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Research Article

Effects of *Sasa borealis* silage on proximate composition, amino acid and fatty acid contents, and antioxidant activity in fresh meat of Korean native goat fed with total mixed ration

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Abstract Jeju *Sasa borealis* (*S. borealis)* is indigenous to the Halla Mountain area of Jeju Island, Republic of Korea. However, its dominance has retarded the development of other plant species and lowered biodiversity in this region. The aim of this study was to determine whether *S. borealis* silage (SS) supplementation affects the chemical composition and antioxidant activity in the fresh meat of Korean native goats (*Capra hircus coreanae*). The experiment was conducted on 12 Korean native goats at the finisher stage. The feeding groups were the Control (total mixed ration, TMR) and the Treatment (80% TMR + 20% SS). The animals were adapted for two weeks and then subjected to a six-month breeding experiment. Meat samples were excised from the neck, loin, rib, front leg, and hind leg of the slaughtered animals. The meat derived from the treatment group contained more taurine and anserine than that derived from the control group. Both groups did not significantly differ in terms of ω-6/ω-3 fatty acid ratio. The loin and front leg of the treatment group contained significantly higher vitamin E levels than those of the control group. DPPH, ABTS, and FRAP analyses disclosed that the loin and front leg had significantly higher antioxidant activity ($p<0.05$) than the other parts. Moreover, the loin and front leg cuts of the treatment group had higher antioxidant activity than those of the control group. The present study demonstrated that *S. borealis* supplementation could effectively improve Korean native goat meat quality.

Keywords antioxidant activity, Korean native goat, proximate composition, *Sasa borealis* silage, total mixed ration

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1. Introduction

Sasa borealis (*S. borealis*) is a widely distributed temperate perennial plant species in Mt. Halla, Jeju, Republic of Korea. It is well adapted to temperate climates and has been less severely affected by recent climate change events than other plant species in the region (Cho et al., 2018). Its superior dominance greatly hinders the growth of other vegetation on Jeju Island, which has become a major social problem in the recent years (Cho et al., 2018; Park et al., 2012). *S. borealis* grows mainly in the lowlands of mountainous regions. Alpine plants such as conifers gradually recede as *S. borealis* advances (Li et al., 1992). Hence, it is necessary to remove *S. borealis* before it can cause major damage to the Mt. Halla forest ecosystem. In response to climate change, however, *S. borealis* reeds have established themselves in areas beyond the mid-mountainous zones. For this reason, the eradication of S. borealis in the region by manpower alone is no longer realistic or economical. in the recent years (Cho et al., 2018; Park et al., 2012).

S. borealis has a higher protein content than conventional forage crops and might, therefore, be suitable as livestock feed (Chung et al., 2018; Lee et al., 2010). However, there is very little published research on *S. borealis* as livestock forage. Korean native goats can use a wide variety of grass species and feed resources such as improved pastures and rough shrubs. Therefore, these animals could potentially graze or browse on *S. borealis* in the forest (Chung et al., 2018). The optimal damming level required to improve breeding Korean native goat growth and meat quality is in the range of 14% to 16% (Choi et al., 2005). As *S. borealis* has a crude protein content of 15.2%, it could effectively serve as a forage source for growing Korean native goats.

The purpose of the present study was to determine the practicality and feed value of *S. borealis* for breeding Korean native goat. Utilization of this natural resource as livestock feed could effectively sustain commercially important animals while attenuating its capacity to hinder the growth of other plant species and lower biodiversity in forest ecosystems (Chung et al., 2021). The present work revealed that Korean native goats fed total mixed ration (TMR) supplemented with *S. borealis* silage (SS) presented with higher daily weight gain than those fed TMR alone. The 80% TMR + 20% SS formulation had relatively higher digestibility (in terms of crude fat and crude protein content and dry matter digestibility) than the other feed formulations. In contrast, meat yield and quality and quantity did not significantly differ among Korean native goats fed the various diets.

The present study confirmed the value of *S. borealis* as a potential forage source by comparing the differences in amino acid and fatty acid content, physical properties, and antioxidant capacity between Korean native goats fed 80% TMR + 20% SS and those administered TMR alone.

2. Materials and methods

2.1. Animal experiments

The experiments were performed on 12 Korean native goats (wethers) at the finisher stage. The feeding groups were the Control (total mixed ration, TMR) and the Treatment (80% TMR + 20% *S. borealis* silage, SS). TMR is a commercial feed formulated for goat finishers. Table 1 shows the approximate composition of the experimental feed. The animals were subjected to a 2-wk adaptation period before the 6-mo breeding experiment. All conditions except the feed composition were the same for both groups. The raw herbs comprising Jeju porridge were collected from their natural habitat, namely, the mid-mountainous region of Jeju-si, Aewol, and Hallasan, converted to silage, and fed to the goats. At the conclusion of the breeding experiment, the

Table 1. Proximate composition of experimental feed

	Control (TMR)	*Sasa borealis* silage	Treatment (TMR+*Sasa borealis* silage)
DM[1] (%)	89.05±2.03	40.05±1.09	78.65±1.56
		--------------------% DM--------------------	
CP[2]	15.33±0.16	7.27±0.55	13.76±0.28
EE[3]	4.97±0.31	4.72±0.40	4.79±0.09
Ash	6.61±0.14	8.66±1.12	7.43±0.20
CF[4]	16.65±1.15	37.13±1.55	21.10±0.77
NDF[5]	38.97±2.84	69.96±2.92	48.40±0.35
ADF[6]	21.09±1.76	41.70±2.53	24.00±1.93

[1] DM, dry matter.
[2] CP, crude protein.
[3] EE, ether extract.
[4] CF, crude fiber.
[5] NDF, neutral detergent fiber.
[6] ADF, acid detergent fiber.

animals were butchered and the characteristics of their neck, loin, rib, front leg, and hind leg meat parts were evaluated.

2.2. Meat sample preparation

The wethers were slaughtered at a local municipal abattoir (Chungju, Korea). Every effort was made to minimize suffering and the number of animals used in this research. All experimental protocols were approved by the Konkuk University Institutional Animal Care and Use Committee (No. KU19004). Fresh loin, front leg, hind leg, neck, and rib meat was analyzed. All meat was dried in a lyophilizer (Ilshin Co., Seoul, Korea) and milled in a grinder (Hanil Co., Seoul, Korea).

2.3. Proximate composition analysis

The amounts of moisture, crude protein, fat, ash, neutral detergent fiber (NDF), and acid detergent fiber (ADF) in all meat cuts were determined in accordance with the recommendations of the Association of Official Analytical Chemists (AOAC, 1990).

2.4. Amino acid analysis

Meat samples were extracted with 70% (v/v) ethanol for 30 min. A ninhydrin reagent kit (Wako Chemical Inc., Osaka, Japan) and an amino acid analyzer (Hitachi L-8900, Tokyo, Japan) fitted with a column packed with ion exchange resin and a UV detector were used to determine the amino acid composition. The amino acid profile was determined using a high-performance liquid chromatograph (HPLC; Hitachi L-8900, Tokyo, Japan) fitted with a column packed with ion exchange resin and a UV detector.

2.5. Fatty acid analysis

The fatty acids extracted from the samples were converted into their respective methyl esters using either (a) 2 mL of 14% BF_3 plus methanolic HCl for 45 min or (b) 2 mL of methanolic HCl under a nitrogen atmosphere at 90℃ for 45 min. The fatty acid methyl esters were analyzed with a gas liquid chromatograph (Hewlett Packard Co., Palo Alto, CA, USA) coupled to an automated injector and fitted with a silica capillary column and a flame ionization detector (FID).

2.6. Vitamin E measurement

The meat samples were extracted with 6% (v/v) pyrogallol-ethanol solution for 10 min in preparation for vitamin E content determination. The extracts were purged with nitrogen for 1 min and then mixed with 7 mL of 60% (w/v) KOH. The solutions were transferred to a cooler and then saponified in a 70℃ water bath for 1 h. The samples were then extracted by shaking with 85:15 (v/v) *n*-hexane:ethyl acetate containing 0.01% (v/v) butylated hydroxytoluene (BHT). The supernatants were then separated. The extracted samples were dissolved in n-hexane in a volumetric flask and injected into a high-performance liquid chromatograph (HPLC; Agilent 1200 series, Agilent Technologies, Palo Alto, CA, USA) fitted with a Lichrosorb 100 Diol column (250 mm×4.6 mm I.D., 10 μm; Merck GmbH, Darmstadt, Germany), a YoungLin M930 solvent delivery pump, and a LC305 fluorescence detector (Thermo^{TM} Separation Products, Inc., Bingham Farms, MI, USA). The injection volume and column temperature were 20 μL and 25℃, respectively. The excitation and emission wavelengths were 290 nm and 330 nm, respectively. The recorder for the HPLC analysis was a JASCO 807-IT (Jasco International Co. Ltd., Tokyo, Japan). The flow rate was 1.0 mL/min and the mobile phase consisted of n-hexane with 1.3% (v/v) isopropanol.

2.7. DPPH (2,2-diphenyl-1-picrylhydrazyl) assay

The DPPH scavenging activity levels of the meat samples were determined according to the method of Tepe et al. (2005). One hundred milliliters of 1.5×10^{-4} M DPPH was reacted with or without 100 mL meat extract at room temperature(20-25℃) for 30 min and the absorbances were then read in a UV/VIS spectrophotometer (UV-1240; Shimadzu Corp., Kyoto, Japan). A standard (Trolox) calibration curve was plotted vs. % inhibition. The Trolox equivalent antioxidant capacity (TEAC) was determined from the ratio of the % inhibition of the sample to the Trolox calibration curve gradient ($x = [y - b] / a$).

2.8. ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)) assay

An improved ABTS procedure (Re et al., 1999) was used to measure the antioxidant activity of the meat samples in terms of their ABTS radical scavenging capacity. A reaction between 7 mM ABTS and 2.45 mM potassium persulphate generated aqueous ABTS radical cation (ABTS+) and the latter was incubated in the dark at room temperature for 16 h. The resultant ABTS+ solution was diluted with 80% (v/v) ethanol until its absorbance at 734 nm was adjusted to 0.700±0.005. The mixture was then stored at 30℃ for 30 min and centrifuged (TGL-16C, Anting Scientific Instrument Factory, Shanghai, China) at 1,430 ×*g* for 10 min. The absorbance of the supernatant was immediately measured at 734 nm in a UV-1240 (Shimadzu Corp.). The absorbance decreased with increasing antioxidant activity.

2.9. Ferric reducing antioxidant power (FRAP) assay

Goat meat samples (1 mg/mL) were analyzed by FRAP assay. The ferric reducing antioxidant power of each sample was determined using the methods of Ka et al. (2016) and Benzie and Strain (1996). The working FRAP solutions were heated to 37℃ before analysis. The meat samples were suspended in 50 μL deionized water, mixed with 1.5 mL working FRAP solution, and allowed to react in the dark at 20-25℃ for 30 min. The color intensity of the ferrous tripyridyl triazine complex product was measured at 595 nm in a UV-1240 (Shimadzu Corp.).

2.10. Statistical analysis

All data are presented as means plus standard deviation (SD) and were subjected to ANOVA or a general linear model procedure in SAS v. 9.3 (SAS Institute, Cary, NC, USA) (SAS, 2012). Statistical significance was defined by the Student's t-test at $p<0.05$.

3. Results and discussion

3.1. Proximate composition

A six-month Korean native goat breeding experiment demonstrated that the amounts of dry matter content in the front limbs of the control (26.3±2.0) and treatment (26.2±2.1) groups were significantly ($p<0.05$) higher than those in other meat parts (Table 2). The quantities of crude protein in the various meat parts did not significantly differ between the control and treatment groups. In both the treatment and control groups, the hind leg contained the most crude protein followed by the loin, front leg, neck, and rib. In both the control and treatment groups, the relative amount of crude fat was in the order rib > neck > loin > front leg > hind leg. The crude ash content was usually higher in all parts of the goats in the treatment group than in those of the animals in the control group. However, the opposite was true for the crude fiber content. Webb et al. (2005) also reported higher protein and ash content but lower fat content in goat meat compared to meat from other livestock. Goat meat have higher collagen content and lower solubility than sheep meat (Heinze et al., 1986; Schonfeidt et al., 1993). Visceral fat develops first and is followed by the formation of intermuscular, intramuscular, and/or subcutaneous fat (Webb et al., 2005). In goats, fat accumulates gradually and its content only reaches substantially high levels at maturity (Owen et al., 1983). The addition of SS to the diet increases the crude fiber content in the TMR and, by extension, the crude ash content in black goat meat. Adding wheat bran and dried carrots to feed rations increased the crude ash content of chicken sausage (Yadav et al., 2018).

3.2. Free amino acid content

Table 3 lists the free amino acid content in each

Table 2. Effect of *Sasa borealis* silage feeding on proximate composition by of Korean native goat meat (%)

	Neck		Loin		Rib		Front-leg		Hind-leg	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
DM1)	24.7 ± 2.7^{b}	25.3 ± 4.4^{ab}	23.7 ± 3.8^{bc}	23.4 ± 2.3^{c}	21.6 ± 2.7^{d}	21.6 ± 3.5^{d}	23.0 ± 2.3^{c}	23.8 ± 2.9^{bc}	26.3 ± 2.0^{a}	26.2 ± 2.1^{a}
				------------------ % DM ------------------						
CP2)	60.1 ± 4.3^{c}	59.3 ± 7.8^{c}	62.9 ± 5.2^{b}	63.1 ± 3.1^{ab}	56.8 ± 2.8^{d}	55.2 ± 1.6^{d}	62.0 ± 4.2^{b}	62.4 ± 6.5^{b}	64.5 ± 3.1^{a}	63.5 ± 6.5^{ab}
EE3)	24.4 ± 0.9^{b}	23.7 ± 0.5^{b}	21.2 ± 0.9^{c}	20.6 ± 1.1^{c}	36.3 ± 1.4^{a}	35.2 ± 1.4^{a}	15.8 ± 0.8^{d}	14.6 ± 1.7^{d}	13.3 ± 0.6^{e}	13.3 ± 1.8^{e}
ASH	3.9 ± 0.3^{c}	$4.1\pm0.2^{b,**}$	3.9 ± 0.2^{c}	$4.2\pm0.4^{ab,**}$	3.9 ± 0.2^{c}	$4.3\pm0.4^{a,**}$	4.0 ± 0.2^{bc}	$4.3\pm0.3^{a,*}$	4.2 ± 0.3^{ab}	4.5 ± 0.4^{a}
CF4)	2.6 ± 0.7^{ab}	2.6 ± 0.9^{ab}	$2.4\pm1.1^{b,*}$	2.2 ± 0.6^{bc}	$2.3\pm1.0^{b,*}$	1.9 ± 0.9^{cd}	$2.6\pm0.7^{ab,*}$	1.7 ± 0.8^{d}	$2.9\pm0.9^{a,*}$	1.7 ± 0.7^{d}

[a–e] Means with different superscript in the same row are significantly different ($p<0.05$).

[*,**] Means with different superscript in the same row within each meat parts are significantly different ($p<0.05$, $p<0.01$).

Control: TMR, treatment: 80% TMR + 20% SS.

1) DM, dry matter.

2) CP, crude protein.

3) EE, ether extract.

4) CF, crude fiber.

Data are expressed as mean±SD of triplicate experiments (n=6).

Table 3. **Effect of *S. borealis* silage feeding on amino acid content of Korean native goat meat (mg/100 g meat)**

Amino acid (mg/100 g meat)	Neck		Loin		Rib		Front-leg		Hind-leg	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
Taurine	283.42	321.25	144.02	133.63	249.52	261.03	279.32	362.70^{*}	222.28	237.00
Aspartic acid	16.92	41.20^{**}	11.15	14.95	9.98	26.05	10.70	32.40^{*}	9.62	11.00
Threonine	12.20^{*}	10.75	11.18^{*}	9.28	11.63	11.00	10.75	10.68	10.74	10.38
Serine	17.43	17.40	16.83	16.00	16.52	18.73	15.27	16.25	15.88	15.33
Glutamic acid	37.42^{*}	26.63	17.00	5.77	27.92	19.73	27.92	27.28	15.25^{**}	5.68
Glycine	71.20	77.90	72.55	115.43	76.26	92.17	73.23	84.97	73.84	74.57
Alanine	116.47	133.30	109.78	121.75	119.24	143.67	108.92	138.60^{**}	125.33	128.80
Valine	15.96	15.27	18.82	18.78	15.53	16.70	16.62	16.08	4.40	4.75
Methionine	3.60	3.87	5.97	7.05	3.83	4.40	3.43	3.98	4.40	4.75
Isoleucine	6.18	5.77	9.35	9.25	6.05	6.50	5.59	6.25	7.10	7.80
Leucine	10.20	9.80	14.57	14.30	9.55	9.93	9.83	10.40	11.17	12.43
Tyrosine	5.28	5.80	10.00	9.98	5.10	5.40	5.25	5.48	6.30	8.03
Phenylalanine	4.93	5.25	10.82	10.90	4.75	5.40	4.78	5.50	5.77	7.67
Ammonia	24.87	24.50	20.00^{*}	16.85	27.50	29.33	22.75	28.38^{*}	21.68	20.95
Lysine	15.635	15.95	12.87	11.58	14.97	13.80	13.85	16.25	12.88	11.00
Histidine	11.28	8.50	7.82	6.43	9.85	8.30	8.82	9.10	7.90^{*}	6.58
Anserine	291.72	307.43	641.73	995.95^{*}	325.2	562.23^{*}	407.62	410.90	553.45	909.40^{**}
Arginine	23.02	19.60	21.43	19.25	19.55^{*}	15.10	19.22	19.33	17.85	14.55
Proline	6.87	6.85	3.32	2.90	5.10	5.80	3.15	7.80^{**}	5.98	7.37
Total	974.60	1,057.02	1,159.21	1,540.03	958.05	1,255.27	1,047.02	1,212.33	1,131.82	1,498.04

*,**Means in the same row within each meat parts are significantly different ($p<0.05$, $p<0.01$).
Control: TMR, treatment: 80% TMR + 20% SS.

part of Korean native goat meat. The treatment and control did not significantly differ in terms of essential amino acid (methionine, isoleucine, leucine, lysine, etc.) content. The glutamic acid levels were significantly higher in the hindlimb region ($p<0.01$) than they were in other body parts. By contrast, the aspartic acid ($p<0.05$), taurine ($p<0.05$), and alanine ($p<0.01$) levels were significantly higher in the forelimbs of the treatment group than they were in those of the control group.

The Korean native goat meat also contained high taurine levels. In general, meat is the richest dietary taurine source (Williams, 2007). Beef and lamb contain ~77 mg/100 g and ~110 mg/100 g taurine, respectively (Purchas et al., 2004). For the treatment group, the front leg contained 362.7 mg/100 g taurine. In addition, the taurine content was generally higher in the treatment than the control group. Several studies reported that taurine has therapeutic efficacy against heart failure (Azuma et al., 1985), diabetes (Schaffer et al., 2009), and inflammation (Marcinkiewicz and Kontny, 2014).

The dipeptide anserine (β-alanyl-3-methylhistidine) is a combination of β-alanine and 1-methylhistidine and was first detected in goose muscle (Boldyrev and Severin, 1990). It has multiple physiological functions.

Human clinical research demonstrated the benefits of anserine to metabolism and renal, neurological, immunological, and cardiovascular function (Wu, 2020). Here, the anserine levels in the loins and hind legs of the treatment group were 995.95 mg/100 g and 909.40 mg/100 g, respectively, while those in the same parts of the control group were only 641.73 mg/100 g and 553.45 mg/100 g, respectively. In contrast, the average anserine content was merely 69.37 mg/100 g in Hanwoo beef (Kwon and Choi, 2018). Lee et al. (2022) reported 1,024 mg/100 g anserine in chicken breast. Hence, both chicken breast and Korean native goat loin are excellent dietary anserine sources. In this study, the goats fed TMR supplemented with 20% SS had higher taurine and anserine levels than those fed TMR alone. Therefore, the addition of 20% SS to TMR enhances the nutritional properties of black goat meat.

3.3. Fatty acid content

Table 4 lists the fatty acid (FA) composition of each part of Korean native goat meat after breeding. The C16:0 (palmitic acid) content was higher in the ribs (4,077.12 mg/100 g) than the other parts of the control group and higher in the neck (4,516.50 mg/100 g) than the other parts of the treatment group. The palmitic acid levels of the front leg meat were 3,094.36 mg/100 g and 1,584.87 mg/100 g in the control and treatment group, respectively, and the difference was significant ($p<0.01$). The C18:0 (stearic acid) content in the front leg meat of the treatment group (1,594.20 mg/100 g) was significantly lower ($p<0.05$) than that of the same tissue in the control group (2,298.00 mg/100 g). The oleic acid (c18:1 cis) content is associated with meat flavor and was the most abundant of all FAs in the goat meat. It was significantly higher ($p<0.01$) in the neck of the treatment group (8,700.45 mg/100 g) than in that of the control group (5,896.47 mg/100 g). On the other hand, the oleic acid content in the loin of the control group (6,678.55 mg/100 g) was significantly higher ($p<0.05$) than that of the same tissue in the treatment group (4,348.35 mg/100 g). The levels of the essential FA linolenic acid (C18:2 cis) were non-significantly higher in all parts of the treatment group than the control group except for the ribs. Palmitic acid (C16:0), stearic acid (C18:0), and oleic acid (C18:1) were the most abundant FAs in the goat meat. Previous studies reported similar results (Casey et al., 1988; Moon et al., 2021).

The ω-3:ω-6 FA ratios did not significantly differ among treatment groups and were in the range of 1:1.22–1:2.41 (Table 5). However, Van Ba Hoa et al. (2020) reported that the ω-3/ω-6 ratio of finishing pork was 1:25.98±3.28 while Yu et al. (2013) demonstrated a ω-3/ω-6 ratio range of 1:6-1:23 for the same type of meat. These findings suggest that black goat meat has a desirably high ω-3:ω-6 ratio. The low ω-3/ω-6 ratios characteristic of modern Western increase lipid mediator production and, by extension, blood clots, allergies, and inflammation (Bentsen, 2017; Kubala et al., 2010). Thus, a dietary ω-3/ω-6 ratio in the range of 1:4–1:5 has been recommended to lower the foregoing risks associated with ω-6 PUFA overconsumption (Mariamenatu and Abdu, 2021; Simopoulos, 2016).

3.4. Vitamin E content

The vitamin E content was higher in the all parts of the treatment than the control group except for the neck (Table 6). The vitamin E levels in the loins of the treatment and control groups were 0.45±0.06 mg/100 g and 0.25±0.07 mg/100 g, respectively. For both the control and treatment groups, the hind legs had the highest vitamin E content of all parts (0.48±0.17 mg/100 g and 0.53±0.05 mg/100 g,

Table 4. Effect of *Sasa borealis* silage feeding on fatty acid content of Korean native goat meat (mg/100 g meat)

Fatty acid (mg/100 g meat)	Neck		Loin		Rib		Front-leg		Hind-leg	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
c10:0	13.07	18.48**	8.82	8.40	15.63	12.47	10.95**	6.10	6.16	8.80
c12:0	44.40	47.43	21.83*	11.83	39.08*	20.00	39.80**	10.93	17.66	24.43
c14:0	447.85	724.10*	333.85*	192.18	560.32	400.57	443.0**	153.53	258.22	226.25
c14:1	36.36	33.80	17.73**	7.07	31.68**	14.30	38.90**	15.63	14.82	16.10
c15:0	83.84	86.23	49.03*	22.23	75.05	52.83	50.08*	19.80	26.64	30.87
c16:0	3,730.23	4,516.50	2,897.26	2,158.53	4,077.12	3,304.87	3,094.36**	1,584.87	1,681.84	2,018.00
c16:1	474.76	490.43	296.38*	161.80	391.90	369.27	405.08*	224.33	236.40	251.93
c17:0	280.02	249.28	240.40**	95.33	277.30	179.37	168.46*	99.28	96.34	94.48
c18:0	2,923.16	3,328.90	2,049.42	1,657.75	3,211.23	2,726.30	2,298.00*	1,594.20	1,558.73	1,568.05
c18:1 trans	381.93	361.10	240.65	178.85	359.82	354.87	310.55*	186.63	199.57	190.25
c18:1 cis	5,896.47	8,700.45**	6,678.55*	4,348.35	8,613.13	6,794.77	5,791.82	4,384.83	4,187.88	4,479.10
c18:2 trans	168.82	161.28	99.60	67.28	160.18*	116.67	136.62**	65.83	84.68	76.73
c18:2 cis	748.60	755.90	474.82	512.60	694.98	687.43	650.02	672.53	629.48	652.40
c20:0	15.58	16.95	15.33*	6.83	20.68	10.90	10.26**	6.88	6.48	7.63
c18:3 trans	8.98	10.23	7.02	5.45	8.30	7.65	7.10	7.17	5.82	6.08
c20:1 n-9	27.94	30.55	17.42	11.45	26.72	23.95	19.83*	13.05	14.13	13.17
c18:3 n-3	25.18	28.28	17.03	14.03	23.28	20.83	19.50	17.30	16.80	16.57
c21:0	38.58	35.40	17.45*	8.80	46.72	27.07	34.46*	17.83	17.48	17.33
c20:2	33.85	40.93	27.4	21.63	26.76	30.13	24.96*	17.43	15.65	16.58
c22:0	52.72	53.25	43.97	46.53	49.73*	28.60	49.13	58.97	56.28	55.87
c20:3 n-6	13.77	17.13*	13.40	12.73	13.92	13.90	14.52	14.38	15.06	15.53
c22:1 n-9	4.56	5.63	3.00*	2.35	3.77	3.70	2.88	2.25	2.36	2.47
c23:0	125.90	144.33*	127.68	145.03	122.72	125.00	143.00	176.20*	184.92	189.10
c24:0	7.97	7.30	5.38	5.67	6.42	5.15	7.35	5.93	7.32	6.05
c20:5 n-3	9.87	7.60	9.87	9.90	9.13	6.05	11.18	10.13	12.32	12.15
c24:1	8.78	8.53	6.60	6.90	6.78	4.95	8.47*	6.15	7.33	6.23
SFA	7,769.88	9,235.08	5,817.3	4,364.28	8,493.74	6,885.31	6,361.76	3,738.47	3,922.74	4,251.86
USFA	7,833.31	10,644.91	7,902.59	5,355.22	10,378.61	8,456.29	7,428.52	5,633.69	5,437.63	5,750.29
Total	15,603.19	19,879.99	13,719.89	9,719.5	18,872.35	15,341.6	13,790.28	9,372.16	9,360.37	10,002.15

*,**Means in the same row within each meat parts are significantly different ($p<0.05$, $p<0.01$).
Control: TMR, treatment: 80% TMR + 20% SS.

respectively). Vitamin E is a crucial non-enzymatic antioxidant. Hence, meat derived from goats fed SS could strongly enhance antioxidant activity in the human body.

3.5. Antioxidant activity

We measured the antioxidant activity in each part of the meat products derived from Korean native goat (Fig. 1). The ABTS assay confirmed higher antioxidant

Table 5. Effect of *Sasa borealis* silage feeding on fatty acid ratio of Korean native goat meat (ω-3 : ω-6)

	Control	Treatment
Neck	1 : 1.64	1 : 2.16
Loin	1 : 1.72	1 : 1.94
Rib	1 : 1.39	1 : 2.41
Front-leg	1 : 1.38	1 : 1.35
Hind-leg	1 : 1.22	1 : 1.27

Control: TMR, treatment: 80% TMR + 20% SS.

Table 6. Effect of *Sasa borealis* silage feeding on vitamin E contents of Korean native goat meat (mg/100 g)

	Control	Treatment
Neck	0.43±0.15	0.40±0.08^{NS}
Loin	0.25±0.07	0.45±0.06*
Rib	0.43±0.17	0.45±0.06^{NS}
Front-leg	0.33±0.06	0.48±0.05*
Hind-leg	0.48±0.17	0.53±0.05^{NS}

*Means in the same row within each meat parts are significantly different ($p<0.05$).
NS, not significant.
Control: TMR, treatment: 80% TMR + 20% SS.
Data are expressed as mean±SD of triplicate experiments (n=6).

activity in the front legs of the treatment group (28.8 μM TE/mg) than in those of the control group (25.5 μM TE/mg) and the difference was significant ($p<0.05$) (Fig. 1(A)). Fig. 1(B) shows that the DPPH results were 6.7 μM TE/mg and 7.9 μM TE/mg for the control and treatment loins, respectively, while the FRAP results were 10.1 μM TE/mg and 13.6 μM TE/mg for the control and treatment loins, respectively. In the treatment group, the forelimb region had significantly higher ($p<0.05$) activity levels of all three types of antioxidant than the other tissues. Overall, the treatment group presented with higher antioxidant activity than the control group. The antioxidant activity levels were closely related to the vitamin E, taurine, and anserine levels in the loins and front legs.

SS sufficed as a forage source for Korean native goat and the quality of the meat derived from the animals feeding on SS was superior to that derived from the goats fed TMR alone. Wu et al. (2020) suggested that supplementation of TMR with 20% SS might also be suitable for horses. A previous study disclosed that as bamboo shoots have good fiber decomposition capacity, they were also satisfactory as feed sources for Korean native goats (Devendra and Burns, 1983). Korean native goats fed TMR supplemented with SS tended presented with higher daily weight gain than those fed TMR alone. A recommended optimal SS:TMR ratio was 2:8 (Chung et al., 2021). The present study analyzed the proximal components, amino acid, fatty acid, and vitamin E content, omega fatty acid ratio, and antioxidant activity in five different meat cuts derived from Korean native goats fed TMR supplemented with 20% SS.

4. Conclusions

We investigated the impact of feeding Korean black native goats total mixed ration supplemented with *S. borealis* silage on the quality of the meat derived from these animals. The meat obtained from the animals fed total mixed ration supplemented with *S. borealis* silage (treatment group) had higher levels of the functional amino acids anserine and taurine than the meat derived from the goats fed total mixed ration alone (control group). The meat derived from the treatment group had a higher fatty acid content than the meat obtained from the control group. However, *S. borealis* silage supplementation resulted in lower total fatty acid content in the loins and forelegs than the other meat parts. The meat from the treatment and control groups did not significantly differ in terms of their omega 3 fatty

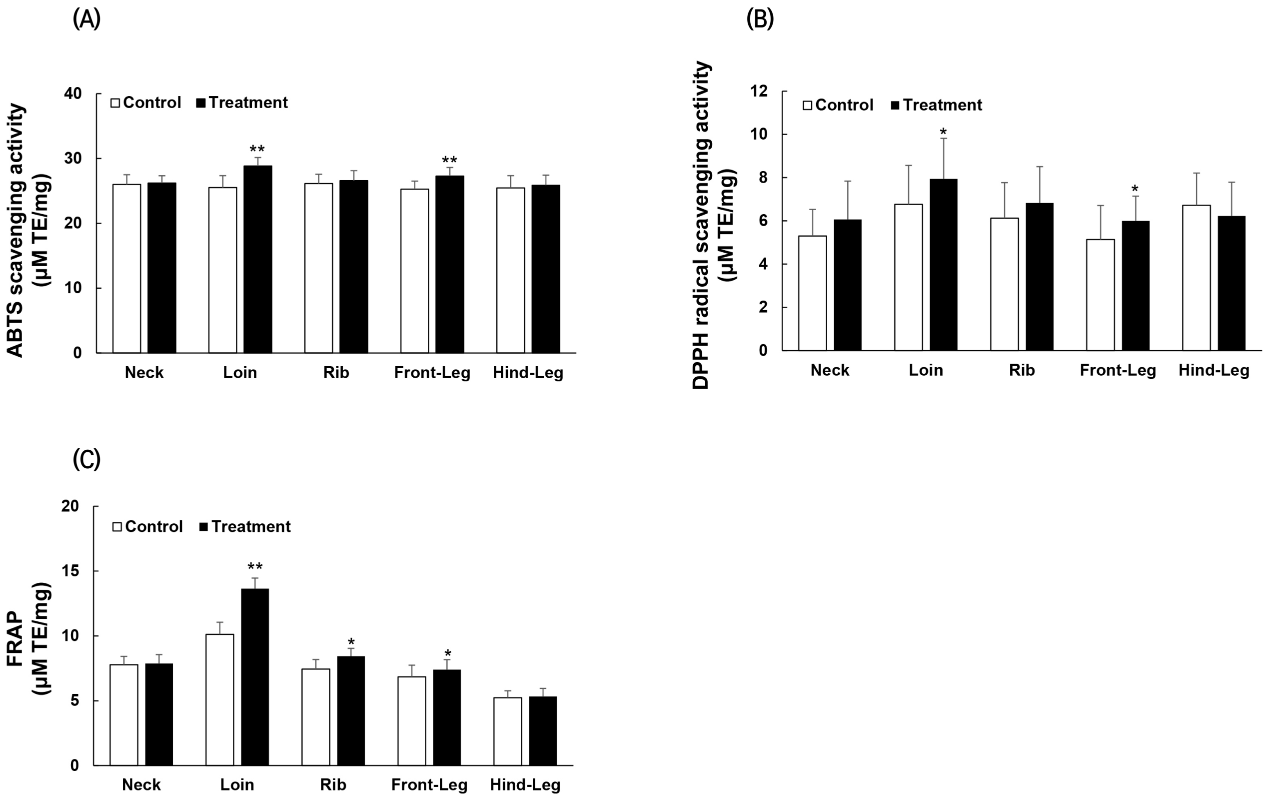

Fig. 1. Antioxidant activity of cuts of Korean native goat meat. (A) ABTS, (B) DPPH, (C) FRAP. Data are presented as the mean±SD from triplicate experiments. $^{*}p<0.05$ and $^{**}p<0.01$ compared with control group. Control: TMR, Treatment: 80% TMR + 20% SS.

acid:omega 6 fatty acid ratios. Nevertheless, *S. borealis* silage supplementation could result in high-quality goat meat that can offset the adverse health effects of excessive dietary omega-6 intake in humans. The vitamin E content and the antioxidant activity were generally higher in the meat derived from the treatment group than the meat originating from the control group. The use of *S. borealis* silage as a livestock feed supplement could add value to this invasive plant species while enhancing the nutritional quality of the meat derived from goat and potentially other livestock animals.

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Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Moon SH. Methodology: Chung SU, Kim NY, Oh M, Moon SH. Formal analysis: Chung SU, Jang SY, Yun YS. Validation: Choi YJ, Jang SY, Moon SH. Writing - original draft: Choi YJ. Writing - review & editing: Choi YJ, Moon SH.

Ethics approval

This research was approved by IACUC from the Konkuk University Institutional Animal Care and Use Committee (approval no. KU19004).

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