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Assessing the Effect of Fermented Chestnuts on Growth Performance, Carcass Traits, and Meat Quality in Hanwoo Steers During the Late Fattening Period

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Abstract | The objective of this study was to examine the effects of dietary fermented chestnuts on the growth performance, carcass parameters, and meat quality in the late fattening period of Hanwoo steers for 72 days. Eighteen castrated Hanwoo steers (615.8 ± 1.0 kg, 28 months old) were assigned into two groups (control vs. treatment), with nine Hanwoo steers in three replicates (three heads per replicate) for each group. The Hanwoo steers in the control group were fed a concentrate mix and rice straws, whereas those in the treatment group supplemented the control diet with 5% fermented chestnuts. Growth performance of Hanwoo steers was not different between the two groups ($p>0.05$), and 5% fermented chestnut supplementation had no effect on carcass trait ($p>0.05$). For meat quality, the application of fermented chestnuts to the Hanwoo steers diet exerted no significant effect in terms of chemical composition and physicochemical characteristics ($p>0.05$), except for pH ($p<0.05$). Considering the fatty acid profiles, the addition of 5% fermented chestnuts resulted in no significant difference ($p>0.05$) in the individual percentages of fatty acids, the relative percentages of saturated fatty acids (SFA) and unsaturated fatty acids (UFA), and the SFA:UFA ratio. However, fermented chestnut supplementation affected the percentages of margaroleic acid, stearic acid, and arachidonic acid ($p<0.05$). In conclusion, supplementation of 5% fermented chestnuts did not improve growth performance, carcass traits, and meat quality in Hanwoo steers. No more did the addition of fermented chestnuts in the diets demonstrate any detrimental effect during fattening Hanwoo steers.

Keywords | Carcass trait, Fermented chestnut, Growth performance, Hanwoo steer, Meat quality

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INTRODUCTION

During the past 70 years, antibiotic growth promoters have been applied in farm animals to improve growth production and meat quality. Over time, farm animals are frequently exposed to not only the overuse of antibiotics but also antibiotic-resistant bacteria, which are important contributors to the increase in antibiotic resistance. Since 2006, countries in the European Union have banned the use of antibiotics growth promoters in the farm as animal diet (Kroismayr, 2007; Kim et al., 2013). Consequently, various strategies to manipulate cattle diets in the pursuit of improved productivity have been extensively studied. These strategies offer natural alternatives to in-feed antibiotics, such as plant compounds, organic acids, and herbs (Yang et al., 2015; Hunag et al., 2018). Chestnut was classified as a fruit rich in tannins, containing water-soluble polyphenolic compounds that exist abundantly in nature

(Goel et al., 2005). Dietary chestnut at 5% for pig increase feed intake and digestibility (Lee et al., 2016). In poultry, supplementation of chestnut tannin at 250/500 mg/kg in the feed increase body weight and feed conversion (Jamroz et al., 2009). On the ruminants, there are numerous studies on the use of chestnuts tannins in nutrition and production that had benefit on N utilization and decreasing CH_4 emission (Deaville et al., 2010; Liu et al., 2011).

In the past, tannins were considered as anti-nutritional substances that decreased the digestibility of grazing animals, but it is now known that the biological activities of dietary tannins positively affect average daily gain and reduce bloating in steers grazing winter wheat (Min et al., 2006). In terms of meat quality, evidence has shown that tannins are mainly related to color stability and shelf life (Luciano et al., 2009; Luciano et al., 2011). That evidence can support that dietary chestnut tannins have similar effects with antibiotics and its advance research can help to decrease the use of antibiotics for livestock production. However, few studies have investigated the effects of fermented chestnuts on the meat quality of animals. Chestnuts are produced annually in South Korea, but part of the annual chestnut production becomes waste. Thus, other strategies to utilize chestnuts include their application as a dietary supplement for Hanwoo steers through the fermentation process. In our hypothesis, application of chestnut tannins in beef cattle could improve performance and its meat quality considering beneficial effect of tannins. Therefore, the aim of this study was to examine the effect of growth performance and meat quality on Hanwoo steers fed fermented chestnuts during the late fattening period.

MATERIAL AND METHODS

All animal procedures were conducted at Woojung farm (Changwon, South Korea) and approved by the administration office of Gyeongsang National University (Jinju, South Korea) under the animal care and use guidelines of the Animal Research Unit.

Fermented Chestnut

Chestnut samples were obtained from the Hapcheon Agricultural Co-operative Society (Hapcheon, South Korea). The chestnut was dried in a forced-air oven at 60°C for 48 h and ground in a hammer mill to obtain particles with a diameter of 5–10 mm. For the fermentation process, 5 kg of chestnut powder was mixed with 2.4 L of distilled water, 15 g of molasses, and 100 mL of *Bacillus subtilis* (2×10^9 CFU/mL). After sealing, the mixture was incubated at 39°C for 48 h in a shaking incubator for seven days. During incubation, the mixture was gently shaken for 30 min at three-hour intervals.

Animals and Diets

A total of 18 castrated Hanwoo steers (average initial body weight of 615.8 ± 1.0 kg, 28 months old) were assigned to two groups (control vs. treatment). Each group consisted of nine Hanwoo steers that were placed in three pens as replications (three steers per pen) for 72 days of feeding period. The Hanwoo steers in the control group were fed a concentrate mix and rice straws, whereas those in the treatment group received the control diet plus 5% as fed of fermented chestnuts. The Hanwoo steers were placed in a pen (5 m × 8 m) installed with a feeder in a slatted floor. Water was offered *ad libitum* during the experimental period. The diet was fed at 2.5% dry matter (DM) of the body weight of the steers in two equal portions at 09:00 h and 17:00 h daily. The Hanwoo steer received concentrate/roughage at a ratio of 60:40 on the DM basis. The experimental diets were formulated isonitrogenous and isocaloric to supply nutrient requirement of late fattening period according to the Korean Feeding Standards for Korean Cattle developed by the National Livestock Research Institute (KFS, 2007). The composition of the ingredients in the experimental diets is summarized in Table 1. Analysis of experimental diets (Table 1) was performed according to the methods of the Association of Official Agricultural Chemists (AOAC, 2005). Feed intake was calculated daily by measuring orts before morning feeding. For growth performance, the Hanwoo steers were weighed at the beginning (initial body weight) and the end of feeding period (final body weight) to determine average daily gain and average daily feed intake for the entire feeding period. Feed efficiency was calculated as the ratio between average body weight gain and feed intake on the basis of DM.

Table 1: Chemical compositions of experimental diets (%, DM)

Item	Concentrates	Rice straw	Chestnut
Dry matter	90.64±0.21[1]	87.94±0.34	89.12±0.30
Crude protein	12.91±0.12	5.02±0.10	9.41±0.23
Ether extract	4.36±0.08	2.01±0.03	1.67±0.19
Crude ash	23.84±0.17	60.03±0.06	1.99±0.13
Neutral detergent fiber	11.24±0.13	49.27±0.34	37.19±0.31
Acid detergent fiber	5.84±0.29	6.48±0.35	20.46±0.47

[1]Mean±standard deviation.

Values represent triplicate assays on triplicate samples.

Carcass Traits

At the end of the feeding period, all Hanwoo steers fasted for 24 h and were moved to a local municipal slaughterhouse (Gosung, South Korea) to evaluate carcass yield and quality. Following a 24-h carcass chill, cold carcass weights were measured, and the left side of the carcass was opened between the 13th rib and the 1st lumbar vertebrae to meas-

ure back fat thickness and the *longissimus* muscle area. The yield and quality grade in each carcass were determined according to the Korean carcass grading procedure classified by the Korean Livestock Enforcement Regulation (KMAF, 2007). The degree of marbling and scores of meat color and fat color were evaluated according to the Korean Beef Marbling Standard and the Color Standard (KAPE, 2012), respectively. Marbling score ranged from 1 (poor) to 9 (excellent) with higher numbers indicating better quality. The score of meat color ranged from 1 (scarlet) to 7 (dark red) and fat color was graded from 1 (white) to 7 (dark yellow).

Analysis

The moisture, crude protein, and crude fat contents of meat samples were determined following the methods of the AOAC (2005). After 24 h postmortem, approximately 10 g of minced meat was added to 90 mL of distilled water and homogenized for 1 min. The pH of the homogenized sample was determined using a pH meter. For cooking loss, approximately 100 g of meat sample in a polyethylene bag was boiled in a water bath at 70°C for 30 min and cooled at room temperature for 30 min. Cooking loss was calculated as the difference in meat weight before and after cooking. Water-holding capacity was measured according to the method described by Kristensen and Purslow (2001). First, 0.5 g of muscle sample in each line was placed in a centrifugation tube with filter units. The samples were heated for 20 min at 80°C and then cooled for 10 min. After centrifuging at 2,000 × *g* for 10 min at 4°C, the water-holding capacity was calculated as the change in sample weight. Shear force values were measured using a rheometer (CR-300, Sun Scientific Co., Tokyo, Japan). Each core was sheared in parallel to the muscle fibers using Warner-Bratzler attachment to the load cell with 5 kg applied at a cross-head speed of 30 mm/min. Fatty acids were extracted from the LD muscle using a mixture of chloroform/methanol (2:1, vol/vol) following the method described by Folch et al. (1957). Fatty acid methyl esters were analyzed by gas chromatography (GA-17A, Shimadzu, Tokyo, Japan) equipped with a flame ionization detector and a CP-Sil 88 column (100 m × 0.25 mm × 0.2 μm; Chrompack, Middelburg, Netherlands). Fatty acid peaks (C14:0 to 24:1) were identified by comparison of the retention times in the standard fatty acid methyl ester mixtures (Sigma-Aldrich, Germany). Fatty acid data were presented as a percentage of each individual fatty acid relative to total fatty acids.

Statistical Analysis

All data are expressed as the mean ± standard error of the mean. All statistical procedures were carried out using the generalized linear model procedure of the SAS statistical package (SAS Institute, 2004). The model was $Y_{ij} = \mu + T_i + e_{ij}$, where Y_{ij} = response variable, μ = overall mean, T_i = the effect of treatment *i*, e_{ij} = error term. The significant differences between the means were declared at $p < 0.05$ using Student's t-test, while the tendency differences were declared at $p < 0.1$.

RESULTS AND DISCUSSION

The growth performance of Hanwoo steers fed fermented chestnuts during the late fattening period are shown in Table 2. The chestnut tannin reduces the N loss production and CH_4 emission in the ruminants that indicate an improvement on digestive utilization of feed (Deaville et al., 2010; Liu et al., 2011). Moreover, it increases flow rate of amino acid in small intestine that can be absorbed highly by ruminant. By these effects, the chestnut tannin may influence the growth performance of ruminant (Frutos et al., 2004). However, initial body weight, final body weight, average daily gain, average daily feed intake, and feed efficiency were not different between the two groups ($p > 0.05$) in the present study. Similar results were reported by Krueger et al. (2010), where tannin treatment did not improve growth performance during the 42-day fattening period. In the current study, supplementation of fermented chestnut at 5% had lower beneficial effects on growth performance and meat quality than control. This might be due to the characteristics of the fermented chestnuts, which depend on the origin of tannins and the fermentation process (Frutos et al., 2004). For example, high tannin intake has no positive effect on productivity, voluntary feed intake, and digestibility, whereas nutrient availability is decreased because of the strongly formed complexes between tannins and other macromolecules (Frutos et al., 2004). Ultimately, the 5% fermented chestnuts applied in our study did not show detrimental effects on growth performance.

Table 2: Effects of fermented chestnut supplementation on growth performance of Hanwoo steer

Item	Control	5% FCN[1]	SEM[2]	p-value
Initial bodyweight (kg)	615.2	616.4	5.006	0.971
Final body weight (kg)	679.0	669.1	6.220	0.807
Average daily gain (kg/d)	0.886	0.732	0.343	0.497
Average daily feed intake (kg/d, DM)	12.0	10.2	1.358	0.538
Feed efficiency (Gain:Intake)	5.32	5.16	1.785	0.325

[1]5% FCN: 5% fermented chestnut.
[2]SEM: Standard error of the mean.

Table 3 presents the carcass traits of Hanwoo steers supplemented with fermented chestnuts. The addition of 5% fermented chestnuts to the diet exhibited no remarkable

effect on cold carcass weight, backfat thickness, *longissimus* muscle area, marbling score, and fat color ($p > 0.05$). The results of this study agree with those of Krueger et al. (2010), as different types of tannins (chestnut tannin and mimosa tannin) exerted no effect on selected carcass traits in steers. However, back fat thickness and *longissimus* muscle area were lower in Hanwoo steers fed 5% fermented chestnuts. Although the most important factors in evaluating beef quality are marbling score, meat color, and fat color, the mechanisms of fermented chestnuts with respect to carcass traits are uncertain. Moreover, the type and concentration of tannin could be different among sources, which might not always be a promising improvement in animal performance and carcass quality (Krueger et al., 2010).

Table 3: Effects of fermented chestnut supplementation on carcass traits loin in Hanwoo steer

Item	Control	5% FCN[1]	SEM[2]	p-value
Cold carcass weight (kg)	397.2	391.4	38.38	0.807
Backfat thickness (mm)	11.2	10.0	3.820	0.633
Longissimus muscle area (cm^2)	83.2	79.2	6.321	0.346
Marbling score[3]	4.4	4.4	2.000	0.760
Meat color[4]	5.0	4.8	0.592	0.608
Fat color[5]	3.0	2.8	0.316	0.347

[1]5% FCN: 5% fermented chestnut.
[2]SEM: Standard error of the mean.
[3]Scored: grade 1 (poor) through grade 9 (excellent).
[4]Scored: grade 1 (scarlet) through grade 7 (dark red).
[5]Scored: grade 1 (white) through grade 7 (dark yellow).

Table 4 summarizes the data concerning the chemical composition, physicochemical characteristics, and fatty acid profiles in Hanwoo steers fed fermented chestnuts. With regards to chemical composition, moisture and crude protein content in the loins of Hanwoo steers fed 5% fermented chestnuts were equal to those of control Hanwoo steers loins. There was a numerical lower crude fat content was observed in Hanwoo steers fed 5% fermented chestnuts compared with control. At present, the reasons for the reduction in crude fat by 5% fermented chestnuts are unclear. In addition, the biological activities of plant tannins and animal responses to tannins have been extensively reviewed, mainly focusing on ruminant nutrition and production with respect to proteins (Hunag et al., 2018). In terms of physicochemical characteristics, changes in meat quality parameters, which contribute to cooking loss, water-holding capacity, and shelf life, can markedly influence meat pH (Li et al., 2014). In the current study, the addition of 5% fermented chestnuts to the diet of Hanwoo steers during the late fattening did not affect these factors. To the best of our knowledge, information on meat quality using fermented chestnuts as a source of tannins for ruminants is rather limited. Considering individual fatty acids, our result showed no significant difference in the percentages of myristic acid (C14:0), palmitic acid (C16:0), palmitoleic acid (C16:1), margaric acid (C17:0), oleic acid (C18:1c-9), and linoleic acid (C18:2n-6) between the two groups ($p > 0.05$). However, fermented chestnut supplementation exerted an effect on the percentages of margaroleic acid (C17:1), stearic acid (C18:0), and arachidonic acid

Table 4: Effects of fermented chestnut supplementation on chemical compositions, physico-chemical characteristics, and fatty acid profiles of loin in Hanwoo steer

Item	Control	5% FCN[1]	SEM[2]	p-value
Chemical compositions (%)				
Moisture	66.97	65.44	0.63	0.163
Crude protein	17.33	17.45	0.60	0.174
Crude fat	9.74	6.00	0.73	0.106
Physicochemical characteristics				
pH	5.46[b]	5.68[a]	0.02	0.001
Cooking loss (%)	33.78	32.98	0.63	0.628
Water-holding capacity (%)	78.27	79.26	1.92	0.762
Shear force (kg/cm^2)	3.48	3.51	0.15	0.821
Fatty acid profiles (%)				
Myristic acid (C14:0)	3.81	3.20	0.789	0.256
Palmitic acid (C16:0)	29.2	28.0	1.982	0.708
Palmitoleic acid (C16:1)	5.03	4.61	0.728	0.256
Margaric acid (C17:0)	0.57	0.54	0.257	0.084
Margaroleic Acid (C17:1)	0.63[a]	0.49[b]	0.067	0.014
Stearic acid (C18:0)	9.91[b]	11.9[a]	0.644	0.041
Oleic acid (C18:1c-9)	47.3	46.2	1.469	0.257
Linoleic acid (C18:2n-6)	3.04	3.97	1.473	0.101
Arachidonic acid (C20:4n-6)	0.51[b]	1.09[a]	0.396	0.049
Saturated fatty acid (SFA)	43.5	43.6	2.135	0.612
Unsaturated fatty acid (UFA)	56.5	56.4	2.135	0.612
SFA/UFA	0.76	0.77	0.067	0.613

[a,b]Means in the same row with different superscripts differ significantly ($p < 0.05$).
[1]5% FCN: 5% fermented chestnut.
[2]SEM: Standard error of the mean.

(C20:4n-6) ($p < 0.05$). As the major fatty acid profile, stearic acid largely is produced throughout biohydrogenated oleic acid by ruminal microbes. Moreover, dietary fiber increases stearic acid concentration in duodenal flow (Smith et al., 2009). Addition of fermented chestnut in the present study could increase the total fiber content in the diet, which might increase stearic acid concentration in the loin. Overall, the percentages of individual fatty acids were similar between the two groups. In the present study, the addition of fermented chestnuts into Hanwoo steers diets did not increase or decrease the relative percentages of saturated fatty acids (SFA) and unsaturated fatty acids (UFA), and the SFA:UFA ratio compared with those in the control groups ($p > 0.05$). This implied that the use of fermented chestnuts led to poor efficiency in improving fatty acids via antioxidant effects. Recently, the potential application of tannins as biological antioxidants has been reported in several studies in cattle and sheep (Dey and De, 2014; Peng et al., 2016). However, the antioxidant mechanism of fermented chestnuts in Hanwoo steers is unknown.

CONCLUSION

The study revealed that the addition of 5% fermented chestnuts to Hanwoo steers diets had no obvious effects on growth performance, carcass traits, and meat quality. In turn, no negative effect of fermented chestnuts was demonstrated. The effects of optimal levels of fermented chestnuts on production and meat quality and their mechanisms in Hanwoo steers fatteners warrant further investigation.

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CONFLICT OF INTEREST

The author declares there is no conflict of interests.

AUTHORS CONTRIBUTION

Young-Ho Joo, Dong-Hyeon Kim, Sam-Churl Kim: Conception and design of study.
Young-Ho Joo, Hyuk-Jun Lee, Hyen-Seok Lee: Acquisition and analysis of data.
Young-Ho Joo, In-Hag Choi, Hyen-Seok Lee, Sam-Churl Kim: Drafting the manuscript.
Dong-Hyeon Kim, In-Hag Choi, Dimas Hand Vidya Paradhipta, Sam-Churl Kim: Critical review.

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