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RESEARCH OPINIONS IN ANIMAL & VETERINARY SCIENCES

Effects of a by-product feed-based silage diet on the performance, blood metabolites, and carcass characteristics of Hanwoo heifers (a field study)

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Abstract

This study was conducted to determine the effects of a by-product feed (BF) based silage diet on the performance, blood metabolite parameters, and carcass characteristics of Hanwoo heifers. The BF-based silage was composed of 50% spent mushroom substrate, 21% recycled poultry bedding, 15% cut ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial additive (on a wet basis), and ensiled for over 5 d. Twelve heifers were allocated to three diets during the growing and fattening periods (6.2 and 8.8 months, respectively): a control diet (concentrate mix and free access to rice straw), a 50% BF-based silage diet (control diet + 50% of maximum BF-based silage intake), and a 100% BF-based silage diet (concentrate mix and *ad libitum* BF-based silage). The BF-based silage was fed during the growing and fattening periods and was replaced with rice straw during the finishing period. After 22.4 months, the resulting steers were slaughtered. Compared with the control diet, the 100% BF-based silage diet significantly increased the average daily gain and feed efficiency of the heifers by 27 and 18% respectively ($P<0.05$), due to an increase in voluntary feed intake. Compared with the control diet, the BF-based silage diet had little effect on levels of serum constituents, electrolytes, or enzymes or on blood cell profiles in growing heifers. The BF-based silage diet did not affect cold carcass weight, yield traits such as back fat thickness, longissimus muscle area, yield index, and yield grade, or quality traits such as meat colour, fat colour, texture, maturity, marbling score, and quality grade. In addition, good quality meat was more frequently obtained when the heifers were fed the BF-based silage diet (75% for the control group vs. 100% for the BF-based silage-fed groups). In conclusion, BF-based silage can be used as a good quality roughage source for Hanwoo heifers.

Keywords: Spent mushroom substrates; by-product feed; silage; meat quality; heifer; Hanwoo

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Introduction

For the stable development of the Korean beef cattle industry, it will be necessary to find ways to reduce Hanwoo herd size. Thus, there is an increased demand for the development of methods for fattening Hanwoo heifers. Feeding good quality roughage to growing beef cattle can be an important way to produce well-marbled beef. For example, feeding good quality timothy hay to Hanwoo steers during the growing period improves growth and meat quality (Matsumoto, 1999; Kim, 2006). In addition, replacing poor quality rice straw with proteinaceous timothy and alfalfa hay increases body weight gain and produces well-marbled beef (Kim et al., 2007a; Oh et al., 2007).

The use of cheap by-product feed, such as spent mushroom substrate (SMS), can reduce feed costs. However, sawdust-based SMS contains too much moisture (over 60%) and neutral detergent fibre (NDF, 78.2%), and not enough crude protein (CP, 7.2%) (Bae et al., 2006). In

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addition, the storage of SMS is problematic, as SMS putrefies quickly due to its high moisture content (Kwak et al., 2008). Therefore, to improve the nutritive quality of sawdust-based SMS, it should be mixed with other complementary feed sources.

Previous studies have reported that cheap, good quality by-product feed (BF)-based roughage can be successfully manufactured by ensiling SMS, recycled poultry bedding (RPB), rice bran, and a minimal amount of straw with added molasses and highly cellulolytic microbes isolated from SMS (Kim et al., 2007b, 2008, 2014a). The silage exhibits favourable ensiling characteristics and has a higher degradability of dry matter (DM) and CP than do rice straw or ryegrass straw (Kim et al., 2014a). When compared with a rice straw diet, a BF-based silage diet tends to increase feed intake, growth, and feed efficiency in growing steers, has little effect on levels of serum constituents, electrolytes, or enzymes or on blood cell profiles in the fattening steers, has little effect on carcass yield traits or quality traits in finishing steers, and leads to high rates of obtaining good quality meat at slaughter (Kim et al., 2014b). However, no information is available on the effects of a BF-based silage diet on Hanwoo heifers. Thus, this study was conducted to determine the effects of a BF-based silage diet on the performance, blood metabolite parameters, and carcass characteristics of Hanwoo heifers.

Materials and Methods

Manufacture of BF-based silage

The SMS was collected fresh from a local oyster mushroom (*Pleurotus ostreatus*) farm. The original mushroom substrate consisted of 47% sawdust, 18% kapok meal, 18% beet pulp, 13% corncobs, and 4% cottonseed meal. BF-based silage was manufactured as described in Kim et al. (2014a) at the Konkuk University experimental farm located in Chung-Ju City in Chung-Buk province. The SMS (50%) was mixed with RPB (21%), ryegrass straw (15%), rice bran (10.8%), molasses (2%), bentonite (0.6%), and microbial additive (0.6%), and ensiled in two folds of polyvinyl bags that were placed in a 1-ton capacity plastic bag for 5 d to 4 wk.

The microbial inoculants used in this experiment had been isolated and identified previously in our lab (Kim et al., 2007b, 2008) and included highly cellulolytic bacteria such as *Enterobacter ludwigii* KU201-3, *Bacillus cereus* KU206-3, *Bacillus subtilis* KU201-7, *Bacillus subtilis* KU3, *Saccharomyces cerevisiae*, and *Lactobacillus plantarum*. Each strain was mixed at 0.12%. *Bacillus* sp. and *Enterobacter* sp. were incubated in plate count broth (5 g casein, 2.5 g yeast extract, 1 g/l dextrose) at 36°C for 24 h, *Saccharomyces* sp. was cultured in yeast malt broth (Difco Laboratories Inc., Detroit, MI, USA) at 30°C for 48 h, and *Lactobacillus* sp. was cultured in MRS broth (Difco Laboratories Inc.) at 36°C for 24 h.

Animals and treatments

All animal care protocols were approved by the Konkuk University Institutional Animal Care and Use Committee. Six to seven-month old Hanwoo heifers were acclimatized to the experimental farm over 1.5 months. A limited number of experimental animals were used to reduce erroneous factors and control the practical onsite farm situation. Twelve Hanwoo heifers (mean age, 7.9 months; mean body weight [BW], 192.8 ± 1 kg) were randomly assigned to three pens (4 heifers/pen/treatment). Each pen was 48 m^2 in area (4 m × 12 m). The feeding phases were as follows: growing period, 6.2 months; fattening period, 8.8 months; and finishing period, 7.3 months.

Heifers were fed one of three diets: a control diet (formulated concentrate mix and free access to rice straw), a 50% BF-based silage diet which consisted of the control diet + 50% of the maximum BF-based silage intake, and a 100% BF-based silage diet, which consisted of concentrate mix and *ad libitum* BF-based silage as a roughage source. The BF-based silage diet was fed during the growing and fattening periods and was replaced with the control diet during the finishing period. During the growing and fattening periods, heifers fed the control diet had free access to rice straw, but during the finishing period, they were restricted to 1.0–1.2 kg/day (as-fed basis). Alfalfa hay (0.5 kg per head) was fed to all groups during the growing period. Microbial culture (2–3% of DM intake [DMI]) was fed to all groups from 15 months of age to the end of the experiment.

The amount of concentrate mix in the diet was calculated based on BW, and all the groups were fed the same amount of concentrate mix. The growing period was from 7.9 to 14.2 months of age, during which time all the animals were fed a mean concentrate mix of 1.7% (as-fed basis) of BW. The fattening period was from 14.2 to 23.0 months of age, during which all the animals were fed a mean concentrate mix of 1.85% of BW. The finishing period was from 23.0 to 30.3 months of age, during which the animals had free access to the concentrate mix. Concentrate mix availability was limited during the growing and fattening periods, in order to prevent excessive weight gain. The total experimental feeding period was 22.3 months.

Feed was supplied twice a day (07:00 and 18:00). Animals had free access to fresh water. The BW of the heifers was measured monthly throughout the feeding trial using a scale (Cas, BI-2RB, Korea). Feed DMI, average daily gain (ADG), and feed efficiency were measured monthly.

Particle size of experimental feeds

The particle sizes of experimental feeds were measured using a Penn State particle separator (PSPS) according to the method employed by Kononoff and Heinrichs (2003). The PSPS consisted of three sieves (1.18, 8.00, and 19.00 mm) that could separate feeds into four different types depending on particle size. For the physical effectiveness factor, the proportion of the particle size above 1.18 mm was denoted as $pef_{1.18}$. The $peNDF_{1.18}$ was calculated by multiplying the NDF% by $pef_{1.18}$. As shown in Table 1, the particle size of BF-based silage was much smaller than that of rice straw.

Blood parameters

A health examination was conducted when the animals were 22.7 months of age. Blood samples were taken from the jugular vein, and equal amounts of blood were added to bottles with or without the anticoagulant EDTA. Serum profiles were analyzed using an Automatic Biochemical Analyzer (Hitachi 7170A, Hitachi Ltd., Tokyo, Japan) using the spectrophotometer and ion selective electrode methods, and whole blood profiles were analyzed using an Automatic Blood Analyzer (Coulter STKS, Beckman Coulter Co., Miami, FL, USA), based on the impedance and VCS (volume, conductivity, and light scattering) methods.

Carcass characteristics

Back fat thickness, marbling score, and longissimus muscle area were measured at 20.8, 26.3, and 30.0 months of age using ultrasound (Aloka SSD-500, USA). The steers were withdrawn from the experimental diets 24 h before slaughter. Following a 48 h carcass chill, the yield and quality grade of each carcass was measured using Korean carcass grading standards specified in the Korean Livestock Enforcement Regulations (KMAF, 2007). Quality grades were classified as 1^{++} (very high quality), 1^{+}, 1, 2, and 3 (low quality). Back fat thickness and longissimus muscle area were measured at the 13th rib. 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 classified as A (high yield; >67.5), B (yields <67.5 and >62.0), and C (low yield; <67.5). The grading ranged between 1 and 27, with higher numbers indicating better quality: marbling (1 = devoid, 27 = abundant); meat color (1 = bright cherry red, 7 = extremely dark red); fat color (1 = white, 7 = dark yellow); texture (1 = soft, 3 = firm); and maturity (1 = youthful, 9 = mature).

Chemical analysis

Representative samples of the test feeds fed to Hanwoo steers were collected and stored at -20°C for later analysis. Immediately before the analysis, all the samples were dried and ground to pass through a 1 mm filter using a sample mill (Cemotec, Tecator, Sweden). The DM fraction was quantified by drying the samples at 60°C for 48 h to reach a constant weight. The CP, ether extract (EE), NDF, acid detergent fiber (ADF), and crude ash were determined by the AOAC method (2000). The nonfibrous carbohydrate content was calculated as 100 – (%NDF + %CP + %EE + % crude ash). The true protein (TP) content was measured by evaluating the nitrogen fractions precipitated in a 5% trichloroacetic acid solution. The nonprotein nitrogen (NPN)-CP fraction was calculated as CP - TP. The indigestible protein (ADF-CP) content was determined using the method described by Van Soest et al. (1991). The chemical compositions of the feed ingredients and concentrate mix are presented in Table 2. Compared with rice straw, BF-based silage had a 3.8-fold higher CP level, which is similar to that of good quality timothy hay (Kim et al., 2007a), 4.5% higher EE, and 27.9% lower NDF.

Statistical analysis

Data were subjected to one-way analysis of variance using the general linear model procedure (Statistix7, 2000). A comparison of the means of the control, the 50% BF-based silage, and the 100% BF-based silage diets was made using Tukey's multiple range test (Statistix7, 2000). Significance was indicated when $P<0.05$.

Results and Discussion

BW gain and feed intake

The effects of a BF-based silage diet on growth performance are presented in Table 3. During the growing period, BW in the 100% BF-based silage group increased up to 34 kg compared with that of the control group ($P<0.05$). Thus, the ADG of the 100% BF-based silage group increased by 0.18 kg ($P<0.05$). Kim et al. (2007a) reported that CP efficiency was highest during the growing period. In the present study, a BF-based silage diet, which contained 3.3-fold more CP than the control diet, improved BW gains during the growing period. However, the difference in BW gain was not significant due to compensation growth in the control group during the fattening and finishing periods. Similarly, Sainz et al. (1995) reported that limited BW gain due to restricted feeding during the growing period is compensated during the finishing period. Because BW gain, which was increased by feeding BF-based silage during the growing period, was similar to the compensation growth of the control group during the finishing period, total BW gain during the whole period remained the same. In addition, the slaughtered BW of Hanwoo heifers was about 40 kg lower than that of Hanwoo steers fed the same BF-based silage (Kim et al., 2014b).

Table 1: Particle size distribution, physical effectiveness factors (pef), and physically effective fibre (peNDF) content of feeds fed to Hanwoo heifers[1]

Item	Rice straw	Alfalfa hay	BF-based silage[2)]	Microbial culture	Concentrate mix		
					Growing	Fattening	Finishing
Particle size							
19.0mm	97.8	54.4	10.3	-	-	-	-
8.0mm	1.2	16.6	8.2	70.4	53.9	47.9	53.9
1.18mm	0.9	19.5	54.6	28.9	45.1	51.3	45.4
Pan	0.2	9.6	26.9	0.7	0.2	0.8	0.6
$pef_{1.18}$	1.00	0.90	0.73	0.30	0.39	0.42	0.39
$peNDF_{1.18}$,%of DM	72.7	45.0	37.8	7.9	12.1	11.3	7.6

[1)] % dry matter (DM) retained on sieves; [2)] BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial additive on a wet basis, and ensiled for 5 d to 4 wk.

Table 2: Chemical composition of feeds fed to Hanwoo heifers

Item	Rice straw	Alfalfa hay	BF-based silage[1)]	Microbial culture	Concentrate mix		
					Growing	Fattening	Finishing
	……………………………. %, DM basis ………………………………						
Dry matter	89.3	85.8	62.1	86.7	88.3	88.9	87.5
Crude protein	3.6	18.0	12.0	16.7	16.5	14.2	12.4
TP/CP	84.1	74.1	52.3	86.7	72.1	73.1	72.9
NPN/CP	15.9	25.9	47.7	11.4	27.9	26.9	27.1
ADF-CP/CP	75.4	18.8	26.4	34.4	12.0	8.7	17.3
Ether extract	1.1	1.2	3.6	0.5	2.8	2.6	2.7
Crude ash	9.3	9.0	11.7	26.8	7.3	7.0	5.8
Neutral detergent fibre	72.8	49.7	51.7	26.4	31.1	27.0	19.6
Acid detergent fibre	47.1	35.8	35.4	10.5	15.2	11.6	8.6
Non-fibrous carbohydrate	13.3	22.1	21.1	29.6	42.3	49.2	59.5

[1)]BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial culture on a wet basis, and ensiled for 5 d to 4 wk.

Table 3: Effects of feeding by-product feed-based silage on the growth (kg) of Hanwoo heifers

Item	Control	Feeding BF-based silage[1)]		SE	P value
		50% of *ad libitum*[2)]	*Ad libitum*[3)]		
Growing period (for 6.2 mo.)					
Initial BW (7.9 mo. old)	191.1	192.0	195.2	10.0	0.914
Final BW (14.2 mo. old)	320.8[b]	324.6[ab]	358.5[a]	14.2	0.049
Gain	129.6[b]	132.6[b]	163.3[a]	6.1	0.001
Average daily gain	0.68[b]	0.70[b]	0.86[a]	0.03	0.001
Fattening period (for 8.8 mo.)					
Initial BW (14.2 mo. old)	320.8[b]	324.6[ab]	358.5[a]	14.2	0.049
Final BW (23.0 mo. old)	550.9	547.1	559.0	23.0	0.872
Gain	230.1	222.5	200.5	11.8	0.080
Average daily gain	0.86	0.83	0.75	0.04	0.080
Finishing period (for 7.3 mo.)					
Initial BW (23.0 mo. old)	550.9	547.1	559.0	23.0	0.872
Final BW (30.3mo. old)	672.0	637.9	652.6	35.9	0.648
Gain	121.1	90.8	93.6	22.1	0.359
Average daily gain	0.55	0.41	0.42	0.10	0.359
Whole period (22.4 mo.)					
Initial BW (7.9mo. old)	191.1	192.0	195.2	10.0	0.914
Final BW (30.3mo. old)	672.0	637.9	652.6	35.9	0.648
Gain	480.9	445.9	457.5	30.3	0.525
Average daily gain	0.71	0.66	0.67	0.04	0.543

[1)]BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial culture on a wet basis, and ensiled for 5 d to 4 wk; [2)] Fifty percent of the *ad libitum* feeding of BF-based silage and free access to rice straw during the growing and fattening periods; [2)]The *ad libitum* feeding of BF-based silage during the growing and fattening periods; [a,b,c] Means with different superscripts within the same row are significantly different (P<0.05).

As there were no pen replications in this experiment, no data on feed intake are available. However, with a BF-based silage diet, DMI for the 50% BF-based silage group and the 100% BF-based silage group during the growing period were increased by 6.8 and 22.5% respectively. However, the DMI values for both experimental groups were less than that for the control group. For the whole period, the DMI for the 100% BF-based silage group was the highest and was 0.23 kg/d higher than that of the control group. The maximum BF-based silage intake from 11 to 13 months of age was 3.3–3.4 kg/d on a DM basis and was approximately two folds higher than the maximum rice straw intake (1.6–1.7 kg/d on a DM basis). Because the particle size of BF-based silage (highly palatable roughage) was smaller than that of rice straw (<19 mm = 90% vs. 2%; Table 1), the DMI increased as, if the particle size of the feed is small, it rapidly leaves the rumen, so the DMI and passage rate to the lower digestive tract increases (Martz and Belyea, 1986). Because the concentrate mix was restricted, the concentrate mix intake from 7 until 23 months of age was the same among all the treatments; however, the intake by the control group from 23 months of age until the end of the experiment was the highest. These results suggest that complete replacement of rice straw with BF-based silage is more effective than partial replacement. The concentrate mix intakes during the whole period for the control group, the 50% BF-based silage group, and the 100% BF-based silage group were 3,958.5, 3,795.0 and 3,849.5 kg, respectively. When BF-based silage was used, the concentrate mix intake during the whole period decreased by 109–163.5 kg. Consequently, feeding BF-based silage increased dietary DMI and decreased concentrate mix intake by Hanwoo heifers during the whole period.

Blood parameters

Constituents and electrolytes

The blood parameters of the heifers were tested at 22.7 months of age. Compared with feeding rice straw, feeding BF-based silage *ad libitum* did not affect blood constituents such as serum triglycerides, cholesterol, high-density lipoproteins, or total protein, although serum glucose levels were lower with BF-based silage than with rice straw ($P<0.05$).

In terms of serum electrolytes, feeding BF-based silage *ad libitum* did not affect concentrations of serum Ca, P, K, Na, or Cl. However, concentrations of serum P were lower with BF-based silage than with rice straw ($P<0.05$); the reason for this result is unclear, and further experiments should be carried out to determine whether this result is repeatable. Nonetheless, all the blood constituent and electrolyte levels were within the normal range for healthy cattle (Wallach, 1974; Church and Pond, 1982).

Other blood parameters

Concerning other blood parameters, feeding BF-based silage did not affect serum albumin, globulin, alkaline phosphatase, alanine aminotransferase, aspartate aminotransferase, creatinine phosphokinase, lactate dehydrogenase, urea-N, or creatinine (Table 5). In addition, the albumin/globulin ratio, the white blood cell count, the red blood cell count, and the platelet count were not affected by feeding BF-based silage (Table 5). In a previous study Kim et al. (2014b) feeding a similar BF-based silage diet to Hanwoo steers increased levels of blood urea-N concentration because of an increased dietary CP and NPN intake. However, in the present study, which used Hanwoo heifers, this result was not observed, although blood urea-N levels were higher for the BF-based silage-fed groups than for the control group. Most of the blood parameters for the BF-based silage-fed groups were within the normal range for healthy cattle (Wallach, 1974; Church and Pond, 1982). In general, feeding BF-based silage did not affect blood parameters associated with health and immunity.

Meat quantity and quality grade evaluation

Meat evaluation by ultrasound scanning

Changes in ultrasound back fat thickness, longissimus muscle area, and marbling score are shown in Table 6. Generally, compared to feeding rice straw, feeding BF-based silage did not affect longissimus muscle area or back fat thickness, as measured at 20.8, 26.3, and 30.0 months of age. However, meat from 26.3-month-old heifers fed BF-based silage had higher marbling scores than meat from 26.3-month-old heifers fed rice straw ($P<0.05$), and marbling scores for meat from 20.8-month-old and 30.0-month-old heifers fed BF-based silage were 54.4% and 31.1% higher than those from the respective control groups, although these differences were not significant. Van Koevering et al. (1995) found that marbling scores in the longissimus muscle area during the finishing phase follow a quadratic pattern before reaching a plateau. Brethour (2000) showed that during a 180-day feeding period, animals with high marbling at slaughter had greater initial marbling values and a more rapidly increasing rate of marbling than animals with low marbling at slaughter.

Carcass characteristics

Feeding BF-based silage did not affect cold carcass weight, yield traits such as back fat thickness, longissimus muscle area, yield index, and yield grade, or quality traits such as marbling score, meat color, fat color, texture, maturity, and quality grade (Table 7). In particular, the marbling scores for the BF-based silage-fed groups were on average 41.6% higher than those for the control group, although this difference was not

Table 4: Blood nutrients and electrolytes of fattening Hanwoo heifers

Item	Control	Feeding BF-based silage[1)]		SE	P value
		50% of *ad libitum*[2)]	*Ad libitum*[2)]		
Triglyceride (mg/dl)	51.4	38.8	46.0	7.7	0.3093
Cholesterol (mg/dl)	88.4	95.9	82.2	9.5	0.3911
High density lipoprotein (HDL) (mg/dl)	30.0	29.6	24.5	2.6	0.1177
Low density lipoprotein (LDL) (mg/dl)	28.5[b]	34.9[a]	26.6[b]	1.7	0.0024
Glucose (mg/dl)	169.4[a]	158.3[ab]	125.4[b]	12.8	0.0188
Total protein (g/dl)	7.5	7.4	7.1	0.3	0.4242
Electrolytes					
Ca^+ (mg/dl)	9.4	9.8	9.7	0.3	0.3600
Inorganic P^- (mg/dl)	9.5[a]	7.0[b]	9.4[a]	0.7	0.0158
K^+ (mmol/l)	4.5	4.4	4.7	0.2	0.3617
Na^+ (mmol/l)	144.3	139.8	144.0	1.9	0.0594
Cl^- (mmol/l)	104.3	113.5	105.0	0.9	0.3617

[1)] BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial culture on a wet basis, and ensiled for 5 d to 4 wk; [2)] Fifty percent of the *ad libitum* feeding of BF-based silage and free access to rice straw during the growing and fattening periods; [3)] The *ad libitum* feeding of BF-based silage during the growing and fattening periods; [a,b,c] Means with different superscripts within the same row are significantly different (P<0.05).

Table 5: Other blood parameters of fattening Hanwoo heifers

Item	Control	Feeding BF-based silage[1)]		SE	P value
		1/2 of *ad libitum*[2)]	*Ad libitum*[3)]		
Albumin (g/dl)	5.8	5.5	5.2	0.3	0.082
Globulin (g/dl)	1.7	1.9	1.9	0.2	0.323
Albumin/globulin	3.4	2.9	2.7	0.3	0.109
Alkaline phosphatase (IU/l)	129.7	100.2	119.5	24.8	0.673
Alanine aminotransferase (ALT) (IU/l)	35.6	33.3	36.7	5.3	0.788
Aspartate aminotransferase (AST) (IU/l)	105.6	128.3	95.3	28.5	0.851
Creatinine phosphokinase (CPK) (IU/l)	386.0	503.1	280.2	95.1	0.117
Lactate dehydrogenase (LDH) (IU/l)	483.4	359.4	206.1	134.3	0.532
Urea-N (mg/dl)	14.9	16.5	17.4	1.4	0.269
Creatinine (mg/dl)	1.0	1.0	0.9	0.1	0.412
White blood cell counts (10^3/ul)	21.8	11.3	8.0	6.3	0.187
Red blood cell counts (10^6/ul)	8.6	8.5	8.0	0.7	0.175
Platelet counts (10^3/ul)	477.5	290.0	255.3	141.8	0.304

[1)]BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial culture on a wet basis, and ensiled for 5 d to 4 wk; [2)]Fifty percent of the *ad libitum* feeding of BF-based silage and free access to rice straw during the growing and fattening periods; [3)] The *ad libitum* feeding of BF-based silage during the growing and fattening periods; [a,b,c] Means with different superscripts within the same row are significantly different (P<0.05).

Table 6: Yield and quality traits of finishing Hanwoo heifers measured by ultrasound scanning

Item		Control	Feeding BF-based silage[1)]		SE	P value
			50% of *ad libitum*[2)]	*Ad libitum*[3)]		
Back fat thickness (mm)	20.8 mo. old	6.3	7.8	5.8	1.3	0.322
	26.3 mo. old	13.0	12.3	7.8	2.2	0.088
	30.0 mo. old	17.1	15.6	11.8	2.3	0.113
LMA[4)] (cm^2)	20.8 mo. old	72.0	72.3	72.0	3.3	0.996
	26.3 mo. old	83.1	86.1	81.6	3.8	0.515
	30.0 mo. old	88.2	89.9	88.5	3.6	0.882
Marbling (score[5)])	20.8 mo. old	6.8	10.5	10.5	1.9	0.128
	26.3 mo. old	9.0[b]	12.0[ab]	13.3[a]	1.4	0.036
	30.0 mo. old	10.3	14.0	13.0	2.5	0.338

[1)] BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial culture on a wet basis, and ensiled for 5 d to 4 wk; [2)] The *ad libitum* feeding of BF-based silage and free access to rice straw during the growing and fattening periods; [3)] The *ad libitum* feeding of BF-based silage during the growing and fattening periods; [4)] Longissimus muscle area; [5)] Marbling score ranges from 1 to 27 (1 = devoid, 27 = abundant); [a,b] Means with different superscripts within the same row are significantly different (P<0.05).

Table 7: Effects of feeding by-product feed-based silage on the cold carcass characteristics of Hanwoo heifers

Item	Control	Feeding BF-based silage[1)]		SE	P value
		50% of *ad libitum*[2)]	*Ad libitum*[3)]		
Cold carcass wt. (kg)	389.0	360.3	375.0	20.2	0.394
Yield traits					
Back fat thickness (mm)	18.0	21.0	12.8	3.7	0.128
LMA[4)] (cm^2)	89.0	82.8	92.0	5.6	0.292
Yield index	62.4	60.4	66.4	2.3	0.071
Yield grade[5)]	2.5	2.8	1.8	0.4	0.060
Quality traits					
Marbling score[6)]	11.3	16.5	15.5	3.7	0.361
Meat color[7)]	4.3	5.0	4.3	0.4	0.054
Fat color[8)]	3.0	3.3	3.3	0.3	0.622
Texture[9)]	1.3	1.0	1.0	0.2	0.405
Maturity[10)]	3.8	3.8	3.8	0.9	1.000
Quality grade[11)]	1.03	0.53	0.53	0.4	0.469
1^{++},head (%)	-	1(25)	1(25)	-	-
1^{+},head (%)	1(25)	1(25)	1(25)	-	-
1,head (%)	2(50)	2(50)	2(50)	-	-
2, head (%)	1(25)	-	-	-	-

1) BF-based silage was a by-product feed-based silage, which was composed of 50% spent mushroom substrates, 21% recycled poultry bedding, 15% ryegrass straw, 10.8% rice bran, 2% molasses, 0.6% bentonite, and 0.6% microbial additive on a wet basis, and ensiled for 5 d to 4 wk; 2) Fifty percent of the *ad libitum* feeding of BF-based silage and free access to rice straw during the growing and fattening periods; 3) The *ad libitum* feeding of BF-based silage during the growing and fattening periods; 4) Longissimus muscle area; 5) Converted to a numeric: grade A = 1, B = 2, and C = 3; 6) Marbling score ranges from 1 to 27 (1 = devoid, 27 = abundant); 7) Meat color ranges from 1 to 7 (1 = brightly cheery red, 7 = extremely dark red); 8) Fat color ranges from 1 to 7 (1 = white, 7 = dark yellow); 9) Texture ranges from 1 to 3 (1 = soft, 3 = firm); 10) Maturity ranges from 1 to 9 (1 = youthful, 9 = mature); 11) Converted to a numeric: grade 1^{++} = 0.01, 1^{+}=0.1, 1 = 1, and 2 = 2; a,b Means with different superscripts within the same row are significantly different (P<0.05).

significant. A quality grade appearance rate >1 was obtained more frequently in BF-based silage-fed groups (100% for both groups) than in the control group (75%). Thus, feeding BF-based silage seems to favorably affect meat quality in Hanwoo heifers. In other studies, supplementing diets with *Eucommia ulmoides* leaves (Kim et al., 2005) or wheat bran and green tea extract (Park et al., 2011) increased the frequency of obtaining high quality meat in Hanwoo steers.

In addition, the increased intake, ADG, and feed efficiency in growing heifers fed BF-based silage seems to have increased the frequency of obtaining good quality meat. Similarly, Vasconcelos et al. (2009) reported that a higher intake of dietary energy increases the accretion of intramuscular fat during the growing phase. However, fermentative end products including organic acids might affect meat quality, so the mechanism underlying the production of high quality meat needs to be further elucidated. Interestingly, the net farm income from steers fed BF-based silage *ad libitum* was 42.6% higher than for those fed rice straw.

Taken together, these results show that compared with feeding rice straw, feeding BF-based silage tends to increase feed intake, growth, and feed efficiency in growing heifers, had little effect on serum constituents, electrolytes, enzymes, or blood cell profiles in fattening heifers or carcass yield traits and quality traits of finishing heifers, and increased the frequency of obtaining good quality meat at slaughter. These findings are similar to observed in our previous study on Hanwoo steers fed BF-based silage.

Conclusions

The results from this study indicate that feeding BF-based silage to growing and early fattening heifers can reduce feed cost, improve meat quality, and increase net farm income without negatively affecting animal health or carcass characteristics. Thus, cheap BF-based silage can be used as a good quality roughage source for beef cattle and can be used in combination with conventional roughage to improve forage quality in Asian countries facing a roughage scarcity. To confirm the practical application of the results from this study, research into the large-scale use of BF-based silage should be conducted.

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