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Effects of nutrient supply level on growth performance, blood metabolites, and carcass characteristics of Hanwoo heifers

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영양소 급여수준이 한우 미경산우의 사양성적, 혈장 대사물질 및 도체특성에 미치는 영향

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Abstract This study examines the effects of nutrient supply levels on the growth performance, plasma metabolites, and carcass characteristics of Hanwoo heifers. Twenty-one heifers were randomly assigned to one of three dietary groups: control (conventional practices), T1 (control + 0.5 kg of formula feed for 17 to 26-month-old heifers), and T2 (control + 0.5 kg of formula feed for 17 to 22-month-old heifers, and control + 1.0 kg of formula feed for 23 to 26-month-old heifers). The average daily weight gain was higher in T1 than in the control and T2 groups, but the difference was not significant. Plasma glucose concentration tended to increase in proportion to the nutrient supply level, whereas the plasma cholesterol concentration was slightly, but not significantly, higher in T2 than in the control and T1. Carcass weight, rib eye area, and marbling score were slightly, but not significantly, higher in T1 than in the control and T2. Thus, the results of this study indicate that from 17 to 26 months of age, a 0.5 kg increase in formula feed exerted a positive effect on growth performance and carcass characteristics in Hanwoo heifers.

요 약 본 연구는 한우 미경산우의 비육기 영양소 급여수준이 사양 성적, 혈장 대사물질, 도체 특성 및 경제성 변화에 미치는 영향을 구명하기 위해 수행되었다. 공시동물은 생후 16개월령의 한우 미경산우 21두를 공시하여 17-30개월령까지 실시하였으며, 시험구 배치는 대조구(관행 프로그램), 처리1구(17-26개월령 : 대조구 대비 배합사료 0.5㎏ 증량) 및 처리2구(17-22개월령 : 대조구 대비 배합사료 0.5kg 증량 및 23-26개월령 : 대조구 대비 배합사료 1.0㎏ 증량)의 3처리로 완전임의배치 하였다. 일당증체량은 대조구 및 처리2구에 비해 처리1구에서 높은 경향을 보였지만, 통계적인 유의차이는 없었다. 혈장 glucose 농도는 영양소 급여수준에 비례해서 증가하는 경향을 보였으며, 혈장 cholesterol 농도는 대조구 및 처리1구에 비해 처리2구에서 높은 경향을 보였다. 도체중, 배최장근단면적 및 근내지방도는 대조구 및 처리2구에 비해 처리1구에서 높은 경향을 보였다. 따라서 한우 미경산우에 있어 생후 17개월부터 26개월까지 배합사료 0.5㎏의 증량 급여는 사양성적 및 도체특성 개선에 도움이 될 수 있는 것으로 판단된다.

Keywords : Hanwoo Heifers, Formula Feed, Energy, Crude Protein, Growth Performance, Carcass Characteristics

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1. Introduction

In Korea, when the number of Hanwoo cattle increases or the price of Hanwoo cows decreases, there is a high tendency to raise Hanwoo heifers as fattening cattle. In general, it is known that the quality of meat is excellent in the order of cow, steer, and bull [1]. In particular, Hanwoo cow meat is of excellent quality than steers because the muscle fiber tissue is thinner and more delicate, the meat is softer, and the fat deposits well between the muscle fibers than those of steers. [2]. However, since Hanwoo cows are used as breeding cows until 4 – 5 parity and slaughtered after a short-term fattening period, cows with high parity group have a disadvantage in that the appearance rate of high-quality meat is lowered due to issues of fattening period and maturity [3]. Until recently, studies have been conducted to improve the marbling score of Hanwoo cattle (e.g., nutrition level and fattening period), and most research has focused on steers [1,2,4,5]. Few studies have been conducted on the effects of improving the meat quality of Hanwoo heifers. Moreover, studies on Hanwoo heifer have been principally conducted on actual growth performance regardless of the feed nutrient level [6], and studies have been conducted on the level of formula feed after sexual maturity without reflecting the physiological conditions of Hanwoo heifer [7]. However, there are few studies on the effects of formula feed level on the supply of nutrients (energy and protein) suitable for the fattening period to improve the growth performance and carcass characteristics of Hanwoo heifers.

Therefore, this study aimed to investigate the effects of the level of nutrient supply (formula feed) on the growth performance, blood metabolites, carcass characteristics, and economic efficacy of Hanwoo heifers.

2. Materials and methods

2.1 Animals, treatments, and management

Twenty-one Hanwoo heifers (average weight 312.8 ± 25.7 kg) were used as experimental animals. In this study, 21 heifers (16 months of age) were selected and subjected to an adaptation period of 1 month, after which the study was conducted from 17 to 30 months of age. The 21 heifers were randomly assigned to one of three dietary groups: control, T1 (control + 0.5 kg of formula feed for 17 to 26 months of age), and T2 (control + by 0.5 kg of formula feed for 17 to 22 months of age and control + by 1.0 kg of formula feed for 23 to 26 months of age).

The heifers (seven individuals) were allocated to 10 × 20 m pens according to the treatment groups. A set amount of formula feed, based on the age, was individually fed twice daily (08:30 and 18:00). Tall fescue straw and water were available ad libitum. Table 1 shows the ingredients and chemical compositions of the experimental diets.

Table 1. Ingredients and chemical composition of experimental diets

Items	Formula feed	Tall fescue straw
Ingredients composition (%)		
Corn grain	35.02	-
Wheat grain	6.00	-
Rice	4.00	-
Cane molasses	4.60	-
Amino acid by-product	2.00	-
Wheat bran	5.00	-
Corn gluten feed	19.00	-
Coconut meal	2.00	-
Palm kernel meal	17.00	-
Lupin flake	2.00	-
Salt dehydrate	0.60	-
Limestone	2.23	-
Sodium bicarbonate	0.30	-
Vitamin premix[1]	0.10	-
Mineral premix[2]	0.10	-
Feed additives[3]	0.05	-

Chemical composition (as-fed basis, %)		
Dry matter	90.47±0.12	94.11±0.12
Crude protein	14.93±0.00	4.66±0.04
Ether extract	2.5±0.03	0.79±0.01
Crude fiber	7.76±0.67	39.46±0.46
Crude ash	8.29±0.19	5.16±0.03
Neutral detergent fiber	33.79±0.59	72.95±0.37
Acid detergent fiber	18.46±0.63	50.96±0.70
Ca	1.11±0.01	0.48±0.01
P	0.47±0.01	0.22±0.01
Total digestible nutrient	84.28±0.74	54.17±0.44

[1]Vitamin premix provided the following quantities of vitamins per kilogram of diet: vitamin A, 10,000IU; vitamin D3, 1,500IU; vitamin E, 25IU; [2]Mineral premix provided the following quantities of minerals per kilogram of diet: Fe, 50mg; Cu, 7mg; Zn, 30mg; Mn, 24mg; I, 0.6mg; Co, 0.15mg; Se, 0.15mg; [3]Feed additives include heat-tolerant probiotics, mold inhibitor, toxin binder, lauric acid and plant extracts;

2.2 Growth performance

Body weight (BW) was measured at birth and at 3-month intervals until the end of the study using a cattle scale before morning feeding. At the end of the experiment, BW was measured immediately before loading for transportation. The average daily gain (ADG) was calculated based on the BW difference and the number of days of feeding. Feed intake was calculated by measuring the quantity of residual feed before feeding. The feed conversion rate (FCR) was calculated based on the dry matter intake (DMI) and ADG values.

Blood samples (10 mL) were collected from the jugular vein of the experimental animals using an 18-gauge needle at 3-month intervals and transferred to heparin-coated blood collection tubes (Vacutainer, Becton-Dickinson, Franklin Lakes, NJ, USA) to analyze the metabolites. Blood samples were centrifuged at 1,250 × *g* for 15 min to separate the plasma and were analyzed using an automatic blood analyzer (Hitachi 7020, Hitachi Ltd., Tokyo, Japan). The following parameters were analyzed: glucose, non-esterified fatty acid (NEFA), blood urea nitrogen (BUN), total protein, albumin, cholesterol, triglycerides, creatinine, aspartate aminotransferase (AST), alanine aminotransaminase (ALT), and γ-glutamyl-transferase (GGT).

2.3 Carcass characteristics

All the heifers were slaughtered at a local slaughterhouse. Carcass yield grades (carcass weight, back fat thickness, rib eye area, and yield index) and quality grades (marbling score, meat color, fat color, texture, and maturity) were examined according to the criteria of the Korean carcass grading system [8]. The carcass was chilled for 24 h, and the weight of the cold carcass was measured. Next, the left side of each carcass was cut between the thirteenth rib and the first lumbar vertebra to determine yield and quality grades. The rib eye area was measured from the longissimus muscle on the thirteenth rib. Backfat thickness was measured at the thirteenth rib. The yield index was calculated as follows:

Yield index = {6.90137 − [0.9446 × back fat thickness (mm)] + [0.31805 × rib eye area (cm^2)] − [0.54952 × carcass weight (kg)]} / carcass weight (kg) × 100.

Yield grades were classified as A (best, yield index 〉 61.83), B (yield index 59.70–61.83), and C (worst, yield index 〈 59.70), as determined by the yield index. The quality grade was determined by assessing the degree of marbling on the rib eye's cut surface and was based on the carcass's maturity, texture, meat color, and fat color. Marbling scores were graded on a scale of 1 to 9, with higher numbers indicating better quality (1 = devoid, 9 = abundant). Additional scores included those for meat color (1 = bright red, 7 = dark red), fat color (1 = creamy white, 7 = yellowish), maturity (1 = youthful, 9 = old), and texture (1 = soft, 5 = firm). Quality grades were evaluated as follows: 1^{++} (excellent quality), 1^{+} 1, 2, and 3 (low quality).

2.4 Economic efficacy

The economic efficacy analysis was performed using calf price, carcass selling price (including by-product imports), and feed cost. The livestock production cost supplied by Statistics Korea was applied to other operating expenses [9].

2.5 Statistical analysis

Statistical analyses to obtain the average values and standard differences were performed using the IBM SPSS (Statistical Package for the Social Sciences, SPSS Inc. Chicago, IL, USA). One-way ANOVA was used to calculate the average value for each treatment group. Statistically significant differences between treatments were determined using Duncan's multiple range test [10] at a level of $p < 0.05$.

3. Results and discussion

3.1 Growth performance

Table 2 shows the effect of nutrient supply level on the growth performance of the Hanwoo heifers.

Although the difference was not statistically significant, ADG was higher in treatment groups 1 and 2 than in the control group. Dry matter intake and FCR was higher in the control group and treatment group 2 than in treatment group 1, but there was no significant difference.

Lee et al. [6] reported that the average live weight at slaughtered of heifers is 651 kg, which agrees with the present study's results. In addition, previous studies have reported similar results, showing that the level of formula feed did not markedly affect the live weight at slaughtered of Hanwoo heifers. This finding is concurrent with that of Choi et al. [11], who found that at 30 months of age, the heifers' live weight at slaughtered was 514.9 kg.

This is thought to be because, in the case of the control group, the unlimited feeding procedure was carried out according to the farm practice from 2 months before shipment, but in the treatment group 1, it was limited to 8.0 kg.

3.2 Plasma metabolites

Table 3 shows the effects of nutrient supply level on plasma metabolites in Hanwoo heifers. During early fattening, serum glucose and BUN concentrations tended to be higher in treatment group 1 than in the control and treatment group 2, and serum NEFA concentration tended to be higher in treatment group 2 than in the control and treatment group 1, but the difference was not significant. There was no effect of nutrient supply level on albumin, total protein, cholesterol, triglycerides, creatinine, AST, ALT, GGT, or magnesium.

During late fattening, serum glucose concentrations tended to be lower and serum NEFA concentration tended to be higher in the control group than in treatment groups 1 and 2; however, the

Table 2. Effects of nutrient supply level on growth performance in Hanwoo heifers

Item	Treatment[1]			*p*-value
	Control	T1	T2	
Initial body weight (kg)	341.6±26.2	334.8±28.0	309.2±20.0	0.06
Final body weight (kg)	664.6±57.6	693.7±63.9	644.7±36.1	0.23
Average daily gain (kg/d)	0.66±0.09	0.74±0.09	0.69±0.09	0.32
Formula feed intake (dry matter, kg)	7.23	7.17	7.44	-
Tall fescue straw intake (dry matter, kg)	1.74	1.74	1.74	-
Dry matter intake (kg)	8.96	8.91	9.18	-
Crude protein intake (dry matter, kg)	1.16	1.15	1.19	-
TDN[3] intake (dry matter, kg)	6.09	6.05	6.27	-
Feed conversion ratio	13.72±1.82	12.27±1.69	13.52±1.73	-

[1]Control: conventional practices, T1: control + 0.5kg, T2: control + 1.0kg.

Table 3. Effects of nutrient supply level on plasma metabolites concentrations in Hanwoo heifers

Item	Treatment[1]			*p*-value
	Control	T1	T2	
Early fattening				
Glucose (mg/dL)	87.79±10.50	112.9±25.88	89.57±24.45	0.760
NEFA[2] (uEq/L)	108.7±28.66	126.2±20.55	145.4±45.39	0.146
BUN[3] (mg/L)	16.83±3.84	17.85±1.65	16.59±1.03	0.612
Albumin (g/dL)	3.74±0.18	3.82±.0.27	3.64±0.39	0.539
Total protein (g/dL)	6.90±0.51	6.94±0.50	6.88±0.79	0.985
Cholesterol (mg/dL)	157.1±19.40	163.9±25.85	142.3±25.99	0.252
Triglyceride (mg/dL)	25.29±7.76	25.43±4.71	21.64±4.94	0.422
Creatinine (mg/dL)	1.05±0.24	1.21±0.09	1.02±0.07	0.063
AST[4] (U/L)	73.14±8.85	77.79±9.46	71.71±9.46	0.455
ALT[5] (U/L)	24.71±5.34	24.79±2.78	23.21±3.76	0.724
GGT[6] (U/L)	26.80±9.12	26.79±3.94	22.17±6.14	0.355
Late fattening				
Glucose (mg/dL)	76.36±6.73	96.64±53.72	93.07±29.58	0.535
NEFA (uEq/L)	294.5±77.12	278.8±35.53	275.1±63.00	0.821
BUN (mg/L)	18.43±4.01	18.64±2.33	18.86±1.57	0.959
Albumin (g/dL)	3.93±0.41	3.86±0.63	3.99±0.21	0.868
Total protein (g/dL)	7.05±0.74	7.07±1.30	7.37±0.34	0.754
Cholesterol (mg/dL)	163.7±39.61	160.6±42.90	162.2±27.95	0.988
Triglyceride (mg/dL)	31.43±9.85	31.50±2.71	32.57±8.10	0.951
Creatinine (mg/dL)	1.45±0.18	1.50±0.17	1.40±0.09	0.483
AST (U/L)	77.71±14.66	65.64±18.15	63.35±5.86	0.165
ALT (U/L)	24.29±4.59	19.29±6.07	21.57±1.72	0.144
GGT (U/L)	32.77±11.49	32.89±11.88	30.76±7.72	0.914

[1]Control: conventional practices, T1: control + 0.5kg, T2: control + 1.0kg; [2]NEFA: non-esterified fatty acid; [3]BUN: blood urea nitrogen; [4]AST: aspartate-amino-transferase; [5]ALT: alanine-amino-transaminase; [6]GGT: γ-glutamyl-transferase.

difference was not significant. There was no effect of the additional supply of energy and crude protein on BUN, albumin, total protein, cholesterol, triglycerides, creatinine, AST, ALT, GGT, and magnesium.

In this study, serum glucose concentration tended to be higher in the treatment groups than in the control group, which could be due to an increase in the supply of nitrogen free extract, non-fiber carbohydrate, and starch by increase of formula feed.

Lee et al. [6] reported that the serum glucose concentration of Hanwoo heifer was highest during the early fattening period (16 to 21 months of age) when the feed intake of formula was higher than that in the growing period and late fattening period. Also, Kook and Kim [12] reported that the blood glucose concentration showed a difference due to an increase in feed intake [13] and an increase in glucose availability according to fat accumulation [14,15]. Lee et al. [6] found that the serum glucose concentration of Hanwoo heifers was in the range of 77.8 to 121.6 mg/dL. In this study, serum glucose concentration was in the range of 87.79 to 112.86 mg/dL in the early fattening period and 76.36 to 96.64 mg/dL in the late fattening period. This finding is consistent with the results of a previous study.

NEFAs are oxidized in the liver and converted into energy and acetate. In the liver, acetate is converted into energy when propionate is available; however, when propionate is insufficient, it is converted into a ketone and released into the blood [16]. Serum NEFA concentrations tended to be higher in the early fattening period than in the late fattening period, which is believed to be due to the incomplete oxidation of NEFA by decreased liver function at early fattening period.

In this study showed that the effect of nutrient supply level on the blood metabolite concentration of Hanwoo heifer was not significant.

3.3 Carcass characteristics

Table 4 shows the effect of nutrient supply level on the carcass characteristics of the Hanwoo heifers. The carcass weight and rib eye area tended to be higher in treatment group 1 than in the control group and treatment group 2. The back fat thickness tended to be higher in treatment group 2 than in the control group and treatment group 1. The marbling scores tended to be higher in the treatment groups than in the control group. The appearance rate of meat quality 1^+ grade and auction cost tended to be higher in the treatment groups than in the control group. There was no effect of nutrient supply level on meat color, fat color, texture, or maturity. Previous studies [17-19] indicated that the rib eye area of Hanwoo heifers ranged from 61.02 to 73.4 cm^2 and back fat thickness ranged from 8.4 to 14.75 mm. However, in this study, the rib eye area was 84.00 to 92.60 cm^2, and the back fat thickness ranged from 12.00 to 15.00 mm. Therefore, the rib eye area and back fat thickness was higher than in the previous studies. Presumably, this is because there was a difference in the supply of energy and crude protein from the formula feed.

In this study, the marbling score tended to be high and in proportion to the feed level of the formula, which is thought to be related to the increase in the amount of carbohydrate supply (Table 1) due to the increased feed amount of the formula. In addition, serum glucose has been reported to have an important role in the biosynthesis of adipose tissue in Hanwoo cows [20]. In this study, the serum glucose concentration was higher in the treatment groups than in the control group (Table 3), which is thought to have

Table 4. Effects of nutrient supply level on carcass characteristics in Hanwoo heifers

Item	Treatment[1]			*p*-value
	Control	T1	T2	
Yield traits[2]				
Carcass weight (kg)	368.3±41.0	392.1±47.8	356.1±14.6	0.213
Rib eye area (cm^2)	89.14±9.91	92.60±6.78	84.00±9.25	0.404
Back-fat thickness (mm)	13.43±4.54	12.00±2.99	15.00±3.98	0.978
Yield index (%)	61.18±1.61	61.67±1.16	60.30±1.54	0.973
Grade (A:B:C, %)	2:3:2	2:4:1	1:4:2	-
Quality traits[3]				
Marbling score	4.00±1.29	5.00±1.46	5.33±2.06	0.298
Meat color	5.43±0.53	5.20±0.58	5.00±0.58	0.284
Fat color	3.29±0.76	3.20±0.38	3.00±0.49	0.862
Texture	1.86±0.38	2.00±0.38	1.67±0.53	0.387
Grade (1^{++}:1^+:1:2:3, %)	0:1:4:2	1:3:2:1	2:2:2:1	-
Auction price (Won/kg)	20,117±1,990	21,610±1,912	21,770±2626	0.324

[1]Control: conventional practices, T1: control + 0.5kg, T2: control + 1.0kg; [2]Area was measured from *longissmus* 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 × back fat thickness (mm)) + (0.130 × rib eye area (cm^2)) - (0.024 × dressed weight amount (kg)); Carcass yield grades from C (low yield) to A (high yield); [3]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); quality grades from 3 (low quality) to 1^{++} (very high quality).

Table 5. Effects of feeding level of formula feed on economic efficacy in Hanwoo heifers

Item	Treatment[1]		
	Control	T1	T2
Gross receipts[2] (×1,000won/heifer)	7,500	8,550	7,854
Operating cost[3] (×1,000won/heifer)	6,397	6,391	6,439
Calf	3,278	3,278	3,278
Formula feed	1,815	1,809	1,857
Tall fescue straw	393	393	393
Other	911	911	911
Income (×1,000won/heifer)	1,103	2,159	1,415
Relative income ratio (%)	100	196	128

[1]Control: conventional practices, T1: control + 0.5kg, T2: control + 1.0kg; [2]Selling price of carcass and by product; [3]Feed price (won/kg): concentrate 450; Rice straw 180 Livestock cost(won/kg): 2,561,000, Water, Power & Fuel cost: 72,830 won, Veterinary & Medicine cost: 37,856 won, Automobile cost: 75,842 won, Farm implements cost: 292,894 won, Farm building & Facilities cost: 194,477 won, Miscellaneous materials cost: 98,128 won, Interest on borrowed capital: 57,433 won, Land rent: 3,015 won, Hired labor cost: 11,610 won, Excretion disposal cost: 25,261 won, Production management cost: 42,414 won.

a positive effect on the increase in marbling score.

On the other hand, previous studies [11,21] reported similar results to the present study, in that the carcass weight and marbling score of Hanwoo cows (before 30 months of age) were 314.0 to 362.6 kg and 2.6 to 4.2, respectively.

3.4 Economic efficacy

Table 5 shows the economic effect of nutrient supply level to Hanwoo heifers. The cost of formula feed tended to be higher in the control group that was fed ad libitum after 27 months of age than in treatment group 1 but tended to be lower than that of treatment group 2, which received a large amount of formula feed. Gross receipt and income tended to be higher in treatment group 1 than in the control and treatment group 2, and the relative income ratio in proportion to gross receipt and income improved by 196 and 128% in treatment groups 1 and 2, respectively, compared to the control group (100%).

The reason for the high gross receipt and income was that the carcass weight and the rib eye area were increased in treatment group 1, which was fed an additional 0.5 kg from 17 to 26 months compared to the control group. It is also thought that the marbling score was increased in treatment group 1 by feeding the heifers an additional 0.5 kg from 17 to 22 months and an additional 1.0 kg from 23 to 26 months.

Previous studies [22] support the results of this study by indicating that limited feeding method improves the economic feasibility than *ad libitum* method at fattening period of Hanwo heifer due to the increase in carcass weight and marbling score.

4. Conclusion

The results of this study indicate that a 0.5 kg increase of formula feed from 17 to 26 months of age exerted a positive effect on average daily gain, marbling score, carcass weight, back fat thickness and rib eye area in Hanwoo heifers. However, there was no improvement of growth performance and carcass characteristics in 1.0 kg increase group than 0.5 kg group, thus it was considered that there was no proportional effect according to level of formula feed supply.

Therefore, this study indicate that a 0.5 kg increase in formula feed from 17 to 26 months of age is thought to be available as a feeding strategy to improve economic feasibility through improvement of growth performance and carcass characteristics. In addition, it is nessesary to further studies using sufficient experimental animals to comfirm more precise effect of nutrient supply level.

References

[1] S. W. Kang, Y. K Oh, K. H. Kim, C. W. Choi, & Y. S. Son, Study on Comparison of Growth Performance, Feed Efficiency and Carcass Characteristics for Holstein and F1 (Holstein♀ x Hanwoo♂) Steers and Heifers. *Journal of Animal Science and Technology*, *47*(4), 593-606. 2005. DOI: http://dx.doi.org/10.5187/JAST.2005.47.2.243

[2] W. M. Cho, S. S. Chang, Y. M. Cho, H. C. Kim, E. G. Kwon, S. H. Yang, & B. H. Paek, Effects of forage source and shipping time on growth performance and carcass characteristics of Hanwoo steers. *Journal of the Korean Society of Grassland and Forage Science*, *29*(4), 375-382. 2009. DOI: http://dx.doi.org/10.5333/KGFS.2009.29.4.375

[3] D. J. Kim, C. W. Lee, C. Y. Lee, & J. B. Kim, The influence of carcass traits on carcass price in mature Hanwoo cow. *Journal of Animal Science and Technology*, *52*(2), 157-164. 2010. DOI: http://dx.doi.org/10.5187/JAST.2010.52.2.157

[4] S. W. Kang, H. Y. Jeong, B. S. Ahn, Y. K. Oh, & Y. S. Son, Effects of feeding type of concentrates during growing period and slaughter age on growth performance, feed efficiency and carcass characteristics in growing-fattening Holstein steers. *Journal of Animal Science and Technology*, *46*(6), 989-998. 2004. DOI: http://dx.doi.org/10.5187/JAST.2004.46.6.989

[5] B. K. Kim, C. B. Choi, S. O. Lee, K. H. Baek, D. J. Jung, & E. G. Hwang, Effects of supplementing herbs on growth performances, blood composition and diarrhea in Hanwoo calves. *Journal of Animal Science and Technology*, *53*(5), 451-459. 2011. DOI: http://dx.doi.org/10.5187/JAST.2011.53.5.451

[6] S. M., Lee, S. S. Chang, K. Y. Jung, H. C. Kim, S. H. Choi, E. G. Kwon, B. S. Yang, S. S. Lee, Y. M. Cho, Effects of feeding patterns of concentrate on growth performance, blood parameters and carcass characteristics in fattening Hanwoo cows. *Journal of Animal Science and Technology*, *55*(1), 33-39. 2013. DOI: http://dx.doi.org/10.5187/JAST.2013.55.1.33

[7] C. S. Jeong, S. S. Jang, S. S. Lee, Y. H. Moon, Effects of concentrate feeding level after sexual maturity on the growth and breeding performances, blood composition, and ultrasonic carcass traits in Hanwoo cows. *Journal of Agriculture & Life Science*, *504*, 113-125. 2016. DOI: http://dx.doi.org/10.14397/jals.2016.50.4.113

[8] Ministry of Agriculture, Food and Rural Affairs (MAFRA). Grade Rule for Cattle Carcass in Korea; Korea Ministry of Government Legislation: Seoul, Korea, [cited 2020 Dec. 29], Available From: https://www.law.go.kr/%ED%96%89%EC%A0%95%EA%B7%9C%EC%B9%99/%EC%B6%95%EC%82%B0%EB%AC%BC%20%EB%93%B1%EA%B8%89%ED%8C%90%EC%A0%95%20%EC%84%B8%EB%B6%80%EA%B8%B0%EC%A4%80 (accessed Feb. 20, 2021)

[9] KOSIS. Korea Statistical Information Service https://www.ekapepia.com/priceStat/grade/gradeCowBody.do (accessed July 20, 2021)

[10] D. B. Duncan, Multiple range and multiple F tests. biometrics, 11(1), 1-42. 1955. DOI: http://dx.doi.org/10.2307/3001478

[11] B. H. Choi, B. J. Ahn, K. Kook, S. S. Sun, K. H. Myung, S. J. Moon, J. H. Kim, Effects of feeding patterns and sexes on growth rate, carcass trait and grade in Korean native cattle. *Asian-australasian journal of animal sciences*, *15*(6), 838-843. 2002. DOI: http://dx.doi.org/10.5713/ajas.2002.838

[12] K. Kook, K. H. Kim, Effects of Supplemental Levels of Bamboo Vinegar on Growth Performance, Serum Profile and Meat Quality in Fattening Hanwoo Cow. *Journal of Animal Science and Technology, 45(1),* 57-68. 2003. DOI: http://dx.doi.org/10.5187/JAST.2003.45.1.057

[13] M. A. Ellenberger, D. E. Johnson, G. E. Carstens, K. L. Hossner, M. D. Holland, T. M. Nett, C. F. Nockels, Endocrine and metabolic changes during altered growth rates in beef cattle. *Journal of Animal Science, 67(6),* 1446-1454. 1989. DOI: http://dx.doi.org/10.2527/jas1989.6761446x

[14] E. N. Bergman, Production and utilization of metabolites by the alimentary tract as measured in portal and hepatic blood. *Digestion and Metabolism in the Ruminant.I* 1975.

[15] R. P. Brockman, E. N. Bergman, P. K. Joo, J. G. Manns, Effects of glucagon and insulin on net hepatic metabolism of glucose precursors in sheep. *American Journal of Physiology-Legacy Content, 229(5),* 1344-1349. 1975. DOI: http://dx.doi.org/10.1152/ajplegacy.1975.229.5.1344

[16] M. J. Kim, *A study on relationship of blood metabolites and carcass traits in Hanwoo steers.* MS thesis Kangwon National University. Chuncheon, Korea. 2018.

[17] I. Galli, G. Teira, F. Perlo, P. Bonato, O. Tisocco, A. Monje, S. Vittone, Animal performance and meat quality in cull cows with early weaned calves in Argentina. *Meat science*, 79(3), 521-528. 2008. DOI: http://dx.doi.org/10.1016/j.meatsci.2007.10.007

[18] J. Jeong, S. S. Lee, N. H. Park, N. I. Sung, Y. H. Jang, S. H. Choi, M. K. Song, H. K. Suh, M. I. Lee, Effects of melengesterol acetate, selenium and vitamin E supplemental feeding on growth, carcass and longissimus dorsi muscle traits in Hanwoo cull cows.

Journal of Animal Science and Technology. 48(2), 255-268. 2006.
DOI: https://doi.org/10.5187/JAST.2006.48.2.255

[19] W. G. Moon, B. W. Kim, S. H. Roh, H. S. Kim, D. J. Jung, D. W. Sun, K. N. Kim, Y. T. Yoon, J. H. Jung, J. T. Jeon, J. G. Lee, Estimation of environmental effect and genetic parameters for the carcass traits in Hanwoo (Korean cattle). *Journal of Animal Science and Technology*, 49(6), 689-698. 2007.
DOI: http://dx.doi.org/10.5187/JAST.2007.49.6.689

[20] C. W. Choi, K. H. Baek, S. J. Kim, Y. K. Oh, S. K. Hong, E. G. Kwon, M. K. Song, C. B. Choi, Effects of polyclonal antibodies to abdominal and subcutaneous adipocytes on ruminal fermentation patterns and blood metabolites in Korean native steers. *Journal of Animal Science and Technology*, *51*(3), 231-240. 2009.
DOI: http://dx.doi.org/10.5187/JAST.2009.51.3.231

[21] Y. M. Kim, J. H. Kim, S. C. Kim, H. M. Ha, Y. D. Ko, C. H. Kim, Influence of dietary addition of dried wormwood (Artemisia sp.) on the performance, carcass characteristics and fatty acid composition of muscle tissues of Hanwoo heifers. *Asian-australasian journal of animal sciences*, *15*(4), 549-554. 2002.
DOI: http://dx.doi.org/10.5713/ajas.2002.549

[22] W. K. Cho, S. S. Chang, H. J. Kim, S. J. Lee, S. S. Lee, Y. H. Moon, Effect of Feeding Level of High Energy-TMR for Growing Phase on Growth Performance, Carcass Characteristics and Economic Analysis in Faatening of Hanwoo Heifers. *Jounal of Agriculture & Life Science 52(5),* 51-61. 2018.
DOI: https://doi.org/10.14397/jals.2018.52.5.51

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