Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1806-2636
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v39i3.35405

Growth performance, meat quality, and carcass characteristics in growing and fattening Hanwoo steers fed bentonite

Kim Young-Jik[1], Jang Woo-Whan[2], Chung Tae-Ho[3*] and Choi In-Hag[3*]

[1]Departamento de Recursos Animais, Daegu University, Gyeongsan-si, South Korea. [2]Departamento de Economia Agrícola, Kyungpook National University, Daegu-si, South Korea, [3]Departamento de Companhia Animal e Ciências de Recursos Animais, Joongbu University, Geumsan-gun, 32713, South Korea. *Author for correspondence. E-mail: wicw@chol.com and taehochung@daum.net

ABSTRACT. Thirty-six castrated, seven months-old Hanwoo steers (initial body weight: 184 ± 5.2kg) were assigned to three treatments over 23 months to evaluate the effects of supplementation with bentonite (0, 0.1 and 0.3%) on growth performance and carcass and meat characteristics. A completely randomized design with three replicates was used. The inclusion of a bentonite-supplemented diet had an influence on final weight, total weight gain, and average daily gain. Bentonite supplementation had no significant effect on proximate composition and meat quality. For carcass characteristics, there were no significant differences in yield traits and quality traits between treatments (but not cold carcass weight, marbling score, and quality grade). It was concluded that supplementation with bentonite (0.1 and 0.3%) improved growth performance, cold carcass weight, marbling score and quality grade compared with the control, except for meat quality.

Keywords: bentonite, Hanwoo steers, quality traits, yield traits.

Desempenho, qualidade da carne e características de carcaça em novilhos Hanwoo em crescimento e engorda alimentados com bentonita

RESUMO. Para avaliar os efeitos da suplementação com bentonita (0, 0,1 e 0,3%) sobre o desempenho de crescimento e características da carcaça e da carne, foram avaliados 36 novilhos Hanwoo, castrados, com sete meses de idade (peso inicial: 184 ± 5,2 kg) distribuídos nos três tratamentos. Utilizou-se um delineamento inteiramente casualizado com três repetições. A inclusão de uma dieta suplementada com bentonita teve influência no peso final, ganho de peso total e ganho médio diário. A suplementação com bentonita não teve efeito significativo na composição centesimal e na qualidade da carne. Para as características de carcaça, não houve diferenças significativas nas características de rendimento e de qualidade entre os tratamentos (mas não o peso da carcaça fria, nível de marmoreio e grau de qualidade). Concluiu-se que a suplementação com bentonita (0,1 e 0,3%) melhorou o desempenho de crescimento, peso de carcaça fria, nível de marmoreio e grau de qualidade em relação ao controle, com exceção da qualidade da carne.

Palavras-chave: bentonita, novilho Hanwoo, características de qualidade, características de rendimento.

Introduction

Bentonites are a clay raw material with strong colloidal characteristics that increase absorption and have high ion exchange capacity because of the presence of hydrated cations (Tiller, Gerth, & Brummer, 1984). Bentonite mostly consists of silicon dioxide (SiO_2), magnesium oxide (MgO), aluminum oxide (Al_2O_3) and sodium oxide (Na_2O) (European food safety authority [EFSA], 2012).

Several studies have demonstrated that bentonites have the ability to absorb toxic products during digestion and to decrease the accumulation of toxic substances in tissues, which results in the reduction of internal disorder occurrences (Fenn & Leng, 1989; Walz, White, Fernandez, Gentry, & Blouin, 1998). For example, bentonites in animal diet effectively bind aflatoxins from the animals' digestive tract, which makes mycotoxins unavailable for absorption. This led to the reduction of their absorption into the organism due to its adsorbent capability (Grant & Phillips, 1998; Phillips, Lemke, & Grant, 2002). Therefore, the addition of bentonite could be used as a dietary supplement in animal rations to improve their nutritive value. Moreover, after supplementation of diets with bentonite or peat with minerals, an improvement in productivity, meat quality, and carcass characteristics has been observed in swine and Hanwoo steer (Kim, Lee, Song, & Cho, 2000; Kang et al., 2002; Lee, Kim, &

Kwak, 2010). This means that bentonite supplementation is a potential method to improve the quality of meat from slaughtered animals.

The use of bentonites as feed additives for all animal species has been proposed. However, EFSA (2011) recommended a maximum level of 0.5% bentonite to be safe for all animal species because of the inconsistency in the currently available data. Thus, using a bentonite (under 0.5%) supplement in a direct-rice straw-based diet might enhance the growth performance and improve meat quality in Hanwoo steer. The objective of this investigation was to evaluate the effects of supplementation with bentonite on growth performance and the carcass and meat characteristics of growing and fattening Hanwoo steers.

Material and methods

Animal experiment and treatment

The experimental protocol was approved by the Taemok farm animal care committee and the animals were conducted according to guidelines of the Taemok Farm Council on Animal Care (Reference No.12-01, Yeongcheon, South Korea). The study included 36 castrated, 7 months-old Hanwoo steers (initial live weight: 184 ± 5.2 kg), that were assigned to three different treatments three replications using a completely randomized design. The treatments were kept in 9 pens with four Hanwoo steers per pen in a stall with a slatted floor.

The animals were fed one of three diets; the control group received a concentrate mix and rice straw, the first treatment group (T1) received the control diets plus 0.1% bentonite, the second treatment group (T2) received the control diets plus 0.3% bentonite. These dietary treatments were given as growing (8 months), fattening (8 months), and finishing (7 months) phase in experiment of Hanwoo steer. The chemical composition of the experimental diets for growing, fattening, and finishing Hanwoo steer are present in Table 1.

Table 1. Chemical composition of experimental diets (Dry matter, g kg^{-1}).

Item	Growing period	Finishing period
Dry matter	887.6	877.5
Crude protein	163.5	146.4
Ether extract	61.5	38.2
Crude ash	64.7	56.2
Ca	12.0	10.0
P	5.8	5.0

Animals were fed twice a day at 9 and 17h and had free access to fresh water during the whole period.

The chemical composition of the rice straw used in this experiment was 43.3 crude protein (CP, g kg^{-1}), 15.5 ether extract (EE, g kg^{-1}), and 150.1% crude ash (CA, g kg^{-1}). The bentonite was a purified powder formulated for animal use, obtained from Donghae Material Co. (Gyeong San, South Korea). The bentonite composition was: 66.54% SiO_2, 20.47% Al_2O_3, 3.18% Fe_2O_3, 3.85% CaO, 2.95% MgO, 0.19% K_2O, 2.79% Na_2O, and 0.03% MnO.

For growth performance, Hanwoo were weighed monthly throughout the study. The total body weight gain and average daily gain were calculated as the difference between the final body weight and the initial body weight divided by the length of the experimental period.

Carcass evaluation, analytical procedures and sample preparation

Chemical analysis (for dry matter, crude protein, ether extract, crude ash, Ca, and P) of experimental diets was performed according to the methods of Association of Official Analytical Chemists (AOAC, 2005). To determine meat and carcass characteristics, the Hanwoo were fasted for 24h at the end of the experimental period before slaughter. Thirty-six castrated Hanwoo were transferred to a local municipal slaughterhouse and slaughtered using conventional methods. After slaughtering, carcasses were washed and immediately moved to a chilling room. After a 24-h period of carcass chill, cold carcass weights were measured. Meat samples were obtained to determine moisture, crude protein, and ether extract, following the methods of AOAC (2005). The pH of each sample was determined 24h postmortem using a pH meter. Approximately 10 g of minced meat was mixed with 90 mL of distilled water and homogenized for 1 min. The pH values were measured immediately.

At the same time, about 100 g of meat samples for determination of cooking loss were placed in a polyethylene bag. The samples were placed in a water bath at 70°C for 30 min. and cooled at room temperature for 30 min. Cooking loss percentage was determined as the ratio of the difference of meat before and after cooking. Shear force values were measure with a rheometer (CR-300, Sun Scientific Co., Tokyo, Japan). Load cell with 5 kg applied at a cross-head speed of 30 mm $min.^{-1}$. Each core sample was sheared parallel to the muscle fibers. Water holding capacity (WHC) was analyzed using a modification of the method described by Kristensen and Purslow (2001). A 0.3 g sample of ground meat was placed in a filter-press device and compressed for 2 min. WHC was calculated from duplicate samples as a ratio of the meat film area to the total area. WHC (%) was calculated using the following equation: WHC (%) = 100 − (total meat area/meat film area × 100).

The yield and quality grade of each carcass were evaluated using the Korean carcass grading procedure classified in the Korean Livestock Enforcement Regulation (KMAF, 2007). The left side of the carcass was cut between the 13th rib and the 1st lumbar vertebrae to measure backfat thickness and the *longissimus* muscle area. Yield index was calculated as follows:

Yield index = 68.184 – (0.625 × back fat thickness (mm)) + (0.130 × *longissimus* muscle area (cm^2)) – (0.024 × cold carcass weight (kg)) + 3.23.

Yield grades were divided into three groups: grade A (lean; higher than 67.5), grade B (higher than 62.0 and lower than 67.5), and grade C (fat; lower than 62.0). The degree of marbling was determined according to the Korean Beef Marbling Standard (Korea Institute for Animal Products Quality Evaluation [KAPE], 2012). Marbling score was graded from 1 (poor) to 9 (excellent), with 9 being the highest higher numbers for better quality. The scores of meat and fat color were measured according to the color standard (KAPE, 2012). The score of meat color range goes from 1 (scarlet) to 7 (dark red) and fat color can be graded from 1 (white) to 7 (dark yellow). The scores for texture ranged from 1 (good) to 3 (bad) and maturity is graded from 1 (fully mature) to 9 (least mature), according to the KAPE reference index (KAPE, 2012). For Korean quality grade, five quality grade groups of carcasses were classified as 1++ (best), 1+, 1, 2 and 3 (poorest).

Statistical analysis

The three treatments were allocated to Hanwoo steers according *to* a completely randomized design. Pen (n=4) means was considered as the experimental unit for statistical analysis. All data were subjected to analysis of variance according to the General Linear Model procedure (Statistical Analysis System [SAS], 2002). The mean values of the different treatments were compared using Duncan's multiple range test at $p < 0.05$ level.

Results and discussion

Growth performance of Hanwoo steers supplemented with bentonite during the complete growth period is presented in Table 2.

Initial body weight was not different among treatments ($p > 0.05$). The inclusion of 0.1% and 0.3% bentonite in a diet has an influence on final body weight, total body weight gain, and average daily gain compared with the controls. The data clearly showed that dietary supplementation with bentonite improves growth performance of Hanwoo steers. In the current study, the improvement in growth performance might be due to bentonite activity, which resulted in the enhanced digestibility of nutrients owing to a delay in the passage of food particles through the gut. These findings disagree with the results of Lee et al. (2010) who found no differences in body weight gain of Hanwoo steers after supplementation with 1% bentonite and concentrate mix during the feeding trials. Berthiaume, Ivan, and Lafrenière (2007) also reported that the average daily gain (ADG) was not affected by the supplementation with bentonite neither in any particular period nor overall, and there was no remarkable interaction between silage types and bentonite additives for this variable.

The comparison of the two levels of bentonite showed no significant effect ($p > 0.05$) in growth performance. According to Southern, Ward, Binde, and Hebert (1994), the addition of bentonite (5% levels) to chicken fed different-type nutient deficient diets can improve growth performance. The studies regarding the efficacy of bentonite are inconsistent. The variation in growth performance may be explained by the type of animal diets and the different levels of bentonite used. In order to evaluate the effectiveness of bentonite supplementation, it is necessary to understand the correlation between present and previous studies that may play a relevant role.

Table 2. Growth performance of Hanwoo steers supplemented with bentonite during the whole period.

Item	Treatment[1)]		
	Control	T1	T2
Initial body weight (kg)	185.21±46.27	186.29±35.48	183.29±34.24
Final body weight (kg)	745.67±43.36^b	790.26±35.10^a	810.66±38.90^a
Total body weight gain (kg)	560.50±34.20^c	603.97±38.24^b	627.37±39.10^a
Average daily gain (kg)	0.81±0.03^b	0.87±0.02^a	0.90±0.05^a

Means±SD (Standard Deviation). a-cMeans with the different superscripts in the same line are significantly different ($p < 0.05$). 1)Control: basal concentrate; T1: 0.1% bentonite powder; T2: 0.3% bentonite powder.

Table 3. Proximate composition and meat quality in the *longissimus* muscle of Hanwoo steers supplemented with bentonite.

Item	Treatment[1)]		
	Control	T1	T2
Proximate composition			
Moisture (%)	63.80±2.43	64.31±1.64	63.81±3.53
Crude protein (%)	20.22±1.22	19.76±1.62	19.23±2.79
Ether extract (%)	15.00±2.61	15.05±3.28	16.15±2.41
Meat quality			
pH	5.60±0.05	5.65±0.02	5.55±0.03
Cooking loss (%)	17.94±3.21	18.34±2.64	17.56±4.89
Shear force (kg cm-2)	3.84±0.99	3.83±0.68	3.83±1.04
Water holding capacity (%)	57.15±12.55	58.66±13.25	57.35±13.88

Means±SD (Standard Deviation). aMeans with the different superscripts in the same line are not significantly different (p > 0.05). 1)Control: basal concentrate; T1: 0.1% bentonite powder; T2: 0.3% bentonite powder

Table 3 shows the approximate composition and meat quality of the *longissimus* muscle of Hanwoo steers supplemented with bentonite. However, no effect (p > 0.05) of the bentonite supplement was noticed for proximate composition. In the current study, no significant difference in the pH, cooking loss, shear force and water holding capacity values (p > 0.05) was observed among treatments. In other words, the addition of bentonite to the diets of growing and fattening Hanwoo steer did not affect meat quality. Kim et al. (2014) performed a study where pigs were fed with Kaolinite (Macsumsuk) and herb mixtures, and reported that there was no significant reduction in cooking loss of the pork from that the control, except for shear force and water holding capacity.

Table 4. Carcass characteristics for Hanwoo steers supplemented with bentonite.

Item	Treatment[1)]		
	Control	T1	T2
Cold carcass weight (kg)	439.94±36.33^b	466.20±35.24^a	478.29±41.33^a
Yield traits			
Backfat thickness (mm)	11.86±3.20	12.10±4.54	13.88±5.91
Longissimus muscle area (cm^2)	96.58±4.20	99.50±6.13	105.00±8.74
Yield index	65.87±2.65	66.64±1.72	65.29±3.52
Yield grade[2)]	1.87±0.66	2.25±0.50	2.28±0.15
Quality traits			
Marbling score[3)]	5.23±1.21^b	6.89±1.16^a	7.12±1.14^a
Meat color[4)]	5.35±0.53	5.12±0.64	4.87±0.43
Fat color[5)]	3.12±0.43	3.56±0.29	3.31±0.28
Texture[6)]	1.38±0.88	1.25±0.54	1.29±0.46
Maturity[7)]	2.12±0.13	2.35±0.46	2.44±0.03
Quality grade[8)]	2.62±0.29^b	3.19±0.34^a	3.31±0.20^a

Means±SD (Standard Deviation). a-bMeans with the different superscripts in the same line are significantly different(p < 0.05). [1)]Control: basal concentrate; T1: 0.1% bentonite powder; T2: 0.3% bentonite powder. [2)]Scored: grade A = 1 (lean), B = 2, C = 3 (fat). [3)]Scored: grade 1 = poor, grade 9 = excellent. [4)]Scored: grade 1 = scarlet, grade 7 = dark red. [5)]Scored: grade 1 = white, grade 7 = yellow. [6)]Scored: grade 1 = good, grade 3 = bad. [7)]Scored: grade 1 = fully mature, grade 9 = least mature. [8)]Scored: grade 1++ = 4, 1+ = 3, 1 = 2, 2 = 1.

Table 4 summarizes the characteristics of Hanwoo steers supplemented with bentonite. Cold carcass weight, marbling scores and quality grade were significantly different among treatments (p < 0.05), and treatments with 0.3% bentonite had more cold carcass weight (478.29 kg), marbling score (7.12) and quality grade (1+=3.31) than other treatments. This may be due to the increase in growth performance observed in Hanwoo steers fed diets with 0.3% bentonite. Marbling scores are often used as the primary predictor of beef palatability among carcasses or as the most important factor in evaluating the beef quality (tenderness, juiciness, flavor, maturity and color of fat) as mentioned by the United States Standards (USDA, 2001) and Kim and Lee (2003). Lee et al. (2010) and Kwak, Kim, Lee, Lee, & Choi (2015) observed no effect of the dietary supplementation of Na-bentonite or a trace minerals-fortified microbial culture (TMC) on carcass yield and quality traits of Hanwoo steer.

In contrast to our expectations, all treatments had no effect (p > 0.05) on yield traits (backfat thickness, *longissimus* muscle area, yield index and yield grade) and quality traits (meat color, fat color, texture and maturity). However, backfat thickness, *longissimus* muscle area, yield grade and maturity tended to increase with increasing levels of bentonite, while meat color gradually tented to reduce as bentonite levels increased (but not yield index, fat color and texture). These results are in accordance with that of Walz et al. (1998) in which the inclusion of 0.75% clay mineral to lamb diets had no significant effect on *longissimus* muscle area, backfat thickness, and yield grade. Constantino et al. (2014) did not observe any significant difference in cold carcass weight, marbling, and fat thickness in ewes supplemented with magnesium oxide.

With the exception of certain parameters such as cold carcass weight, marbling score and quality grade, the effects of bentonite additives on yield traits and quality traits of growing-fattening Hanwoo steer is still unknown.

Conclusion

Supplementation of Hanwoo steer diets with bentonite did bring slight improvement in growth performance, carcass weight, marbling score and quality grade compared with controls. However, growth performance, meat quality, and carcass characteristic were not affected by the inclusion of 0.3% bentonite in comparison with 0.1% bentonite in Hanwoo steer diets.

Acknowledgements

This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project title: Functional feed material development and efficacy evaluation for detector dog's ability improvement, Project No: PJ011989)" Rural Development Administration, Republic of Korea.

References

Association of Official Analytical Chemists [AOAC]. (2005). *Official methods of analysis* (18th ed.). Washington, DC: AOAC.

Berthiaume, R., Ivan, M., & Lafrenière, C. (2007). Effects of sodium bentonite supplements on growth performance of feedlot steers fed direct-cut or wilted grass silage based diets. *Canadian Journal of Animal Science*, *87*(4), 631-638.

Constantino, C., Azambuja Ribeiro, E. L., Bridi, A. M., Tarsitano, M. A., Castro, F. A. B., Pereira, E. S. (2014). Performance, carcass and meat quality of ewes supplemented with magnesium oxide. *Revista Brasileira de Zootecnia*, *43*(1), 27-35.

European Food Safety Authority [EFSA]. (2011). Scientific Opinion on the safety and efficacy of bentonite (dioctahedral montmorillonite) as feed additive for all species. *EFSA Journal*, *9*(2), 2007.

European food safety authority [EFSA]. (2012). Scientific opinion on the safety and efficacy of bentonite as a technological feed additive for all species. *EFSA Journal*, *10*(7), 2787.

Fenn, P. D., & Leng, R. A. (1989). Wool growth and sulphur amino acid entry rate in sheep fed roughage based diets supplemented with bentonite and sulphur amino acids. *Australian Journal of Agricultural Research*, *40*(4), 889-896.

Grant, P. G., & Phillips, T. D. (1998). Isothermal adsorption of aflatoxin B(1) on HSCAS clay. *Journal of Agricultural and Food Chemistry*, *46*(2), 599-605.

Kang, S. W., Kim, J. S., Cho, W. M., Ahn, B. S., Ki, K., & Son, Y. S. (2002). Effect of domestic clay minerals on growth performance and carcass characteristics in growing-fattening Hanwoo steers. *Journal of Animal Science and Technology*, *44*(3), 327-340.

Kim, B. K., Hwang, E. G., Jung, D. T., Ha, J. J., Oh, D. Y., & Choi, C. B. (2014). Effects of Kaolinite (Macsumsuk) and herb mixtures on the quality and physicochemical properties of pork. *Korean Journal for Food Science of Animal Resources*, *34*(3), 395-402.

Kim, C. J., Lee, E. S., Song, M. S., & Cho, J. K. (2000). Effects of illite supplementation on the meat quality of finishing pigs. *Korean Journal for Food Science of Animal Resources*, *20*(2), 152-158.

Kim, C. J., & Lee, E. S. (2003). Effects of quality grade on the chemical, physical and sensory characteristics of Hanwoo (Korean native cattle) beef. *Meat Science*, *63*(3), 397-405.

Korea Institute for Animal Products Quality Evaluation [KAPE]. (2012). *The beef carcass grading*. Retrieved on May 15, 2012 from www.kormeat.co.kr/01-intro/13-2.asp

Korean Ministry of Agriculture and Forest [KMAF]. (2007). *Carcass grading standards.* Livestock Regulation Practice (Appendix no. 4). Sejong, KOR: KMAF.

Kristensen, L., & Purslow, P. P. (2001). The effect of ageing on the water-holding capacity of pork: role of cytoskeletal proteins. *Meat Science*, *58*(1), 17-23.

Kwak, W. S., Kim, Y. I., Lee, S. M., Lee, Y. H., & Choi, D. Y. (2015). Effect of feeding a mixed microbial culture fortified with trace minerals on the performance and carcass characteristics of late-fattening Hanwoo steers: a field study. *Asian Australasian Journal of Animal Science*, *28*(11), 1592-1598.

Lee, S. M., Kim, Y. I., & Kwak W. S. (2010). Effects of Dietary Addition of bentonite on manure gas emission, health, production, and meat characteristics of Hanwoo (*Bos taurus coreanae*) Steers. *Asian-Australasian Journal of Animal Science*, *23*(12), 1594 -1600.

Phillips, T. D., Lemke, S. L., & Grant, P. G. (2002). Characterization of clay-based enterosorbents for prevention of aflatoxicosis. *Advances in Experimental Medicine and Biology*, *504*(1), 157-171.

Statistical Analysis System [SAS]. (2002). *SAS User's Guide*. Cary, NC: SAS.

Southern, L. L., Ward, T. L., Binde, T. D., & Hebert, L. G. (1994). Effect of sodium bentonite or hydrated sodium calcium aluminosilicate on growth performance and tibia mineral concentration in broiler chicks fed nutrient deficient diets. *Pouytry Science,* *73*(6), 848-854.

Tiller, K., Gerth, J., & Brummer, G. (1984). The relative affinities of Cd, Ni, and Zn for different soil fractions and goethite. *Geoderma, 34*(1) 17-35.

United States Department of Agriculture [USDA]. (2001). *United States standards for grades of carcass beef.* Retrieved on March 13, 2001, from www.ams.usda.gov/lsg/stand/standards/beefcar. pdf

Walz, L. S., White, T. W., Fernandez, J. M., Gentry, L. R., & Blouin, D. C. (1998). Effects of fish-meal and sodium bentonite on daily gain, wool growth, carcass characteristics and ruminal and blood characteristics of lambs fed concentrate diets. *Journal of Animal Science*, *76*(8), 2025-2031.

Received on January 30, 2017.
Accepted on April 4, 2017