



Effects of Dietary Multi-nutritional Targeted Supplementation According to Different Growth Stages on Performance and Carcass Characteristics of Hanwoo Steers

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ABSTRACT : This study was conducted to determine the effects of dietary multi-nutritional targeted supplementation according to different growth stages on performance, blood metabolites and carcass characteristics of Korean native Hanwoo steers. Thirty two Hanwoo steers, 6 months of age and weighing 159.2±24.1 kg, were distributed into 2 groups: control group without any supplements, and multi-nutritional targeted supplementation (MNTS) treatment group supplied with wheat bran and catechins (WBC, 8 to 16 months of age), ruminally protected amino acid-enriched fatty acid (RPAFA, 17 to 28 months of age) and ruminally protected choline with vitamin E (RPCV, 22 to 28 months of age), respectively. Average daily gain was not significantly different between the two groups. During the late fattening period, concentrate, rice straw and dry matter intakes were relatively lower in MNTS than in the control group. Rib eye area, back fat thickness and yield index were similar between the two groups. Meat color was relatively lower in MNTS compared with the control group. The appearance rate of high quality grade (1⁺⁺, 1⁺ and 1) tended to be higher in MNTS compared with the control group. Thus, the present results indicate that dietary multi-nutritional targeted supplementation at different growth stages could be recommendable to increase income according to production of high quality Hanwoo beef without any negative effects on growth performance and carcass characteristics. (**Key Words :** Hanwoo Steers, Growth Performance, Carcass Characteristics)

INTRODUCTION

Unlike Western society, Korean and Japanese consumers prefer well-marbled and lightly-colored beef. In Korea, Hanwoo steers have been fattened until almost 30 months of age to improve meat quality with high marbling. Hanwoo steers dramatically increase their marbling fat in muscle between 12 and 27 months of age (Lee et al., 2007). Marbling plays a particularly important role in determining the juiciness and tenderness of beef, and is one of the main

factors used to determine beef quality grade in Korea (Lee, 2004). However, the color of the beef tends to become darker as the animals become older, although high-marbled beef is produced from animals fed for more than 2.5 years (Zembayashi et al., 1999). Meat purchasing decisions are influenced by color more than any other quality factor because consumers use discoloration as an indicator of freshness and wholesomeness (Mancini and Hunt, 2005). Meat color in beef is related to age. This is because the content of myoglobin in meat steadily increases until 24 months of age, and pigment content increases from birth to 16 months of age (Boccard et al., 1979). In the beef industry, various plant materials containing phenolic compounds have been demonstrated to be effective antioxidants in meat color. Over past years, many experimental feeding trials have focused on vitamin E (α -tocopherol) supplementation of diets of meat-producing animals as a means of enhancing the oxidative stability of post-slaughter meat (Faustman et al., 1989; O'Grady et al., 2006). In addition, Zembayashi et al. (1999) found that the addition of wheat bran or green tea

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(catechins) to the diet decreased color saturation because these supplements were responsible for low muscle iron concentrations. Oh et al. (2008) also reported that iron and metmyoglobin content of the *longissimus dorsi* and hemoglobin content of blood were lower in Hanwoo steers fed wheat bran and catechins compared with steers fed a basal diet.

While Park et al. (2008) reported that supplementation with 100 g of ruminally protected amino acid-enriched fatty acid (RPAFA) had a preferential effect on meat quality graded as well-marbled due to increasing supply of fatty acids and limiting amino acids (methionine and lysine) in finishing Hanwoo steers. In addition, previous studies found that ruminally protected choline had positive effects on DMI, ADG, feed conversion ratio and carcass weight in finishing cattle fed high concentrate diets (Drouillard et al., 1998; Bryant et al., 1999).

Thus, the objective of the present study was to determine the effects of dietary multi-nutritional targeted supplementation such as WBS, RPAFA and RPCV at different growth stages on performance, blood metabolites and carcass characteristics of Hanwoo steers.

MATERIALS AND METHODS

Animal, experimental design, feeding and management

Thirty two Hanwoo steers, 6 months of age and weighing 159.2 ± 24.1 kg, were distributed into 2 groups of 16 steers. The steers were randomly assigned to one of two treatment groups: control group without any supplements, and multi-nutritional targeted supplementation (MNTS) treatment group supplemented with wheat bran and catechins (WBC, 8 to 16 months of age), RPAFA (17 to 28 months of age) and RPCV (22 to 28 months of age). In the treatments, 8 pens (5.3×10.6 m), each with a concreted floor with sawdust bedding, were arranged with 4 steers per pen. The pens were equipped with electronic head gates (Calan system, Seil Tech, Korea) to allow individual measurement of feed intake.

The experiment was conducted with the animals at 6 months of age. The study was categorized into the following periods: growing (6 to 11 months of age), early fattening (12 to 16 months of age), mid-fattening (17 to 21 months of age) and late fattening (22 to 28 months of age).

During the growing period, animals were offered commercial concentrate at 1.5-1.6% of body weight. In the early- and mid-fattening periods, animals were offered commercial concentrate at 1.7-1.8% of body weight. They were offered concentrate approximately *ad libitum* during the late fattening period until slaughtered.

Grass hay was offered from 2.5 kg/animal/d (1.6% of BW) to 4 kg/animal/d (1.3% of BW) between 6 and 12 months of age. From 13 to 15 months of age, the hay was changed to rice straw, and animals were offered hay at 2.0, 1.5 and 1.0 kg/animal/d, and rice straw at 2.0, 2.1 and 2.2 kg/animal/d at 13, 14 and 15 months of age, respectively. From 16 months of age, only rice straw was offered at 2.2 kg/animal/d. The amount of rice straw offered was decreased with increasing age, and it was restricted to 0.6 kg/animal/d during the late fattening period.

During 8 to 16 months of age, 22.5% of wheat bran was mixed with 77.5% of commercial concentrate, and then the catechins (green tea extract) was supplemented at 0.3% of the mixture. The concentrates contained approximately 30% of wheat bran, and were offered to animals of the MNTS treatment group. 100 g of RPAFA (76% of protected fatty acid, 8% of DL-methionine and 16% of L-lysine) and 40g of RPCV (25% of choline chloride and 500 IU of vitamin E) were fed to animals of the MNTS treatment group as a top dressing at the morning feeding. The RPAFA and RPCV were provided by Nuvo Bio & Technologies Co. (Seoul, Korea).

Forage was fed at 08:00 h daily, and the concentrates in two equal portions at 08:00 and 16:00 h. The chemical composition of the experimental concentrates, hay and rice straw offered at different growth stages are presented in Table 1. Steers had free access to fresh water and mineral block during the whole period.

Table 1. Chemical composition of the experimental diets

Item	Concentrates			Hay	Rice straw
	Growing	Early fattening	Mid and late fattening		
DM ¹ (%)	90.24±0.04	88.58±0.06	90.52±0.12	90.13±0.13	91.43±0.08
CP ² (%)	16.42±0.16	15.04±0.42	14.08±0.23	15.87±0.02	4.39±0.14
EE ³ (%)	3.34±0.02	3.74±0.12	4.80±0.02	2.78±0.02	2.36±0.01
CA ⁴ (%)	10.28±0.80	9.94±0.43	9.41±0.05	7.15±0.20	13.07±0.12
CF ⁵ (%)	5.62±0.12	5.53±0.41	5.54±0.56	28.74±0.38	29.57±0.09
NDF ⁶ (%)	31.67±0.28	31.97±1.29	28.05±0.68	76.29±0.27	70.21±0.96
ADF ⁷ (%)	12.07±0.16	12.02±0.06	11.10±0.17	40.15±0.60	38.13±0.40

Means±standard deviation.

¹ DM = Dry matter. ² CP = Crude protein. ³ EE = Ether extract. ⁴ CA = Crude ash.

⁵ CF = Crude fiber. ⁶ NDF = Neutral detergent fiber. ⁷ ADF = Acid detergent fiber.

Sampling, measurements and analyses

The diets used in this study were dried by forced-air oven (at 60°C, 48 h), ground by a Wiley mill (Thomas scientific, Model 4, USA) and analyzed for moisture, crude protein, ether extract, crude fiber and crude ash according to the procedures of AOAC (1990). The concentration of neutral detergent fiber (NDF) corrected for residual ash was determined with heat-stable amylase and sodium sulphate according to the method of Van Soest et al. (1991), while the content of acid detergent fiber (ADF) corrected for residual ash was determined according to the procedure of AOAC (1990).

Steers were weighed every month during the experimental period. Dietary refusals were collected and weighed every day. Feed conversion ratio was expressed as average dry matter intake (DMI) per average daily gain (ADG).

Jugular blood samples were collected into tubes (Becton Dickinson Co., USA) before morning feeding to determine serum metabolite concentrations at two-month intervals. The tubes were centrifuged (for 30 min at 3,000×g) to obtain serum. The resulting serum supernatant was analyzed for metabolite concentrations by Autohumalyzer 900S plus (Human GmbH, German).

Back fat thickness and marbling score were predicted between the 13th thoracic and 1st lumbar vertebrae of steers using ultra-sound scanning equipment (Aquila, 3.5 MHz, 18 cm linear probe, Pie Medical, Netherlands) at two-month intervals.

Carcass characteristics such as yield and quality grades were assessed at 24 h *post-mortem* by an experienced official grader of the Animal Products Grading Service (APGS, 2009), Korea, for characteristics of quality (marbling score, meat color, fat color, texture and maturity) and yield (cold carcass weight, back fat thickness and rib eye area). After a 24-h chill, cold carcass weights were measured and then the left side of each carcass was cut between the last rib and the first lumbar vertebrae to determine quality grade.

The quality grade was determined by assessing the degree of marbling and firmness in the cut surface of the rib eye, in relation to the maturity, meat color and fat color of the carcass. Quality grades were classified as 1⁺⁺ (very high quality), 1⁺, 1, 2 and 3 (low quality) according to the Korean beef quality grading system. The rib eye area was measured from *longissimus* muscle taken at the 13th rib and back fat thickness was also measured at the 13th rib. Yield index was calculated as follows: Yield index: 68.184-(0.625×back fat thickness (mm))+(0.130×rib eye area (cm²)-(0.024×dressed weight amount (kg))+3.23. Yield grades were classified as A (high yield), B and C (low yield) according to the Korean beef yield grading system as

determined by yield index (grade A = more than 67.50, grade B = more than 62.00 ~ less than 67.50 and grade C = less than 62.00).

The degree of marbling was evaluated with the Korean Beef Marbling Standard, and the scores of meat color and fat color were made using the color standard (APGS, 2009). The scores for texture and maturity were made using the APGS reference index (APGS, 2009). The grading ranges were 1 to 9 for marbling score with higher numbers for better quality (1 = devoid, 9 = abundant); meat color (1 = bright red, 7 = dark red); fat color (1 = creamy white, 7 = yellowish); texture (1 = soft, 3 = firm); maturity (1 = young, 9 = old).

Statistical analysis

Comparisons of growth performance, blood metabolites, ultra-sound scanning data and carcass characteristics of Hanwoo steers were analyzed by t-test to compare significant differences between the two groups.

RESULTS AND DISCUSSION

The ADG was similar between the two groups during the whole experimental period, although final body weight and ADG during the late-fattening period tended to be higher in MNTS compared with the control group (Table 2). During the growing, early fattening and mid-fattening periods, there were no significant differences in concentrate intake, hay intake and DMI between the two groups. During the late fattening period, concentrate intake, rice straw intake and DMI were relatively lower in MNTS than in the control group ($p < 0.08$). Feed conversion ratio was similar between the two groups from the growing to mid-fattening period, whereas it tended to be lower in MNTS compared with the control group during the late-fattening period.

From 8 to 16 months of age, supplementation of WBC did not influence ADG, DMI and feed conversion ratio of Hanwoo steers. The concentrates contained approximately 30% wheat bran, which was substantially greater than the amounts used in general commercial concentrate (from 5 to 10%). This suggests that wheat bran, when fed at sufficiently high contents, has no negative effect on growth performance during the growing and early-fattening periods. Similarly, Oh et al. (2008) reported that ADG, DMI and feed conversion ratio were similar between WBC and control groups.

When only RPAFA was supplemented at 100 g/animal/d from 17 to 21 months of age, there were no positive effects on ADG, DMI and feed conversion ratio. However, when RPAFA and RPCV were simultaneously supplemented to the concentrate from 22 to 28 months of age during the late-fattening period, there was a lower feed conversion ratio

Table 2. Effects of dietary multi-nutritional targeted supplementation at different growth stages on growth performance of Hanwoo steers

Item	Control	Treatment	Pr> t
Initial body weight (kg)	158.8±19.8	159.5±27.7	0.9381
Final body weight (kg)	699.8±49.7	725.1±52.8	0.2016
Average daily gain (kg/d)			
Growing period	0.85±0.07	0.86±0.09	0.6803
Early-fattening period	0.86±0.06	0.85±0.06	0.4995
Mid-fattening period	0.83±0.12	0.86±0.10	0.6259
Late-fattening period	0.66±0.17	0.71±0.10	0.3472
Intake (kg/d)			
Growing period			
Concentrate	3.65±0.05	3.65±0.09	0.9086
Hay	3.15±0.28	3.28±0.23	0.1641
Dry matter intake	6.00±0.26	6.12±0.24	0.2110
Early-fattening period			
Concentrate	6.18±0.02	6.18±0.05	0.6408
Hay/rice straw	2.69±0.27	2.64±0.33	0.6946
Dry matter intake	7.83±0.25	7.79±0.31	0.6775
Mid-fattening period			
Concentrate	8.56±0.26	8.37±0.46	0.1762
Rice straw	1.36±0.26	1.25±0.24	0.2046
Dry matter intake	8.76±0.41	8.49±0.59	0.1546
Late-fattening period			
Concentrate	8.56±0.65	8.09±0.74	0.0730
Rice straw	0.73±0.09	0.66±0.11	0.0450
Dry matter intake	8.22±0.63	7.73±0.72	0.0589
Feed conversion ratio			
Growing period	7.12±0.54	7.20±0.83	0.7475
Early-fattening period	9.15±0.71	9.25±0.75	0.7231
Mid-fattening period	10.74±1.74	10.10±1.69	0.9162
Late-fattening period	14.64±9.58	11.08±1.27	0.1894

Means±standard deviation.

related to higher ADG. This is because potential effects of RPCV might be mediated through alterations in fat metabolism and/or metabolic hormones related to fat metabolism.

The concentrations of albumin, cholesterol, glucose, total protein, triglyceride, urea, glutamic oxalacetic transaminase (GOT) and glutamic pyruvate transaminase (GPT) were not significantly different between the two groups (Table 3).

The present results indicated that the concentrations of serum metabolites were not significantly influenced by any supplement from the growing to late-fattening period. Similarly, previous studies have shown that supplementation of RPC did not significantly affect blood cholesterol (Bryant et al., 1999), glucose (Hartwell et al., 2000) and triglyceride (Erdman and Sharma, 1991).

In general, the concentration of GOT in serum indicates damage to the liver cell. In the present study, there was a slight increase of GOT concentration (from 93.99 to 94.05 U/L) in steers fed RPCV but a considerable increase (from 86.86 to 99.87 U/L) in steers fed the control diet from the mid-fattening to late-fattening period. It was assumed that liver function remained more stable in steers fed RPCV due to the various beneficial effects of choline, such as secretion of fatty acid (Bryant et al., 1999) and enhanced gluconeogenic capacity (Overton et al., 1998).

Marbling score and back fat thickness measured by ultra-sound scanning were not significantly different between the two groups (Table 4). In carcass yield traits, rib eye area, back fat thickness and yield index were similar between the two groups (Table 5). In the appearance rate of yield grades for A, B and C, the control group resulted in

Table 3. Effects of dietary multi-nutritional targeted supplementation at different growth stages on serum metabolites of Hanwoo steers

Item	Control	Treatment	Pr> t
Growing period			
Albumin (mg/dL)	5.69±0.67	5.91±0.53	0.3138
Cholesterol (mg/dL)	256.88±47.33	264.34±37.36	0.6352
Glucose (mg/dL)	137.09±26.07	132.25±28.62	0.6320
Total protein (mg/dL)	8.58±1.05	8.74±0.91	0.6532
Triglyceride (mg/dL)	107.68±5.85	110.32±7.85	0.3039
Urea (mg/dL)	28.46±5.31	30.48±5.60	0.3206
GOT ¹ (U/L)	74.45±11.81	77.98±15.58	0.4895
GPT ² (U/L)	27.06±4.34	29.31±5.61	0.2274
Early-fattening period			
Albumin (mg/dL)	5.45±0.52	5.46±0.45	0.9447
Cholesterol (mg/dL)	263.31±66.29	282.26±42.07	0.3574
Glucose (mg/dL)	139.07±21.61	128.29±18.48	0.1526
Total protein (mg/dL)	7.84±1.52	8.63±2.89	0.3601
Triglyceride (mg/dL)	69.45±25.30	71.73±20.64	0.7886
Urea (mg/dL)	31.02±8.00	33.73±4.97	0.2799
GOT (U/L)	70.77±13.30	75.53±12.80	0.3258
GPT (U/L)	19.98±5.12	19.94±3.31	0.9843
Mid-fattening period			
Albumin (mg/dL)	5.47±0.64	5.37±0.71	0.6990
Cholesterol (mg/dL)	295.44±56.76	266.01±75.08	0.2520
Glucose (mg/dL)	102.81±20.05	102.53±12.29	0.9656
Total protein (mg/dL)	11.85±15.62	7.61±1.52	0.3297
Triglyceride (mg/dL)	65.87±14.56	58.59±10.34	0.1387
Urea (mg/dL)	30.53±8.47	30.19±11.00	0.9277
GOT (U/L)	86.84±17.80	93.99±21.06	0.3401
GPT (U/L)	19.66±4.94	20.59±5.93	0.6546
Late-fattening period			
Albumin (mg/dL)	5.28±0.82	5.56±0.47	0.2592
Cholesterol (mg/dL)	251.76±57.51	248.02±49.26	0.8527
Glucose (mg/dL)	120.18±21.41	119.91±23.07	0.9743
Total protein (mg/dL)	7.37±2.05	7.44±1.64	0.9186
Triglyceride (mg/dL)	77.77±15.77	80.37±14.72	0.6496
Urea (mg/dL)	25.64±9.81	24.33±6.79	0.6809
GOT (U/L)	99.87±39.13	94.05±17.97	0.6081
GPT (U/L)	19.38±2.90	18.83±3.89	0.6726

Means±standard deviation.

¹ GOT = Glutamic oxalacetic transaminase. ² GPT = Glutamic pyruvate transaminase.

13.5, 68.8 and 18.8%, respectively, whereas the MNTS group resulted in 6.3, 75.0 and 18.8%, respectively. In carcass quality traits, marbling score, fat color, texture and maturity were similar between the two groups. Meat color was lower in MNTS than in the control group ($p < 0.09$). The appearance rate of high quality grade (1⁺⁺, 1⁺ and 1) was 87.5 and 100% in control and MNTS groups, respectively. The appearance rate of best 1⁺⁺ grade was 18.8 and 31.3% in control and MNTS groups, respectively.

In the present study, the relatively bright meat color was attributable to supplementation of WBC from 8 to 16 months of age, and RPCV from 22 to 28 months of age. During the growing and early-fattening periods, the supplementation of WBC might have decreased color saturation due to reduction of muscle iron content (Zembayashi et al., 1999). The improved meat color might be linked to the retardation of lipid, protein and myoglobin oxidation in meat because of the supplementation of

Table 4. Effects of dietary multi-nutritional targeted supplementation at different growth stages on marbling score and back fat thickness measured by ultra-sound scanning of Hanwoo steers

Item	Age (Month)	Control	Treatment	Pr> t
Marbling score	20	1.81±0.95	2.19±1.13	0.3331
	22	2.75±1.20	3.38±1.36	0.1925
	24	3.44±1.37	4.19±1.59	0.1763
	26	4.75±1.85	5.60±1.58	0.1960
	28	5.13±1.86	5.80±1.42	0.2955
Back fat thickness (mm)	20	6.00±1.73	6.44±2.15	0.5440
	22	7.41±1.69	8.06±2.47	0.4020
	24	8.72±1.29	9.34±2.94	0.4586
	26	9.66±2.13	9.83±2.41	0.8352
	28	9.97±2.73	10.47±3.15	0.6569

Means±standard deviation.

catechins (Zhong et al., 2009). Also, the improved meat color was due to supplementation of RPCV (contained 500 IU of vitamin E) during the late-fattening period. In beef, improvements in color stability following dietary vitamin E supplementation have been reported and are attribute to a vitamin E-mediated reduction in lipid and myoglobin oxidation (Faustman et al., 1989). In addition, meat color may be affected by marbling levels (Fiems et al., 2000; Mancini and Hunt, 2005).

The appearance rate of high quality grade increased in steers fed RPAFA from 17 to 28 months of age and RPCV from 22 to 28 months of age. Similarly, Park et al. (2008) reported that supplementation with 100 g of RPAFA had positive effects on meat quality grade due to increasing

supply of fatty acids and limiting amino acids such as methionine and lysine in finishing Hanwoo steers. In addition, it was hypothesized that inclusion of the methionine of RPAFA could be associated with increase in high quality grade related to marbling score. This is most likely related to the role of methionine as a methyl donor in transmethylation reactions occurring during lipid biosynthesis (Mayes, 1981). Indirectly, it was responsible for improved liver function due to the beneficial effects of RPCV (contained 25% choline chloride), such as secretion of fatty acid (Bryant et al., 1999) and enhanced gluconeogenic capacity (Overton et al., 1998).

There was a tendency for the MNTS group to have slightly increased (approximately 6%) gross receipts (426

Table 5. Effects of dietary multi-nutritional targeted supplementation at different growth stages on carcass characteristics of Hanwoo steers

Item	Control	Treatment	Pr> t
Yield traits ¹			
Carcass weight (kg)	414.8±33.3	424.5±43.3	0.4977
Rib eye area (cm ²)	92.63±8.19	89.00±7.66	0.2204
Back fat thickness (mm)	13.19±3.43	13.50±3.72	0.8182
Yield index	65.25±2.34	64.35±2.38	0.3050
Yield grade (A:B:C, head)	2:11:3	1:12:3	-
Quality traits ²			
Marbling score	6.06±1.95	6.56±1.46	0.4327
Meat color	4.69±0.46	4.38±0.48	0.0810
Fat color	3.06±0.24	3.00±0.00	0.3332
Texture	1.13±0.33	1.00±0.00	0.1639
Maturity	2.44±0.50	2.38±0.48	0.7294
Quality grade (1 ⁺⁺ :1 ⁺ :1:2:3, head)	3:6:5:2:0	5:7:4:0:0	-

Means±standard deviation.

¹ Area was measured from *longissimus* muscle taken at 13th rib and back fat thickness was also measured at 13th rib; Yield index was calculated using the following equation: $68.184 - (0.625 \times \text{back fat thickness (mm)}) + (0.130 \times \text{rib eye area (cm}^2\text{)}) - (0.024 \times \text{dressed weight amount (kg)})$; Carcass yield grades from C (low yield) to A (high yield).

² Grading ranges are 1 to 9 for marbling score with higher numbers for better quality (1 = devoid, 9 = abundant); meat color (1 = bright red, 7 = dark red); fat color (1 = creamy white, 7 = yellowish); texture (1 = soft, 3 = firm); maturity (1 = young, 9 = old); quality grades from 3 (low quality) to 1⁺⁺ (very high quality).

Table 6. Effects of dietary multi-nutritional targeted supplementation at different growth stages on economic analysis of Hanwoo steers

Item	Control	Treatment	Pr> t
Gross receipts ¹ (1,000 won*)	7,738±801	8,164±837	0.1648
Operating costs (1,000 won)	5,293±121	5,476±149	0.0009
Calf ²	2,447	2,447	-
Feed ³	2,353±121	2,180±148	0.0015
Feed additives ⁴	-	356	-
Others ⁵	493	493	-
Income ⁶ (1,000 won)	2,445±740	2,687±760	0.3832

Means±standard deviation.

¹ Selling price of carcass by grade and by-product in February 2010.

² Average price of calf in the livestock market of the whole country in March 2008.

³ Applied the unit price of commercial concentrate (500 won/kg), rice straw (288 won/kg) and wheat bran (200 won/kg).

⁴ Applied the unit price of catechins (20,000 won/kg), ruminally protected amino acid-enriched fatty acid (6,000 won/kg) and ruminally protected choline with vitamin E (6,930 won/kg).

⁵ On the basis of the standard income of agricultural and livestock products (RDA, 2009).

⁶ Calculated from gross receipts-operating costs.

* 1,000 Korean won was equal to approximately 0.86 US dollar in February 2010.

thousand won/head) compared with the control group (Table 6). The MNTS group had 7.4% lower feed cost but 3.5% higher operating costs mainly due to expensive feed additive. At the same time, an increased income in MNTS compared with the control group could be due to a higher sale price of carcass with better carcass traits (Table 5). Thus, the MNTS group had approximately 10% higher income (242 thousand won/head) compared with the control group. Also, the present results indicated that 22.5% substitution of wheat bran for a commercial concentrate from 8 to 16 months of age could have an influence on lowering feed cost.

CONCLUSION

The present results indicated that growth performance and meat quality were improved by supplementation of RPAFA from 17 to 28 months of age, and by RPCV supplementation from 22 to 28 months of age. In addition, supplementation of WBC from 8 to 16 months of age, and of RPCV from 22 to 28 months of age had a preferential effect on meat color of Hanwoo steers. Thus, the present results indicate that dietary multi-nutritional targeted supplementation, such as WBC, RPAFA and RPCV at different growth stages, could be recommendable to increase income from high quality Hanwoo beef.

REFERENCES

- Animal Products Grading Service (APGS). 2009. Grade Rule for Cattle Carcass in Korea. Available: <http://www.ekape.or.kr/gradeinfo/statistics/>
- Association of Official Analytical Chemists (AOAC). 1990. Official Methods of Analysis, Association of Official Analytical Chemists, Washington, DC.
- Boccard, R. L., R. T. Naude, D. E. Cronje, M. C. Smit, H. J. Venter and E. J. Rossouw. 1979. The influence of age, sex and breed of cattle on their muscle characteristics. *Meat Sci.* 3:261-280.
- Bryant, T. C., J. D. Rivera, M. L. Galyean, G. C. Duff, D. M. Hallford and T. H. Montgomery. 1999. Effects of dietary level of ruminally protected choline on performance and carcass characteristics of finishing beef steers and on growth and serum metabolites in lambs. *J. Anim. Sci.* 77:2893-2903.
- Drouillard, J. S., A. S. Flake and G. L. Kuhl. 1998. Effects of added fat, degradable intake protein, and ruminally protected choline in diets of finishing steers. *Cattlemen's Day Rep. Prog.* 804. Kansas Agric. Exp. Sta., Manhattan. pp. 71-75.
- Erdman, R. A. and B. K. Sharma. 1991. Effect of dietary rumen-protected choline in lactating dairy cows. *J. Dairy Sci.* 74:1641-1647.
- Faustman, C., R. G. Cassens, D. M. Schaefer, D. R. Buege, S. N. Williams and K. K. Scheller. 1989. Improvement of pigment and lipid stability Holstein steer beef by dietary supplementation with vitamin E. *J. Food Sci.* 54:858-862.
- Fiems, L. O., S. De Campeneere, S. De Smet, G. Van de Voorde, J. M. Vanacker and Ch. V. Boucqué. 2000. Relationship between fat depots in carcasses of beef bulls and effect on meat colour and tenderness. *Meat Sci.* 56:41-47.
- Hartwell, J. R., M. J. Cecava and S. S. Donkin. 2000. Impact of dietary rumen undegradable protein and rumen protected choline on intake, peripartum liver triglyceride, plasma metabolites and milk production in transition dairy cattle. *J. Dairy Sci.* 83:2907-2917.
- Lee, D. H. 2004. Methods of genetic parameter estimations of carcass weight, longissimus muscle area and marbling score in Korean cattle. *Kor. J. Anim. Sci. Technol.* 46:509-516.
- Lee, S.-H., E.-W. Park, Y. M. Cho, S.-K. Kim, J.-H. Lee, J.-T. Jeon, C.-S. Lee, S.-K. Im, S.-J. Oh, J. M. Thompson and D. Yoon. 2007. Identification of differentially expressed genes related to intramuscular fat development in the early and late fattening stages of Hanwoo steers. *J. Biochem. Mol. Biol.* 40:757-764.
- Mancini, R. A. and M. C. Hunt. 2005. Current research in meat color. *Meat Sci.* 71:100-121.
- Mayes, P. A. 1981. Metabolism of lipids: II. Role of the tissue. In:

- Harper's Review of Biochemistry (18th Ed.) (Ed. D. W. Martin, P. A. Mayes and V. W. Rodwell). pp. 222-244. Lange Med. Publ., Los Altos, CA.
- O'Grady, M. N., M. Maher, D. J. Troy, A. P. Moloney and J. P. Kerry. 2006. An assessment of dietary supplementation with tea catechins and rosemary extract on the quality of fresh beef. *Meat Sci.* 73:132-143.
- Oh, Y. K., K. H. Kim, S. W. Kang, S. K. Hong, I. S. Nam, S. S. Chang, G. G. Park, S. Y. Han, K. J. Chun and J. S. Kum. 2008. Study on meat color of Hanwoo beef related to the concentration of heme iron. Annual Research Report of National Institute of Animal Science, Korea. pp. 491-525.
- Overton, T. R., J. K. Drackley, G. N. Douglas, L. S. Emmert and J. H. Clark. 1998. Hepatic gluconeogenesis and whole-body protein metabolism of periparturient dairy cows as affected by source of energy and intake of the prepartum diet. *J. Dairy Sci.* 81 (Suppl. 1):295 (Abstr.).
- Park, B. K., E. G. Kwon, T. I. Kim, N. J. Choi, Y. M. Cho, S. S. Chang, Y. K. Oh, B. H. Paek and H. S. Kim. 2008. Effects of ruminally protected amino acid-enriched fatty acid on growth performance, carcass characteristics and economic analysis in Hanwoo steers. Proceedings of the 8th Annual Congress. Kor. *J. Anim. Sci. Technol.* p. 99.
- Rural Development Administration (RDA). 2009. The standard income of agricultural and livestock products. p. 142.
- Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods of dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:3583-3597.
- Zembayashi, M., D. K. Lunt and S. B. Smith. 1999. Dietary tea reduces the iron content of beef. *Meat Sci.* 53:221-226.
- Zhong, R. Z., C. Y. Tan, X. F. Han, S. X. Tang, Z. L. Tan and B. Zeng. 2009. Effect of dietary tea catechins supplementation in goats on the quality of meat kept under refrigeration. *Small Rumin. Res.* 87:122-125.