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Physicochemical attributes, free amino acids, and fatty acids of the five major cuts from Korean native black goat

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Abstract

This study aimed to investigate the physicochemical traits, free amino acids, and fatty acid compositions of five different muscle cuts (loin, hind leg, neck, and foreleg) from Korean native black goat (KNBG). In a total, 21 castrated male KNGBs of 16 mon of age were reared with similar diets, conditions, and slaughtered. Results reveal that moisture content was lowest in rib compared to all tested groups ($p < 0.05$). Moreover, rib implied the highest lipid content compared to all cuts ($p < 0.05$). Protein and ash contents were lowest in the rib than all treatments except for the foreleg ($p < 0.05$). Shear force (kg.f) values related to meat tenderness did not show any significant differences among the five different cuts. Regards to free amino acid contents, glutamic acid was the highest in the neck ($p < 0.05$). The taurine and asparagine contents were highest in the foreleg ($p < 0.05$). The essential fatty acids; linoleic acid (18:2), and arachidonic (20:4) acid were highest in the meat excised from the hind leg ($p < 0.05$). Eicosatrienoic acid (20:3), and nervonic acid (24:1) were deemed important to brain functions highest in the hind leg ($p < 0.05$). Also, a similar trend was noted for polyunsaturated fatty acids (PUFA) contents in the hind leg ($p < 0.05$). Saturated fatty acids (SFA) were highest in rib compared to all treatments ($p < 0.05$). Taken together, our results indicate that proximate compositions, lipid contents, free amino acids, fatty acid compositions vary considerably with the anatomical locomotion of the muscles from KNBGs which could be a stratagem for consumer's preference of the meat and given nutritional and functional profile elsewhere.

Keywords: Korean native black goat, Goat meat cuts, Physicochemical traits, Free amino acid, Fatty acid compositions

INTRODUCTION

Korean native black goat (*Capra hircus coreanae*) is a typical native goat breed comprising more than 80% of the whole goat population in South Korea. Although KNBG meat has been consumed as medicine more than food [1], consumption of KNBG muscles has increased tremendously during the last few decades. Particularly, KNBG meat is consumed as a health-promoting food, especially for pregnant women, and for medicinal purposes for curing

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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions
Conceptualization: Nam KC.
Data curation: Ali M.
Formal analysis: Ali M.
Methodology: Ali M, Choi YS.
Software: Choi YS.
Validation: Choi YS.
Investigation: Ali M, Nam KC.
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ulcer healing or stomach inflammation [2]. Goats compared to sheep deposit more internal fat and less subcutaneous and intramuscular fat reported by many researchers [3–7]. Hence, consumers are attentive to goat meat as a country with a high prevalence of cardiovascular diseases. Relatively lean meat, especially influenced by many elements such as breed, age, sex, the plane of nutrition, and muscle compositions has been the subject of numerous reviews [8–13]. Although, there have been some studies with the lipid composition of goat meat in single muscles, different cuts of meat, and the entire carcass technological factors such as pH value, color, tenderness, protein content, fat content, and connective tissue content affect the meat quality. With the desire for leaner meat by consumers, meat from goats is attractive linked with other types of red meat [14]. However, goat meat is a darker red than lamb [15].

The fatty acid compositions of KNBG meat are not well known, although the physical characteristics and proximate composition of goat meat are influenced by muscle types [16]. Unlike the muscle type, postmortem (p.m.) changes in muscle tissues, pre-slaughter effects, stress, product handling, processing, and storage, microbiological numbers, and populations, etc. also influence the meat quality [17].

Moreover, the influence of anatomical location of muscles on the quality of goat meat was investigated by several authors [18,19]. Having in mind that the anatomical location of muscle can affect the meat quality [16].

The muscle fibers from meat are characterized by their morphological characters, and contractile and metabolic possessions [20]. Also, the contractile and metabolic possessions of muscle are distinguished by muscle fiber types. Generally, there are five diverse muscle fiber types in adult skeletal muscle, named slow-oxidative or type I, fast oxido-glycolytic or type IIA, and fast glycolytic IIX and IIB [21]. These muscle fibers are found in the muscle of meat from animals regulated by the predominant metabolic properties in their composition, and structure [22].

However, no data is available addressing the physicochemical characteristics, free amino acids, and fatty acid compositions of the major five meat cuts from KNBGs. Therefore, this study examined to investigate the physicochemical traits, free amino acids, and fatty acid compositions of five major cuts from KNBGs.

MATERIALS AND METHODS

Animals and sample preparation for laboratory analysis

A twenty-one castrated male of KNBGs were raised under the same diet and farming conditions at Gangin Jeollanamdo farm and slaughtered at 16 mon of age. After slaughtering and dressing, five separate cuts (loin, hind leg, neck, and foreleg) were collected and analyzed. The meat quality characteristics, free amino acid concentrations, and fatty acid compositions were investigated.

Proximate composition

Moisture contents of five different meat cuts excised from KNBGs were determined by drying the samples (3 g) at 102℃ [23]. The contents of crude protein were measured by the method

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suggested by [23]. With a ratio to chloroform/methanol (2:1), using 5 g of meat, lipids were determined under the procedure described by [24].

Water holding capacity, pH, and cooking loss

With a slightly modified method, adopted elsewhere [25], 5 g of the ground meat sample from each cut was centrifuged at 4℃ for 10 min at 1,200×g with a centrifuge machine (Combi 514-R, HANIL, Gimpo, Korea), and the water holding capacity was measured. The pH values from five different muscle cuts were measured by taking 2 g of the blending meat samples mixed with 18 mL of distilled water followed by homogenization at 1,200×g for 30 s using a homogenizer (Polytron PT 10-35 GT, Kinematica, Malters, Switzerland). By using a pH meter (Seven Excellence^{TM}, METTLER TOLEDO, Greifensee, Switzerland) at room temperature pH was recorded. For cooking loss, an electric grill (Nova EMG-533, 1,400 W, Evergreen enterprise, Yongin, Korea) was used to heat the meat cuts for 60 s until to reach the internal temperature of the meat sample at 72℃ with the standardized cuts sample (30 × 50 × 10 mm). Meat color was performed by a colorimeter (CR-410, Minolta, Tyoko, Japan). The shear force values of the five different goat meat (cooked meat sample) were designed in a cubic form (30 × 50 × 10 mm) by using a Warner-Bratzler shear attachment equipped on a texture analyzer (TA-XT2, Stable Micro System, Surrey, UK.). The maximum shear force value (kg·f) was recorded for each sample. The test and pre-test of the speeds were set to 2.0 mm/s, and post-test speeds set to 5.0 mm/s.

Free amino acids

The soluble amino acid compositions of five goat meat cuts were quantified by using a slightly modified method described by [26]. HPLC analyses of free amino acids were attained with an S433 auto analyzer, separation of cation column (LCAK07/li; 4.6 × 150 mm), at buffer revolution (A: pH 2.90; B: pH 4.20; C: pH 8.00), lithium citrate buffer solution with a buffer flow rate 0.45 mL/min, ninhydrin flow rate 0.25 mL/min, and column temperature 37℃.

Fatty acid compositions

The fatty acid compositions of five meat cut from KNBGs were estimated by the method of [27], with a minor modification. The test was performed via a Gas Chromatograph-Flame Ionization Detector (7890 series, Agilent, Santa Clara, CA, USA) under the following conditions: injector split mode with a split ratio of 25:1, temperature 250℃. High pureness air, high purity of H_2, and high purity of He were used as hauler gases. The flow rate was maintained at 40 mL/min for H_2 and 400 mL/min for air. An HP-88 column (60 m × 250 μm × 0.2 mm) was used for the investigation. The fatty acid compositions were stated as a percentage.

Statistical analysis

Data obtained were studied by multiple assay techniques, applying the Student-Newman-Keuls for significance test ($p < 0.05$) adopting the general linear model of the SAS program [28].

Significant differences were marked by applying the one-way ANOVA. Each treatment was executed in five replication, and results are presented as the SEM.

RESULTS AND DISCUSSION

Proximate composition

The proximate compositions of the five different goat meat cuts from KNBGs are presented in Table 1. In this study, muscles or cuts significantly varied owing to proximate compositions. The result shows that moisture content in all five muscles or cuts varied ranges from 65.98% (rib) to 75.99% (neck). The result shows that meat from rib implied the lowest moisture and ash contents compared with all tested groups ($p < 0.05$). Subsequently, much higher lipid content was found in the rib compared to the all tested groups ($p < 0.05$) and was due to individual muscle fat deposition capacity [20]. However, lipid content dominant in rib occupied with intermediate muscles structure (previously reported) might be explained by the propensity to accumulate fat cells in the extravascular area [29]. Notably, a significant variation was observed among the tested groups for crude protein contents ($p < 0.05$). In between loin and rump [30] found a similar proximate composition with black goat meat. The variation of the proximate composition within the breed in different muscles or cuts due to attributes as muscle composition and their specific metabolic activities [20]. It has been reported by [31] that meat from black goat implied 74.40% to 76.04% moisture, 19.83% to 20.47% crude protein, 1.64% to 3.56% crude fat, and 1.04% to 1.11% crude ash as a part of the proximate compositions. Hwang et al [32] have reported that the black goat meat contained fat between 1.12% and 1.59%. On the other hand, [33] have coincided that the crude fat content of the black goat meat was 7.81% to 9.43% at different ages of castration. Apart from these studies, a study was conducted owing to the proximate composition of the black goat meat was 67.0% to 75.2% moisture, 18.9% to 24.8% crude protein, 3.25% to 12.6% crude fat, and 0.95% to 1.19% crude ash, depending on the breed [34]. Castration increases fat contents compared to the noncastrated animal because castration changes hormonal mediation of nitrogen metabolism controlling the accumulation of muscle tissue [35] and is related to the control and concentrations of growth hormones and metabolites. It is well defined that, numerous biochemical and fundamental physiognomies of muscle fibers have an independent role in the muscle resulting in meat quality variation with different

Table 1. Proximate composition (%) of five different meat cuts from KNBG

Items	Cuts					SEM[1)]
	Loin	Hind leg	Neck	Rib	Foreleg	
Moisture	74.53[a]	75.65[a]	75.99[a]	65.98[b]	74.73[a]	0.64
Fat	2.38[b]	1.82[b]	2.92[b]	14.06[a]	4.56[b]	0.85
Crude protein	23.40[a]	22.80[a]	21.22[b]	19.74[c]	20.37[bc]	0.39
Crude ash	0.92[a]	0.96[a]	0.87[a]	0.73[b]	0.93[a]	0.03

[1)]n = 5.
[a–c]Mean values with different letters within the same row differ significantly ($p < 0.05$).
KNBG, Korean native black goat.

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anatomical location [35]. These factors, which are often difficult to control between studies, include differences in maturity, breed, production systems, and feeding management of animals used in these studies.

Quality characteristics (meat color, pH, water holding capacity, cooking loss, and shear force)

Table 2 lists the meat quality characteristics of five different meat cuts from KNBGs. Among the quality characteristics of meat color is one of the most appraisal traits of fresh meat [9]. Results imply that a significant variation was noted among the five meat cuts for lightness ($p < 0.05$) whereas no significant break was noted for redness and yellowness among the tested groups ($p > 0.05$). The most important quality parameter pH ranged from 6.21 to 6.63 among the five meat cuts and varied significantly in the line of tested groups. Almost all individual pH values in all five muscles or cuts, were within the characteristics range for red (goat) meat [36]. In a previous study, it has been reported that muscle pH varied following the muscle types of the examined sample. Many researchers reported that meat with type I muscles showed a higher pH, lower buffering capacity with lower lactate production whereas meat with type IIB muscles resembles the lower pH, higher lactate, and higher buffering activity [37]. Owing to cooking loss, varied ranges from 11.20% to 14.93% in all tested cuts. It is also related to protein denaturation and cooking processes, such as temperature and time at the heating phase [38]. Shear force values that resemble the meat tenderization did not show any significant variation in the meat cuts from KNBGs ($p > 0.05$). Nevertheless, numerically, shear force values varied to the anatomical location of the muscles or cuts. Unlike values we found in our study, shear force values for muscles from castrated males were not significantly different while the author reported with leg and loin from goat meat [39]. Our data from this study indicate that castration effects to meat tenderness may depend on the measurement of postmortem and have implicated increased collagen solubility in the myofibrillar tenderness system [40]. It has been reported that castrated animals have a lower shear force value than non-castrated animals implying that castration would lead to increased mRNA levels of calpains and ultimately reduce calpastatin. However, apart from castration meat tenderness also depend on various intrinsic factors such as

Table 2. The physicochemical traits of five different meat cuts from KNBG

Items	Cuts					SEM[1)]
	Loin	Hind leg	Neck	Rib	Foreleg	
CIE L*	32.48[abc]	31.06[bc]	30.47[c]	34.64[a]	34.04[ab]	0.90
CIE a*	18.84	18.08	19.39	20.35	19.49	1.00
CIE b*	5.20	4.77	7.13	6.72	6.51	0.88
pH	6.21[b]	6.37[ab]	6.63[a]	6.23[b]	6.56[a]	0.08
Cooking loss (%)	11.22[b]	11.20[b]	14.37[a]	14.93[a]	12.86[ab]	0.74
Shear force (kg.f)	4.81	6.04	5.60	5.93	4.31	0.90

[1)] n = 5.
[a–c] Mean values with different letters within the same row differ significantly ($p < 0.05$).
KNBG, Korean native black goat.

production systems and the age of slaughter [41]. In general shear force values depends on muscle's fiber density, muscle fiber size, myofibril index, sarcomere length, collagen content, and intrinsic enzymes of the meat. Meat tenderness is affected by the origin of the animal as well as their age, breed, gender, and environmental conditions, and period of meat aging [42].

Free amino acids

Table 3 lists the free amino acid compositions excised from five different meat cuts of KNBGs. The most important functional amino acid, taurine contents were higher in the foreleg cut compared with all treatments (p < 0.05) that might be attributed to the oxidative muscle's activity and capacity [43]. A similar trend found for asparagine resembles as biosynthesis of proteins in meat in the foreleg. One of the savory or umami amino acids, glutamic acid contents

Table 3. Free amino acid (mg/100 g) of five different meat cuts from KNBG

FAA[1)]	Cuts					SEM[2)]
	Loin	Hind leg	Neck	Rib	Foreleg	
Taurine	51.03[dc]	81.96[b]	84.72[b]	83.44[b]	119.65[a]	6.58
Aspartic acid	5.67	5.59	7.16	6.33	5.90	0.88
Threonine	4.26	3.35	3.48	4.75	4.29	0.70
Serine	6.64	5.04	4.51	4.88	5.87	0.89
Asparagine	3.38[b]	4.67[b]	2.40[b]	3.27[b]	12.80[a]	1.40
Glutamic acid	31.23[b]	28.26[b]	54.27[a]	37.96[b]	14.01[c]	4.60
Glycine	22.28	19.73	20.77	28.84	30.75	3.20
Alanine	21.34	24.88	27.81	33.19	33.36	2.76
Valine	4.71[a]	3.30[ab]	2.78[ab]	2.56[b]	3.34[ab]	0.49
Methionine	3.04	2.09	1.79	1.76	1.82	0.32
Isoleucine	3.01[ab]	2.52[b]	4.32[a]	4.51[a]	4.62[a]	0.42
Leucine	7.22[a]	4.59[b]	2.05[b]	2.42[b]	2.17[b]	0.73
Tyrosine	4.21[a]	2.13[ab]	0.91[b]	2.31[ab]	2.53[ab]	0.53
Histidine	3.13	1.71	3.06	2.64	2.51	0.60
Tryptophan	3.73[a]	2.45[b]	1.90[b]	2.52[b]	1.88[b]	0.31
Carnosine	3.11[a]	2.21[b]	1.66[b]	2.05[b]	1.77[b]	0.28
Lysine	4.71	3.22	3.62	3.47	6.67	0.82
Arginine	2.22	2.34	2.79	2.16	4.32	0.77
Total free amino acids	184.96[b]	200.07[b]	231.75[ab]	230.77[ab]	259.82[a]	13.02
(Sweet + Umami) A.A.	93.82	89.15	116.86	116.36	107.74	7.62
Bitter A.A.	23.31	16.53	16.78	16.05	18.76	2.08
(Sweet + Umami) A.A. / Bitter A.A.	4.15[b]	5.43[ab]	7.17[a]	7.45[a]	5.85[ab]	0.66

[1)](Sweet + Umami) A.A.: asparagine + threonine + serine + glutamic acid + glycine + alanine + lysine
Bitter A.A.: valine + methionine + isoleucine + leucine + histidine + arginine.
[2)]n = 5.
[a–d]Mean values with different letters within the same row differ significantly (p < 0.05).
KNBG, Korean native black goat; FAA, free amino acid.

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were significantly higher in the neck in the all tested groups (p < 0.05) mostly found in oxidative or intermediate types of muscle [43]. ATP generating amino acid, leucine contents were significantly higher in loin than other cuts. Moreover, antioxidative amino acid, carnosine contents were significantly higher in loin muscle or cut compared with all other tested groups. It has been reported that carnosine content is highly correlated with glycolytic muscle fiber [43]. The varied amino acids among the five muscles or cuts can be attributed to muscle compositions and functional effect, which depends on the aminopeptidase and hydrolytic activity toward the increased group with the proteolysis of muscle by an enzyme known as calpain [44,45]. Thus different muscles of meat cuts from KNBGs show their unique amino acid characteristics could be helpful from a nutritional point of view as well as meat flavor chemistry.

Fatty acid compositions

Table 4 lists the fatty acid compositions of the different meat cuts from KNBGs. The fatty acid compositions of muscles are an important factor in determining the nutritional quality of meat or adipose tissue subjected with special attention in human health. Result reveals that the essential fatty acids; linoleic acid (18:2), and arachidonic acid (20:4) contents were significantly higher in the hind leg compared with the other tested groups (p < 0.05). The hind leg also

Table 4. Fatty acid compositions (%) of five different meat cuts from KNBG

Fatty acid	Cuts					SEM[1)]
	Loin	Hind leg	Neck	Rib	Foreleg	
14:0	3.81^{ab}	3.30^{b}	4.26^{ab}	5.02^{a}	4.08^{ab}	0.33
16:0	23.44^{a}	20.78^{b}	23.03^{a}	23.73^{a}	22.14^{ab}	0.60
16:1	2.82^{bc}	2.39^{c}	3.39^{a}	2.65^{bc}	3.06^{ab}	0.15
18:0	9.94^{b}	10.84^{b}	10.26^{b}	12.54^{a}	10.26^{b}	0.52
18:1	44.42^{a}	38.49^{b}	39.70^{ab}	37.48^{b}	40.51^{ab}	1.37
18:2	3.60^{b}	6.12^{a}	4.05^{b}	3.83^{b}	4.58^{b}	0.44
18:3	0.26	0.27	0.29	0.28	0.26	0.02
20:2	0.27	0.70	0.35	0.40	0.47	0.11
20:3	0.14^{b}	0.28^{a}	0.14^{b}	0.14^{b}	0.18^{b}	0.03
20:4	1.73^{b}	3.72^{a}	1.56^{b}	1.62^{b}	2.21^{b}	0.36
24:1	0.21^{b}	0.41^{a}	0.24^{b}	0.20^{b}	0.28^{b}	0.03
SFA	37.65^{b}	35.35^{b}	38.08^{b}	41.95^{a}	36.99^{b}	1.09
UFA	55.80^{a}	54.49^{a}	52.22^{ab}	49.16^{b}	53.64^{a}	1.20
MUFA	49.80^{a}	43.39^{b}	45.85^{ab}	42.89^{b}	45.95^{ab}	1.34
PUFA	6.00^{b}	11.10^{a}	6.37^{b}	6.28^{b}	7.70^{b}	0.85
UFA/SFA	1.50^{a}	1.55^{a}	1.37^{ab}	1.18^{b}	1.46^{a}	0.07
n-6/n-3	14.25	22.76	15.04	14.15	18.13	2.19

[1)] n = 5.

[a–c] Values with different superscripts letters within the same row differ significantly (p < 0.05).

KNBG, Korean native black goat; SFA, saturated fatty acid; UFA, unsaturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

riches with eicosatrienoic acid (20:3) and nervonic acid (24:1) related to the development of the human brain. And even, most desirable fatty acids, polyunsaturated fatty acids (PUFAs) were also higher in the hind leg compared with other treatments in the same line ($p < 0.05$). Moreover, total SFAs were highest in the meat from the rib and that was the propensity of lipid content mentioned in the proximate composition's segment. Differences in muscle fiber types, fatty acid compositions are reflected with phospholipid and intrinsic mechanism of the individual muscle and reported [46]. Due to having higher phospholipids in the red muscle (hind leg), it occupies a higher percentage of PUFA [46] resulting in a rich with linoleic acid, arachidonic acid, eicosatrienoic acid and, nervonic acid content. Likewise, our compiled data suggested that the different anatomical locations of the muscles contained different fatty acids agreed with [47]. The fatty acid contents varied within the breed in the five muscles might be attenuated to muscle types with their metabolic activities and deposition pattern in the muscle [48]. Regarding breed, age, live weight, rearing condition, and age insist the fatty acid compositions based on muscle composition and metabolic functions of perspective muscle [17] resulting in the depots of higher internal fat. Thus, it needs to research and attention regards to goat meat's fatty acid composition might be beneficial to the nutrition as well as breeding policy with improved goat meat production. However, the quantitative quality of fatty acids contents observed in this study among the different five meat cuts will be helpful to the health conscience consumers while preferring the cuts.

CONCLUSIONS

Data from the current study confirms that variation to proximate composition, meat quality attributes, free amino acid concentrations, and fatty acid compositions among five different cuts varied by muscle's locomotion, types, and instinct mechanism within the breed. Moreover, of them, certain cuts were nutritionally got preferred, which could be attenuated as a stratagem for health conscience consumers. However, despite having differences in the cuts regards to muscle types and compositions, five different cuts offer similar tenderness in the line that could be attenuated in further goat meat tenderization with emphasis on castration and ages. With the least amount of consumer satisfaction, further studies should be warranted with morphology traits such as total number of fiber (TNF) and cross-sectional area of the fibers (CSFA) of the chevon to describe the overall goat meat quality precisely.

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