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The effects of including corn silage, corn stalk silage, and corn grain in finishing ration of beef steers on meat quality and oxidative stability

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ABSTRACT

The effect of cattle feed on beef quality and oxidative stability was investigated. A corn silage (CS)-based finishing diet was compared with the diets based on corn stalk silage (SS) or corn stalk silage combined with its expected corn grain (SSC), containing a ratio of stalk to grain of corn plant of 1.5:1. Replacing CS with SS in the finishing diet had no effect on the proximate nutrients, cholesterol content, fatty acids profile, pH, color, water holding capacity, tenderness, texture profile, or oxidative stability of beef muscle. Compared to the CS diet and SS diet, cattle fed SSC diet showed an inferior antioxidant capacity, lower SOD and higher MDA concentrations in blood. SSC diet fed cattle also showed higher MDA and protein carbonyl concentrations in beef muscle indicating increased oxidation damage, and potentially resulting in a greater drip loss of the beef muscle. Corn silage can be replaced in the finishing feed of beef cattle with corn stalk silage without any negative effects on measures of beef quality.

1. Introduction

Corn silage is commonly used as fodder in dairy production systems around the world and in beef cattle production in Europe and America (Adesogan, 2009; Keady, Kilpatrick, Mayne, & Gordon, 2008; Millen, Pacheco, Arrigoni, Galyean, & Vasconcelos, 2009). However, corn stalk silage is still a preference for beef cattle production in districts with less availability of feed resources due to its advantages of large-scale production and low-price. Corn stalk silage-based diets with various levels of added concentrate are utilized during different stages of beef cattle growth in some many production systems. Noteworthily, continuous increases in corn production over years and the resulting surpluses in supply have badly pushed down the value of corn grain. In order to rejuvenate corn production and make the production efficiency improved, some policy implemented will encourage farmers to harvest their own corn plants for corn silage, which is a more profitable feed production model that transferring corn produced from food-oriented production to feed-oriented production. A result of policy guidance will be the inclusion of a larger proportion of corn silage in the diets of beef cattle.

Diet has been shown to influence the fatty acids profile, antioxidant capacity, color, flavor, tenderness, and others aspects of meat quality suggesting that the inclusion of increasing amounts of corn silage in diet of beef cattle may result in altered beef properties (Kim, Stuart, Rosenvold, & Maclennan, 2013; Wood et al., 2004). However, the results of alterations in dietary compositions on animal performance and meat quality are often contradictory with some studies reporting more favorable differences in eating quality after grain feeding but others after grass (forage)-based feeding (Melton, 1990; Moloney & Drennan, 2013). Based on a review of 15 studies, Muir, Deaker, and Bown (1998) concluded that there were no consistent differences between cereal and pasture-based rations on meat color, pH, tenderness, or juiciness. Relatively little comparative data is available on the effects of substituting corn stalk silage with corn silage on the nutrition values and organoleptic properties of beef muscle. Despite the popularity of corn silage, it remains unclear whether feeding corn silage is always more economical than corn stalk silage combined with its expected corn grain in beef production.

The aim of this study was to determine the effects of substituting corn silage for corn stalk silage in a finishing diet on meat quality of beef muscle. We hypothesized that the inclusion of corn silage in the diet of beef cattle would show an improved effect on beef quality similar to the addition of concentrate to the diet because of its much corn grain inclusion. A second objective was to investigate the effects of

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supplementing corn grain in corn stalk silage-based diet on meat quality and make a comparison between the inclusion effects of corn silage and corn stalk silage combined with equivalent corn in a finishing ration on beef quality. We hypothesized that beef quality would be consistent between these different diets due to their nutritional similarity.

2. Materials and methods

2.1. Experimental design and animal management

This study was undertaken at the cooperative farm of the China Agricultural University. All procedures were approved by the Animal Care and Use Committee of China Agricultural University. Forty-five Bohai crossbred black steers aged 20 months old and weighing 565.5 ± 21.4 kg were selected and randomly allocated into three dietary treatments (15 cattle per group). The corn silage (CS) diet was used as the control diet with corn silage forming 30% of the diet as dry mass. The corn stalk silage (*SS*)-based diet was formulated by replacing the corn silage with stalk silage as 30% dry mass. The corn stalk silage + corn grain (SSC) diet was formulated by substituting a portion of the corn stalk silage with corn grain with a ratio of corn stalk to corn grain of corn plant is 1.5:1 (Table 1). The total mixed ration (TMR) was formulated according to NRC (2000) recommendations for beef cattle and made isonitrogenous with the addition of urea. All the cattle were reared in separate pens with *ad libitum* access to TMR and water. To adapt to high levels of dietary concentrate, the cattle were fattened in a finishing procedure divided into three phases with Phase 1 lasting 4 weeks, Phase 2 lasing 4 weeks, and Phase 3 lasting 16 weeks. During each phase the level of dietary concentrate was increased from 45%, to 60%, and finally to 75% of the feed. Individual feed intake was manually recorded in seven consecutive days during the mid-term of each finishing phase. Individual body weight was measured at the end of each phase.

2.2. Blood and meat sampling

At the end of the 24 weeks of finishing, after a 12-h fast, cattle were bled by jugular vein puncture into anticoagulant-free tube using blood needle. Blood samples were centrifuged at 2500 × *g* and 4 °C for 15 min and then serum was separated from the blood for oxidative status analysis. Cattle were then slaughtered in Islamic Halal way (simultaneous cut-off of the jugular veins, esophagus, trachea and then electrical stimulation exsanguination). After a 48-h aging period, meat samples were taken in duplicate on the left sirloin (between the 12th and 13th rib) of each carcass, of which one was stored at 4 °C for immediate physical analysis and then freeze dried and powdered for chemical analysis, and the other one was capped in a tube and stored in liquid nitrogen for the determination of oxidative stability and glycolytic potential (GP).

2.3. Color, pH, tenderness, water holding capacity and texture profile of beef muscle

Beef muscle was analyzed for pH, color (L*, a* and b*), tenderness (shear force), water holding capacity (WHC) including both drip loss and cooking loss, and texture profile analysis (TPA) including hardness, cohesiveness, springiness, gumminess, chewiness, and adhesiveness. The pH was determined by inserting a portable pH meter (Testo 205, Testo AG, Schwarzwald, Germany) probe directly into the muscle. Color measurement (lightness, L*; redness, a*; yellowness, b*) was performed on a slice of meat using a CR 400/410 Minolta Chroma Meter (Minolta, Osaka, Japan). Cooking loss was measured by immersing the beef cut (6 cm × 4 cm × 4 cm) in a resealable pack bag in a water bath at 80 °C until its internal temperature reached 70 °C, as determined using a Hanna Foodcare digital thermometer (HI 9041, Hanna Instruments Ltd., Bedfordshire, UK). Then after cooling the surface water was removed with paper towel and the weight difference before and after cooking was calculated as cooking loss, expressed as a ratio of initial weight (%). Meat cores (1.25 cm diameter) were taken parallel to the fiber direction on the cooked steak with a special sampler and then sheared by a texture analyzer (TMS-Pro, Food Technology Corp., Sterling, VA, USA) with a 1000 Newton (N) tension/compression load cell using across head speed of 60 mm/min, during which the maximum shear force was recorded. Drip loss was determined by the weight

Table 1
Ingredients and nutritional composition of experimental finishing diets fed to steers during different fattening phases.

Item	Phase 1			Phase 2			Phase 3		
	CS[a]	SS	SSC	CS	SS	SSC	CS	SS	SSC
Ingredient, % DM[b]									
Corn grain[c]	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[c]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium 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 level,[d] % 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

[a] CS: corn silage; SS: corn stalk silage; SSC: corn stalk silage with equivalent corn grain.
[b] 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.
[c] 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 except that corn grain supplementation in SSC was less than given amount in phase 1 with the consideration of gradual adaptation to high concentrate level.
[d] Calculated values.