). In sheep, high concentrate feeding could increase dressing percentage and improve carcass quality and sensory panel tenderness evaluations (McClure *et al*., 1994). Effects of grass or concentrate feeding on cattle and lamb have been reported (Priolo *et al*., 2002). However, the effects of different concentrate levels in combination with roughage on the carcass and meat quality attributes of Korean black goats have not been published yet. Thus, the objective of the present study was to evaluate the effects on the carcass traits and meat quality to different levels of concentrate finishing diets in combination with roughage of Korean black goats.

Table 1. Ingredients and chemical composition of experimental diets

Ingredients	% of DM	
	Concentrate	Rice straw
Corn	14.2	
Wheat	15.0	
Wheat bran	19.3	
Tapioca	5.0	
Corn gluten feed	16.0	
Coconut meal	7.0	
Canola meal	7.0	
Distillers grains	5.0	
Palm kernel meal	9.5	
Molasses	3.0	
Limestone	1.1	
Premix	1.9	
Total	100	
Chemical composition		
Moisture	11.50	11.55
Crude Protein	15.15	4.20
Crude Fat	3.88	1.65
Crude Ash	6.75	11.50
ADF[1)]	16.40	44.27
NDF[1)]	39.02	66.50
TDN[1)]	68.00	39.70

[1)]ADF, acid detergent fiber; NDF, neutral detergent fiber; TDN, total digestible nutrients.

Materials and Methods

Animals and feeding

Forty bucks of 5 mon of age and weighting 15±0.5 kg (mean±standard deviation) were equally assigned to four pens of four different treatments: T1 (1.5%), T2 (2.0%), T3 (2.5%) and T4 (*ad libitum*) feeding of concentrate with *ad libitum* rice straw as shown in Table 1. Rice straw, which is a major roughage source for farm animals in Korea, was used. All the animals were born and raised at the Animal Genetic Resources Station, the National Institute of Animal Science (NIAS), Namwon, Korea from May 14th until October 10th, 2013. Ingredients and chemical composition of experimental diets are shown in Table 1. Feed were provided *ad libitum* twice a day. We provided it to animals once a day in the morning in the amount of 2.0% of goats' body weight after they were checked it. Goats could drink freshwater any time in water buckets.

Sampling and physicochemical analysis

Forty bucks at the end of the feeding were fasted for 12 h before slaughter. An electrical stunner was used to stun (about 210 voltages) the goats which were then slaughtered at the meat plant of NIAS using standard procedures of NIAS-RDA, Korea. Cold buck carcasses were examined after 24 h of chilling at 5°C. For carcass measurement, slaughter weight, cold carcass weight, dressing and fat percentage were measured using mechanical weighing balance (150 kg, HB Series, Korea). The carcasses were chilled in refrigerator at 2±2°C for 24 h, then the *longissimus dorsi* muscle was removed from the carcasses for the experiment. The samples were separately vacuum packaged, frozen and stored at -20°C for up to 1 mon, prior to physic-chemical evaluations. Chemical compositions were analyzed by the methods of AOAC (1996). To measure Warner-Bratzler shear force (WBS), loin muscles were cut into cubes (3 cm thickness), heated to an internal temperature of 77°C in a water bath, cooled and measured the WBS with an Instron Universal Testing Machine (Model 4465, USA). For cooking loss, after the samples were thawed at 4°C overnight before analyses and sliced with a thickness of 2 cm. The samples were weighed and cooked in an electric grill (EMG-533, AIJIA electric appliance, China) until they reached a final internal temperature of 72°C. Cooking loss was determined by the ratio of the difference between raw weight and final cooked weight as follows:

Cooking loss (%) = 100 × (raw weight − final cooked weight) / raw weight

The water holding capacity (WHC) was conducted by the method of Ryoichi *et al*. (1993) with minor modifications. Meat samples were placed on a pre-weighed centrifugal micro filter (Centrex glass fiber filter, Schleicher & Schuell, Germany) without the collection vial, and weighed. The vial was attached, and tubes were centrifuged at 2,000 *g* for 15 min. The collection vial containing the expressed fluid was removed, and tubes reweighed, enabling water loss to be calculated by difference. WHC (%) was calculated as the percentage of remaining moisture content of meat samples after centrifugation.

WHC (%) = [1 − (moisture content extracted by centrifugation/moisture content in original meat)] × 100.

Sensory evaluations

The samples were cut into 20×20×10 mm thickness. During the sensory training sessions there was both discussion and sensory assessment of representative samples. The sensory scores were evaluated independently by 10 trained sensory panelists for random cubes of each sample. The sensory characteristics were determined by ten trained panelists for tenderness, juiciness, flavor and acceptability using a six-point scale (6 = very intense, very juicy, very tender; 1 = very weak, very dry and very tough). The mean value from three repeated measurements was determined.

Fatty acid analysis

Total fat for fatty acid analysis was extracted according to the method of Folch *et al*. (1957). After thawing the samples, the lipids in a 5 g sample were extracted in chloroform/methanol (2:1), with BHT as an antioxidant (Bligh and Dyer, 1959). The methyl esters from fatty acids (FAMES) were formed using a KOH solution in methanol. The FAMES were extracted with water and hexane. The top hexane layer containing FAME was dehydrated through the anhydrous Na_2SO_4. The extracted and dehydrated hexane was transferred to a vial to be analyzed. Separation and quantification of the fatty acid methyl esters was carried out using a gas chromatograph (GC, Agilent 7890N, Agilent Technologies Seoul, S.L., Korea) equipped with a flame ionization detector automatic sample injector HP 7693, and using a DB-WAX fused silica capillary column (30 m, 0.25 mm i.d., 0.2 mm film thickness, Agilent Technologies Seoul, S.L., Korea). Helium was used as carrier gas at linear flow of 1 mL/min and the injection volume was 1 mL. The oven temperature was initially held at 180°C for 1 min then increased at 2.5°C/min to 230°C and held for 12 min. The injector (split mode) and detector temperatures were maintained at 280°C. The FAME in the total lipids was identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue number 47885-UP, Lot number, LB-85684. Sigma-Aldrich Inc., USA). Fatty acids were expressed as a percentage of total fatty acids identified and grouped as follows: SFA, MUFA, PUFA and PUFA/SFA ratios were calculated.

Statistical analyses

Analysis of variance was performed using SAS software (SAS, 2010). The results of each experiment were presented as mean±SD using one-way repeated measures analysis of variance. Duncan's multiple range tests ($p<0.05$) was used to determine the differences between the means.

Results and Discussion

Carcass characteristics

Effect of different levels of concentrate feeding on carcass yields of Korean black goats are summarized in Fig. 1. High concentrate feeding in goats has been increased overall carcass yields in this experiment. Slaughter and cold carcass weights of the goats tend to be heavier for T4 diet compared to T1 ($p<0.05$). Similar results were observed for dressing and fat percentage. T4 diet had higher dressing and fat percentage compared to T1 ($p<0.05$). Mushi *et al.* (2009) proposed that concentrate supplemented goats had higher amount of fat than the unsupplemented ones. Dressing percentages of experimental animals were somewhat lower than those reported by Ha and Kim (48.3%, 1973) and by Sye and Ham (47.6%, 1980). Overall growth performance was similar to the results of Kim *et al.* (2012) on effects of rice-straw feeding in combination with concentrate in goats. Previous study has shown high concentrate feeding of sheep has been increased dressing percentage (McClure *et al.,* 1994). Those results confirmed those reported previously in other studies (Mushi *et al.,* 2009; Shahjalal *et al*., 1992) indicated that carcass weight, dressing percentage, and chemical fat weight of goats increased when increasing levels of high-energy concentrate diets. Ra (1977) reported that goats raised under intensive management with additional concentrate supplement showed much higher growth rate than those raised on less intensive management. In this study, carcass yields in goats were greatly affected by the

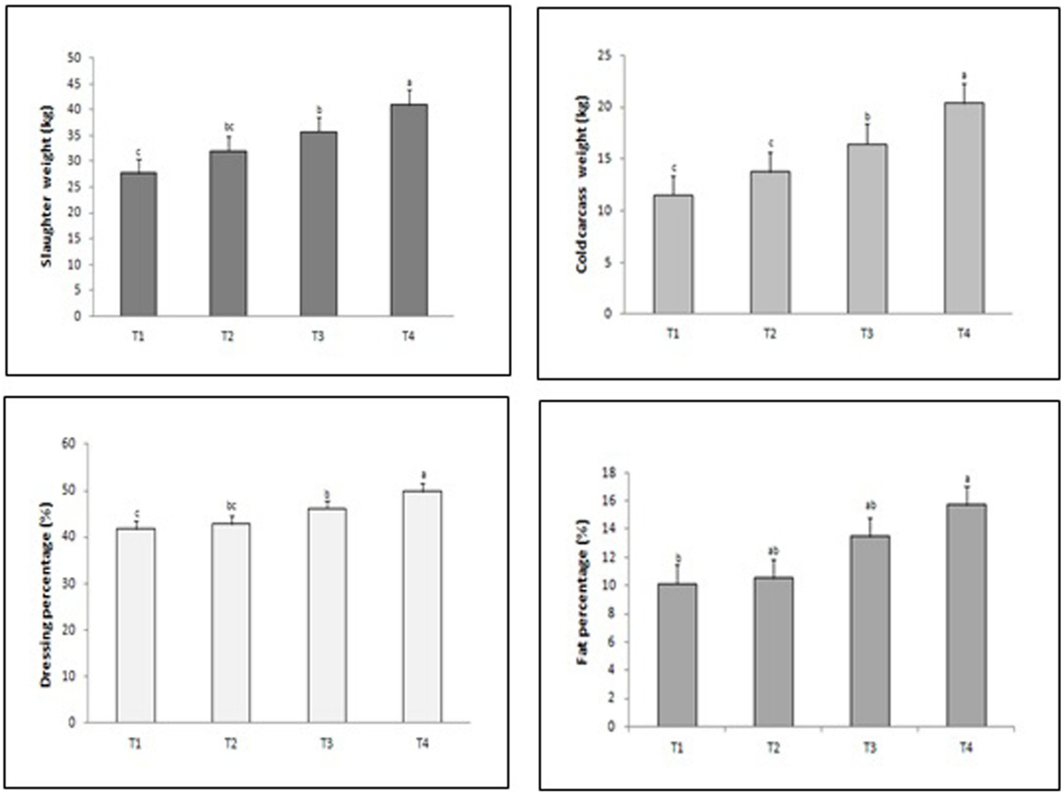

Fig. 1. Significant differences were observed among the different treatment groups.

feeding varying levels of concentrate. Goats fed roughage in combination with more concentrate were better in growth performances. Increasing concentrate supplementation increased carcass performance. These differences in carcass traits could be attributed to difference of chemical composition in goat diets (Choi *et al*., 2005).

Physicochemical properties

Effect of different levels of concentrate feeding on physicochemical characteristics of Korean black goat meats are presented in Table 2. Moisture, crude protein and fat contents were in the range of 72.8-75.9%, 1.9-3.9% and 20.7-21.7%, respectively. Dietary treatments made any significant differences. The moisture contents were lower in T4 compared with other treatments, while the crude protein and fat contents were higher (p<0.05). Results of crude protein and fat contents increased significantly as increasing concentrate level. Previous studies (Mushi *et al.,* 2009; Safari *et al*., 2009) reported that increasing concentrate supplementation decreased moisture content and increased fat content. This is in agreement with our result. In previous studies on proximate composition of Korean black goat meat, the moisture, crude protein, crude fat and crude ash contents 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%, indicating a similar results compared to our study.

There were no differences found of crude ash, shear force, cooking loss and WHC among the treatments. Similar results were observed by Safari *et al*. (2009) mentioned no differences in cooking loss or shear force were observed among treatments, while these variables were affected by the type of muscle. Babiker *et al.* (1990) observed goat meats fed with rice straw: shear force 4.0 kg/cm^2. Shear force of the meats from our experiments were slightly lower than their observations.

Tenderness is the most critical index of sensory evaluation because it is the most important factor affecting meat taste (Platter *et al*., 2003). Overall, T4 scored highest in sensory test. In particular, tenderness and flavor were scored better with T4 than others (p<0.05). Tenderness and flavor values were positively correlated with carcass

Table 2. Effect of concentrate levels in combination with roughage on the physicochemical characteristics of Korean black goats

	Treatments[2)]			
	T1	T2	T3	T4
	Chemical composition			
Moisture (%)	75.96±1.13[a1)]	74.54±0.35[ab]	73.71±1.03[bc]	72.80±0.47[c]
Crude protein (%)	1.96±0.74[b]	2.23±0.42[b]	2.86±1.06[ab]	3.91±0.42[a]
Crude fat (%)	20.69±0.48[b]	21.40±0.28[ab]	21.51±0.15[a]	21.68±0.61[a]
Crude ash (%)	0.75±0.02	0.75±0.01	0.75±0.01	0.75±0.02
	Physical properties			
Shear force (kg/cm^2)	3.43±0.55	2.93±0.23	3.75±0.43	3.49±0.47
Cooking loss	31.86±4.81	29.90±1.72	30.74±2.45	29.56±1.80
WHC	58.48±0.44	56.57±2.47	57.08±1.07	57.95±0.79
Juiciness[3)]	4.17±0.47	4.20±0.17	4.17±0.35	4.03±0.25
Tenderness[3)]	3.97±0.15[c]	4.27±0.21[b]	4.57±0.23[a]	4.97±0.21[a]
Flavor[3)]	3.60±0.17[c]	3.80±0.10[c]	4.57±0.32[b]	4.90±0.10[a]
Overall acceptability[3)]	4.01±0.73[b]	4.26±0.54[b]	4.56±0.34[a]	4.96±0.59[a]

[a-c]Different letters in the same row indicate statistical difference (p<0.05).
[1)]Data are expressed as means ± SD (n=10).
[2)]T1, *ad libitum* rice straw + concentrate 1.5%; T2, *ad libitum* rice straw + concentrate 2.0%; T3, *ad libitum* rice straw + concentrate 2.5%; T4, *ad libitum* rice straw + *ad libitum* concentrate.
[3)]Panel test scores (juiciness, tenderness, flavor and overall acceptability) are integers from 1 (poorest) to 5 (excellent) with 3 as moderate.

fatness (Priolo *et al*., 2002). Higher tenderness in muscles is associated with higher values for intramuscular fat (Mushi *et al*., 2009). Results of sensory assessments increased significantly as increasing concentrate level. Overall conclusion from physicochemical properties is that T4 produced better in meat quality. Goat meat composition is influenced by concentrate feed supplementation. These differences in physicochemical traits could be attributed to difference of chemical composition in goat diets (Choi *et al*., 2007). Further research is required to identify concentrate feeding effects on goat meat quality.

Fatty acid composition

The effects of different concentrate levels in combination with roughage on fatty acid composition of Korean black goats are shown in Table 3. The most abundant compound in goat meats is oleic (C18:1), followed by palmitic (C16:0), and stearic (C18:0) acids. The results were similar to other studies on goat meat (Ding *et al.*, 2010; Pratiwi *et al*., 2006). Significant differences in most of fatty acid composition were found among the treatments. Consequently, significant changes in percentage of saturated fatty acid (SFA), unsaturated fatty acid (UFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) among the treatments were observed. The percentage of UFA was higher than that of the SFA in goat meats regardless of treatments (p<0.05). This is in agreement with the previous studies (Park and Washington, 1993) that the levels of SFA and UFA in goat meat muscle were from 40-50% for SFA, from 50-60% for UFA. However, it might be changeable according to various environmental factors. SFA (%) in T1 samples was significantly higher than other treatments. However, UFA, especially, MUFA in T4 was significantly higher than others, which showed the highest percentages of oleic acid (C18:1). In the present study, PUFA was higher in T2 and this is due to the high content of linoleic acid (C18:2n6). The PUFA/SFA ratio is used to assess the nutritional quality of the lipid fraction in meats. Tshabalala *et al*. (2000) reported the PUFA/SFA ratios for different muscles that ranged from 0.06 to 0.08 in goat meat. From our experiments, PUFA/SFA ratios were in the range of 0.08-0.12%, which were slightly higher than their studies. In the present experiment, T4 fed high concentrate was superior in MUFA. These differences in fatty acid composition could be attributed to different feeding system, especially, a higher crude protein and TDN in the concentrate diet. Also, this effect could be attributed to a modification in the microbial composition in the rumen, with increasing concentrate level (Majdoub-Mathlouthi *et al*., 2013).

Conclusion

Korean black goats fed concentrate in combination with roughage were better in carcass yield and meat quality. High concentrate feeding in goats was increased overall carcass yields. The crude protein and fat contents increa-

Table 3. Effect of concentrate levels in combination with roughage on the fatty acid composition (%) of Korean black goats

	Treatments[2)]			
	T1	T2	T3	T4
Myristic acid (C14:0)	3.91±0.41[a1)]	3.38±0.38[ab]	3.02±0.29[b]	3.28±0.38[ab]
Palmitic acid (C16:0)	25.30±0.92	24.02±1.66	23.19±0.67	24.34±1.11
Palmitoleic acid (C16:In7)	2.99±0.36	3.14±0.27	2.99±0.35	3.12±0.63
Stearic acid (C18:0)	19.05±0.94[a]	18.42±2.44[ab]	19.26±1.32[a]	15.15±2.32[b]
Oleic acid (C18:In9)	43.51±0.40[c]	44.77±0.87[c]	46.97±0.58[b]	48.90±1.39[a]
Vaccenic acid (C18:In7)	0.48±0.11	0.47±0.11	0.42±0.03	0.39±0.03
Linoleic acid (C18:2n6)	3.39±0.30[b]	4.28±0.31[a]	3.15±0.33[b]	3.67±0.54[ab]
γ-Linolenic acid (C18:3n6)	0.20±0.01[a]	0.14±0.03[b]	0.12±0.02[bc]	0.10±0.01[c]
Linolenic acid (C18:3n3)	0.36±0.09	0.28±0.04	0.22±0.09	0.23±0.10
Eicosenoic acid (C20:1n9)	0.34±0.04	0.33±0.02	0.32±0.02	0.34±0.02
Arachidonic acid (C20:4n6)	0.48±0.04[b]	0.78±0.13[a]	0.34±0.04[c]	0.48±0.01[b]
SFA[3)]	48.27±0.66[a]	45.82±1.13[b]	45.47±0.68[b]	42.78±1.96[c]
UFA[3)]	51.73±0.66[c]	54.18±1.13[b]	54.53±0.68[b]	57.22±1.96[a]
MUFA[3)]	47.31±0.61[c]	48.69±0.93[bc]	50.70±0.88[ab]	52.75±1.66[a]
PUFA[3)]	4.42±0.43[b]	5.49±0.21[a]	3.83±0.28[b]	4.47±0.46[b]
PUFA /SFA[3)]	0.09	0.12	0.08	0.10

[a-c]Different letters in the same row indicate statistical difference (p<0.05).
[1)]Data are expressed as means±SD (n=10).
[2)]T1, *ad libitum* rice straw + concentrate 1.5%; T2, *ad libitum* rice straw + concentrate 2.0%; T3, *ad libitum* rice straw + concentrate 2.5%; T4, *ad libitum* rice straw + *ad libitum* concentrate.
[3)]SFA, saturated fatty acids; UFA, unsaturated fatty acids, MUFA, monounsaturated fatty acids, PUFA, polyunsaturated fatty acids.

sed significantly as increasing concentrate level. Goats fed with concentrate in addition to roughage diet yielded more tender and produced better flavor. Dietary inclusion of concentrate could affect fatty acid composition and T4 found the highest MUFA. Therefore, the addition of concentrate in combination with roughage in goat feeding could be more effective to improve growth performance and meat quality characteristics. The results have shown finishing goats with concentrate supplementation could affect the carcass characteristics and meat quality.

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