AJAS

Asian-Australasian Journal of Animal Sciences

Physicochemical characteristics and fatty acid profiles of muscle tissues from Hanwoo steers fed a total mixed ration supplied with medicinal plant by-products

Shin Ja Lee[1,a], Do Hyung Kim[2,a], Han Sul Yang[3], Ki Chang Nam[4], Seung Kyu Ahn[3], Sung Kwon Park[5], Chang Weon Choi[6], and Sung Sill Lee[3,*]

* **Corresponding Author:** Sung Sill Lee
Tel: +82-55-772-1883, **Fax:** +82-55-772-1880,
E-mail: lss@gnu.ac.kr

[1] Institute of Agriculture and Life Science and University-Centered Labs, Gyeongsang National University, Jinju 52828, Korea
[2] Department of Animal Science, Gyeongbuk Provincial College, Yecheon 36830, Korea
[3] Division of Applied Life Science (BK21 Program), Graduate School of Gyeongsang National University & Institute of Agriculture and Life Science, Jinju 52828, Korea
[4] Department of Animal Science and Technology, Sunchon National University, Sunchon 57922, Korea
[5] Department of Food Science and Technology, Sejong University, Seoul 05006, Korea
[6] Department of Animal Resources, Daegu University, Gyeongsan 38453, Korea

[a] These authors contributed equally to this work and co-first authors.

Objective: Using medicinal plant by-products (MPBP) as feed additives may be an eco-friendly option as substitutes for feedstuffs and may assist in reducing the improper disposal of MPBP. Therefore, this study was conducted to evaluate the influences of MPBP on the meat quality of Hanwoo steers fed a total mixed ration (TMR).
Methods: Twenty seven steers (body weight = 573±57 kg) were randomly divided into three treatments with a control group and two tested groups as follows: control, 1,000 g/kg TMR; treatment 1 (MPBP30), 970 g/kg TMR and 30 g/kg MPBP; treatment 2 (MPBP50), 950 g/kg TMR and 50 g/kg MPBP.
Results: Average daily gain, feed conversion ratio and the Commission Internationale de l'Eclairage L* of muscle were improved (p<0.05, respectively) by MPBP30. Stearic acid ($C_{18:0}$) was decreased (linear effect, p = 0.012), while oleic acid ($C_{18:1}$) was increased (linear effect, p = 0.055) by MPBP level. Saturated fatty acid (SFA) and polyunsaturated fatty acid (PUFA) were decreased for MPBP50 while unsaturated fatty acid (USFA) and monounsaturated fatty acid (MUFA) were increased for MPBP 50. USFA and SFA ratio was increased for MPBP50 as well.
Conclusion: These results indicated that MPBP supplementation in Hanwoo steers fed a TMR increased feed efficiency and meat color (lightness) with altering fatty acid proportions. Therefore, MPBP may be successfully used in ruminant feeding.

Keywords: Medicinal Plant By-products; Muscle Characteristic; Muscle Fatty Acid Profile; Hanwoo Steer

INTRODUCTION

Antibiotics are used in livestock for the purpose of growth promotion and feed efficiency improvement in contemporary intensive animal farming. However, the use of antibiotic has been banned in South Korea since June 2011 [1] due to food contamination or concern about increasing antibiotic resistance and what some consider antibiotic misuse. This ban has led to animal performance problems and a rise in the incidence of certain diseases [2]. There is nowadays a real demand among animal producers for alternative feed additives, and among consumers for more natural and safe products in the human food chain. Consequently, a variety of substances are used in conjunction with or as alternatives to antibiotics in animal diets. Among them, natural substances like the herbs and plant extracts have been attempted as alternatives to antibiotic because of their potential efficacy as feed additives in South Korea.

Increasing consumers' demand for herbal health products, combined with an enhanced technology in liquid extraction procedure from medicinal plants, has led to an increased production in medicinal plant by-products (MPBP). It was estimated that more than 1.9 million tons MPBP

were produced per year in South Korea [3]. These is increasing public concern regarding the use of pharmaceutical by-products in the animal industry. Medicinal plants consist of various substances such as antimicrobials, antiviral, and stimulants of immune system which can be beneficial for animal health. Similarly, MPBP may have positive effects in animal production by providing a decrease in stress and an improvement in their health and productivity. However, limited *in vivo* research has been conducted to evaluate the effects of MPBP as feed additives in ruminants. Therefore, this study was undertaken to determine the effects of MPBP on muscle physicochemical characteristics and fatty acid profiles in Hanwoo steers fed a total mixed ration (TMR).

MATERIALS AND METHODS

Animals and diets

Table 1. Ingredient and chemical compositions of total mixed ration (DM basis)

Items	Treatment[1]		
	Control	MPBP30	MPBP50
Ingredients		g/kg	
Corn	223	216	212
Barley	130	126	124
Wheat bran	35	34	33
Coconut meal	30	29	29
Palm meal	24	23	23
Wheat ground	18	17	17
Distiller dried grains	18	17	17
Malt meal	18	17	17
Walnut meal	9	9	9
Plum meal	6	6	6
Molasses	12	12	11
Vitamin-mineral premix[2]	8	8	8
Limestone	5	5	5
Salt	2	2	2
Probiotics[3]	217	210	206
Rice straw	80	78	76
Italian ryegrass	80	78	76
Tangerine by-product	80	78	76
Cotton seed meal pellet	5	5	5
Medicinal plant by-products[4]		30	50
Chemical composition			
Crude protein	118	117	119
Ether extract	35	35	35
Crude fiber	202	190	190
Ash	84	88	86

DM, dry matter; MPBP, medicinal plant by-products.
[1] Medicinal plant by-products supplied to a total mixed ration: control, no supplement; MPBP30, 30 g/kg; MPBP50, 50 g/kg.
[2] Supplied per kilogram of diet: 3,800 IU vitamin A, 400 IU vitamin D, 500 IU vitamin E, 2.5 mg vitamin B_2, 2.0 mg vitamin B_6, 2.6 mg niacin, 4.0 mg pantothenic acid, 50 mg Fe, 7.0 mg Cu, 2.4 mg Mn, 30 mg Zn, 6.0 mg I, 1.5 mg Se, and 1.5 mg Co.
[3] The probiotics was used liquid cultivation type and it was contained 3.3×10^6 colony forming unit (cfu)/mL *Lactobacillus* spp., 2.9×10^6 cfu/mL *Rhodobacter* spp. and 4.0×10^6 cfu/mL Saccharomyces cerevisiae, and contained more than 95% of moisture.
[4] The ingredient and chemical compositions of medicinal plant by-products are presented in Table 2.

All experimental procedures involving animals were approved by the Animal Care Committee of Gyeongsang National University. Twenty seven Hanwoo steers (body weight [BW] = 573±57 kg) were used in a randomized complete block design experiment. Each steer was blocked by initial BW and randomly allocated to 3 blocks of 9 steers each. Steers were offered free access to water and fed twice daily a TMR (Cha-Hwang environment-friendly Livestock and Agricultural Union Corporation, San-Cheong, Korea) *ad libitum* lasting 180 days from 24 to 30 months of age. The MPBP were dried in a forced-air oven at 60°C for 24 h using a waste from herbal decoction and then substituted for TMR in the 3 treatment groups at the following levels: control, 1,000 g/kg TMR and 0 g/kg MPBP; treatment 1 (MPBP30), 970 g/kg TMR, and 30 g/kg MPBP; and treatment 2 (MPBP50), 950 g/kg TMR and 50 g/kg MPBP, respectively. In the present study, the MPBP was waste from Ssanghwatang, an oriental herbal cocktail, that is a widely used in Korea for the treatment of fatigue, pain, inflammation, hypothermia, erectile dysfunction, cancer, and osteoporosis. The majority of herbs in this cocktail include Rehmanniae radix preparata, Angelica gigas nakai, Zingiber officinale roscoe, Paeoniae radix, Cnidii rhizoma, and Zizyphus jujube and are rich in polyphenol, flavonoids and polysaccharides, which are reported stimulate the immune system and have antioxidant abilities [4]. The levels of MPBP in the present study were chosen according to Lee et al [5] and Lee et al [6] *in situ* and *in vitro* studies. The ingredients and composition of TMR with the MPBP are presented in Table 1, 2, respectively.

Feed samples were dried in a forced-air oven at 130°C for 2 h, ground through a 2-mm screen in a Wiley mill (Model 4; Thomas Scientific, Swedesboro, NJ, USA). The dried ground samples were analyzed for dry matter (DM) and crude protein (CP) according

Table 2. Ingredient and chemical compositions of medicinal plant by-products (DM basis)

Items	g/kg
Ingredient	
Rehmanniae radix preparata	118
Angelica gigas nakai	118
Zingiber officinale roscoe	108
Paeoniae radix	108
Cnidii rhizoma	97
Zizyphus jujuba	97
Citrus nobilis makino	97
Bupleuri radix	86
Plantago asiatica L.	86
Prunus mume	86
Chemical composition	
Crude protein	92
Crude fat	36
Crude fiber	207
Ash	39
Neutral detergent fiber	554
Acid detergent fiber	285

to the procedure of AOAC [7]. Ether extract was analyzed by the diethyl ether extraction in an Extraction System (B-811; Buchi, Flawil, Switzerland). Crude fiber (CF) was analyzed by the filtration method in Fiber Analyzer (Ankom A220; Mill tech, Seongnam, Korea), and ash was analyzed by the electric muffle furnace (KMF-500; Lab Corporation, Seoul, Korea) at 550°C.

Sampling, measurements and chemical analysis

The BW was measured at the beginning of the feeding trial for each animal followed by once every month and at the end of experiment. Steers were transported to an abattoir near the experimental station at the end of feeding trial, slaughtered by stunning with electrical tongs (300 V for 3 s) 12 h after feed restriction, and exsanguinated. Carcasses were eviscerated, split and placed in a chiller set at 5°C for 12 h.

The quality of beef carcass was graded based on marbling, lean color, fat color and maturity, while the yield was graded on the basis of backfat thickness, rib eye area and carcass weight using the 13th rib at three-quarters the distance along the Longissimus dorsi (LD). Carcass grade of quality was applied as 1 (extremely good), 2 (good), 3 (normal), 4 (bad), and 5 (extremely bad), while grade of yield as 1 (good), 2 (normal), and 3 (bad).

The chemical composition (moisture, 950.46; CP, 981.10; CF, 991.36 and ash, 900.02, respectively) of LD was analyzed using the standard analytical method [7]. For the determination of pH, 24 h post-slaughter LD samples of 5 g were homogenized in 10 volumes of distilled water using a polytrom homogenizer (MSE, Westbury, NY, USA) and then the homogenized suspension was read in Hanna HI 9025 pH meter (Woonsocket, RI, USA) with an Orion 8163 glass electrode (Berverly, MA, USA). A slice of LD muscle measuring a thickness of 1.5 cm and weighing 80 g was sealed in a polyethylene bag, heated in a water bath at 75°C for 1 h and then cooled at room temperature for 30 min. The cooking loss percentage was determined using the muscle weights that were taken before and after cooking. The drip loss was measured by determining the weight loss during the suspension of a standard meat (5×4 cm) sample of 50 g at 4°C for 7 days and record the loss. The shear force of Warner-Bratzler was determined. Cubes of 4 cm×2.5 cm×1.5 cm (i.e. length×width×height) were cut from the LD and the shear force of fresh samples was immediately measured. The samples were cooked in a water bath at 75°C until the internal temperature of LD cubes reached 70°C then the samples were cooled for 4 h at 25°C. The shear force was measured by the Instron 3343 (US/MX50, A&D Co., Norwood, MA, USA) equipped with one Warner-Bratzler shear blade (crosshead speed of 1 mm/s). Each sample was measured 3 times and averaged.

Meat color of LD was evaluated on freshly cut surface (3 cm thick slice) using a Chroma Meter CR-300 (Minolta, Osaka, Japan) after 20 min at room temperature. Three color measurements were carried out across individual sample surfaces and the average of five replicates was expressed as lightness, redness and yellowness (Commission Internationale de l'Eclairage [CIE]) L*, CIE a*, and CIE b*, respectively). The Chroma Meter CR-300 was calibrated against a white tile (L* = 93.30, a* = 0.32, and b* = 0.33) on a daily basis. Chroma (saturation) and Hue angle were calculated as $(a^{*2}+b^{*2})^{1/2}$ and arctan b^*/a^*.

For the determination of fatty acid composition, total lipid was extracted by a modified Folch method. Saponification and esterification were done using a 0.5 N potassium hydroxide in methanol and 140 g/kg boron trifluoride methanol solution and then fatty acid methyl esters in the hexane were injected into a gas chromatograph (Agilent 6890, Agilent HP, Palo Alto, CA, USA) fitted with a capillary column (HP-5MS capillary GLC column, 30 m× 0.32 mm i.d. 0.25 mm film thickness, Agilent HP, USA) and a mass spectrometry detector (G1530A, Agilent HP, USA). The mass spectrometry interface and injector temperature were fixed at 270°C and 260°C, respectively, and oven temperature was instituted at 160°C for 2.5 min, 160°C to 260°C at 4°C per min and then 260°C for 5 min. Each fatty acid was identified by comparing its retention time with those fatty acid methyl esters of standard (FAME Mix C8-C24, Supelco, PA, USA) and expressed as a percentage of standard.

Statistical analysis

Data for animals within each treatment were averaged and analyzed using the general linear model procedure of SAS (SAS Inst. Inc., Cary, NC, USA) with steer as random effects, and treatments as fixed effects. Duncan's multiple range test was used to interpret any significant differences among the mean values of the treatments. An orthogonal contrast was used to assess linear and quadratic relationships between the increasing supplemental level of MPBP and dependent variable to Hanwoo steers fed a TMR. Differences among treatment groups were considered significant if p≤0.05.

RESULTS

Initial and final BW were not different among the treatments (Table 3). However, average daily gain was higher (Quadratic effect, p = 0.051) in MPBP30 despite that total feed intake did not differ among treatments. Consequentially, feed conversion ratio was lower (Quadratic effect, p = 0.042) for MPBP30.

Meat grade was improved (p<0.05, Table 4). Yield grade was lower for MPBP50 and quality grade was lower for MPBP30 and intermediate for MPBP50. Chemical and physical characteristics were not significant difference among treatments, excluding the cooking loss which decreased (p<0.05) by substituting TMR with MPBP50 (Table 4). The supplementation of MPBP to TMR was decreased CIE L* (Table 5).

The major fatty acids were palmitic acid ($C_{16:0}$), stearic acid ($C_{18:0}$), and oleic acid ($C_{18:1}$). Stearic acid ($C_{18:0}$) was decreased (linear effect, p = 0.012) for MPBP50, while oleic acid ($C_{18:1}$) was increased (linear effect, p = 0.055) for MPBP50 (Table 6). Linoleic acid ($C_{18:2}$) and arachidonic acid ($C_{20:4}$) were decreased (p<0.05)

Table 3. Supplemental effect of medicinal plant by-products on the intake and growth performance of Hanwoo steers fed a total mixed ration (Lee et al [31])

Items	Treatment[1]			SEM	p-value	
	Control	MPBP30	MPBP50		Linear	Quadratic
Numbers of animals	9	9	9	-	-	-
Growth performance (kg)						
Initial body weight	569	580	570	57.4	0.966	0.803
Final body weight	653	682	655	52.0	0.904	0.486
Average daily gain (kg/d)	0.469[b]	0.560[a]	0.470[b]	0.04	0.173	0.051
Feed intake (kg/d)	9.23	8.71	9.14	0.11	0.122	0.142
Feed conversion ratio	19.7[a]	16.5[b]	19.5[a]	0.39	0.075	0.042

SEM, standard error of the means; MPBP, medicinal plant by-products.
[1] Medicinal plant by-products supplied to a total mixed ration: control, no supplement; MPBP30, 30 g/kg; MPBP50, 50 g/kg.
[a,b] Values in the same row with different superscripts differ at p<0.05.

Table 4. Supplemental effect of medicinal plant by-products on the meat grade and physicochemical characteristic of Longissimus dorsi muscle in Hanwoo steers fed a total mixed ration

Items[1]	Treatment[2]			SEM	p-value	
	Control	MPBP30	MPBP50		Linear	Quadratic
Numbers of animals	9	9	9	-	-	-
Meat grade						
Yield grade	2.00[a]	2.11[a]	1.00[b]	0.26	0.035	0.291
Quality grade	3.00[a]	1.67[b]	2.33[ab]	0.27	0.057	0.338
Chemical characteristic (g/kg raw meat)						
Moisture	57.5	64.2	57.3	1.50	0.951	0.262
Crude protein	18.5	17.3	18.3	0.28	0.689	0.187
Ether extract	18.3	15.9	17.3	0.84	0.657	0.357
Ash	0.98	0.85	0.76	0.05	0.069	0.077
Physical characteristic						
pH	5.67	5.66	5.53	0.04	0.223	0.409
Cooking loss (g/kg raw meat)	35.1[ab]	38.1[a]	29.2[b]	1.19	0.029	0.011
Drip loss (g/kg raw meat)	1.48	1.17	1.56	0.09	0.720	0.471
Shear force (kg/cm^2)	3.09	3.26	2.03	1.01	0.213	0.446

SEM, standard error of the means; MPBP, medicinal plant by-products.
[1] Carcass characteristics were measured from Longissmus dorsi taken at 13th rib; yield grade (1 = high yield, 3 = low yield), quality grade (1 = very high quality, 5 = low quality).
[2] Medicinal plant by-products supplied to a total mixed ration: control, no supplement; MPBP30, 30 g/kg; MPBP50, 50 g/kg.
[a,b] Values in the same row with different superscripts differ at p<0.05.

for MPBP50 whereas palmitoleic acid ($C_{16:1}$) was increased (p<0.05) for MPBP50. Saturated fatty acid (SFA) and polyunsaturated fatty acid (PUFA) were decreased for MPBP50 while unsaturated fatty acid (USFA) and monounsaturated fatty acid (MUFA) were increased for MPBP 50. USFA and SFA ratio was increased for MPBP50 as well. There were no differences between control and MPBP30.

Table 5. Supplemental effect of medicinal plant by-products on the meat color of Longissimus dorsi muscle in Hanwoo steers fed a total mixed ration

Items	Treatment[1]			SEM	p-value	
	Control	MPBP30	MPBP50		Linear	Quadratic
Numbers of animals	9	9	9	-	-	-
Meat surface color						
CLE L*	37.2[ab]	35.4[b]	41.5[a]	2.69	0.070	0.117
CLE a*	21.3	19.5	21.1	2.10	0.988	0.290
CLE b*	8.28	7.10	9.83	2.25	0.365	0.303
Chroma	22.7	20.8	23.3	2.84	0.707	0.329
Hue angel	20.2	19.8	24.8	3.56	0.140	0.406

SEM, standard error of the means; MPBP, medicinal plant by-products.
[1] Medicinal plant by-products supplied to a total mixed ration: control, no supplement; MPBP30, 30 g/kg; MPBP50, 50 g/kg.
[a,b] Values in the same row with different superscripts differ at p<0.05.

Table 6. Supplemental effect of medicinal plant by-products on the fatty acid compositions of Longissimus dorsi muscle in Hanwoo steers fed a total mixed ration

Items	Treatment[1]			SEM	p-value	
	Control	MPBP30	MPBP50		Linear	Quadratic
Numbers of animals	9	9	9	-	-	-
Fatty acid composition (g/kg meat)						
Capric acid (C10:0)	0.60	0.60	0.40	0.23	0.112	0.260
Lauric acid (C12:0)	1.16	1.20	0.92	0.08	0.229	0.562
Myristic acid (C14:0)	38.0	37.8	33.1	2.46	0.442	0.641
Palmitic acid (C16:0)	292	291	248	9.65	0.082	0.259
Palmitoleic acid (C16:1)	45.1[b]	42.4[b]	56.5[a]	2.40	0.035	0.322
Margaric acid (C17:0)	6.00	6.52	5.45	0.24	0.356	0.984
Heptadecenoic acid (C17:1)	5.76	5.66	7.54	0.32	0.090	0.153
Stearic acid (C18:0)	110[a]	122[a]	93[b]	3.73	0.012	0.591
Oleic acid (C18:1)	465[ab]	454[b]	527[a]	13.8	0.055	0.338
Linoleic acid (C18:2)	25.5[a]	27.7[a]	17.5[b]	1.17	<0.001	0.021
Linolenic acid (C18:3)	4.41	4.23	4.12	0.16	0.501	0.531
Arachidic acid (C20:0)	0.50	0.56	0.75	0.08	0.239	0.392
Eicosenoic acid (C20:1)	3.60	3.20	5.30	0.34	0.207	0.176
Arachidonic acid (C20:4)	2.95[a]	3.21[a]	1.14[b]	0.29	0.003	0.103
SFA	448[a]	460[a]	381[b]	13.4	0.028	0.265
USFA	550[b]	540[b]	619[a]	13.2	0.020	0.214
MUFA	517[b]	505[b]	596[a]	14.3	0.011	0.172
PUFA	35.1[a]	32.9[a]	22.8[b]	1.41	<0.001	0.007
USFA/SFA	1.27[b]	1.19[b]	1.64[a]	0.08	0.028	0.278

SEM, standard error of the means; MPBP, medicinal plant by-products; SFA, saturated fatty acid; USFA, unsaturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.
[1] Medicinal plant by-products supplied to a total mixed ration: control, no supplement; MPBP30, 30 g/kg; MPBP50, 50 g/kg.
[a,b] Values in the same row with different superscripts differ at p<0.05.

DICUSSION

Medicinal plant by-products

It is reported that the supplementation of a herbal mixture (Lonicera japonica, Taraxacum platycarpum, Geranium thunbergii, Agastache rugosa, and Glycyrrhiza uralensis) to Hanwoo calves was beneficial to improve growth performance and prevent diarrhea [8]. Although medicinal plants contain high levels of effective components which can be beneficial to animal, however, feeding these to animals may increase production costs because they may be too expensive to be used as additives. Therefore, one of the alternatives is to use their by-products as an animal feed supplement. Lee et al [9] conducted a study to investigate medicinal herbal by-products (Rehmanniae radix preparata, Angelica gigas nakai, Zingiber officinale roscoe, Paeoniae radix, Cnidii rhizoma, Zizyphus jujube, Citrus nobilis makino, Bupleuri radix, Plantago asiatica L., and Prunus mume) on *in situ* ruminal degradability. They suggested that the by-products were suitable an ingredient of TMR for Hanwoo steers when substituting for TMR by 30 g/kg. In addition, Lee et al [6] reported that the average DM degradation of MPBP (Panax ginseng, Poria cocos, Glycyrrhiza uralensis, Angrlica gigas, Cnidium officinale, Paeonia lactiflora, Astragalus membranaceus, Zingiberis officinale, Ziziphus jujube var. inermis, and Citrus unshiu) at 12 and 24 h *in vitro* was higher than that of timothy hay. The total phenolics and flavonoids of Angelica

gigas nakai and Zingiber officinale roscoe were 2.23, 45.1 and 9.90, 11.1 mg/g of dry material, respectively [5]. The chemical composition of the MPBP is appropriate to substitute for rough grass and hay in an aspect of CP, neutral detergent fiber (NDF), and acid detergent fiber (92, 554, and 285 g/kg, respectively). In addition, it was previously reported that the effective degradation of CP and NDF was increased when substituting for TMR by 30 g/kg MPBP [9]. Supplementing animal diets with phytochemicals exhibiting antioxidant property produces meat products which contain antioxidant substances [10] and thus may enhance meat quality.

Intake and growth performance

Feed efficiency is a major influence on the unit cost of production. There are many components which can affect feed efficiency, which include environmental factors, nutrition, implants, and animal factors. However, improving on any of these can improve profitability. In ruminants, ionophores have the ability to alter the rumen bacterial population resulting in improved rumen fermentation. The improved fermentation results in more energy derived from the feed ultimately resulting in improved feed efficiency. Feed conversion ratio was 19% better (quadratic effect, p = 0.042) for MPBP30 than that of control in the present result. Herbs have been evaluated for their ability to alter ruminal fermentation and improve nutrition utilization in ruminants. It was

reported that some herbs stimulated appetite and digestion process of calves when fed in the appropriate quantity [11], because medicinal plants have antimicrobial characteristics which could affect harmful microbes in the rumen. Therefore, the substituting of TMR with 50 g/kg may not be the appropriate quantity in aspects of feed efficiency and feeding behavior. The present results suggest that substituting TMR with 30 g/kg MPBP may be the appropriate quantity to use for an alternative to antibiotics in the late fattening period of Hanwoo steers to improve feed efficiency. Medicinal herbs have been found to enhance pancreatic lipase activity, intestinal lipase, disaccharidase, surcease, and maltase activities in rats [12]. All of these have favorable effects on gut function, which is the primary mode of action for growth promoting feed additives [13].

Physicochemical characteristic of Longissimus dorsi muscle

Plant bioactives affect not only animal growth but also carcass composition [14]. Both yield and quality grades were improved (p<0.05) by the supplementation of MPBPs in the present study whereas chemical and physical characteristics were not affected by the supplementation of MPBP except for cooking loss which was decreased (p<0.05) by MPBP50. Significant difference in cooking loss of beef was due to different marbling scores in which beef with higher marbling had lower cooking loss [15]. However, Kim et al [16] reported that cooking loss did not differ in Hanwoo cows belonging to different quality grade groups.

Antioxidants prevent discoloration [17], therefore, the oxidative status of the feed given to animals has a significant influence on the final meat quality. Antioxidants correlated with a greater stability of meat color. Their supplementation to feedlot cattle increased the color of beef products, increased α-tocopherol concentration in beef cuts and subsequently increased its retail case life [18]. Flavonoids and phenolic acids, the most persistent groups of plant phenolics, are widely present in medicinal plants. These compounds are effective against the deleterious effect of reactive oxygen species. In addition, beef color tends to improve with supplementation of antioxidant substances, resulting in reduced absorption of iron [19]. Bray et al [20] reported that iron supplementation increased pigment concentration in muscular tissues, resulted in the production of darker colored meat. Zembayashi et al [21] confirmed that there was a correlation ($y = 64.4 - 19.4x + 3.54x^2$, $r^2 = 0.79$) between iron concentration and L* value (lightness), and suggested that beef color could be improved by a reduction in iron concentration of muscle. The total phenolics in Rehmanniae radix was 13.9 mg/g of which the Korea was the highest among cultivars [22]. The total phenolics and flavonoids of Angelica gigas nakai and Zingiber officinale roscoe were 2.23, 45.1, and 9.90, 11.1 mg/g of dry material, respectively [9]. Therefore, antioxidants in the MPBP50 probably play significant role in beef color, especially lightness, which acts post-mortem to delay oxidative deterioration of the beef. Since light meat has L*>38.5 [23], the color of the meat in the presented study could be attrac-

tive to consumers that prefer lighter meat. However, redness (a*) and yellowness (b*) remained unaffected by treatments. Values encountered in literature for a* and b* were used to measure beef color in the CIELAB space [24] being in the following ranges of variation: 11.1 to 23.6 and 6.1 to 11.3, respectively. Values obtained in the present study were within the range given.

Fatty acid composition of Longissimus dorsi muscle

Intramuscular fat composition is an important determinant of the dietetic value of beef. Animal-derived lipids have often been blamed as health-risk factors. Intramuscular fat content depends on nutrient consumption and utilization, and its composition affect sensory attributes of meat such as flavor and juiciness [25]. The three major fatty acids in LD fat were palmitic acid ($C_{16:0}$), stearic acid ($C_{18:0}$), and oleic acid ($C_{18:1}$), and their combined proportion was 87%, regardless of treatments. In the present result, MPBP50 had a lower proportion of palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) and a higher proportion of oleic acid ($C_{18:1}$) compared with control and MPBP30: control, 33.7%, 12.7%, and 53.6%; MPBP30, 33.6%, 14.1%, and 52.4%; MPBP50, 28.6%, 10.7%, and 60.7%, respectively. Stearic acid ($C_{18:0}$) is one of the main fatty acids that can dictate fat hardness [26]. Accordingly, any dietary or production factor that enhances the conversion of stearic acid ($C_{18:0}$) to oleic acid ($C_{18:1}$) will increase fat softness [26]. In addition, sensory panel score especially with umami was positively associated with oleic acid ($C_{18:1}$) and the proportion of oleic acid compared with palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$) proportions was higher in the LD of well fatten cattle [27]. In the present results, stearic acid ($C_{18:0}$) was decreased and oleic acid ($C_{18:1}$) was increased by the supplementation of MPBP50, consequently, quality grade was improved. Especially, fat can be soft, mainly due to an increase in oleic acid relative to stearic acid and palmitic acid.

Beef with higher USFA and lower SFA may be better for consumers because of a possible link between some SFA and cardiovascular diseases. Beef contains cholesterol and fat which is a significant source of SFA in the human diet. It is, therefore, important to manipulate cholesterol levels and fatty acid profiles in beef meat by diet or additives. Levels of SFAs are mainly affected by palmitic acid ($C_{16:0}$) and stearic acid ($C_{18:0}$), and USFAs are related to the oleic acid ($C_{18:1}$) content in beef [28]. The PUFA concentration in intramuscular fat rather than SFA is considered important, because PUFA have a beneficial effect on human health [29]. Feeding MPBP50 decreased the ratio of PUFA/SFA compared to the control in the present study. On the other hand, the ratio of USFA/SFA was increased for MPBP50, meaning that the beef is softer than that of control because the fatty acid profile is more unsaturated. The MPBP, rehmanniae radix preparata, angelica gigas nakai, zingiber officinale roscoe, paeoniae radix etc., supplied to steers fed a TMR are speculated that have a high antioxidant sources. Thus, MPBP may serve as an alternative natural antioxidant. There are some reported examples of tissue

fatty acid composition being changed via antioxidants, which involve manipulation of rumen fermentation patterns. Chinese herbal mixtures supplemented at the levels of 20 g/kg DM of concentrate increased post-ruminal enzymes activity and enhanced serum antioxidant status [30]. Therefore, the antioxidants of MPBP in the present study probably caused higher blood levels of antioxidants in these animals with benefits.

Although the relationship between consumption of fatty acid and their recovery in the animals' tissues is complex in ruminants due to the ruminal biohydrogenation, nevertheless, nutrition is a key factor to enhance beneficial fatty acid portions in ruminant-source products. Therefore, further study is required to better understand the present results to determine the botanical characteristics and fatty acid profiles of the MPBP because the interrelationship between fatty acid composition, in both lipid fractions and tissue antioxidants in ruminants is crucial to of the animal's metabolism, with eventual implications for meat quality.

CONCLUSION

Although MPBP have enormous potential to be developed as a possible alternative to antibiotics and an enhancer of production efficiency, indigenous medicinal plants as well as their by-products have not been well considered as a dietary supplement intended for Hanwoo steers. This study attempted to evaluate the potential use of MPBP as an additive and the results suggested that MPBP supplementation in Hanwoo steers fed a TMR increased feed efficiency and meat color (lightness) with altering fatty acid proportions.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

ACKNOWLEDGMENTS

REFERENCES

1. Ministry of Agriculture Food and Rural Affairs. Pre-announcement of legislation and administration [Internet]. MAFRA; 2010 [cited 2010 Jul 23]. Available from: http://www.mafra.go.kr/list.jsp?id=27315&pageNo=1&NOW_YEAR=2016&group_id=1&menu_id=49&link_menu_id=&division=B&board_kind=C&board_skin_id=C1&parent_code=33&link_url=&depth=2&code=left&link_target_yn=&menu_introduction=&menu_name=입법・행정 예고&popup_yn=N&reference=3&tab_yn=N

2. Dibner JJ, Richards JD. Antibiotic growth promoters in agriculture: history and mode of action. Poult Sci 2005;84:634-43.

3. Lee SJ, Shin NH, An JJ, et al. Effects of replacing rice straw with by-products of medical herbs on the *in vitro* fermentation characteristics. J Agric Life Sci 2006;45:69-79.

4. Al-Reza SM, Yoon JI, Kim HJ, Kim JS, Kang SC. Anti-inflammatory activity of seed essential oil from Zizyphus jujuba. Food Chem Toxicol 2010;48:639-43.

5. Lee SJ, Shin JH, Lee HJ, et al. Antioxidant and anti-inflammatory activities of functional plant materials. J Agric Life Sci 2013;23:869-78.

6. Lee SJ, Ahn SK, Kim JY, et al. Effects of herbal medicine by-products on ruminal in vitro degradability, *in situ* disappearance, and effective degradability. J Agric Life Sci 2014;48:77-87.

7. AOAC. Official Methods of Analysis, 16th ed. AOAC International, Washington, DC: Association of Official Analytical Chemists; 2005.

8. Kim BK, Choi CB, Lee ID, et al. Effects of supplementing herbs on growth performances, blood composition and diarrhea in Hanwoo calves. J Anim Sci Technol 2011;53:451-9.

9. Lee SK, Lee SJ, Moon YH, et al. Effects of supplementation of medicinal herbal residues on the *in situ* ruminal degradability of TMR. J Agric Life Sci 2013;47:193-201.

10. Lien TF, Lin KJ, Yang LL, Chen LG. Effects of supplemental levels of bazhen on growth performances, serum traits, immunity, meat quality and antioxidant activity of taiwan country chickens. Asian-Australas J Anim Sci 2013;26:675-82.

11. Hadiya K, Maini S, Rekhe DS, Ravikanth K. Accelerated growth programme with polyherbal formulations for dairy calves. Vet World 2009;2:62-4.

12. Platel K, Spinivasan K. Influence of dietary spices or their active principles on digestive enzymes of small intestinal mucosa in rats. Int J Food Sci Nutr 1996;47:55-9.

13. Windisch WM, Schedle K, Plitzner C, Kroismatr A. Use of phytogenic products as feed additives for swine and poultry. J Anim Sci 2008;86:140-8.

14. Rochfort S, Parker AJ, Dunshea FR. Plant bioactives for ruminant health and productivity. Phytochemistry 2008;69:299-322.

15. Moon SS, Yang HS, Park GB, Joo ST. The relationship of physiological maturity and marbling judged according to Korean grading system to meat quality traits of Hanwoo beef females. Meat Sci 2006;74:516-21.

16. Kim CJ, Lee ES. Effects of quality grade on the chemical, physical and sensory characteristics of Hanwoo (Korean native cattle) beef. Meat Sci 2003;63:397-405.

17. Waylan AT, O'Quinn PR, Unruh JA, et al. Effects of modified tall oil and vitamin E on growth performance, carcass characteristics, and meat quality of growing-finishing pigs. J Anim Sci 2002;80:1575-85.

18. Roeber DL, Belk KE, Tatum JD, Wilson JW, Smith GC. Effects of three levels of alpha-tocopheryl acetate supplementation to feedlot cattle on performance of beef cuts during retail display. J Anim Sci 2001;79:1814-20.

19. Goto T, Yoshida Y, Kiso M, Nagashima H. Simultaneous analysis of individual catechins and caffeine in green tea. J Chromatogr A 1996;749:295-9.

20. Bray RW, Rupnow EH, Hanning FM, Allen NN, Niedermie RP. Effect of feeding methods on veal production and carcass quality. II. Carcass gades, liver, hide, specific gravity, yield and chemical analysis of the muscle. J Anim Sci 1959;18:732-7.

21. Zembayashi M, Lunt DK, Smith SB. Dietary tea reduces the iron content of beef. Meat Sci 1999;53:221-6.

22. You BR, Kim HR, Kim HJ, et al. Catalpol content and antioxidant activities in various cultivars of Rehmannia glutinosa. J Korean Soc Food Sci Nutr 2011;40:481-5.

23. Abularach MLS, Rocha CE, Felício PE. Características de qualidade do contrafilé (M. L. dorsi) de touros jovens da raça Nelore. Ciencia Tecnol Alime 1998;18:205-10.

24. CIE (Commission Internationale de l'Eclairage). Recommendations on uniform color spaces, color difference equations, psychometric color terms. CIE Supplement #2 to Report #15, TC-2.4, Paris, France: CIE publication; 1978.

25. Elmore JS, Mottram DS, Enser M, Wood JD. Effect of the polyunsaturated fatty acid composition of beef muscle on the profile of aroma volatiles. J Agric Food Chem 1999;47:1619-25.

26. Smith SB, Yang AJ, Larsen TW, Tume RK. Positional analysis of tri-acylglycerols from bovine adipose tissue lipids varying in degree of unsaturation. Lipids 1998;33:197-207.

27. Westerling DB, Hedrick HB. Fatty acid compostion of bovine lipids as influenced by diet, sex and anatomical location and relationship to sensory characteristics. J Anim Sci 1979;48:1343-8.

28. May SG, Dolezal HG, Gill DR, Ray FK, Buchanan DS. Effects of days fed, carcass grade traits, and subcutaneous fat removal on postmortem muscle characteristics and beef palatability. J Anim Sci 1992;70: 444-53.

29. Williams CM. Dietary fatty acids and human health. Ann Zootechonol 2000;49:165-80.

30. Wang H, Yang W, Wang Y, Yang Z, Chi Y. The study on the effects of chinese herbal mixtures on growth, activity of post-ruminal digestive enzymes and serum antioxidant status of beef cattle. Agric Sci China 2011;10:448-55.

31. Lee SJ, Kim DH, Guan LL, et al. Effect of medicinal plant by-products supplementation to total mixed tation on growth performance, carcass characteristics and economic efficacy in the late fattening period of Hanwoo steers. Asian-Australas J Anim Sci 2015;28:1729-35.