Effects of Steam-Flaked Corn Replacing Different Proportions of Ground Corn in the Diet on Growth Performance, Slaughter Performance, Meat Quality, and Conventional Chemical Composition of Luxi Castrated Yellow Cattle: Postprint

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Date: 2017-10-23T00:00:00+00:00

Abstract

This experiment was conducted to investigate the effects of different ratios of steam-flaked corn to ground corn in diets on growth performance, slaughter performance, meat quality, and conventional chemical composition of Luxi castrated yellow cattle. Forty-eight Luxi castrated yellow cattle approximately 21 months of age [body weight (459.6$±$10.3) kg] were selected and randomly assigned to 4 groups based on body weight, with 12 cattle per group, and allocated to 3 pens for feeding, with 4 cattle per pen. The four groups of experimental cattle were fed four different diets, namely SFC0, SFC33, SFC67, and SFC100, representing replacement ratios of steam-flaked corn for ground corn in the diets of 0, 33%, 67%, and 100%, respectively, with a corn content of 35.85% in the diets. The experimental period lasted 180 d, divided into two phases: Phase 1 lasted 84 d, including a 14 d preliminary period and a 70 d formal experimental period, after which growth performance was measured; Phase 2 lasted 96 d, during which the beef cattle were fattened, and after which slaughter performance, meat quality, and conventional chemical composition were measured. The results showed that the average daily gain (ADG) of the SFC100 group increased by 14.95%, 25.77%, and 38.20% compared with the SFC67, SFC33, and SFC0 groups, respectively, and significant differences were observed among the SFC100, SFC67, and SFC0 groups ($P<0.05$); Meanwhile, compared with the SFC0 group, the feed conversion ratio of the SFC33, SFC67, and SFC100 groups decreased by 7.73%, 17.01%, and 25.34%, respectively, with significant differences among all groups ($P<0.05$). Except that the loin eye area of the

SFC100 group was significantly larger than that of the SFC0 group (P<0.05), replacement of different proportions of ground corn with steam-flaked corn in the diets did not significantly affect slaughter performance, meat quality, or conventional chemical composition (P>0.05). Additionally, with increasing replacement ratio of steam-flaked corn in the diets, the final body weight, ADG, loin eye area, and marbling score of the beef cattle increased linearly (P<0.05), while the feed conversion ratio and dressing percentage decreased linearly (P<0.05). Thus, complete replacement of ground corn with steam-flaked corn in diets can significantly improve ADG and feed conversion efficiency of Luxi castrated yellow cattle without affecting slaughter performance and meat quality, and can improve the quality grade of premium beef cuts to a certain extent.

Full Text

Effects of Different Proportions of Steam-Flaked Corn Substituted for Milling Corn in Diets on Growth Performance, Slaughter Performance, Beef Quality and Conventional Chemical Components of Luxi Crossbred Steers

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Abstract

This study was conducted to evaluate the effects of different proportions of steam-flaked corn substituted for milling corn in diets on growth performance, slaughter performance, beef quality, and conventional chemical components of Luxi crossbred steers. Forty-eight 21-month-old Luxi crossbred steers [(459.6$±$10.3) kg body weight] were randomly divided into 4 groups according to body weight, with 12 steers per group housed in three pens (4 steers per pen). Four dietary treatments (SFC0, SFC33, SFC67, and SFC100) were randomly assigned to the four groups, representing substitution proportions of steam-flaked corn for milling corn of 0, 33%, 67%, and 100%, respectively. The corn content in all diets was 35.85%. The experiment lasted 180 days and consisted of two stages: Stage 1 (84 days, including a 14-day adaptation period and a 70-day formal trial period) for measuring growth performance, and Stage 2 (96 days) for finishing and subsequent measurement of slaughter performance, beef quality, and conventional chemical components.

The results showed that the average daily gain (ADG) of the SFC100 group increased by 14.95%, 25.77%, and 38.20% compared with the SFC67, SFC33, and SFC0 groups, respectively, with significant differences among the SFC100,

SFC67, and SFC0 groups (P<0.05). Meanwhile, the feed-to-gain ratio of the SFC33, SFC67, and SFC100 groups decreased by 7.73%, 17.01%, and 25.34% compared with the SFC0 group, with significant differences among all groups (P<0.05). Except for the ribeye area, which was significantly greater in the SFC100 group than in the SFC0 group (P<0.05), different proportions of steam-flaked corn substituted for milling corn had no significant effects on other slaughter performance metrics, beef quality, or conventional chemical components (P>0.05). Furthermore, final body weight, ADG, ribeye area, and marbling grade increased linearly (P<0.05), while feed-to-gain ratio and dressing percentage decreased linearly (P<0.05) as the substitution proportion of steam-flaked corn increased. These results indicate that complete substitution of milling corn with steam-flaked corn can significantly improve ADG and feed conversion efficiency of Luxi crossbred steers without affecting slaughter performance and beef quality, while also enhancing the quality grade of premium beef cuts to some extent.

Keywords: steam-flaked corn; milling corn; Luxi crossbred steers; growth performance; slaughter performance; beef quality; conventional chemical components

Introduction

Corn is rich in carbohydrates and serves as an important energy source in beef cattle diets, particularly for finishing cattle. However, the structure of corn kernels, endosperm type, and crystalline structure of starch all affect animal digestion and absorption of corn. Grain processing can partially or completely eliminate structural limitations to digestion caused by the protein matrix and endosperm type in grain kernels. Processing methods include dry, wet, cold, and thermal treatments, among which steam flaking is an important hydrothermal processing method and the most commonly used technique in U.S. beef feedlots. Steam flaking technology improves corn digestibility by destroying the crystalline structure of starch, protein matrix structure, and dense seed coat structure through hydrothermal conditioning and mechanical rolling during processing. Zinn et al. estimated based on 12 studies that compared with conventional dry processing methods, steam-flaked corn can increase average daily gain (ADG) by 6.3% and reduce dry matter intake (DMI) by 5.0% in beef cattle.

However, the effectiveness of steam-flaked corn is influenced by various factors including animal breed and type, feed intake, and diet composition. Consequently, research results from abroad may not be entirely applicable to local Chinese cattle breeds, and few studies have investigated the effects of steam-flaked corn on Chinese indigenous yellow cattle breeds. Therefore, this study used Luxi crossbred steers as experimental animals to investigate the effects of different proportions of steam-flaked corn substituted for conventional milling

corn on growth performance, slaughter performance, and beef quality, aiming to provide references for the application of steam-flaked corn in local Chinese yellow cattle production.

1.1 Experimental Design and Diets

This experiment employed a randomized block design. Forty-eight 21-month-old Luxi crossbred steers [(459.6$±$10.3) kg body weight] were randomly divided into 4 groups according to body weight, with 12 steers per group allocated to three pens for loose housing (4 steers per pen). Experimental diets were formulated according to NRC (2000) with a concentrate-to-forage ratio of 55:45 and corn content of 35.85%. Four dietary treatments with different substitution proportions of steam-flaked corn for milling corn (SFC0, SFC33, SFC67, and SFC100; composition and nutrient levels shown in Table 1) were randomly assigned to the four groups. The substitution proportions of steam-flaked corn for milling corn in diets SFC0, SFC33, SFC67, and SFC100 were 0, 33%, 67%, and 100%, respectively. Both steam-flaked corn and milling corn were produced by Hebei Kate Feed Group using locally sourced corn from Hebei Province. Steam-flaked corn was processed using a steam flaking unit (SERIES 999, Roskamp, USA) with a conditioning time of 60 min, flake thickness of 2.5 mm, hot-air drying after flaking, and bulk density of 380 g/L. Milling corn was produced using a hammer mill with a 1.2 mm screen.

1.2 Animal Management

The experiment lasted 180 days and consisted of two stages. Stage 1 lasted 84 days, including a 14-day adaptation period and a 70-day formal trial period, after which growth performance was measured. Stage 2 lasted 96 days for finishing, after which slaughter performance, beef quality, and conventional chemical components were measured. During the adaptation period of Stage 1, all steers were fed the same diet and underwent deworming, hoof trimming, and ear tagging. From the formal trial period of Stage 1 through the end of Stage 2, the four groups were fed their respective experimental diets. Cattle were fed total mixed rations twice daily at 08:00 and 17:00 with ad libitum access to feed and water. The feeding trial was conducted at Beijing Xinnong Animal Husbandry Co., Ltd.

1.3 Growth Performance Measurement

During the formal trial period of Stage 1, feed offered was accurately weighed and recorded daily by pen, and orts were collected and weighed every 3 days. Feed samples were collected every 4 weeks to determine moisture and conventional chemical components for calculating DMI by group. At the beginning and end of each period, cattle were weighed on two consecutive days before morning feeding, and the average was used as the initial and final body weight to calculate ADG. Feed-to-gain ratio (F/G) was calculated using ADG and DMI.

1.4 Slaughter Performance Measurement

At the end of Stage 2, one steer was randomly selected from each pen (12 steers total across 4 groups) and transported to the slaughterhouse of Beijing Jinghe Beef Cattle Co., Ltd. for processing after 24 hours of feed withdrawal. Live weight, carcass weight, and weights of heart, liver, spleen, lungs, rumen-reticulum, and small intestine were measured at slaughter to calculate dressing percentage. After 3 days of chilling at 0–4°C, backfat thickness and ribeye area between the 6th and 7th ribs were measured, and marbling grade was assessed according to Japanese beef carcass grading standards.

1.5 Beef Quality and Conventional Chemical Component Analysis

At slaughter, 500 g samples of the longissimus dorsi (between the 10th–11th ribs) and gluteus medius muscles were collected. Meat color, pH, tenderness, water loss rate, and cooking percentage of the longissimus dorsi were measured immediately after sampling. The gluteus medius was freeze-dried for determination of conventional chemical components including moisture, crude protein (CP), ether extract (EE), and crude ash. Conventional chemical components were determined as follows: dry matter (DM), calcium (Ca), and phosphorus (P) contents were measured according to methods recommended by Zhang Liying; crude protein content was determined using a nitrogen analyzer (Leco F-P528, USA); crude fat content was measured using a semi-automatic fat analyzer (ANKOM XT10, USA); starch content was determined using the method described by Xiong et al.; neutral detergent fiber (NDF) and acid detergent fiber (ADF) were measured using a fiber analyzer (ANKOM A220, USA).

1.6 Data Processing and Statistical Analysis

Experimental data were initially processed using Excel 2007 and then subjected to one-way ANOVA using the GLM procedure of SAS 9.00 statistical software. Means were compared using Duncan' s multiple range test, and orthogonal polynomial contrast analysis was used to fit linear and quadratic curves for the substitution proportion of steam-flaked corn in diets. Significance level was set at $P<0.05$.

Results

2.1 Growth Performance

As shown in Table 2 , no significant differences were observed in initial body weight or DMI among groups ($P>0.05$). However, final body weight of the SFC100 group was 3.66%, 5.02%, and 5.80% higher than that of the SFC67, SFC33, and SFC0 groups, respectively, with a significant difference between SFC100 and SFC0 ($P<0.05$), while no significant differences were found among SFC67, SFC33, and SFC0 ($P>0.05$). The ADG of the SFC100 group reached 1.23 kg, representing increases of 14.95%, 25.77%, and 38.20% compared with

the SFC67 (1.07 kg), SFC33 (0.97 kg), and SFC0 (0.89 kg) groups, respectively, with significant differences among the SFC100, SFC67, and SFC0 groups ($P<0.05$). Meanwhile, compared with the SFC0 group, the feed-to-gain ratio of the SFC33, SFC67, and SFC100 groups decreased by 7.73%, 17.01%, and 25.34%, respectively, with significant differences among all groups ($P<0.05$). Additionally, orthogonal polynomial contrast analysis revealed that final body weight and ADG increased linearly ($P<0.05$), while feed-to-gain ratio decreased linearly ($P<0.05$) as the substitution proportion of steam-flaked corn increased.

2.2 Slaughter Performance

As shown in Table 3 , no significant differences were observed among groups in dressing percentage, marbling grade, backfat thickness, heart weight, liver weight, spleen weight, or rumen-reticulum weight ($P>0.05$). The ribeye area of the SFC100 group was significantly greater than that of the SFC0 group (47.6 cm^2 vs. 36.8 cm^2; $P<0.05$). Lung weight of the SFC33 group was significantly greater than that of the SFC67 group ($P<0.05$), while no significant differences were found among other groups ($P>0.05$). Regarding small intestine weight, the SFC33 and SFC67 groups were significantly greater than the remaining two groups ($P<0.05$). Furthermore, dressing percentage decreased linearly ($P=0.044$), while ribeye area and marbling grade increased linearly ($P<0.05$) with increasing substitution proportion of steam-flaked corn. However, a significant quadratic effect was observed between small intestine weight and steam-flaked corn substitution proportion ($P<0.05$).

2.3 Beef Quality and Conventional Chemical Components

As shown in Table 4 , no significant differences were observed among groups in meat color score, pH, water loss rate, shear force, cooking percentage of the longissimus dorsi, or moisture, crude protein, crude fat, and crude ash contents of the gluteus medius ($P>0.05$). No significant linear or quadratic effects were observed with increasing substitution proportion of steam-flaked corn ($P>0.05$).

Discussion

3.1 Effects of Different Proportions of Steam-Flaked Corn on Growth Performance of Luxi Crossbred Steers

The results of this experiment showed no significant differences in DMI among the four groups, which differs from reports by Zinn et al. showing that steam-flaked corn reduced DMI by approximately 6.9% compared with dry processing methods. Similar to previous reports, ADG of the SFC100 group increased by 38.20% compared with the SFC0 group. Zinn et al. estimated based on 12 studies that steam-flaked corn increased ADG by 6.3% and reduced DMI by 5% compared with conventional dry processing. Ruminant feed intake is influenced by multiple factors including dietary energy level and rumen effective volume. In this experiment, as the substitution proportion of steam-flaked corn increased,

the dietary net energy for maintenance (NEm) and net energy for gain (NEg) values gradually increased, while no significant differences in DMI were observed among groups. This indicates that under the conditions of this experiment, dietary energy level was not the main factor limiting DMI, meaning that the energy levels of all experimental diets had not reached the point of limiting DMI in Luxi crossbred steers.

As the substitution proportion of steam-flaked corn increased, feed-to-gain ratio gradually decreased, with the SFC100 group showing a 25.34% reduction compared with the SFC0 group, representing a substantial improvement in feed conversion efficiency. This is consistent with findings by Buttrey et al., who reported that substituting steam-flaked corn for dry-rolled corn improved feed conversion efficiency by 9%. The gradual decrease in feed-to-gain ratio with increasing steam-flaked corn substitution indicates improving feed conversion efficiency, likely because the steam flaking process destroys the crystalline structure of starch and protein matrix structure in corn, increasing the contact area between corn kernels and digestive enzymes or microorganisms, thereby improving whole-tract digestibility of starch and other nutrients and ultimately increasing overall energy utilization efficiency. Zinn et al. reported that the NEm and NEg values of steam-flaked corn were 10.04 and 7.07 MJ/kg, respectively, significantly higher than those of milling corn at 9.04 and 6.44 MJ/kg.

Based on evaluating the effects of steam-flaked corn substitution proportion on growth performance of Luxi crossbred steers, this experiment further determined the optimal substitution proportion. ADG increased linearly while feed-to-gain ratio decreased linearly with increasing steam-flaked corn substitution proportion, which is consistent with the gradual increase in dietary energy level (Table 1). Huck et al. obtained similar results when substituting different proportions of steam-flaked corn for steam-flaked sorghum, finding that ADG and feed conversion efficiency increased gradually with increasing substitution proportion. Under the conditions of this experiment, higher substitution proportions of steam-flaked corn for milling corn resulted in higher feed conversion efficiency, with complete substitution maximizing feed conversion efficiency.

3.2 Effects of Different Proportions of Steam-Flaked Corn on Slaughter Performance of Luxi Crossbred Steers

Among slaughter performance indicators, dressing percentage and backfat thickness reflect beef yield to some extent, while ribeye area and marbling grade determine the quality and quantity of premium beef cuts, and weights of visceral organs, rumen-reticulum, and small intestine reflect digestive and organ development. Similar to previous reports, substituting different proportions of steam-flaked corn for milling corn in diets had no significant effects on dressing percentage, marbling grade, or backfat thickness in Luxi crossbred steers. However, unlike these studies, complete substitution with steam-flaked corn in this experiment significantly increased ribeye area, whereas previous research found no significant effect of corn processing on ribeye area. In contrast to our results,

Leibovich et al. found that steers fed steam-flaked corn-based diets had greater backfat thickness and carcass quality grades but relatively smaller ribeye area compared with those fed dry-rolled corn-based diets. This discrepancy may be attributed to differences in dietary grain inclusion levels, as their experimental diets contained approximately 70% corn, significantly higher than the 36% corn content in our diets.

Buttrey et al. suggested that the lack of significant effects of corn processing on slaughter performance was because changes in feed conversion efficiency were primarily achieved through altered DMI, and resulting body weight changes had minimal impact on slaughter performance. In this experiment, however, no significant differences in DMI were observed among groups of Luxi crossbred steers, so improvements in feed conversion efficiency were mainly due to differences in diet digestibility. This may explain why the SFC100 group had significantly greater ribeye area than the SFC0 group while other slaughter performance indicators remained unchanged.

Furthermore, ribeye area and marbling grade of Luxi crossbred steers increased linearly with increasing steam-flaked corn substitution proportion, while dressing percentage decreased linearly, possibly related to the gradual increase in dietary NEm and NEg values (Table 1). These results indicate that feeding steam-flaked corn can help improve the grade of premium beef cuts in Luxi crossbred steers, with the degree of improvement increasing with substitution proportion.

3.3 Effects of Different Proportions of Steam-Flaked Corn on Beef Quality and Conventional Chemical Components

The ultimate goal of beef production is to provide beef, making beef yield and quality the most powerful indicators for evaluating beef cattle production performance. Few studies have reported on the effects of steam-flaked corn on beef composition and quality. Buttrey et al. reported that corn processing method could affect lipid composition in the longissimus dorsi, with steam-flaked corn-based diets significantly reducing stearic acid content and increasing α-linolenic acid content compared with dry-rolled corn-based diets, while having no significant effects on sensory traits. Li Ruijing found that steam-flaked corn-based diets increased crude protein and crude fat contents in the longissimus dorsi and significantly improved cooking percentage while reducing water loss rate compared with milling corn-based diets. However, our results showed no significant effects of corn processing method on beef composition and quality, possibly for two reasons: First, the meat samples for conventional chemical component analysis in this experiment were taken from the gluteus medius, whereas previous studies used the longissimus dorsi, and the effects of corn processing method may differ between muscle sites. Second, the corn content in our experimental diets was approximately 36%, significantly lower than the 75% and 66% in the aforementioned studies, with obvious differences in diet composition and energy level, which may be the main reason why corn processing method had no sig-

nificant effects on beef quality and conventional chemical components of Luxi crossbred steers in this experiment.

In summary, complete substitution of milling corn with steam-flaked corn in diets can significantly improve ADG and feed conversion efficiency of Luxi crossbred steers, enhance the quality grade of premium beef cuts to some extent, but has no significant effects on dressing percentage, beef quality, or conventional chemical components. Moreover, ADG, feed conversion efficiency, ribeye area, and marbling grade of Luxi crossbred steers increased linearly with increasing substitution proportion of steam-flaked corn in diets, indicating that under the conditions of this experiment, complete substitution of milling corn with steam-flaked corn maximized production performance of Luxi crossbred steers.

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Note: Figure translations are in progress. See original paper for figures.