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Sea tangle (*Laminaria japonica*) supplementation on meat quality of Korean native black goat

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Abstract

The supplementation effects of sea tangle powders were determined for the meat quality in Korean native black goats. A total 90 castrated male black goats at 3-month age were divided into 3 dietary treatment groups: control (basal diet + mineral block), T1 (0.3% sea tangle feeding with the basal diet), T2 (0.9% sea tangle feeding with the basal diet). At 9-months feeding, 10 goats per treatment group were slaughtered, and the *longissimus dorsi* muscle samples were vacuum-packed, and subsequently analyzed for physicochemical evaluations. Analysis revealed decrease in the shear force and TBARS values of meat in the sea tangle dietary groups ($p < 0.05$). The T2 group exhibited increased levels of unsaturated fatty acids such as C16:1, C18:1, C18:2, and C20:4 ($p < 0.05$). The content of free amino acids with desirable taste such as aspartic acid, glutamic acid, glycine, histidine, and serine were higher in T2, whereas alanine content was higher in both sea tangle dietary groups, as compared to control ($p < 0.05$). These data indicate that feeding dietary sea tangle as an alternative mineral source results in an improvement in the physicochemical profiles of goat meat.

Keywords: Black goat, Sea tangle, Physicochemical quality, Fatty acid, Free amino acid

Background

Of the 512 native species, amounting to 809 million goats being raised around the world, goats are known as a remarkable livestock product since ancient times. Particularly, goat meat has gained popularity over the years, accounting for the greatest production and consumption in Asia [1]. Korean Native Black Goat (KNBG, *Capra hircus coreanae*) is a unique species of native goats found in Korea, which have been domesticated since nearly 1,900 years. Even though goat production has a long history, goat meat was not popular compared to other meat species (beef, pork, or chicken) and the market share in the supply of livestock product was low [2]. Statistics indicate that 40,000 farm households reared above 600,000 heads of KNBG in Korea [3].

Traditionally, KNBG have been known for a healthy food for pregnant women, patients recovering from the disease, and fragile children [4]. Castrated KNBGs are mostly slaughtered in fall, and its production is restricted owing to goaty odor and off-flavor. Furthermore, the European and American population do not prefer goat meat [5]. Different dishes prepared with KNBG include soups/stews, and juice extracts with added spices [4]. The nutritional value of KNBG is excellent as compared to beef and pork, comprising lower fat contents and cholesterol, and higher mineral contents such as calcium and iron, as compared to other meat sources [4]. They are good for health due to the inherent property in regulating blood cholesterol levels [6]. Due to the deposition of comparatively higher proportions of polyunsaturated fatty acids compared to beef and pork, goat is an excellent source of meat

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containing essential fatty acids [7]. KNBG is an excellent source of nutrition consisting of lower fat contents and cholesterol and higher mineral contents such as calcium and iron compared to other meat sources [4].

The goat meat quality is strongly affected by diet, genotype, age, sex, body weight, and production methods [8]. In Korea, the ordinary goat farming system is complex. Big areas of plant resources are fenced and employed for pasturing; the goats return to barns where feedstuff is supplemented with concentrates, thereby permitting more consumption of forest grasslands [2]. To make up for lack of mineral supplementation, mineral blocks are provided containing 96% NaCl and others such as Ca, P, Mg, Fe, and others. Sea tangle (*Laminaria japonica*) is edible brown marine plants that has widely been produced in coastal region of Korea [9]. Although sea tangle nutrient content varies with species, geographical position, season, and temperature, it is high in carbohydrates, protein, lipids, vitamins, and minerals [10,11]. Wando Kelp had 751.61, 177.71, 39.58, 34.11, 33.20, and 17.56 mg/100 g of K, Na, Ca, Mg, P, and I, respectively [12]. Especially, brown seaweeds are high in polysaccharides (soluble dietary fibre) such as alginic acid, laminarin, and fucoidan and minerals such as NaCl and iodine [13]. It is reported to have several biological activities, including antioxidant [14], anti-mutagenic, and antibacterial effects [15]. Dietary supplementation of a sea tangle extract has been reported to have the serum antioxidant in ruminants [16].

Although seaweed supplementation has been published to have beneficial impacts in non-ruminants [17,12,18], the influences of sea tangle extract supplementation on the meat quality of Korean black goats have yet not been studied. Our study was therefore undertaken to examine the effects of feeding sea tangle to KNBG as an alternative supplementation of mineral source, by evaluating the meat quality attributes.

Materials and Methods

Animals and feeding

Sea tangle (*L. japonica*) produced in Goheung (Jeonnam province) was sun-dried and prepared in powder form containing 10.3% of moisture content. A total of 90 castrated male black goats aged 3-months were categorized into 3 dietary treatment groups: control (basal diet with mineral block), T1 (0.3% sea tangle feeding with the basal diet), and T2 (0.9% sea tangle feeding with the basal diet). The basal diet was a mixture concentrate comprising 14% corn, 15% wheat, 19% wheat bran, and 16% corn gluten feed. The mineral block was 96% NaCl and other minor minerals such as Ca, P, Mg, and others. The experimental feeding period was 9 months. At the end of the feeding period, randomly selected 10 goats per treatment group, having an average live weight of 60 ± 1.1 kg each, were slaughtered and the *longissimus dorsi* muscle was subsequently harvested. All muscle samples were separately vacuum-packaged to minimize physicochemical change and subjected to further analysis for physicochemical evaluations.

Physicochemical analysis

pH values were read using an MP-230 pH meter (Mettler Toledo, Greifensee, Switzerland). Moisture, and fat contents of the goat meats were examined by the modified method of [19]. The surface color value of the samples was measured using the CIE L*, a*, and b* system using a Minolta chromameter (Model CR-410, Minolta Co. Ltd., Japan), Water holding capacity was measured by a centrifugal method. The shear force of cooked samples was performed using a texture analyzer (TA-XT3, Stable Micro Systems, Godalming, UK) equipped with a Warner Bratzler shearing device. Briefly, samples (2 × 2 × 1 cm) were compressed to 55% of the original height with a crosshead speed of 100 mm/min. The average shear force value was obtained for each treatment and is indicated in kg/cm^2. The TBARS values of the samples were determined in duplicate, according to the method proposed by [20].

Carnosine and creatine analysis

The contents of carnosine and anserine were determined using the slightly modification method ascribed by [21] where 2.5 g of minced meat samples from each chicken were homogenized with 7.5 mL of 0.01N HCl at 1,130 ×g for 30 s (T25 basic, IKA, Breisgau, Germany). After homogenization then the samples were centrifuged at 10,000 × g for 30 min at 4℃ (1580 R, GYROZEN, Gimpo, Korea). 0.5 mL of centrifugated supernatant was taken in 2 mL tube and mixed with 1.5 mL of acetonitrile and performed centrifuge again for 10 min at 10,000 ×g at 4℃ (1580R, GYROZEN). Filtrated through 0.2 μm membrane filter the supernatant was injected into HPLC (1580R, GYROZEN) column.

Fatty acids analysis

Total fat was extracted by the method of [22]. Briefly, the lipids were extracted from 5 g of sample using Folch solution (chloroform:methanol = 2:1), with BHT as an antioxidant [23]. After methylation of the samples, the methyl esters from fatty acids (FAMES) were prepared using KOH solution in methanol. Hexane was subsequently added to the samples, and the top layer was separated. Prepared samples were then subjected to FAMES using a GC 7890N (Agilent Technologies, Seoul, Korea) gas chromatograph equipped with an HP 7693 automatic sample injector. The oven temperature was initially held at 180℃, and final temperature was 280℃.

Free amino acids analysis

The free amino acids were extracted by the procedures of the HPLC method presented by [24]. The amino acid content of samples was examined using HPLC (Novapak C18. 60 Angstrom, 4 μm, 3.9×150 mm, Waters, Milford, MA, USA). The chromatographic conditions were as follows: volume of injection 8 μL; solvent A (sodium acetate, pH 6.4, 5,000 ppm EDTA, triethylamine [1:2,000] and 6%, v/v, acetonitrile); solvent B, (60%, v/v, acetonitrile and 5,000 ppm EDTA). UV detection was carried out using 2,487 dual wavelength.

Statistical analysis

The statistical analysis of the obtained results was performed using the SAS software for Windows 7.0, version 9.1.3 [25]. The differences among the means at a 5% significance level were compared using the Duncan's multiple range tests. Mean values and standard errors of the means (SEM) were also reported. p-values < 0.05 are considered to be significant.

Results and Discussion

Physicochemical traits

The carcass weights of control, T1, and T2 were 25.17, 23.03, and 21.03 kg, respectively. The carcass weight of sea tangle supplemented black goats at high dose was significantly lower than the control. It can be thought that sea tangle lowered the preference of feed consumption. In terms of meat quality traits, the influences of sea tangle (*L. japonica*) supplementation on physicochemical traits of KNBG are presented in Table 1. No significant difference was observed among the treatment groups for pH, moisture and fat contents, color values, and water holding capacity. The pH of goat LD muscle ranged from 5.87 to 5.96 and was uninfluenced by sea tangle supplementation. Moroney el al. [17] also reported insignificant differences of pork quality by sea tangle feeding. Previously, [26] indicated that no significant differences were observed among the sea tangle dietary groups on the moisture and fat contents of duck when compared to control. In the current study, moisture and fat contents were determined to be in the range of 72.78%–74.04% and 3.22%–3.99%, respectively. Another study had reported that fat and protein contents were greater in broiler chicks fed the 10% green seaweed [27]. Color was not changed by supplementation of sea tangle, even though only a* values except L* and b* values were not included in the table. Water holding capacity was intended to decrease by addition of sea tangle, but the differences were not significant.

Control exhibited higher shear force values compared to all other treatment samples ($p < 0.05$). It is not clear how the shear force was decreased by supplement of sea tangle. According to the sensory evaluation (data not included), the treatments with sea tangle showed tender texture attribute compared with the control. There is some extra study needed. The TBARS values of the treatment samples were lower than the control ($p < 0.05$). This might be owing to the antioxidant property of sea tangle. Similarly, previous studies found that dietary seaweed extracts decreased the lipid oxidation in pork muscle [17,28,18]. This result supports the findings of [26] who reported that the highest TBARS values were recorded in control, while the sea tangle dietary groups exhibited a reduced lipid oxidation. TBARS values above 1.0 are generally involved in off-odor and flavor of meat [29]. In the current study, the TBARS values were below 1.0 (0.15 to 0.24 mg MDA/kg) for all samples. The reduced lipid oxidation was compared with the functional compounds such as antioxidant dipeptide (carnosine) and energy metabolism-related compound (creatine, creatinine) (Table 2). However, those functional compounds analyzed in goat

Table 1. Effect of sea tangle (*Laminaria japonica*) supplementation on carcass weight and physicochemical traits of loin of Korean native black goat (KNBG)

	Treatments[1)]			
	Control	T1	T2	SEM[2)]
Carcass weight (kg)	25.17[a]	23.03[ab]	21.03[b]	1.12
pH	5.87	5.96	5.93	0.02
Moisture (%)	72.78	74.04	73.37	0.24
Fat (%)	3.99	3.22	3.48	0.21
a* value	17.71	18.40	18.36	0.17
Water holding capacity (%)	81.67	79.63	79.43	0.59
Shear force (kg·f)	4.34[a]	3.42[b]	3.42[b]	0.14
TBARS (mg MDA/kg)	0.24[a]	0.15[b]	0.15[b]	0.01

[1)]Treatments: control (basal diet + mineral block), T1 (0.3% sea tangle feeding with the basal diet), T2 (0.9% sea tangle feeding with the basal diet).

[2)]Standard error of means (n = 10).

[a,b]Figures with different letters within a same row differ significantly ($p < 0.05$).

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Table 2. Effect of sea tangle (*Laminaria japonica*) supplementation on carnosine, creatine, and creatinine contents of loin of Korean native black goat (KNBG)

	Treatments[1)]			
	Control	T1	T2	SEM[2)]
Carnosine	286.30	265.95	247.02	69.59
Creatine	1,399.92	1,244.11	1,393.43	64.36
Creatinine	42.73	38.43	37.13	2.67

1)Treatments: control (basal diet + mineral block), T1 (0.3% sea tangle feeding with the basal diet), T2 (0.9% sea tangle feeding with the basal diet).

2)Standard error of means (n = 10).

muscles were not significantly different by feeding sea tangle. The antioxidant acidity in sea tangle treatments might be attributed to other components.

Fatty acids composition

The effects of sea tangle (*L. japonica*) supplementation on fatty acid composition of KNBG are presented in Table 3. The richest compound in LD muscles of goat was detected to be oleic (C18:1), followed by palmitic (C16:0), and stearic (C18:0) acids. Our findings agree with a previous study on goat muscle [30]. Among the individual fatty acids, palmitoleic acid, linoleic acid, and arachidonic acid contents were increased in the T2 supplementation group, as compared to control and T1 groups ($p < 0.05$). Considering unsaturated fatty acids, enhanced oleic acid content was reported in T1 and T2 dietary samples as compared to control ($p < 0.05$). These fatty acids increased significantly with increasing sea tangle concentrations.

Significant changes were observed in the percentage of polyunsaturated fatty acid (PUFA) between the control and treatment groups. In the present study, PUFA levels were enhanced in the T2 group as compared to control and T1. This is probably considered to be the high level of linoleic acid (C18:2). Islam et al. [26] reported similar results indicating that the higher contents of polyunsaturated fatty acids in ducks supplemented with sea tangle were owing to the presence of phospholipids and glycolipids. Similarly, [28] reported higher contents of polyunsaturated fatty acids in pork from dietary seaweed treatments. Furthermore, [31] supported that dietary supplementation of seaweed impacted fatty acid composition in pork. These differences in fatty acid composition could be due to the inclusion of sea tangle in goat feed. Present findings conclude that dietary sea tangle beneficially impacts the fatty acid profile of goat meat without harmful effects on lipid oxidation.

Free amino acids

The effects of sea tangle (*L. japonica*) supplementation on ami-

Table 3. Effect of sea tangle (*Laminaria japonica*) supplementation on the fatty acid composition (%) of loin of Korean native black goat (KNBG)

	Treatments[1)]			
	Control	T1	T2	SEM[2)]
C16:0	19.79	19.22	20.06	0.69
C16:1	2.49[b]	2.49[b]	2.68[a]	0.09
C18:0	12.23	12.78	11.43	1.47
C18:1	44.83[b]	46.3[a]	47.00[a]	1.01
C18:2	4.15[b]	4.60[b]	5.32[a]	0.57
C18:3	0.09	0.11	0.10	0.01
C20:4	2.21[b]	2.50[b]	2.96[a]	0.37
SFA	34.99	34.85	34.36	0.69
UFA	57.25	56.98	57.56	0.73
PUFA	6.45[c]	7.17[b]	8.38[a]	0.42
MUFA	50.80	48.60	50.38	1.93
UFA/SFA	1.64	1.64	1.68	0.04

1)Treatments: control (basal diet + mineral block), T1 (0.3% sea tangle feeding with the basal diet), T2 (0.9% sea tangle feeding with the basal diet).

2)Standard error of means (n = 10).

a,bFigures with different letters within a same row differ significantly ($p < 0.05$).

SFA, saturated fatty acids; UFA, unsaturated fatty acids, MUFA, monounsaturated fatty acids, PUFA, polyunsaturated fatty acids.

Table 4. Effect of sea tangle (*Laminaria japonica*) supplementation on the free amino acid composition (mg/100 g) of loin of Korean native black goat (KNBG)

	Treatments[1)]			
	Control	T1	T2	SEM[2)]
Ala	34.04[b]	38.13[a]	38.80[a]	2.26
Arg	278.05	261.50	268.02	19.88
Asp	1.82[b]	1.57[b]	2.82[a]	0.39
Cys	2.02	2.81	3.10	1.32
Glu	16.52[b]	16.72[b]	20.75[a]	3.1
Gly	17.12[b]	18.31[b]	20.84[a]	1.78
His	57.47[b]	65.96[b]	82.72[a]	15.87
Ile	4.64	4.27	4.87	0.74
Leu	9.32	8.62	9.35	1.59
Lys	9.29	8.67	10.13	1.85
Met	4.09	3.82	4.07	0.67
Phe	5.37	5.15	5.28	0.80
Pro	6.11	4.80	7.79	3.82
Ser	11.85[b]	11.35[b]	15.01[a]	1.86
Thr	143.21	148.16	117.47	35.28
Tyr	8.27	8.39	7.43	1.52
Val	8.05	7.13	8.66	1.86

[1)]Treatments: control (basal diet + mineral block), T1 (0.3% sea tangle feeding with the basal diet), T2 (0.9% sea tangle feeding with the basal diet).

[2)]Standard error of means (n = 10).

[a,b]Figures with different letters within a same row differ significantly ($p < 0.05$).

no acid profile of KNBG are presented in Table 4. Arginine was detected as the free amino acid having the highest level in LD muscles of KNBG. Differences in amino acid composition were significant ($p < 0.05$), with the exception of some amino acids. The levels of aspartic acid (Asp), glutamine (Glu), glycine (Gly), histidine (His), and serine (Ser) were higher in T2, as compared to the control ($p < 0.05$). Moreover, alanine (Ala) content was higher in both sea tangle dietary treatments compared to control ($p < 0.05$). Amino acids such as asparagine, threonine, serine, glutamic acid, glycine, and alanine impart the umami taste or tasty (sweet) flavor, whereas valine, isoleucine, leucine, phenylalanine, methionine, arginine, histidine and proline are strongly involved with bitter taste in meat [32]. Taken together, our results suggest that dietary sea tangle has a great impact on increase taste free amino acids composition of KNBG.

Conclusion

Research with goat meat, especially Korean native black goats, have not been investigated to date. Our finding reveals that goat meat was positively affected by sea tangle supplementation as compared to those fed basal diet with mineral block, which therefore merits the inclusion of sea tangle in goat feed. The improved fatty acid and amino acid composition, along with reduced shear force and lipid oxidation of goat meat, validates the dietary supplementation of sea tangle for improved meat qualities. The overall conclusion from the physicochemical attributes is that 0.9% sea tangle supplementation with the basal diet produces better meat quality evaluation, even though a negative effect on carcass weight. This finding can help provide new animal feed additives for goat production based on sea tangle as an alternative of mineral block showing improving the meat quality traits. However, more research is required to determine the optimal concentration of feeding dietary sea tangle and the mechanisms of meat quality changes, in order to optimize the goat meat quality and shelf-life.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Not applicable.

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: Yim DG, Choi YS.
Methodology: Nam KC, Yim DG
Validation: Choi YS.
Investigation: Nam KC.
Writing - original draft: Yim DG, Choi YS.
Writing - review & editing: Yim DG, Choi YS, Nam KC.

Ethics approval and consent to participate

This article does not require IRB/IACUC approval because there are no human and animal participants.

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