

# Effects of Reduced Crude Protein Level in Total Mixed Ration on the Growth Performance and Carcass Characteristics of Hanwoo Steers

Chae Hwa Ryu, Byeonghyeon Kim, Hyunjung Jung, Seul Lee, Youl Chang Baek\*

Animal Nutrition and Physiology Division, National Institute of Animal Science,  
Rural Development Administration, Wanju, Korea

\*Corresponding author: [chang4747@korea.kr](mailto:chang4747@korea.kr)

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**Abstract** This study aimed to determine the effect of regulating crude protein (CP) levels in total mixed ration (TMR) on the growth performance and carcass characteristics of Hanwoo steers. The regimens were divided into a control group (TMR with 15% CP) and treatment group (TMR with 12.5% CP). The viable cell count and fermentation potential of the prepared experimental feed and the nutrient digestibility were evaluated. Growth performance and carcass characteristics were confirmed by evaluating the weight and intake of Hanwoo steers, and an economic analysis was performed. Only CP digestibility was higher in the control group than in the treatment group ( $p < 0.05$ ). There were no significant differences in the initial and final body weights, daily gain, and feed requirements between the groups ( $p > 0.05$ ). There were no significant differences in carcass weight, yield index, back fat thickness, and loin area ( $p > 0.05$ ), but the appearance rate of quality grade A was higher in the treatment group than in the control group. In addition, there was no difference in the meat quality characteristics, such as marbling, meat color, fat color, texture, and maturity ( $p > 0.05$ ), and the treatment group had a higher rate of 1++ grade than the control group. Economic analysis showed that when 10 cattle were shipped, the control group received a price of 100,041 thousand won, and the treatment group received a price of 102,033 thousand won. When the income for each group was calculated, the production cost of the treatment group was 8% lower than that of the control group; thus, a higher net profit could be expected considering the low feed cost. Therefore, the economic feasibility of steer raising could be improved while maintaining productivity by controlling CP levels in feed. In addition, this study provides useful basic data for precisely adjusting the CP levels in feed for Hanwoo steers.

**Keywords:** carcass characteristics, crude protein, growth performance, Hanwoo, total mixed ration

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## 1. Introduction

The Hanwoo feeding program produces high-quality meat through long-term fattening. Cattle raised for more than 30 months are exposed to a variety of diseases, compared with those raised for a short period, but long-term Hanwoo fattening achieves high marbling and high consumer preference [1]. In particular, high-quality Hanwoo beef is sold at a price 2-3 times higher than imported beef. Long-term beef fattening has been preferred in accordance with farmer interest in high-quality meat production since the early 2000s [2].

As feed costs account for a high percentage of the operating costs of Korean cattle farms, countermeasures are needed, but the feed cost ratio is increasing as long-term fattening programs continue. The feed cost ratio

continued to rise from 31.8% in 2005 to 40.6% in 2018, which is a negative factor for farm income [3].

Previous studies showed that increasing farm income requires lower feed costs; therefore, precise feed specifications are required [4]. Precision standards represent appropriate nutrient requirements for improving livestock productivity in a unique environment in Korea [5]. A more precise feeding system in a domestic situation, where most feed materials are imported, would play a very important role in improving livestock competitiveness.

Crude protein (CP) level is a primary factor when determining whether the nutrients supplied to livestock products are insufficient. Knowing exactly how much CP is needed could help farmers raise livestock. Choi *et al.* [6] reported that CP in feed affects meat yield as well as meat quality, which was also reported by Atti *et al.* [7]. However, Gunn *et al.* [8] found that excessive CP management could have a negative economic impact, because high CP in the feed resulted in lower meat

quantity and quality in the treatment group compared to the control group. The CP content in the feed affects feed price. Therefore, regulating CP levels as required is important, because high CP could result in economic loss for farmers.

Studies on CP levels have been conducted in various forms but have been evaluated based on the protein content of each forage and concentrate [6,9,10,11]. In addition, total mixed ration (TMR) shows differences in moisture content compared with concentrate, complicating the application of existing research results. Therefore, in this study, we attempted to determine how TMR protein levels affect the growth performance and carcass characteristics of Hanwoo cattle.

## 2. Materials and Methods

### 2.1. *In vivo* Apparent Digestibility

Four Hanwoo steers (39 months old;  $645.8 \pm 8.82$  kg initial body weight) were used for *in vivo* studies. Each animal was housed in a metabolic cage (127 cm width  $\times$  250 cm depth  $\times$  200 cm height) for collection of the remaining feed and excretions. The animals were fed twice a day (07:00 and 16:00 h) and provided free access to water. According to the Korean Feeding Standard for Hanwoo steer, experimental diets based on 1.0% body weight were supplied by TMR on a dry matter (DM) basis. All excretions were collected to measure the total digestible nutrients. Two  $2 \times 2$  balanced Latin square designs were used for this study, with 14 days in one period, 10 days for feed adaptation, and 4 days for fecal collection. The protocols used for the animal experimental procedures were reviewed and approved by the Institutional Animal Care and Use Committee of the National Institute of Animal Science (NIAS 2019-357).

### 2.2. Growth Performance, Carcass Characteristics, and Economic Analysis

We used TMR in a feeding trial using Hanwoo steers ( $667 \pm 11.7$  kg;  $n = 24$ ; 24 months of age). The experimental animals were divided into two groups ( $n = 12$  each), with an initial body weight. Treatments were divided into two groups depending on the level of CP in TMR (control, 15%; treatment, 12.5%). TMR was prepared by mixing 15% rice straw silage with 85% concentrate for late fattening. The ingredients and chemical composition of the TMR are shown in Table 1. Each steer was fed 8.7 kg per day on a DM basis. The daily ration was split into two feeding times: 07:00 and 16:00 h. Mineral blocks and water were freely available.

Body weight and feed intake were measured at 2-month intervals to calculate daily weight gain and feed requirement.

For evaluation of after-slaughter carcasses, diets were withdrawn from the steers 24 h prior to slaughter. After 48 h post-mortem, each carcass was evaluated for yield and quality grade by official graders according to the Korean Carcass Grading Standards. Economic analysis was conducted based on the meat price on the day of the Korea Institute for Animal Product Quality Evaluation.

### 2.3. Chemical Analysis

TMR was used for chemical analysis. Before nutrient analysis, all samples were dried at 60°C for 48 h and ground in a cyclone mill (Foss, Hillerød, Denmark) fitted with a 1-mm screen. DM (930.15), acid detergent fiber (973.18), ash (942.05), and ether extract (EE; 2003.05) were analyzed, as described by Horwitz and Latimer [12]. Neutral detergent fiber (NDF) was analyzed using a heat-stable amylase and expressed inclusive of residual ash (aNDF) [13]. CP was calculated as 6.25 times the nitrogen content, and total nitrogen was measured using the Dumas combustion method, using an elemental combustor (Vario Max Cube, Elementar GmbH, Frankfurt, Germany). The acid detergent-insoluble CP and neutral detergent-insoluble CP (NDICP) levels in each sample were determined according to the method described by Licitra *et al.* [14]. Non-fiber carbohydrates (NFC) were calculated as  $100 - \text{ash} - \text{EE} - \text{CP} - (\text{aNDF} - \text{NDICP})$  based on the guidelines of NRC [15]. The TMR prepared for the experiment is described in Table 1. Most of the nutrients, except CP, were measured at similar levels. In this study, a price difference of more than 20 won per kg was observed in the high-protein control group compared to the treatment group.

**Table 1. Ingredients and chemical composition of the experimental diets [%]**

Items	CON	TRT
Corn	49.23	49.35
Soybean hull	6.29	14.14
Wheat bran	6.96	4.97
Corn gluten feed	5.77	9.94
Soybean meal	6.96	2.98
Cotton seeds meal	3.18	-
Lupine seeds	4.97	1.99
Vitamin	0.20	0.20
Salt	0.30	0.30
Limestone	0.64	0.64
Sodium bicarbonate	0.50	0.50
Rice straw silage	15.00	15.00
Total	100.00	100.00
DM	68.88	68.83
	..... % DM .....	
CP	15.00	12.63
EE	2.30	2.84
NDF	35.35	33.54
ADF	20.97	20.34
NFC	45.64	50.13
Ash	5.74	5.08
NDICP	4.02	3.11
ADICP	1.80	1.38
Price [won/kg]	390.57	369.85

CON, control; TRT, treatment; DM, dry matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; ADF, acid detergent fiber; NFC, non-fiber carbohydrate; NDICP, neutral detergent-insoluble; CP; ADICP, acid detergent-insoluble CP.

### 2.4. Statistics Analysis

Data were analyzed using Student's unpaired t-test using SPSS software package (version 26 for Windows; SPSS Inc., Chicago, IL, USA). Statistical significance was set at  $p < 0.05$ .

### 3. Results and Discussion

Table 2 shows the apparent digestibility and energy provided from each TMR nutrient with different CP levels. There was no significant difference between the treatments in terms of DM, crude fat, and NDF levels and NFC digestibility. Higher CP digestibility was observed in the control group than in the treatment group ( $p < 0.05$ ). Poos *et al.* [16] demonstrated that DM and protein digestibility could be increased by increasing dietary CP. Additionally, Dabiri and Thonney [17] argued that CP digestibility was higher in the 17% CP group than in the 13% CP group, although the different CP amounts fed did not differ in terms of DM and organic matter digestibility. These results could be attributed to the difference in the CP content in TMR, but there was no difference between the treatments in terms of energy production and total digestible nutrients. Despite the difference in CP in the diet, there was no significant difference in total digestible nutrient. As reported by Derno *et al.* [18], the energy that livestock can digest is limited, and feeding more than that is not positive for ruminant growth. Therefore, CP may not have significantly affected fermentation or growth of the rumen.

**Table 2. Effect of reduced CP level in TMR on the apparent total tract digestibility of nutrients in Hanwoo steers**

Items	CON	TRT	SEM	p-value
DM [%]	70.14	70.30	0.599	0.897
CP [% DM]	65.12	59.68	0.906	<0.05
EE [% DM]	85.96	89.45	1.093	0.118
NDF [% DM]	55.21	52.06	0.941	0.100
NFC [% DM]	87.90	88.35	0.364	0.548
TDN [%]	75.12	74.71	0.575	0.731
DE [Mcal/kg]	3.02	2.99	0.026	0.574

CON, control; TRT, treatment; SEM, standard error of mean; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber; NFC, non-fiber carbohydrate; TDN, total digestible nutrient; DE, digestible energy.

Table 3 shows the growth performance of late-fattening Hanwoo steers after administering the experimental feed for 4 months. There was no significant difference in the initial and final body weights between the control and treatment groups. The treatment group had a higher daily gain than the control group, and the feed requirement in the treatment group was lower than that in the control group. However, the difference was not statistically significant. Lee *et al.* [19] reported that increasing CP in the feed does not affect growth performance. Similarly, in our study, reduced CP level in the feed did not affect the growth of Hanwoo steers.

The carcass characteristics of each treatment group are shown in Table 4. There were no significant differences between the treatment groups in terms of carcass weight, loin area, back fat thickness, and yield index. However, the rate of yield grade A was 8% in the control group and 33% in the treatment group. Regarding meat quality characteristics, there was no significant difference in the marbling score, meat color, fat color, texture, and maturity between the treatment groups. Regarding quality grade, the rate of 1++ grade was 15% in the control group and 25% in the treatment group. The treatment group was fed a low-CP diet, which had no negative effects on growth and carcass performance compared to the control group, but a positive impact on the quantity and quality grade of meat was observed.

**Table 3. Effects of reduced CP level in TMR on the growth performance of Hanwoo steers**

Items	CON	TRT	SEM	p-value
IBW [kg]	676.38	655.18	11.739	0.380
Period 1 (0–2 months)				
ADG [kg/day]	0.73	0.81	0.038	0.326
FR [kg/day]	23.20	19.20	0.730	0.264
FBW [kg]	722.42	706.00	12.523	0.526
Period 2 (2–4 months)				
ADG [kg/day]	0.76	0.81	0.040	0.560
FR [kg/day]	22.60	19.10	0.755	0.326
FBW [kg]	778.81	765.95	13.148	0.637
Over all (0–4 months)				
ADG [kg/day]	0.75	0.81	0.029	0.297
FR [kg/day]	22.10	18.70	0.384	0.302

CON, control; TRT, treatment; SEM, standard error of mean; IBW, initial body weight; ADG, average daily gain; FR, feed requirement; FBW, final body weight.

**Table 4. Effect of reduced CP level in TMR on the carcass characteristics of Hanwoo steers**

Items	CON	TRT	SEM	p-value
Yield traits				
Carcass weight [kg]	478.38	466.83	7.917	0.478
Loin area [cm <sup>2</sup> ]	94.38	97.08	1.882	0.486
Backfat thickness [mm]	15.15	12.50	1.001	0.191
Yield index	60.67	61.66	0.312	0.116
Yield grade (A:B:C) [%]	8:54:38	33:59:8	-	-
Quality traits				
Marbling score	5.69	5.83	0.318	0.830
Meat color	4.62	4.75	0.095	0.492
Fat color	3.00	3.00	0.000	1.000
Texture	1.00	1.17	0.055	0.136
Maturity	2.31	2.42	0.098	0.589
Meat grade (1 <sup>++</sup> :1 <sup>+</sup> :1:2) [%]	15:38:46:0	25:17:58:0	-	-

CON, control; TRT, treatment; SEM, standard error of mean.

The average wholesale prices as per 1 kg of Livestock Quality Assessment Service in October 2020 were 23,927 won (21.8 USD) for 1++ quality grade, 21,804 won (19.8 USD) for 1+ grade, 20,290 won (18.4 USD) for grade 1, 16,822 won (15.3 USD) for grade 2, and 13,105 won (11.9 USD) for grade 3 of 1 kg beef. Table 5 shows the grade evaluation results for the control and treatment groups. The 1++ grade contribution rate in the low-CP treatment group was 25%, and the rates of grade 1+ and grade 1 were 17% and 58%, respectively. The quality grade rates in the control group with high CP levels were 15% 1++ grade, 38% 1+ grade, and 46% 1 grade, and economic feasibility was analyzed based on the appearance rate of each grade. When 10 Hanwoo steers in were shipped to each treatment group, the control group received a price of 100,041 thousand won (90,946 USD), and the treatment group received a price of 102,033 thousand won (92,757 USD). When calculating the income for each group, the treatment group obtained an additional profit of 1,992 thousand won (1,811 USD) compared with the control group, and a higher net profit could be expected considering the low unit price of feed. Therefore, TMR with low-CP levels for late-fattening of Hanwoo steers may have a positive effect on the profitability of farmers.

**Table 5. Economic benefits from Hanwoo steers fed with TMR containing reduced CP level (control and treatment groups)**

Carcass grade	Carcass price [won/kg] (USD/kg)	Average carcass weight [kg/head]	Quality grade appearance rate [%]		Yield price [× 1,000 won] (USD)	
			CON	TRT	CON	TRT
1 <sup>++</sup>	23,927 (21.8)	483	15	25	17,334 (15,758)	28,891 (26,265)
1 <sup>+</sup>	21,804 (19.8)	462	38	17	38,279 (34,799)	17,125 (15,568)
1	20,290 (18.4)	476	46	58	44,427 (40,388)	56,017 (50,924)
Sum	-	-	100	100	100,041 (90,946)	102,033 (92,757)

CON, control; TRT, treatment. Economic analysis was performed based on the productivity of breeding 10 herds, and the used price status was based on the price in 2020, 1 USD = 1,100 won.

## 4. Conclusion

The decreased CP levels in the TMR in the late-fattening period of Hanwoo steers showed a similar effect. Economic evaluation was performed using the meridian price, including the quantity and quality of meat, and higher profits were obtained in the treatment group than in the control group. Considering the feed cost, it is expected that the interval between treatments could be longer. Therefore, this study provides useful basic data for the suggested CP levels in feed for Hanwoo steers.

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