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# Growth Performance, Carcass Traits, Blood Parameters, Rumen Enzymes, and Fattening Earnings of Cattle Fed Corn Silage/Corn Stalk Silage Based Finishing Diets

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**Abstract**

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This study was conducted to investigate the growth performance, carcass traits, blood parameters, rumen enzymes, and fattening earnings of beef cattle when substituting corn stalk silage with corn silage or corn grain in finishing rations. Forty-five Bohai Black steers were selected and fattened in a three-phase (4 weeks–4 weeks–16 weeks) way with one of three diets based on corn silage (CS), corn stalk silage (SS) without/with equivalent corn grain supplement (SSC), respectively. During the 24-week trial, individual feed intake and body weight were recorded every four weeks. By the end, blood and rumen fluid were sampled, and all the cattle were slaughtered to evaluate carcass performance. There were no significant differences found in the body weight gain, daily feed intake or feed efficiency among different dietary treatments over the whole finishing period except that the cattle fed CS achieved higher weight gain and feed efficiency in Phase 2 than those fed SS or SSC along with a lower feed intake than that of cattle fed SSC. No significant effect was found on the hot carcass weight, chilled carcass weight, dressing percentage, aging loss, loin eye area, and the weights of chuckeye, ribeye, striploin, and tenderloin. The cattle fed CS showed lower blood concentrations of ALT and glucose along with a higher ratio of AST and ALT than those fed SS. The cattle fed SSC also presented a higher activity of avicelase in the rumen fluid and their fattening earnings were approximately $27.50 less than those of the cattle fed CS or SS. These results suggest that substituting corn stalk silage with corn silage or corn grain could not improve animal performance and it is more economical to substitute corn stalk silage with corn silage rather than supplement equivalent corn grain in a high-concentrate finishing ration.

**Keywords**: beef cattle; animal performance; physiological status; forage quality; production benefit

Over the years, consecutive increases in grain yield have led to the surplus of corn grain supply, largely bringing down its price and marginal incomes of corn planting. Corn silage has been becoming popular in cattle production around the world (Keady et al. 2008; Burken 2014), but corn stalk silage is still the main forage in the region or during the season short in feedstuff. Meanwhile,

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corn grain is always used as the main energy feed in animal feeding, which annually consumes about 60% of corn production (http://www.fao.org/faostat/en/#data). Therefore, it is suggested that partly transferring the production target from grain-driven to corn silage utilization would increase the planting income, which is expectantly maintained by the increasing consumption of corn silage in ruminant production, ultimately resulting in the change of dietary structure.

Corn silage is obviously higher in nutrient value than corn stalk silage because of corn grain inclusion, and it is usually regarded as partial concentrate. Improvements in cattle's feed intake with inclusion of corn silage in grass silage-based diets have been demonstrated in previous studies, implying that inclusion of relatively higher-quality roughage could promote feed intake (O'Kiely and Moloney 2000). It is generally proposed that animal growth performance is positively related to its dietary concentrate level, but improvements in feed intake would not necessarily result in improved animal performance. Because the dietary digestibility would discount when its concentrate level is high enough, consequently resulting in non-additive effect of concentrate inclusion, even worse. The study of Dawson (2012) showed that silage type (lupins/triticale silage, grass silage, corn silage) had no significant effect on body live weight, live weight gain, carcass gain, forage dry matter intake or feed efficiency of finishing beef cattle. Given the large fluctuation in price and variation in production mode, the benefit of incorporating corn silage into the corn stalk silage-based diet of beef cattle is still in doubt. The study of Burken (2014) showed that the benefit of incorporating increased corn silage in finishing diets mostly depended on the comparison prices of corn grain and corn silage as well as the management of silage production.

Though corn (stalk) silage is common forage, there is scarce literature that has compared the performance of finishing cattle offered corn silage or corn stalk silage based diet. It is hypothesised that substituting corn stalk silage with corn silage in a finishing ration would show a concentrate-like effect on the performance of beef cattle and it is more economical to harvest corn plant as corn silage rather than separately produce corn grain along with corn stalk silage in beef production. Thus, the objective of this study was to compare the performance of cattle fed different finishing diets separately based on corn silage or corn stalk silage without/with corn grain supplement.

## MATERIAL AND METHODS

***Experimental design and animal management.*** Whole corn plant (Dehai 6701, W917×DH382, Shangdong Denghai Seed Industry Co., Ltd, China) was harvested at its maturation stage of 1/2 milk line with a theoretical particle length of 2 cm using a JAGUAR 830 forage harvester (CLAAS KGaA mbH, Germany) and ensiled into semi-underground silo. Meanwhile, corn stalk silage was produced with fresh corn stalk (corn plant removed ears at 2/3 milk line) in the same procedure. Silage was uncovered for use after a 60-day fermentation.

Forty-five crossbred Bohai black steers (20-month old) weighing 565.5 ± 21.4 kg were selected and randomly allocated into three dietary treatments (15 animals per group). The total mixed ration (TMR) was formulated based on whole corn silage (CS) or corn stalk silage (SS) according to NRC (2000) recommendations for beef cattle and made *iso*-nitrogenous with the addition of urea, and the corn stalk silage + corn grain (SSC) diet was formulated by substituting a portion of corn stalk silage with corn grain. The ratio between the outputs of corn stalk and corn grain was supposed to be 1.5 : 1 for corn silage, thus corn grain was supplemented in group SSC to make its dietary corn inclusion equal to that of group CS (Table 1). To adapt to a high level of dietary concentrate, the cattle were fattened in a stepwise procedure divided into three phases with Phase 1 lasting 4 weeks, Phase 2 lasting 4 weeks, and Phase 3 lasting 16 weeks, where the level of dietary concentrate was increased progressively. During the 24-week feeding trial, all the cattle were reared in separate pens with *ad libitum* access to TMR and clean water. Individual feed intake (FI) was manually recorded in seven consecutive days during the mid-term of each finishing phase and periodical rations were sampled for dry matter (DM) determination; body weight (BW) was individually recorded at the end of each phase; feed efficiency (FE) was calculated as kg body weight gain per kg of feed intake. This study was performed at the cooperative farm of China Agricultural University and all the procedures were approved by the Animal Care and Use Committee of China Agricultural University (Beijing, China).

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***Measurements of carcass traits, blood parameters, rumen enzymes, and $NH_3$-N concentration.*** Following the 24-week finishing period, all the cattle were bled in a 12-hour fast by jugular vein puncture into anticoagulant-free tubes with blood needle, and then slaughtered to evaluate carcass performance. Meanwhile, rumen fluid was sampled after eviscerating and filtered through four layers cheese cloth for the determination of digestive enzymes and ammonium nitrogen ($NH_3$-N).

Following a 48-hour aging period, chilled carcass was recorded and then segmented to record individual weight of chuckeye, ribeye, striploin, and tenderloin as well as loin eye area, which was delineated with parchment paper and measured by a rolling planimeter (QCJ-2A; Shanyin, China). Dressing percentage and aging loss were also calculated. The blood samples were centrifuged at 3000 *g* and 4°C for 15 min to prepare serum, and then alanine transaminase (ALT), aspartate aminotransferase (AST), glucose (GLU), cholesterol (CHO), triglyceride (TG), total protein (TP), and creatinine (Cre) were analysed with commercial test kits (Zhongsheng Beikong Bio-technology and Science Inc., China) as specifications by an Auto-Biochemical Analyzer (Vital Scientific, the Netherlands). Rumen fluid was also centrifuged as blood done, and then was detected for the enzyme activities of filter paper activity (FPA), carboxy-methyl cellulase (CMCase), avicelase, β-glucanase, xylanase, and amylase using a Varioskan Flash Multimode Reader (Varioskan LUX;

Table 1. Diet formulas for finishing steers in different fattening phases

| Item | Phase 1 | | | Phase 2 | | | Phase 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | CS | SS | SSC | CS | SS | SSC | CS | SS | SSC |
| **Ingredient** (% DM) | | | | | | | | | |
| Corn grain[1] | 22.3 | 22.3 | 22.3 + 18.4 | 37.0 | 37.0 | 37.0 + 16.0 | 57.0 | 57.0 | 57.0 + 10.0 |
| Corn husk | 6.0 | 5.8 | 5.7 | 6.0 | 6.0 | 6.0 | 5.0 | 5.0 | 5.0 |
| Wheat bran | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 7.0 | 7.0 | 7.0 |
| Soybean meal | 6.0 | 6.0 | 6.0 | 5.7 | 5.7 | 5.7 | 2.0 | 2.0 | 2.0 |
| Urea | 0.0 | 0.5 | 0.2 | 0.0 | 0.3 | 0.1 | 0.5 | 0.7 | 0.6 |
| Limestone | 0.8 | 0.8 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 |
| Premix[2] | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Bicarbonate | 0.6 | 0.4 | 0.5 | 1.0 | 0.7 | 1.0 | 1.1 | 0.9 | 1.0 |
| MgO | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 |
| Silage | 55.0 | 55.0 | 36.8 | 40.0 | 40.0 | 24.0 | 25.0 | 25.0 | 15.0 |
| **Nutrient content**[3] (% DM) | | | | | | | | | |
| ME (Mcal/kg) | 2.50 | 2.20 | 2.44 | 2.60 | 2.40 | 2.60 | 2.70 | 2.58 | 2.72 |
| CP | 12.10 | 12.10 | 12.10 | 12.15 | 12.15 | 12.15 | 12.20 | 12.20 | 12.20 |
| Starch | 32.70 | 20.05 | 31.10 | 38.20 | 29.00 | 38.80 | 46.50 | 40.70 | 46.80 |
| NDF | 36.00 | 46.00 | 36.70 | 31.00 | 38.50 | 30.00 | 25.20 | 30.00 | 24.80 |
| ADF | 17.50 | 24.50 | 18.60 | 14.50 | 19.70 | 14.50 | 11.00 | 14.20 | 10.90 |
| Ca | 0.45 | 0.43 | 0.42 | 0.49 | 0.48 | 0.46 | 0.46 | 0.45 | 0.43 |
| P | 0.40 | 0.38 | 0.39 | 0.41 | 0.39 | 0.41 | 0.38 | 0.37 | 0.38 |

CS = corn silage, SS = corn stalk silage, SSC = corn stalk silage with corn grain supplement, DM = dry matter, ME = metabolisable energy, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre

[1]ratio between outputs of corn stalk and corn grain was supposed to be 1.5 : 1 for corn silage (thus corn grain was supplemented in group SSC to make its dietary corn inclusion equal to that of group CS except that corn grain supplementation in SSC was less than given amount in Phase 1 with consideration of gradual adaptation to high concentrate level

[2]provided per kg: Fe 2400 mg, Zn 3580 mg, Cu 680 mg, Mn 2500 mg, Zn 2000 mg, I 150 mg, Se 15 mg, vitamin A 350 000 IU, vitamin D 65 000 IU, vitamin E 800 IU

[3]calculated based on analysed nutrients of each ingredient

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Thermo Fisher Scientific, USA) according to the methods of 3,5-dinitrosalicylic acid (DNS reagent) reported by Liu et al. (2014). $NH_3$-N concentration was measured as the method described by Broderick and Kang (1980).

***Chemical analysis of feedstuff***. Corn silage, corn stalk silage, and corn grain were analysed according to AOAC (2000) methods for dry matter (DM, method 934.01), crude protein (CP, method 968.06), ether extract (EE, method 920.39), neutral detergent fibre (NDF, method 973.18), acid detergent fibre (ADF, method 973.18), acid detergent lignin (ADL, method 973.18), and ash (method 942.05) determination (Table 2). Specifically, DM was measured in drying oven at 105°C for 4 h; total N was determined using the combustion nitrogen analysis (FP-528; Leco, USA) and CP was calculated with the 6.25 nitrogen conversion factor (N × 6.25); EE was extracted with an Extraction System (ANKOM Technology Corp., USA); NDF, ADF, and ADL were analysed using an A220 Fiber Analyzer (ANKOM Technology Corp.) with NDF assayed using a heat-tolerant alpha amylase and sodium sulfite; ash was measured by combustion in muffle furnace at 550°C for 4 h following carbonization. Starch was measured by determining the glucose content after gelatinization and enzyme hydrolysis as the method stated by Xiong (2000).

***Economic accounting of beef cattle production in the finishing period.*** The comparative earnings of steers fattened with different finishing rations were merely calculated as the difference between the income of live body weight gain and the cost of feed intake, not including the expense of labour and facility depreciation, etc., i.e., earnings = BW gain income – feed cost. The unit-price ($/kg DM) of feedstuff and live cattle ($/kg BW) was based on the local market at that time, i.e., corn 0.27; corn husk 0.24; wheat bran 0.23; soybean meal 0.45; urea 0.35; limestone 0.03; salt 0.14; premix 0.91; sodium bicarbonate 0.27; MgO 0.38; corn silage 0.18; corn stalk silage 0.12; live cattle 3.94.

Table 2. Chemical compositions of corn silage, corn stalk silage, and corn grain used in rations

| Item (% DM) | Corn silage | Corn stalk silage | Corn grain |
|---|---|---|---|
| DM | 27.03 | 30.88 | 86.74 |
| CP | 8.91 | 7.90 | 10.05 |
| EE | 2.81 | 1.34 | 4.42 |
| NDF | 45.66 | 64.37 | 12.55 |
| ADF | 24.93 | 37.62 | 4.63 |
| ADL | 1.76 | 6.78 | 1.24 |
| Ash | 7.38 | 8.43 | 4.88 |
| Starch | 26.17 | 4.33 | 64.78 |

DM = dry matter, CP = crude protein, EE = ether extract, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin

***Statistical analysis.*** Each animal was considered as an experimental unit ($n$ = 45) in all analyses. The average value of repeated measurements for each parameter was used to conduct comparison analysis. Analyses of variance were performed using the MIXED procedure of SAS (version 9.1, 2003) with the dietary treatment (CS, SS, and SSC) as fixed effect according to the following model:

$$Y_{ij} = \mu + T_i + e_{ij}$$

where:
$Y_{ij}$ = dependent variable
$\mu$ = overall mean
$T_i$ = effect of dietary treatment i ($n$ = 1, 2, 3; CS, SS, and SSC)
$e_{ij}$ = residual error

Reported values are Least Squares Means and SEM generated with the LSMEANS command in SAS (version 9.1, 2003) software. The differences between Least Squares Means were evaluated by Duncan's method, where $P$-values < 0.05 were considered statistically significant, and $P$-values < 0.10 were considered trends in the data.

## RESULTS

***Growth performance of beef cattle fed different finishing rations.*** The periodical weight gain, feed intake, and feed efficiency of beef cattle offered alternative silage-based finishing diets are summarised in Table 3. The weight gains (kg/(day × head)) of the cattle fed CS were higher ($P$ < 0.01) than those of the cattle fed SS or SSC in Phase 2, and their daily feed intake (kg/(day × head)) was lower ($P$ < 0.05) than that of the cattle fed CS, thus the feed efficiency of the cattle fed CS was higher ($P$ < 0.01) relative to those of the other two groups. The grow performance of the cattle fed different diets showed no difference ($P$ > 0.05) in Phase 1 and Phase 3 as well as over the whole feeding period.

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Table 3. Weight gain, feed intake, and feed efficiency of beef steers fed corn (stalk) silage-based finishing rations

| Item | Period | Treatment | | | SEM | *P*-value |
|---|---|---|---|---|---|---|
| | | CS | SS | SSC | | |
| WG (kg/(day × head)) | Phase 1 | 0.86 | 0.88 | 0.99 | 0.06 | 0.24 |
| | Phase 2 | 1.23[a] | 0.77[c] | 0.98[bc] | 0.07 | < 0.01 |
| | Phase 3 | 0.49 | 0.59 | 0.47 | 0.06 | 0.18 |
| | total | 114.91 | 109.79 | 107.86 | 6.68 | 0.72 |
| | average | 0.71 | 0.68 | 0.67 | 0.04 | 0.72 |
| FI (kg/(day × head)) | Phase 1 | 9.46 | 9.18 | 9.45 | 0.15 | 0.25 |
| | Phase 2 | 10.16[b] | 10.30[ab] | 10.89[a] | 0.22 | 0.04 |
| | Phase 3 | 9.31 | 9.80 | 9.01 | 0.29 | 0.11 |
| | total | 1533.33 | 1575.92 | 1525.81 | 33.65 | 0.46 |
| | average | 9.52 | 9.79 | 9.48 | 0.21 | 0.45 |
| FE (kg/kg) | Phase 1 | 0.09 | 0.10 | 0.11 | 0.01 | 0.30 |
| | Phase 2 | 0.12[a] | 0.08[bc] | 0.09[b] | 0.01 | < 0.01 |
| | Phase 3 | 0.05 | 0.06 | 0.05 | 0.01 | 0.45 |
| | average | 0.07 | 0.07 | 0.07 | 0.00 | 0.57 |

CS = corn silage, SS = corn stalk silage, SSC = corn stalk silage with corn grain supplement, SEM = standard error of the means, WG = weight gain, FI = feed intake, FE = feed efficiency (calculated as kg body weight gain per kg of feed intake (FE = WG/FI)), total = total feed intake or weight gain per head over the finishing period (kg/head), average = mean of the parameter over the finishing period

[a–c]means in the same row with different superscripts differ significantly at $P < 0.05$

***Carcass performance of beef cattle fed different finishing rations.*** The final body weight, hot carcass weight, chilled carcass weight, dressing percentage, aging loss, loin eye area, and the weights of chuckeye, ribeye, striploin, and tenderloin are showed in Table 4. No differences ($P > 0.05$) were found in the carcass traits between different dietary treatments.

***Blood parameters of beef cattle fed different finishing rations.*** The concentrations of ALT, AST, ALT/AST, GLU, CHO, TG, TP, and Cre in serum are summarised in Table 5. The cattle fed

Table 4. Carcass traits of beef steers fed corn (stalk) silage-based finishing rations

| Item | Treatment | | | SEM | *P*-value |
|---|---|---|---|---|---|
| | CS | SS | SSC | | |
| Body weight (kg) | 670.56 | 663.60 | 670.10 | 20.25 | 0.96 |
| Hot carcass (kg) | 378.00 | 367.30 | 376.20 | 9.66 | 0.69 |
| Chilled carcass (kg) | 353.40 | 347.24 | 354.35 | 11.04 | 0.89 |
| Dressing percentage (%) | 56.53 | 55.46 | 56.18 | 0.41 | 0.19 |
| Aging loss (%) | 5.09 | 5.58 | 5.85 | 0.56 | 0.63 |
| Loin eye area ($cm^2$) | 48.26 | 47.21 | 44.15 | 2.12 | 0.38 |
| **Quality segments** | | | | | |
| Chuckeye (kg) | 13.52 | 13.80 | 14.17 | 0.53 | 0.69 |
| Ribeye (kg) | 14.51 | 14.54 | 14.25 | 0.51 | 0.91 |
| Striploin (kg) | 9.54 | 9.12 | 8.38 | 0.45 | 0.20 |
| Tenderloin (kg) | 4.60 | 4.74 | 4.45 | 0.18 | 0.67 |
| Total (kg) | 42.16 | 42.19 | 41.24 | 1.48 | 0.83 |
| Percentage (%) | 11.93 | 12.28 | 11.63 | 0.35 | 0.44 |

CS = corn silage, SS = corn stalk silage, SSC = corn stalk silage with corn grain supplement, SEM = standard error of the means

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Table 5. Blood parameters of beef steers fed corn (stalk) silage-based finishing rations

| Item | Treatment | | | SEM | *P*-value |
|---|---|---|---|---|---|
| | CS | SS | SSC | | |
| ALT (U/l) | 17.46[b] | 23.71[a] | 20.86[ab] | 1.49 | 0.02 |
| AST (U/l) | 44.33 | 44.36 | 40.93 | 1.64 | 0.21 |
| AST/ALT | 2.70[a] | 2.03[b] | 2.03[b] | 0.19 | 0.02 |
| GLU (mmol/l) | 3.26[b] | 3.57[a] | 3.45[ab] | 0.08 | 0.02 |
| CHO (mmol/l) | 1.91 | 2.44 | 2.01 | 0.18 | 0.08 |
| TG (mmol/l) | 0.23 | 0.24 | 0.24 | 0.01 | 0.85 |
| TP (g/l) | 55.35 | 56.45 | 53.76 | 1.02 | 0.17 |
| Cre (mmol/l) | 150.22 | 135.25 | 132.40 | 6.09 | 0.09 |

CS = corn silage, SS = corn stalk silage, SSC = corn stalk silage with corn grain supplement, SEM = standard error of the means, ALT = alanine transaminase, AST = aspartate aminotransferase, GLU = glucose, CHO = cholesterol, TG = triglyceride, TP = total protein, Cre = creatinine

[a,b]means in the same row with different superscripts differ significantly at $P < 0.05$

CS showed lower ($P < 0.05$) concentrations of ALT and GLU along with higher ($P < 0.05$) ALT/AST ratio in the blood than the cattle fed SS. There was a tendency to increase in the CHO concentration of group SS ($P = 0.08$) and the Cre concentration of group CS ($P = 0.09$). No difference ($P > 0.05$) was detected in the concentrations of AST, TG, and TP.

***Rumen enzyme activities and $NH_3$-N concentration of beef cattle fed different finishing rations.*** The activities of FPA, CMCase, avicelase, β-glucanase, xylanase, and amylase, and the concentration of $NH_3$-N in the rumen are showed in Table 6. The cattle fed SSC showed a higher ($P < 0.01$) activity of avicelase than those fed CS or SS. The activities of other enzymes and $NH_3$-N concentration showed no difference ($P > 0.05$) between dietary treatments.

***Fattening earnings of beef cattle fed different finishing rations.*** The detail accounting of steers fattened with different finishing rations is presented in Table 7. Numerically, the price of diet SS was almost \$0.02/kg less than those of diet CS and diet SSC in each finishing phase; the ranks of feed cost varied in each phase; income derived from body weight gain ranked as group CS > group SS > group SSC; the earnings of group SSC over the whole finishing period were approximately \$27.50

Table 6. Rumen enzyme activities and $NH_3$-N concentration of beef steers fed corn (stalk) silage-based finishing rations

| Enzyme activity (mU[1]) | Treatment | | | SEM | *P*-value |
|---|---|---|---|---|---|
| | CS | SS | SSC | | |
| FPA | 58.17 | 53.71 | 69.74 | 7.15 | 0.27 |
| CMCase | 76.64 | 61.27 | 76.47 | 13.99 | 0.65 |
| Avicelase | 140.51[b] | 87.77[b] | 229.31[a] | 26.68 | < 0.01 |
| β-Glucanase | 71.61 | 52.97 | 72.06 | 13.32 | 0.49 |
| Xylanase | 1584.48 | 1541.95 | 1610.23 | 35.67 | 0.40 |
| Amylase | 362.11 | 296.76 | 411.14 | 43.00 | 0.19 |
| $NH_3$-N (mg/100 ml) | 10.26 | 9.94 | 8.71 | 1.01 | 0.52 |

CS = corn silage, SS = corn stalk silage, SSC = corn stalk silage with corn grain supplement, SEM = standard error of the means, FPA = filter paper activity, CMCase = carboxymethyl cellulose, $NH_3$-N = ammonium nitrogen

[1]milli-unit: 1 ml rumen fluid catalysing the substrate (filter paper, carboxymethyl cellulose, avicel, salicin, xylan or soluble starch) to produce 1 μmol monosaccharide (glucose or xylose) under the given reaction condition (pH 6.8, 39°C) in 1 min is defined as 1 unit of enzyme activity (U)

[a,b]means in the same row with different superscripts differ significantly at $P < 0.05$

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Table 7. Economic accounting of beef steers fattened with fed corn (stalk) silage-based finishing rations

| Item | Period | Treatment | | |
|---|---|---|---|---|
| | | CS | SS | SSC |
| Price of diet[1] ($/kg) | Phase 1 | 0.23 | 0.20 | 0.22 |
| | Phase 2 | 0.24 | 0.22 | 0.24 |
| | Phase 3 | 0.25 | 0.23 | 0.25 |
| Feed cost[2] ($/head) | Phase 1 | 65.01 | 54.10 | 63.38 |
| | Phase 2 | 81.03 | 73.98 | 89.78 |
| | Phase 3 | 227.93 | 225.52 | 220.65 |
| BWG income[3] ($/head) | whole | 452.68 | 432.51 | 424.90 |
| Earnings[4] ($/head) | whole | 78.71 | 78.91 | 51.10 |

CS = corn silage, SS = corn stalk silage, SSC = corn stalk silage with corn grain supplement, BWG = body weight gain
[1]calculated based on unit-price ($/kg) of dietary ingredients (i.e. corn 0.27, corn husk 0.24, wheat bran 0.23, soybean meal 0.45, urea 0.35, limestone 0.03, salt 0.14, premix 0.91, sodium bicarbonate 0.27, MgO 0.38, corn silage 0.18, corn stalk silage 0.12)
[2]calculated based on feed intake and unit-price of diet
[3]calculated as BWG in the period × unit-price of live cattle (3.94 $/kg BW)
[4]calculated as BWG income – feed cost

less while those of group CS and group SS were almost the same.

## DISCUSSION

***Growth performance and carcass traits of beef cattle fed different finishing rations.*** In the present study, no difference was found in the growth performance and carcass traits of beef cattle fattened with different silage-based diets (CS, SS, and SSC) over the whole finishing period, though there were some differences in certain time, inferring that the better forage (corn silage) did not necessarily attain improved performance. It is proposed that the increasing concentrate proportion might exert a disappointing effect on the dietary digestibility, especially fibre digestibility, because of the potential negative associative effects between starch and fibre digestion (Hoover 1986). Russell et al. (2016) reported that the optimal corn inclusion for growth and diet utilization of beef cattle in the soybean hulls-based diets fell between 0.4% and 0.2% BW corn supplementation. Supplementing soybean hulls diets with corn can increase dietary energy concentration, but corn inclusion in fibre-based diets negatively affects fibre digestibility (Faulkner et al. 1994; Garces Yepez et al. 1997). Moreover, differences in the rates of fermentation, particle breakdown, and clearance should be to partly blame for the undifferentiated growth performance of cattle fed corn silage or stalk silage. Consistently, Dewhurst et al. (2009) speculated that more rapid particle breakdown and clearance from rumen could explain why ruminants consuming legumes had higher intakes than those consuming grass forages (Beever and Thorp 1996), and beef cattle fed whole crop wheat in grass silage-based diets would increase intakes relative to grass silage (Keady et al. 2007).

As common silage, corn silage is usually used as a reference for the evaluation of other forages, but there is little literature reporting the comparison effects of corn silage and corn stalk silage on the performance of finishing cattle. It is rather challenging to make fair comparisons of different forage sources because of their complex effect of grain and forage inclusion. Similarly, Walsh et al. (2008) reported that the growth rates of cattle fed fermented whole-crop wheat based diet were similar to those in cattle fed corn silage; Dawson (2012) reported that forage type (lupins/triticale silage and grass silage) had no effect on live weight gain, carcass gain or feed efficiency. Pesonen et al. (2014) observed no difference in feed intake, growth rate, carcass weight, dressing proportion, and carcass conformation for growing and finishing bulls fed either pure timothy or mixed timothy and red clover silage; Lee et al. (2009) reported no difference between feeding treatments in slaughter weight or carcass conformation when dairy cull cows were fed either grass or red clover silage. Carcass performance is counted as an important indicator for beef production and largely determines the economic potency of the beef cattle. No difference in carcass performance inferred that higher input with addition of high-quality forage or more concentrate in finishing ration would be not economical in the production. In addition, the rates of live weight gain for SS tended to show a compensatory growth effect. Moloney et al. (2008) concluded that, comparing with those fed silage *ad libitum* and concentrate at a constant rate throughout a 5–6 month period, the cattle fed concentrate *ad libitum* with a delayed introduction showed better production efficiency. It suggested that a proper concentrate level with

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a great implementation strategy may contribute to increased production benefit.

***Blood parameters and rumen enzyme activities of beef cattle fed different finishing rations***. Blood biochemical index is generally used to evaluate the level of healthiness and nutritional status, where the concentrations of ALT, AST, GLU, TG, CHO, TP, and Cre may be useful biomarkers of nutrient metabolism and organ functions, which could be affected by dietary factors, environment factors, growth stage, etc. (Zhang et al. 2008). The cattle fed CS showed lower blood concentrations of glucose and cholesterol, inferring a relative lower energy metabolism activity. Protein metabolism also showed a similar comparative effect, since ALT concentration was also lower in group CS, indicating a poorer protein synthesis, consequently resulting in a higher level of creatinine through an increased renal activity as more metabolites were needed to be excreted (Pagana and Pagana 2010). These results were well in line with the growth performance that the growth rate of the cattle fed CS during the last finishing phase was slower than that of the cattle fed SS, and the fluctuation of blood biomarkers tightly correlated with animal performance. In general, it is really challenging to make clear the fluctuation of blood parameters due to the dietary treatments because of the complex homeostasis regulation.

It is always proposed that efficient rumen fermentation would lead to superior performance, which is essentially based on the enzymolysis of rumen microorganism. Thus, the enzyme activities would reflect the digestive potency of nutrients. According to the current results, the cattle fed SSC showed a higher activity of avicelase in the rumen, and the cattle fed SS were numerically lower in all the enzymes activities. It sounds illogical that the higher level of dietary concentrate showed higher activities of cellulolytic enzymes because the pH decrease caused by high concentrate level would discount the enzyme activity. Maybe the differences of clearance rate and ineffective adsorption of the diets should be to blame. It is reported that the remaining lignin fraction of acid pretreatment possesses higher affinity for cellulolytic enzyme components than the carbohydrates (Mooney et al. 1998; Kumar and Wyman 2009).

***Fattening earnings of beef cattle fed different finishing rations***. In practice, the feedlots make production decisions on such as feedstuff selecting, fattening mode, and marketing mostly based on economic benefits. For example, if the production cost of alsike clover silage is lower than that of grass silage and its inclusion in ration brings benefits, using alsike clover may increase the overall profitability of the farm. However, in many studies, improvements in feed intake with higher-quality forage inclusion in the diet have not consistently resulted in improved levels of animal performance (O'Kiely and Moloney 2000), thus financial implications of incorporating corn silage into the diet of beef cattle are not clear. In the present study, based on the local market, the fattening earnings of the cattle fed corn stalk silage based diet with corn grain supplementation were approximately $27.50 less than those of the cattle fed corn silage or corn stalk silage based diets, suggesting that (1) the economic effectiveness of including corn silage in the finishing diet is better than that of including both corn stalk silage and equivalent corn grain; (2) supplementing corn stalk silage based diet with equivalent corn grain is not economical when the concentrate level of the finishing diet is high enough. Therefore, taking into account the benefits and convenience of production, it is recommended to harvest corn plant as corn silage other than corn grain with corn stalk silage. The study of Burken (2014) showed that the benefit of incorporating increased corn silage in finishing diets mostly depended on the comparison prices of corn grain and corn silage as well as the management of silage production. An estimated break-even point of different diets would contribute to decision making.

## CONCLUSION

In this study, the overall body weight gain, dry matter feed intake, and feed efficiency of beef cattle fed corn (stalk) silage-based finishing rations along with their carcass performance were undifferentiated except for periodical differences in Phase 2; the concentrations of alanine transaminase and glucose in blood and the activity of avicelase in the rumen fluid were significantly different. The fattening earnings of the cattle offered corn stalk silage based diet supplemented with equivalent corn grain were approximately $27.50 less than those of the cattle offered corn silage or stalk silage based diets. These results suggest that it is more economical to substitute corn stalk silage with corn silage rather than supplement equivalent corn grain in a high-concentrate finishing ration.

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