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Effect of Medicinal Plant By-products Supplementation to Total Mixed Ration on Growth Performance, Carcass Characteristics and Economic Efficacy in the Late Fattening Period of Hanwoo Steers

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ABSTRACT: This study was conducted to evaluate the effect of medicinal plant by-products (MPB) supplementation to a total mixed ration (TMR) on growth, carcass characteristics and economic efficacy in the late fattening period of Hanwoo steers. Twenty seven steers (body weight [BW], 573±57 kg) were assigned to 3 treatment groups so that each treatment based on BW contained 9 animals. All groups received *ad libitum* TMR throughout the feeding trial until slaughter (from 24 to 30 months of age) and treatments were as follows: control, 1,000 g/kg TMR; treatment 1 (T1), 970 g/kg TMR and 30 g/kg MPB; treatment 2 (T2), 950 g/kg TMR and 50 g/kg MPB. Initial and final BW were not different among treatments. Resultant data were analyzed using general linear models of SAS. Average daily gain and feed efficiency were higher ($p<0.05$) for T1 than control, but there was no difference between control and T2. Plasma albumin showed low-, intermediate- and high-level ($p<0.05$) for control, T1 and T2, whereas non-esterified fatty acid was high-, intermediate- and high-level ($p<0.05$) for control, T1 and T2, respectively. Carcass weight, carcass rate, backfat thickness and rib eye muscle area were not affected by MPB supplementation, whereas quality and yield grades were highest ($p<0.05$) for T1 and T2, respectively. Daily feed costs were decreased by 0.5% and 0.8% and carcass prices were increased by 18.1% and 7.6% for T1 and T2 compared to control, resulting from substituting TMR with 30 and 50 g/kg MPB, respectively. In conclusion, the substituting TMR by 30 g/kg MPB may be a potential feed supplement approach to improve economic efficacy in the late fattening period of Hanwoo steers. (**Key Words:** Medicinal Plant By-products, Growth Performance, Carcass Characteristic, Hanwoo Steer)

INTRODUCTION

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 (MPB). It was estimated that more than 1.9 million tons MPB were produced per year in South Korea (Lee et al., 2006). Medicinal plants contain various substances such as antimicrobials, antiviral, and stimulants of immune system which can be beneficial for animal health. Similarly, MBP may have positive effects in animal production by providing a decrease in stress and an improvement in their health. Therefore, using MPB as additives to animal diets may be an economically feasible alternative and eco-friendly option as low cost feed additives or substitutes for feedstuffs (Choi et al., 1996; Park and Yoo, 1999) and may assist in reducing the improper disposal of MPB as environmental pollutants.

Although medicinal plants or their by-products should be used with care because elevated supplementation can stimulate undesirable side effects for animals (Vandergrift, 1998), some studies have reported an increased body gain

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and improved meat quality when the effects of MPB on swine and poultry diets were evaluated (Kim et al., 2008; Park and Song, 1997). They suggested that supplementing diets with phytochemicals exhibiting antioxidant properties may produce meat products that contain antioxidant substances and thus enhance meat quality. Also, there are reports that beef color tends to improve with supplementation of antioxidant substances, resulting in reduced absorption of iron (Disler et al., 1975; Goto et al., 1996). However, no information on MPB as feed additives for ruminants is available. Therefore, this study was conducted to determine the effects of MPB supplementation to a total mixed ration (TMR) for Hanwoo steers on growth performance, blood characteristics, carcass characteristics and economic efficacy.

Table 1. Ingredient and chemical compositions of total mixed ration

Item	Value (g/kg)
Ingredients, as-fed basis	
Concentrate	
Corn	223
Barley	130
Wheat bran	35
Coconut meal	30
Palm meal	24
Wheat ground	18
Distiller dried grains	18
Malt meal	18
Walnut meal	9
Plum meal	6
Molasses	12
Vitamin-mineral premix[1]	8
Limestone	5
Salt	2
Liquid probiotics[2]	220
Rice straw	80
Italian ryegrass	80
Tangerine by-product	80
Cotton seed meal pellet	5
Chemical composition, as-fed basis	
Moisture	455
Crude protein	64
Ether extract	19
Crude fiber	121
Ash	46

DM, dry matter.

[1] 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.

[2] 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.

MATERIALS AND METHODS

All experimental procedures involving animals were approved by the Animal Care Committee of Gyeongsang National University.

Animals, diets and management

A feeding trial was conducted using twenty seven Hanwoo steers aged 24.0±0.3 months with an average initial body weight (BW) of 573±57 kg to evaluate the effects of MPB supplementation. Steers were assigned to 3 treatments based on BW and each treatment contained 9 animals. They were housed with a free access to water and were fed a TMR (Cha-Hwang environment-friendly Livestock and Agricultural Union Corporation, San-Cheong, Korea) *ad libitum* for 180 days. The ingredients and composition of TMR and MPB are presented in Table 1 and 2, respectively.

The MPB were substituted for TMR in the 3 treatment groups at the following levels: control, 1,000 g/kg TMR and 0 g/kg MPB; treatment 1 (T1), 970 g/kg TMR and 30 g/kg MPB; and treatment 2 (T2), 950 g/kg TMR and 50 g/kg MPB, 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 and crude protein according to the procedure of AOAC (2005). Ether extract was analyzed by the diethyl ether extraction in an Extraction System (B-811, Buchi, Flawil, Switzerland). Crude fiber 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.

Table 2. Ingredient and chemical compositions of medicinal plant by-products

Item	Korean name	Value (g/kg)
Ingredient, as-fed basis		
Rehmanniae radix preparata	Sukjihwang	118
Angelica gigas nakai	Danggui	118
Zingiber officinale roscoe	Sangkang	108
Paeoniae radix	Jakyak	108
Cnidii rhizome	Cheongung	97
Zizyphus jujuba	Daechu	97
Citrus nobilis makino	Kyul	97
Bupleuri radix	Siho	86
Plantago asiatica L.	Jilkyungi	86
Prunus mume	Maesil	86
Chemical composition, DM basis		
Crude protein		92
Crude fat		36
Crude fiber		207
Ash		39

DM, dry matter.

Sampling, measurements and chemical analysis

BW was measured at the beginning of the feeding trial for each animal followed by once every month and at the end of experiment. At the end of the feeding trial, blood samples (10 mL) were taken by venipuncture from the jugular veins using heparinized vacuum tubes and were stored on ice until analysis. Whole blood was subjected to analysis in an automatic hematological analyzer (VET abc, Montpellier, France) within 2 h after sampling. The plasma was obtained from a portion of collected whole blood by centrifugation at 2,500×g for 30 min at 4°C and stored at –20°C until analysis. Total protein, albumin, calcium, phosphorus, non-esterified fatty acid (NEFA), blood urea nitrogen (BUN) and corticoid were analyzed by an automatic blood analyzer (Express Plus, Bayer, Medfield, MA, USA).

At the end of feeding trial all steers were slaughtered after a 24 h fasting period. They were stunned, exsanguinated, and immediately eviscerated. Carcasses were chilled at between 0°C to 2°C for 24 h. The carcasses were then graded for quality and yield factors from the *longissmus dorsi* taken at 13th rib. Quality and yield grading were performed by trained personnel of the Animal Products Grading Service in Seoul, South Korea. Carcass weight, back-fat thickness and size of loin-eye area were assessed. Yield grade was classified with a scale of 1, 2, or 3, where 1 is high yield and 3 is low yield. Quality grade was scored on a scale of 1, 2, 3, 4, and 5, which was mainly determined by marbling score but also by meat color, fat color and maturity.

Economic efficacy analysis

The economic analysis of carcass production was calculated based on the cost of feed input and the price of carcass. The total feed cost did not include basic costs such as labor, equipment, electricity and water. The carcass price was determined based on the meat grades and carcass weight of steers.

Statistical analysis

Data for steers within each treatment were averaged and analyzed using the general linear model procedure of SAS (SAS Institute 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. Differences among treatment groups were considered significant if $p<0.05$, whereas when $0.05<p\leq0.10$, differences were considered to indicate a trend towards significance.

RESULTS AND DISCUSSION

Growth performance

Initial and final BW were not different among treatment groups (Table 3). Average daily gain and feed efficiency were higher ($p<0.05$) for T1 than control, whereas feed intake was not different among treatments. BWs are commonly used for monitoring nutritional status and growth of animals (Ndlovu et al., 2009). In beef cattle production, total weight gain and daily gain are very important factors from an economic point of view. The higher feed efficiency for T1 might be a result of higher average daily gain and numerically lower total feed intake for T1 compared with control and T2, suggesting that 30 g/kg MPB supplementation to TMR may improve feed efficiency in Hanwoo steers. It is supported by the fact that in appropriate quantities some herbs stimulated the appetite and digestion process of calves (Aboul-Fotouh et al., 2000; Ahmed et al., 2009; Hadiya et al., 2009), because medicinal plants have antimicrobial characteristics which could affect inappropriate microbes in the rumen. However, such an effect was not observed with elevated supplementation of MPB to TMR (T2 group) in the present study which decreased the feed efficiency. There are medicinal plants with suspected adverse effects, either alone or in combination (Elvin-Lewis, 2001). In general, the safety and effectiveness of alternative feeds for animals have not been

Table 3. Substitution effect of a total mixed ration by medicinal plant by-products on growth and feed efficiency in the late fattening period of Hanwoo steers

Item	Treatment[1]			SEM
	Control	Treatment 1	Treatment 2	
No. of animals	9	9	9	
Growth performance				
Initial body weight (kg)	569	580	570	57.4
Finished body weight (kg)	653	682	655	52.0
Average daily gain (kg/d)	0.469^{y}	0.560^{x}	0.470^{y}	0.05
Feed intake (kg/d)				
Total feed intake	9.23	8.71	9.14	0.50
Feed efficiency (kg/kg)	0.051^{y}	0.089^{x}	0.051^{y}	0.001

SEM, standard error of the means.

[1] Medicinal plant by-products supplied to total mixed ration: control, no supplement; treatment 1, 30 g/kg; treatment 2, 50 g/kg.

[x,y] Values in the same row with different superscripts differ at $p<0.05$.

fully proven and remain largely unknown. Therefore, they should be used with care because elevated supplementation of some medicinal plants may stimulate undesirable side effects (Vandergrift, 1998) which warrants further investigations on health aspects of MPB as feed additives.

Blood characteristics

White blood cells, which play a major role in defending the body against disease-producing bacteria, viruses and fungi, binds to infectious agents and helps in preventing them from damaging the body. Therefore, a deficiency of white blood cells may result in an increased susceptibility to infections. Although no statistically difference was observed among treatments ($p>0.05$, Table 4), numerically increased white blood cell counts with MPB supplementation may indicate an improved sign of immunity.

No significant differences were observed for red blood cell and platelets among treatments, whereas hemoglobin and hematocrit were higher ($p<0.05$) for T1 and T2 than control group (Table 4). A shortage of red cells produces a condition of anemia, which can cause weakness, dizziness, shortness of breath and headaches (LSA, 1994). On the other hand, Feldman et al. (2006) reported that the normal range of hemoglobin values was 8 to 15 g/dL in cattle. Therefore, the values of these measures in the current study were within the normal range, indicating no significant changes in such health related symptoms.

Plasma albumin showed low-, intermediate- and high-level ($p<0.05$) for control, T1 and T2, whereas NEFA was high-, intermediate- and high-level ($p<0.05$) for control, T1 and T2, respectively (Table 4). The higher albumin concentration may be due to the improvements of ruminal microbial protein synthesis or by greater absorption of protein. Various substances such as amino acids adhere particularly to albumin in the blood, which plays a role in their transport (Rivera et al., 2005). However, it was not supported by the total protein concentration being the highest in T1 group though there was no significantly difference. Hart et al. (2008) reported that essential oils from medicinal plants apply their main effects on the rumen through reduction of protein and starch and the degradation of amino acids. The degradation depends on dose, chemical structure, and ration combinations of MPB. Therefore, further study is required to investigate the effect of MPB on rumen turnover rate and microbial protein synthesis.

Lower feed intake is associated with increased NEFA which contributes to the risk of fatty liver and negative energy balance (Allen et al., 2009). Decreasing concentrations of plasma insulin could allow the glucocorticoids to express a ketogenic effect resulting in the release of NEFA from adipose tissue through a negative energy balance (Mills and Jenny, 1979; Veenhuizen et al., 1991). On the other hand, NEFA concentration is increased by up-regulated lipolysis as a feature of metabolic disorder (Van Hoeck et al., 2011), suggesting that NEFA concentration was increased by cytotoxic effects on several cell types, such as Leydig cells, nerve growth factor differentiated cells and hepatocytes. The results of feed intake and corticoid concentration in the present study were not affect by the treatments (Tables 3 and 4), indicating that

Table 4. Substitution effect of a total mixed ration by medicinal plant by-products on blood corpuscles and plasma chemical composition in the late fattening period of Hanwoo steers

Item	Treatment[1]			SEM
	Control	Treatment 1	Treatment 2	
No. of animals	9	9	9	
Blood corpuscles				
White blood cell (K/μL)	7.29	8.50	12.65	14.6
Red blood cell (M/μL)	7.00	7.19	7.89	0.47
Hemoglobin (g/dL)	11.03^{y}	13.03^{x}	14.07^{x}	0.71
Hematocrit (mg/mL)	292^{y}	353^{x}	387^{x}	21.7
Platelets (10^3/mm^3)	339	325	311	62.9
Plasma chemical compositions				
Total protein (g/dL)	3.10	3.83	3.70	0.46
Albumin (g/dL)	3.77^{y}	3.93^{x,y}	4.10^{x}	0.16
Calcium (U/L)	9.53	9.10	9.53	0.52
Phosphorus (mg/dL)	8.00	7.57	7.40	1.26
Non-esterified fatty acid (ueq/L)	0.18^{x}	0.11^{x,y}	0.09^{y}	0.04
Blood urea nitrogen (mg/dL)	12.33	15.00	13.33	2.43
Corticoid (ng/dL)	3.99	1.96	3.17	2.26

SEM, standard error of the means.

[1] Medicinal plant by-products supplied to total mixed ration: control, no supplement; treatment 1, 30 g/kg; treatment 2, 50 g/kg.

[x,y] Values in the same row with different superscripts differ at $p<0.05$.

Table 5. Substitution effect of a total mixed ration by medicinal plant by-products on the carcass traits and meat grades in the late fattening period of Hanwoo steers

Item[1]	Treatment[b]			SEM
	Control	Treatment 1	Treatment 2	
No. of animals	9	9	9	
Carcass trait				
Carcass weight (kg)	366	382	375	42.7
Carcass rate (g/kg)	560	561	572	8.20
Backfat thickness (mm)	11.0	14.3	7.00	6.11
Eye muscle area (cm^2)	80.7	90.0	90.3	10.1
Meat grade				
Yield grade	2.00[y]	2.11[y]	1.00[x]	0.26
Quality grade	3.00[x]	1.67[y]	2.33[x,y]	0.27

SEM, standard error of the means.

[1] Carcass characteristics were measured from *longissmus dorsi* taken at 13th rib; carcass yield grade (1 = high yield, 3 = low yield), quality grade (1 = very high quality, 5 = low quality).

[2] Medicinal plant by-products supplied to total mixed ration: control, no supplement; treatment 1, 30 g/kg; treatment 2, 50 g/kg.

[x,y] Values in the same row with different superscripts differ at $p<0.05$.

MPB supplementation in Hanwoo steers was not adverse to their health and energy balance.

Carcass characteristics

In the present study, carcass weight, carcass rate, backfat thickness and rib eye muscle area were not affected by MPB supplementation to TMR, whereas the meat grade was improved ($p<0.05$, Table 5). Yield grade was highest ($p<0.05$) in the T2 group and quality grade was highest ($p<0.05$) in the T1 group. Antioxidants prevent discoloration (Waylan et al., 2002; Zhong et al., 2009), therefore, the oxidative status of the feed given to animals has a significant influence on the final meat quality. For instance, antioxidant vitamin E in feed guarantees high α-tocopherol deposition in meat, while feeding animals with oxidizing feed clearly results in lower α-tocopherol contents in the meat (Lo Fiego et al., 2004). The α-tocopheryl acetate supplemented in the feed does not function as an antioxidant until it is hydrolyzed in the small intestine into free α-tocopherol. However, once liberated in the small intestine, α-tocopherol regains its antioxidant activity. Free radicals, peroxides and other reactive oxygen species present in the feed will thus be neutralized by α-tocopherol leading to a reduction of the α-tocopherol content to be deposited in the muscle (Lauridsen et al., 1994; Lauridsen et al., 1995; Dirinck et al., 1996; Tesoriere et al., 2002). 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. Therefore, we speculate that MPB supplementation to diets may play significant role in meat quality as an antioxidant in feed. However, further detailed studies are needed to clarify the effect of MPB as an antioxidant in feed on meat quality for Hanwoo steers, which active substances will affect to improve meat quality.

Economic efficacy

Daily feed costs were decreased by 0.5% and 0.8% for T1 and T2 compared to control (Table 6). Consequently, carcass prices were increased by 18.1% and 7.6% for T1 and T2, respectively. Based on the results in the present study, it is suggesting that substitution of a TMR by a MPB may be more profitable to the late fattening period of Hanwoo steers. Again, further study is required to demonstrate the effect of substituting concentrate by a MPB in the late fattening of

Table 6. Substitution effect of a total mixed ration by medicinal plant by-products on the economic efficacy in the late fattening period of Hanwoo steers

Item	Treatment[1]		
	Control	Treatment 1	Treatment 2
Total feed cost (Won/180 d/head)	1,054,440	1,049,645	1,046,448
Concentrate	864,000	864,000	864,000
Total mixed ration	190,440	185,645	182,448
Daily feed cost (Won/d/head)	5,688.0	5,661.4	5,643.6
Index (%)	100.0	99.53	99.22
Carcass price (Won/head)	5,119,380	6,044,608	5,507,662
Index (%)	100.0	118.1	107.6

[1] Medicinal plant by-products supplied to total mixed ration: control, no supplement; treatment 1, 30 g/kg; treatment 2, 50 g/kg.

Hanwoo steers. Plant secondary metabolites contained in medicinal plants can modulate ruminal fermentation and improve nutrient utilization in ruminants (Hristov et al., 1999). Consequently, the supplementation of medicinal plants or their by-products containing antimicrobials, antioxidants and stimulants of immune system may alter rumen microbial activity and rumen fermentation of cattle fed a high-concentrate diet. Therefore, appropriate use of MPB as feed additives may influence production efficiency as well as being an alternative to synthetic compounds (i.e., antibiotic) in the late fattening period of Hanwoo steers.

CONCLUSION

Although medicinal plants and their by-products have enormous potential to be developed as a possible alternative to antibiotics and enhancers of production efficiency, indigenous medicinal plants and its by-products have not been seriously considered as a dietary supplement for Hanwoo steers. Therefore, this study attempted to evaluate the potential use of MPB as a feed additive and the results suggest that the substituting TMR with 30 g/kg MPB may have potential as a feed supplement during in the late fattening period of Hanwoo steers to improve feed efficiency, meat quality and possibly carcass price. However, further study is required to better understand the extent to which MPB supplementation to TMR affected ruminal metabolites before recommending their use as dietary supplements.

CONFLICT OF INTEREST

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

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