Correlations between circulating ghrelin concentrations and growth performance, carcass traits, meat quality indices in finishing bulls fed high-concentrate diets

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Abstract. Circulating ghrelin concentrations could potentially be used as a predictor of production traits in cattle. This study aimed to clarify the correlations between circulating total ghrelin concentrations and growth performance, carcass traits, meat quality indices in finishing bulls fed high-concentrate diets. Fifty-seven Simmental × Luxi F1 crossbred bulls (approximately 24 month of age, mean body weight ± SD: 514 ± 27 kg) were used for 112-days finishing experiment. Circulating total ghrelin concentrations and relevant indices of growth performance, carcass traits and meat quality were measured during or after finishing trial. The results indicated that the total ghrelin concentrations were positively correlated with dry matter intake (DMI) (r = 0.278, P = 0.046) and were not correlated to other growth indices including initial body weight (BW), final body weight, average daily gain (ADG) and feed efficiency (feed : gain) (P > 0.05). The total ghrelin concentrations were positively correlated with meat-bone ratio (r = 0.269, P = 0.045) and tended to be positively correlated to high rib weight (r = 0.234, P = 0.083). Moreover, total ghrelin concentrations were not correlated to other carcass traits indices such as hot carcass weight, dressing percentage, Longissimus dorsi muscle (LM) area and 12th rib fat thickness (P > 0.05). Total ghrelin concentrations tended to be negatively correlated to the shear force of beef (r = -0.299, P = 0.064), and were not correlated to other meat quality indices such as moisture, pH, drip loss, cooking loss, meat color conventional chemical composition and fatty acid composition (P > 0.05). In conclusion, circulating total ghrelin concentrations were associated with DMI, meat-bone ratio and beef tenderness in finishing bulls fed high concentrated diet, and it could be used as a potential biomarker for evaluation of animal production traits such as DMI and beef tenderness in finishing bulls fed high concentrate diets.

1. Introduction
Ghrelin is peptide composed of 27 amino acid peptide in ruminants [1], and it is mainly synthesized by the abomasal and ruminal tissues of cattle [2]. Ghrelin is thought to be able to stimulate growth hormone release and appetite by binding to the growth hormone secretagogue receptor (GHSR1α) [3,4]. In addition, it's reported that ghrelin plays a prominent role in the regulation of fat metabolism in ruminants [5]. Given the potential functions of ghrelin on growth, appetite regulation and body composition, it is possible that circulating ghrelin concentrations could be used as a biomarker for evaluation of animal production traits [6].

Up till now, although the correlations analysis of circulating ghrelin concentrations with dry matter intake, growth performance, and carcass characteristics of finishing beef cattle have been carried out...
[6,7], relationship of circulating ghrelin concentrations with meat quality traits is still unclear in finishing cattle. Therefore, the objective of this study was to clarify the associations of circulating total ghrelin concentrations with animal production traits including growth performance, carcass traits and meat quality in finishing bulls.

2. Materials and methods

All procedures involving animal care were under the approval of the Yanbian University Institutional Animal Care and Use Committee.

2.1. Animals feeding and management

Fifty-seven crossbred bulls (Simmental × Luxi, approximately 24 month of age, mean body weight ± SD: 514 ± 27 kg) were used in this study. All bulls were ear tagged and dewormed before finishing trial. All bulls were individually fed the same high-concentrate basal diets (Table 1). The bulls were fed twice a day. The finishing trial lasted 112 days, and dietary dry matter intake (DMI), average daily gain (ADG) and feed efficiency (feed: gain, F: G) were recorded and calculated during the trial.

Table 1. Ingredient and nutritional composition of basal diets.

| Ingredient composition | % of DM | Nutritional composition b | % of DM |
|------------------------|---------|--------------------------|---------|
| Corn meal              | 51.14   | Dry matter, DM           | 71.45   |
| Corn silage            | 30.61   | Crude protein, CP        | 12.23   |
| Cottonseed meal        | 7.79    | Ether extract, EE        | 2.98    |
| Soybean meal           | 5.79    | Calcium, Ca              | 0.63    |
| Salt                   | 0.40    | Phosphorus, P            | 0.37    |
| Sodium bicarbonate     | 1.04    | Sulphur, S               | 0.16    |
| Compound premix a      | 3.45    | Net energy for growth, NEg (Mcal/kg DM) | 1.29    |
| Total (%)              | 100.00  | Net energy for maintenance, NEm (Mcal/kg DM) | 1.94    |

Abbreviation: DM, dry matter.

aCompound premix, supplied per kilogram of product. Ca: 160 g; P: 30 g; Cu: 450 mg; Zn: 1600 mg; Mn: 800 mg; I: 10 mg; Co: 10 mg; Se: 5 mg; vitamin A: 120 000 IU; vitamin D: 55000 IU; vitamin E: 400 mg; vitamin B3: 600 mg; vitamin B5: 200 mg; Monesin: 1000 mg.

bThe value for nutritional composition of diets including DM, CP, EE, Ca and P was calculated based on the nutrient analysis from ingredient samples. S, NEg and NEm was estimated from NRC (2000) values.

2.2. Sample collection, processing, and analyses

Blood samples were collected on the last day of the study prior to feeding in the early morning by 10 ml vacuum blood collection tubes. Tubes were centrifuged for 15 min (3200 rpm, 4°C) and the separated plasma was used for measurement of concentration of total ghrelin concentration. The plasma total ghrelin concentration was analyzed by a r-911 full automatic radio-immune counter (University of Science and Technology of China, Co. Ltd, China) with radioimmunoassay methods in a service corporation (Beijing Sino-Uk of Biological technology, Beijing, China).

The dressing percentage of each bull was calculated according to Live weight and hot carcass weight (HCW). Other carcass characteristics were measured during Carcass segmentation (24-h chill), including 1) subcutaneous fat thickness between the 12th and 13th ribs (12th-rib fat thickness), 2) LM area between the 12th and 13th ribs (LM area), meat weight in carcass (net meat weight), meat percentage in carcass (net meat percentage), bone weight in carcass (bone weight), meat-bone ratio in carcass, weight and proportion of high quality beef (high rib, ribeye, sirloin and tenderloin) in carcass. Briefly, 12th-rib fat thickness was directly measured with vernier calipers, and LM area was measured by a planimeter (QCJ-2000, Harbin optical instrument factory, China) after drawing the cross-sectional figure of LM with transparent sulfuric acid paper. Other indices including live weight, hot carcass weight, weight of bone and high quality beef were all from plant personnel.

Thirty nine samples of LM (sirloin) were randomly selected from fifty-seven samples for meat quality evaluation, including water content, pH, cooking loss, drip loss, shear force, color indices, crude ash, intramuscular fat, protein and cholesterol content. The water content, protein and ash...
contents of beef were determined according to standard procedures [8], and the details of determination of drip loss, cooking loss percentage, shear force and cholesterol content of beef refer to method of Geng et al [9].

Fatty acid methyl ester (FAME) synthesis was conducted according to method of O’Fallon [10]. Saturated fatty acids (SFA) were the sum of C10:0, C12:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0, C21:0 and C22:0. Monounsaturated fatty acids (MUFA) were the sum of C14:1n5, C16:1n7, C17:1n7, C18:1n9c and C20:1n9. Polyunsaturated fatty acids (PUFA) were the sum of C18:2n6, C:18:2n6c, C18:3n6c, C20:3n6, C:20:3n6c, C20:2, C20:4n6, C22:2 and C20:5n3. N-6 fatty acids were the sum of C18:2n6t, C:18:2n6c, C:18:3n6c, C20:3n6 and C20:4n6. N-3 fatty acids were the sum of C18:3n3, C20:3n3 and C20:5n3.

2.3. Statistical analysis
All production traits indices were sorted into three equal groups according to descending order of total ghrelin concentrations, and data were statistically described by GLM model of SPSS 18.0 (SPSS Inc., Chicago, IL, USA), and multiple comparisons were conducted by one-way with method of Duncan. The correlation analysis were performed by the Pearson option (2-tailed). Significance for correlation was declared at $P < 0.05$, and tendencies were declared at $P < 0.10$.

3. Results

3.1. Association of circulating total ghrelin concentrations with growth performance traits
The statistical description and correlation analysis between circulating total ghrelin concentrations and growth performance indices of cattle were showed in table 2. There was no significant difference in growth traits indices among three groups ($P > 0.05$), and the final body weight (BW), average daily gain (ADG) and feed conversion (FC) improved with the increase of total ghrelin concentrations ($P > 0.05$; table 2). The total ghrelin concentrations showed a positive correlation with dry matter intake (DMI) ($r = 0.278$, $P = 0.046$), and were not correlated to other indices including initial BW, final BW, ADG and FC ($P > 0.05$; table 2).

### Table 2. The description of the growth performance and correlations analysis with circulating total ghrelin concentrations in finishing bulls fed high-concentrate diets.

| Items                        | Data description | Correlation analysis |
|------------------------------|------------------|----------------------|
|                             | LC ghrelin (n=19) | MC ghrelin (n=19)   | HC ghrelin (n=19) | SEM | $P$ value | Correlation coefficient (r) | $P$ value |
| Ghrelin, ng/mL               |                  |                     |                  |     |           |                             |            |
| Initial BW, kg               | 513.17           | 517.20              | 513.00           | 6.757 | 0.892     | -0.010                       | 0.945      |
| Final BW, kg                 | 584.88           | 592.48              | 594.53           | 11.07 | 0.811     | 0.131                        | 0.338      |
| ADG, kg/day                  | 0.73             | 0.84                | 0.88             | 0.078 | 0.392     | 0.206                        | 0.139      |
| Average DMI, kg/day          | 9.35             | 9.70                | 9.98             | 0.353 | 0.454     | 0.278**                      | 0.046      |
| Feed conversion (feed: gain) | 14.07            | 13.29               | 13.57            | 1.170 | 0.897     | -0.059                       | 0.675      |

Abbreviation: BW, body weight; ADG, average daily gain; DMI, dry matter intake; LC ghrelin, low concentration of ghrelin; MC ghrelin, medium concentration of ghrelin; HC ghrelin, high concentration of ghrelin.

Data were blocked into three equal groups according to descending order of measured circulating total ghrelin concentrations.

Standard error of the mean (n = 57).

** Significant correlation ($P < 0.05$); * Correlation tendency (0.05 < $P < 0.1$).

3.2. Association of circulating total ghrelin concentrations with carcass traits
There was no significant difference in carcass traits indices but proportion of tenderloin in carcass

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among three groups (\(P > 0.05\); table 3). The proportion of tenderloin in carcass was significantly decreased with the increase of total ghrelin concentrations (\(P = 0.038\); table 3). The total ghrelin concentrations were positively correlated with meat-bone ratio (\(r = 0.269, P = 0.045\)), and tended to be positively correlated to high rib weight (\(r = 0.234, P = 0.083\); table 3). In addition, total ghrelin concentrations tended to be negatively correlated to proportion of tenderloin in carcass (\(r = -0.259, P = 0.057\); table 3). Moreover, total ghrelin concentrations did not show association with other carcass traits indices including hot carcass weight, dressing percentage, LM area, 12th rib fat thickness, bone weight, net meat percentage, ribeye weight, sirloin weight, tenderloin weight, proportion of high rib in carcass, proportion of ribeye in carcass and proportion of sirloin in carcass (\(P > 0.05\); table 3).

### Table 3. The description of the carcass traits and correlations analysis with circulating total ghrelin concentrations in finishing bulls fed high-concentrate diets.

| Items                          | Data description \(^d\) | Correlation analysis |
|-------------------------------|-------------------------|----------------------|
|                               | LC ghrelin (n=19)       |                      |
|                               | HC ghrelin (n=19)       |                      |
|                               | HC ghrelin (n=19)       |                      |
|                               | SEM\(^e\)               | \(P\) value          |
|                               | Correlation coefficient (r) | \(P\) value |
| Ghrelin, ng/mL                | 73.18\(^a\)            |                      |
|                               | 94.50\(^b\)            |                      |
|                               | 121.40\(^a\)           | 1.981 \(<0.001\)    |
| Hot carcass weight, kg        | 319.16                  |                      |
|                               | 331.11                  |                      |
|                               | 328.11                  | 6.346 0.396          |
| Dressing percentage, %        | 55.15                   |                      |
|                               | 56.47                   |                      |
|                               | 55.87                   | 0.674 0.399          |
| LM area, cm\(^2\)            | 69.11                   |                      |
|                               | 72.36                   |                      |
|                               | 70.33                   | 2.178 0.579          |
| 12th rib fat thickness, cm    | 0.77                    |                      |
|                               | 0.80                    |                      |
|                               | 0.84                    | 0.080 0.835          |
| Net meat weight, kg           | 271.06                  |                      |
|                               | 281.70                  |                      |
|                               | 281.29                  | 5.738 0.343          |
| Bone weight, kg               | 48.10                   |                      |
|                               | 49.41                   |                      |
|                               | 46.82                   | 1.190 0.323          |
| Net meat percentage, %        | 46.83                   |                      |
|                               | 48.05                   |                      |
|                               | 47.88                   | 0.655 0.373          |
| Meat-bone ratio               | 5.69                    |                      |
|                               | 5.75                    |                      |
|                               | 6.03                    | 0.142 0.201          |
| High quality beef\(^f\), kg  | 53.82                   |                      |
|                               | 55.63                   |                      |
|                               | 55.67                   | 1.157 0.440          |
| Highrib, kg                   | 22.25                   |                      |
|                               | 23.19                   |                      |
|                               | 23.57                   | 0.552 0.232          |
| Ribeye, kg                    | 11.97                   |                      |
|                               | 11.98                   |                      |
|                               | 12.17                   | 0.356 0.904          |
| Sirloin, kg                   | 12.79                   |                      |
|                               | 13.52                   |                      |
|                               | 13.25                   | 0.342 0.323          |
| Tenderloin, kg                | 6.81                    |                      |
|                               | 6.95                    |                      |
|                               | 6.68                    | 0.159 0.515          |
| Proportion of high            | 16.86                   |                      |
|                               | 16.83                   |                      |
|                               | 16.99                   | 0.214 0.863          |
| quality beef in               | 0.114 0.404             |
| carcass, %                    | 6.97                    |                      |
|                               | 7.02                    |                      |
|                               | 7.20                    | 0.143 0.497          |
| Highrib, %                    | 3.75                    |                      |
|                               | 3.63                    |                      |
|                               | 3.73                    | 0.091 0.591          |
| Ribeye, %                     | 4.00                    |                      |
|                               | 4.08                    |                      |
|                               | 4.02                    | 0.072 0.705          |
| Sirloin, %                    | 2.14\(^a\)             | 2.10\(^ab\)         |
|                               | 2.03\(^b\)             | 0.028 0.038          |
| Tenderloin, %                 | -0.259**                |

Abbreviation: LM, Longissimus dorsi muscle; LC ghrelin, low concentration of ghrelin; MC ghrelin, medium concentration of ghrelin; HC ghrelin, high concentration of ghrelin.

\(a, b, c\) Values within row with differing superscripts differ \(P < 0.05\).

\(d\) Data were blocked into three equal groups according to descending order of measured circulating total ghrelin concentrations.

\(e\) Standard error of the mean (\(n = 57\)).

\(f\) High quality beef included highrib, ribeye, sirloin and tenderloin.

**\(, \) Significant correlation (\(P < 0.05\)); \(*\), Correlation tendency (0.05 < \(P < 0.1\)).

### 3.3. Association of circulating total ghrelin concentrations with conventional indices of meat quality and chemical composition

There was no significant difference in conventional indices of meat quality and chemical composition among three groups (\(P > 0.05\); table 4). The total ghrelin concentrations tended to be negatively correlated to shear force of beef (\(r = -0.299, P = 0.064\); table 4). Moreover, total ghrelin
concentrations were not correlated to other meat quality indices including moisture, pH, drip loss, cooking loss, meat color and chemical composition including content of ash, protein, intramuscular fat and cholesterol (\(P > 0.05\); table 4).

**Table 4.** The description of the conventional indices of meat quality and chemical composition and correlations analysis with circulating total ghrelin concentrations in finishing bulls fed high-concentrate diets.

| Items                      | Data description | Correlation analysis |
|----------------------------|------------------|----------------------|
|                            | LC ghrelin (n=13) | HC ghrelin (n=13)    | SEM        | \(P\) value | Correlation coefficient (r) | \(P\) value |
| Ghrelin, ng/mL             | 74.82\(^a\)      | 125.37\(^a\)        | 3.614      | <0.001      | /                         | /           |
| Moisture, %                | 72.40            | 73.27                | 0.280      | 0.273       | 0.134                     | 0.415       |
| pH                         | 5.62             | 5.70                 | 0.057      | 0.534       | 0.094                     | 0.570       |
| Drip loss, %               | 35.79            | 29.04                | 1.629      | 0.231       | -0.185                    | 0.260       |
| Cooking loss, %            | 43.74            | 41.14                | 1.30       | 0.724       | -0.079                    | 0.631       |
| Shear force, kg            | 7.35             | 6.36                 | 0.268      | 0.327       | -0.299*                   | 0.064       |
| L                          | 35.59            | 35.36                | 0.661      | 0.990       | -0.042                    | 0.800       |
| a                          | 21.82            | 20.60                | 0.596      | 0.619       | -0.103                    | 0.534       |
| b                          | 10.61            | 9.48                 | 0.451      | 0.603       | -0.135                    | 0.414       |
| Ash, % of DM               | 3.97             | 4.02                 | 0.051      | 0.904       | 0.022                     | 0.896       |
| Protein, % of DM           | 84.42            | 86.45                | 0.650      | 0.435       | 0.123                     | 0.460       |
| Intramuscular fat, % of DM | 10.75            | 8.09                 | 0.805      | 0.348       | -0.143                    | 0.386       |
| Cholesterol, mg/100g DM    | 118.98           | 118.14               | 1.606      | 0.586       | 0.031                     | 0.854       |

Abbreviation: DM, dry matter of beef; LC ghrelin, low concentration of ghrelin; MC ghrelin, medium concentration of ghrelin; HC ghrelin, high concentration of ghrelin.

\(a, b, c\) Values within row with differing superscripts differ \(P < 0.05\).

\(d\) Data were blocked into three equal groups according to descending order of measured circulating total ghrelin concentrations.

\(e\) Standard error of the mean (n = 39).

\(**\) Significant correlation (\(P < 0.05\)); \(*\), Correlation tendency (0.05 < \(P < 0.1\)).

3.4. Association of circulating total ghrelin concentrations with fatty acid composition

There was no significant difference in proportions and concentrations of SFA, MUFA and PUFA fatty acids and some nutritional values including n-6/n-3, PUFA/SFA and C18:2n6/C:18:3n3 among three groups (\(P > 0.05\); table 5). Moreover, total ghrelin concentrations did not show significant correlation with these indices above (\(P > 0.05\); table 5).

**Table 5.** The description of the proportions (% of total fatty acids) and concentrations (mg/100g fresh muscle tissue) of saturated (SFA), monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids and some nutritional values and correlations analysis with circulating total ghrelin concentrations in finishing bulls fed high-concentrate diets.

| Items                     | Data description | Correlation analysis |
|---------------------------|------------------|----------------------|
|                           | LC ghrelin (n=13) | HC ghrelin (n=13)    | SEM        | \(P\) value | Correlation coefficient (r) | \(P\) value |
| Ghrelin, ng/mL            | 74.82\(^c\)       | 125.37\(^a\)        | 3.614      | <0.001      | /                         | /           |
| % of total fatty acids    |                  |                      |            |             |                           |             |
| SFA                       | 46.78            | 45.75                | 0.425      | 0.261       | -0.235                    | 0.151       |

Abbreviation: DM, dry matter of beef; LC ghrelin, low concentration of ghrelin; MC ghrelin, medium concentration of ghrelin; HC ghrelin, high concentration of ghrelin.
association of total ghrelin concentrations with feed efficiency, study indicated that total ghrelin concentrations showed a positive correlation with dry matter intake (DMI) in finishing cattle even tended to be negatively associated with DMI in finishing beef steers. Finishing bulls and high concentrate diets were used, which may cause a disparity for relationship of circulating total ghrelin concentration with production traits. It was reported that exogenous AG can increase time spent eating and ADG in beef cattle. Presently, for finishing bulls fed high-concentrated diets, the report of relationship of circulating total ghrelin concentration with production traits is limited. Our study indicated that circulating total ghrelin concentrations showed a positive correlation with DMI in finishing bulls. However, in other studies, total ghrelin concentrations have no significant association with DMI in finishing cattle even tended to be negatively associated with DMI in finishing beef steers and heifers.

It was reported that the ratio of AG to total ghrelin or AG concentrations rather total ghrelin concentrations showed a positive correlation with dry matter intake (DMI) in finishing cattle. It is likely to be more rational for AG or active: total ghrelin ratio to show a positive association with DMI in cattle because only AG can bind the GHSR for stimulating appetite. However, it is worth noting that circulating active and total ghrelin concentrations and their ratio in plasma may alter with different physiological stages, sex and diets composition in ruminants. In the present study, the intact finishing bulls and high concentrate diets were used, which may cause a disparity for relationship of circulating total ghrelin concentration and feed intake in different studies. Given this, it is interesting and necessary to further research into the relationship of changes of AG, UAG and GOAT concentrations with DMI in finishing bulls fed high concentrate diets.

It was reported that administration of ghrelin can cause an increased BW gain and improved feed efficiency in rats and mice. Nevertheless, in cattle, published literature regarding ghrelin did not show consistent benefit to ADG and feed efficiency. For ADG, a previous study reported that total ghrelin was negatively correlated to ADG, however, the data presented here or reported by another study indicated that total ghrelin did not show a significant association with ADG. For feed efficiency, total circulating ghrelin concentrations showed a negative correlation to feed efficiency or tended to be positively associated with feed efficiency in cattle, and our data did not show any association of total ghrelin concentrations with feed efficiency ($P > 0.01$; table 2).

### Table 1: Nutritional Value of Dietary Fatty Acids

| Fatty Acid Type | Value (g/100 g Fresh Muscle) |
|-----------------|-----------------------------|
| SFA             | 1333.92                     |
| MUFA            | 1288.96                     |
| PUFA            | 235.77                      |
| n-6             | 228.75                      |
| n-3             | 5.12                        |

**Abbreviation:**

- **SFA:** C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C21:0 + C22:0
- **MUFA:** C14:1n5 + C16:1n7 + C17:1n7 + C18:1n9c + C20:1n9
- **PUFA:** C18:2n6 + C18:3n6c + C20:3n6 + C20:4n6 + C20:5n3
- **n-6:** C18:2n6t + C:18:2n6c + C:18:3n6c + C20:3n6 + C20:4n6 + C20:5n3
- **n-3:** C:18:3n3 + C20:3n3 + C20:5n3

| Component       | Value (g/100 g Fresh Muscle) |
|-----------------|-----------------------------|
| C18:2n6/C18:3n3 | 46.73                       |

**Abbreviation:**

- **PUFA:** C18:2n6 + C18:3n6
- **SFA:** C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C21:0 + C22:0
- **MUFA:** C14:1n5 + C16:1n7 + C17:1n7 + C18:1n9c + C20:1n9

### 4. Discussion

Ghrelin is a 28 amino acid peptide. In the circulation, ghrelin is presented as acylated (AG) and un-acylated (UAG) forms which play opposing action on appetite. AG was considered as the bioactive form of ghrelin on appetite, and UAG can be transformed into AG by the enzyme ghrelin o-acyltransferase (GOAT). It was reported that exogenous AG can increase time spent eating and DMI in beef cattle. Presently, for finishing bulls fed high-concentrated diets, the report of relationship of circulating total ghrelin concentration with production traits is limited. Our study indicated that circulating total ghrelin concentrations showed a positive correlation with DMI in finishing bulls. However, in other studies, total ghrelin concentrations have no significant association with DMI in finishing cattle even tended to be negatively associated with DMI in finishing beef steers and heifers.

It was reported that the ratio of AG to total ghrelin or AG concentrations rather total ghrelin concentrations showed a positive correlation with dry matter intake (DMI) in finishing cattle. It is likely to be more rational for AG or active: total ghrelin ratio to show a positive association with DMI in cattle because only AG can bind the GHSR for stimulating appetite. However, it is worth noting that circulating active and total ghrelin concentrations and their ratio in plasma may alter with different physiological stages, sex and diets composition in ruminants. In the present study, the intact finishing bulls and high concentrate diets were used, which may cause a disparity for relationship of circulating total ghrelin concentration and feed intake in different studies. Given this, it is interesting and necessary to further research into the relationship of changes of AG, UAG and GOAT concentrations with DMI in finishing bulls fed high concentrate diets.

It was reported that administration of ghrelin can cause an increased BW gain and improved feed efficiency in rats and mice. Nevertheless, in cattle, published literature regarding ghrelin did not show consistent benefit to ADG and feed efficiency. For ADG, a previous study reported that total ghrelin was negatively correlated to ADG, however, the data presented here or reported by another study indicated that total ghrelin did not show a significant association with ADG. For feed efficiency, total circulating ghrelin concentrations showed a negative correlation to feed efficiency or tended to be positively associated with feed efficiency in cattle, and our data did not show any association of total ghrelin concentrations with feed efficiency ($P > 0.01$; table 2).
There are very limited reports for relationship between ghrelin and carcass characteristics. A previous study reported that total ghrelin concentrations did not show significant correlation with carcass characteristics including HCW, LM area, 12\(^{th}\) rib fat, marbling score and yield grade (\(P > 0.10\)) [7]. In present study, we also found that circulating total ghrelin concentrations have no significant relationship with these carcass indices above. However, total ghrelin concentrations showed a positive correlation meat-bone ratio (\(r = 0.269, P = 0.045\); table 3). In addition, total ghrelin concentrations tended to be positively correlated with high rib weight high-quality beef (\(r = 0.234, P = 0.083\); table 3) and tended to be negatively correlated with tenderloin proportion of high-quality beef in carcass (\(r = -0.259, P = 0.057\); table 3).

It was reported that sheep with high levels of adiposity have higher ghrelin concentrations compared with lean animals after overnight fasting [18], which may lead to increased meat-bone ratio with ghrelin concentration increased. Moreover, ghrelin can increase time spent eating and DMI of beef cattle [4], which may lead to difference in weight of related muscle tissue.

It was reported that ghrelin has a certain effect on cattle accreting fat [5], which hinted that circulating ghrelin concentrations may have a relationship with meat quality of cattle. For the first time, we revealed the relationship between circulating total ghrelin concentrations and meat quality traits in finishing bulls fed high-concentrate diets. The results indicated that total ghrelin concentrations tended to be negatively correlated to shear force of beef (\(r = -0.299, P = 0.064\); table 4). Moreover, total ghrelin concentrations was not correlated to other meat quality indices such as moisture, pH, drip loss, cooking loss, meat color, chemical composition and fatty acid composition (\(P > 0.05\); tables 4 and 5).

The muscle characteristics depend on many factors such as feeding management, age, sex, and breed, which is related to the variability of beef tenderness [19,20]. In this study, intact bulls were used and a negative correlation tendency between total ghrelin concentrations and shear force of beef was found which indicating that ghrelin may contribute to regulation of beef tenderness in finishing bulls fed concentrate diets. It was reported that the degradability of muscle connective tissue protein is a key factor for meat tenderness [19]. Available evidences have indicated that increased intracellular Ca\(^{2+}\) concentrations play an important role in improving the beef tenderness by regulating degradability of connective tissue protein [21-23], and increased endogenous ghrelin concentrations can increase intracellular Ca\(^{2+}\) concentration in muscle cells [24]. These results suggest that ghrelin may potentially contribute to regulation of beef tenderness by increasing Ca\(^{2+}\) concentrations in muscle, and further research is necessary for effect of ghrelin on beef quality.

5. Conclusion
In conclusion, circulating total ghrelin concentrations are associated with DMI, meat bone ratio and beef tenderness in finishing bulls fed high concentrate diet. It is probable that circulating total ghrelin concentrations could be used as a potential biomarker for evaluation of animal production traits such as DMI and beef tenderness in finishing bulls fed high concentrate diets.

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