

Effects of steam-flaked corn on the performance and blood biochemical parameters in finishing steers

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Abstract This paper aims at studying the effect of steam-flaked corn instead of corn in the diet for finishing steers on the growth performance and blood biochemical parameters. A single-factor design was used. There were 28 simmental crossbred steers with the similar bodyweight (414.4 ± 29.3 kg, $P > 0.05$) selected and allotted to four groups with seven duplicates in each group. Steam-flaked corn replaced the proportion of normal cracked corn, which was of 0, 30%, 60%, or 90% in the concentrate of Groups I, II, III, or IV, respectively. The results showed that the steam-flaked corn replacing ordinary cracked corn could significantly improve the growth of steers. The daily growth rate (ADG) was increased by about 37.16% from 985.3 g/d to 1351.4 g/d. The feed efficiency was significantly improved by 27.46%. The feed to gain ratio was decreased from 5.68 to 4.12. Serum urea nitrogen was decreased from 4.59 mmol/L to 3.66 mmol/L. Under the experiment conditions, steam-flaked corn replacing ordinary cracked corn could increase the feed efficiency with an optimal replacing ratio of 90%.

Keywords steam-flaked corn, feed to gain ratio, daily growth rate (ADG), digestibility, blood biochemical parameters

Introduction

In the recent years, the amount of beef cattle is gradually increasing. Beef cattle industry plays an important role in improving the development of animal husbandry. How to improve the growth performance and the beef quality through dietary nutrition regulation becomes a research hotspot in this field. Corn is a main energy source in ruminant diets due to its high content in starch, and the digestibilities of corn for animals directly affect the performance and beef quality (Shi et al., 2006). It is reported that steam-flaked processing for corn could significantly increase starch and feed availability (Owens et al., 1998) and decrease feed waste and the pollution to the environment (Chen et al., 2009), thereby improving cattle performance (Owens et al., 1997; Bengochea et al., 2005; Reed et al., 2005) and BW gain efficiency (Xiong et al., 1991). Steam-flaked corn (SFC) has been utilized as dietary ingredients in finishing beef cattle overseas, but it was not reported in China. The objective of our research

was to supply theoretical basis for SFC application through making clear the effects of steam-flaked corn instead of common cracked corn in the diet of finishing steers on the growth performance and blood biochemical parameters.

Materials and methods

SFC sources

The SFC used in this study was manufactured commercially in the same process, and vice versa (Kaite Feed Corp., Hebei, China). Briefly, corn was steam-flaked in a 300-kg vertical stainless steel chamber at 100–110°C for about 50 min. Moisture in the chamber was raised to 18%–19%. The corn was then passed through a prewarmed roller mill (50 cm × 75 cm) to produce flakes at 360 g/L density, which were then bagged in plastic bags and sealed.

Experimental design and diets

The study was carried out in the Xinshengyuan Beef Cattle Farm. Twenty eight healthy Simmental beef cattle hybrids with 414.4 ± 29.3 kg body weight (BW) at age of 20–24 months were used and randomly allocated to four groups with

seven replicates each. The diets for the beef cattle included concentrate, corn silage, and distilled grains. The replacing ratio of SFC to FGC in diets was 0%, 30%, 60%, and 90%, respectively, of the diet DM. Energy and protein were maintained similar among treatments. In Stage 1, each beef cattle was fed with 4.45 kg concentrate, 6.11 kg corn silage, and 3.11 kg distilled grains per day. During Stage 2, each beef cattle was fed with 6.05 kg concentrate, 7.6 kg corn silage, and 2.3 kg distilled grains per day. The ingredient and nutrient composition of concentrate for beef cattle during Stage 1 and Stage 2 are shown in Tables 1 and 2.

After being dewormed, all the experimental cattle were weighed and randomly allotted to one of the four groups with similar average BW with the diets offered in an equal portion twice daily at 7:00 and 16:00. All the cows were housed in the

stalls, fed individually, with free access to water during 12:00 to 12:30. The cattle were weighed on three consecutive days at the beginning and the end of the experiment.

Feed ingredients were sampled weekly. Composite samples were mixed thoroughly and subsampled for chemical analyses. The status of feed offered and excreta from individual cows were recorded daily. Orts were mixed in each treatment, and a representative sample was frozen daily. Samples of corn silage and distilled grains were frozen daily, and samples of individual TMR were used for analysis of DM, ether extract, NDF, ADF, and CP.

Weekly, feed samples were dried at 60°C in a forced air oven for 48 h (AOAC, 1999) and then grounded through a 1-mm screen of a standard Wiley mill (model 3; Arthur H. Thomas Co., Philadelphia, PA). Daily DMI for individual

Table 1 Ingredient and nutrient composition of concentrate for beef cattle during Stage 1

Items		Treatments			
		I (0%)	II (30%)	III (60%)	IV (90%)
Ingredient /% DM basis	FGC	66	46.2	26.4	6.6
	SFC	0	19.8	39.6	59.4
	Wheat	8	8	8	8
	Cottonseed meal	20	20	20	20
	Urea	1.5	1.5	1.5	1.5
	Limestone powder	1.8	1.8	1.8	1.8
	Salt	1.0	1.0	1.0	1.0
	Sodium bicarbonate	1.5	1.5	1.5	1.5
	Premix	0.2	0.2	0.2	0.2
	Total	100	100	100	100
	Nutrient contents of the diets	NEg/(MJ/kg)	3.36	3.79	4.22
CP/% of DM		14.44	14.37	14.31	14.24
Ether extract/% of DM		3.03	3.05	3.07	3.1
Calcium/% of DM		0.756	0.760	0.764	0.768
Phosphorus/% of DM		0.374	0.374	0.373	0.373

Table 2 Ingredient and nutrient composition of concentrate for beef cattle during Stage 2

Items		Treatments			
		I (0%)	II (30%)	III (60%)	IV (90%)
Ingredient /% DM basis	FGC	73	51.1	29.2	7.3
	SFC	0	21.9	43.8	65.7
	Wheat	5	5	5	5
	Cottonseed meal	16	16	16	16
	Urea	1.5	1.5	1.5	1.5
	Limestone powder	1.8	1.8	1.8	1.8
	Salt	1.0	1.0	1.0	1.0
	Sodium bicarbonate	1.5	1.5	1.5	1.5
	Premix	0.2	0.2	0.2	0.2
	Total	100	100	100	100
	Nutrient contents of the diets	NEg/(MJ/kg)	3.39	3.86	4.34
CP/% of DM		12.92	12.85	12.78	12.71
Ether extract/% of DM		3.09	3.11	3.14	3.16
Calcium/% of DM		0.745	0.750	0.754	0.758
Phosphorus/% of DM		0.320	0.319	0.318	0.318

cattle was calculated by subtracting the weekly mean of orts from the weekly mean of feed offered.

The DM contents of feed, orts, and fecal samples were determined by oven drying at 105°C for 48 h (AOAC, 1999). The total N contents of feed, orts, and fecal samples were determined by auto Kjeltec™ 8400 Analyzer (FOSS, Technology, Eden Prairie, MN). Crude proteins were calculated as N × 6.25. NDF and ADF were determined using the modified filter bag method of Van Soest et al. (1991) and an ANKOM 2000i Auto Fiber Analyzer (ANKOM Technology Corp., Fairport, NY). Ether extraction of feed ingredient and diets was conducted with a Soxhlet system HT6 apparatus (Tecator, Fisher Scientific) according to method 920.39 (AOAC, 1999).

The total feces were collected for three consecutive days at the last week of the second period from a rubber mat placed behind the cattle and stored in plastic containers. The mass of the feces was recorded on an individual cow basis. The collected amount was thoroughly mixed, and 10% subsample was taken and stored at -20°C for subsequent analyses. The samples were dried in a forced draft oven at 60°C for 72 h, ground through a 1-mm screen (Wiley mill), and analyzed for DM, NDF, ADF, ether extract, and CP as described earlier for feeds.

All cattle were weighed individually using the squeeze chute-scale at the beginning and end of the experiment for three consecutive days before feeding in the morning. On each weighing day, feed bunks were swept.

Blood samples were collected by means of jugular vein puncture. After coagulation, the serum was obtained by centrifugation at 3000 r/min for 20 min at 4°C. Serum was stored at -20°C. The concentrations of glucose, urea nitrogen, total cholesterol, and triglyceride were measured according to the methods from commercial kits (Nanjing Jiancheng Bioengineering Institute, China).

Statistical analyses

The ADG and F:G was calculated on a BW. The F:G was computed as the quotient of ADG divided by daily DMI. All data were analyzed with pen as the experimental unit as a randomized complete block design using the MIXED

procedure of SAS. Differences between treatment means at the 5% level were determined using the least significant difference test.

Results

Growth performance and feed efficiency

The bodyweight at the beginning and the end, average daily weight gain (ADG), and the feed efficiency are shown in Table 3. Initial BW did not differ between the four groups ($P > 0.05$). The total DMI measured during the experiment was similar among treatments. With the increasing of SFC substituting ratio in the diet, the total growth weight, and ADG were extremely significantly higher than those of the control group ($P < 0.01$). However, there was no difference between Groups III and IV ($P > 0.05$). Compared with the control group, the ADG was increased by 19.92%, 29.27%, and 37.16% for diets with SFC replacing common cracked corn at 30%, 60%, and 90%, respectively. SFC in diet could significantly improve feed efficiency, with a decrease of the feed to growth ratio by 16.40%, 23.52%, and 27.78%.

The apparent digestibility of nutrients

Effects of dietary on apparent total tract digestibility of nutrients are shown in Table 4. There was no significant effect on the apparent digestibility of DM, NDF, ADF, and phosphorus ($P > 0.05$). The apparent digestibility of crude proteins, ether extract and calcium was significantly higher in the treatment with SFC ($P < 0.05$).

Blood biochemical parameters

Effects of SFC replacing common cracked corn in the diet on blood parameters of beef cattle are shown in Table 5. There was no significant difference of glucose, urea nitrogen (BUN), triglyceride, and cholesterol in blood among treatments ($P > 0.05$). With the increasing of replacing ratio, BUN tended to decrease ($P > 0.05$).

Table 3 The bodyweight at the beginning and the end, ADG, and the feed efficiency

Items	Treatments			
	Group I (0%)	Group II (30%)	Group III (60%)	Group IV (90%)
Initial BW/kg	413.2±26.2 ^a	415.7±40.4 ^a	415.7±24.1 ^a	412.9±31.2 ^a
BW at the end/kg	531.4±26.1 ^b	557.5±50.7 ^{ab}	568.6±28.7 ^{ab}	575.0±38.1 ^a
Total bodyweight gain/(kg/d)	118.2±11.6 ^{Bc}	141.8±17.5 ^{BAb}	152.9±10.7 ^{ABab}	162.1±22.4 ^{AAa}
ADG/g	985.3±96.8 ^{Bc}	1181.6±45.6 ^{BAb}	1273.7±89.3 ^{ABab}	1351.4±186.5 ^{AAa}
DMI/(kg/d)	7.88	7.90	7.78	7.80
F:G	7.99	6.68	6.11	5.77

Means in the same line with different small letter superscript differ significantly ($P < 0.05$), with same small letter superscript showing no significant difference ($P > 0.05$), with different capital letter superscript meaning extremely significant difference ($P < 0.01$).

Table 4 Effect of dietary on apparent total tract digestibility of nutrients (%)

Items	Treatments			
	Group I (0%)	Group II (30%)	Group III (60%)	Group IV (90%)
DM/%	95.15±0.49	95.73±0.39	95.99±0.32	96.30±0.43
CP/%	70.76±2.08 ^b	72.10±1.02 ^{ab}	73.44±0.17 ^a	73.77±0.65 ^a
Ether extract/%	91.18±0.39 ^c	92.10±0.51 ^{bc}	93.26±0.59 ^{ab}	93.61±1.29 ^a
NDF/%	60.89±2.60 ^a	61.84±1.81 ^a	61.95±2.69 ^a	61.14±1.12 ^a
ADF/%	52.37±4.19 ^a	56.74±1.57 ^a	57.05±2.17 ^a	56.84±0.98 ^a
Ash/%	27.47±12.44 ^a	32.95±3.47 ^a	29.06±3.32 ^a	22.11±3.14 ^a
Ca/%	36.41±4.02 ^c	41.22±1.63 ^b	43.52±1.18 ^{ab}	46.24±2.34 ^a
P/%	75.39±4.58 ^a	77.89±1.95 ^a	79.26±3.09 ^a	75.71±0.93 ^a

Means in the same line with different small letter superscript differ significantly ($P < 0.05$), with the same small letter superscript showing no significant difference ($P > 0.05$), with different capital letter superscript meaning extremely significant difference ($P < 0.01$).

Table 5 Effect of SFC in diet on blood parameters of beef cattle

Items	Group I (0%)	Group II (30%)	Group III (60%)	Group IV (90%)
Glucose (mmol/L)	5.91±0.01 ^a	5.92±0.04 ^a	5.93±0.01 ^a	5.94±0.02 ^a
Urea nitrogen(mmol/L)	4.59±0.11 ^a	4.56±0.06 ^a	4.54±0.16 ^a	3.66±0.23 ^b
Triglyceride (mmol/L)	0.37±0.03 ^a	0.37±0.04 ^a	0.37±0.06 ^a	0.37±0.07 ^a
Cholesterol (mmol/L)	2.49±0.43 ^a	2.38±0.24 ^a	2.12±0.08 ^a	2.09±0.06 ^a

Means in the same line with different small letter superscript differ significantly ($P < 0.05$), with same small letter superscript showing no significant difference ($P > 0.05$), with different capital letter superscript meaning extremely significant difference ($P < 0.01$).

Discussion

Growth performance and feed efficiency

Our results are consistent with previous studies using corn (Barajas and Zinn, 1998; Li et al., 1998; Reinhardt et al., 1998; Liang et al., 2007). Reinhardt et al. (1998) and Barajas and Zinn (1998) researched the feeding value of dry-rolled and steam-flaked corn in finishing diets for feedlot cattle and found that steam flaking corn reduced DMI (9%, $P < 0.10$) and increased ($P < 0.01$) feed efficiency (14%), dietary NEm (13%), and NEg (15%). In the report of Liang et al. (2007), steam-flaked corn also improved feed efficiency through reducing the ratio of feed to growth weight and improved the total growth weight and ADG. Increased ADG was thought to result from the digestibility of crude proteins, ether extract, starch, NDF, and ADF. In contrast, Xiong et al. (1991) noted that feeding steam-flaked sorghum processed to bulk densities of 283, 360, or 437 g/L did not affect ADG. A tendency was noted by Zinn (1990) for reduced ADG when steers were fed with corn steam flaked to 300 vs.360 or 420 g/L. Decreased ADG was thought to result from lower ruminal pH and a subsequently decreased DMI that was accompanied with the lighter bulk density flake (Zinn, 1990). Similarly, Swingle et al. (1999) reported the similar result with decreasing the bulk density of steam-flaked sorghum. Hales et al. (2010) also researched the effects of varying bulk densities of steam-flaked corn (SFC) and level of inclusion of roughage in feedlot diets and found that cattle fed on the 335 g/L SFC had greater overall G:F ($P = 0.04$) than those feeding on the

386 g/L SFC, with a tendency ($P < 0.10$) to improve G:F with the lighter flake weight evidently.

The apparent digestibility of nutrients

It is reported that steam-flaked processing for corn could significantly increase starch and feed availability (Owens et al., 1998). Defoor et al. (2000) also reported that steam-flaked sorghum had a greater total starch content and starch availability as a proportion of total starch than high-moisture sorghum. Moe and Tyrrell (1977) showed a negative effect of increasing intake on digestibility but found that diets containing whole corn were more susceptible to intake-modulated digestibility depression than diets containing cracked or ground corn. This interaction was also observed by Murphy et al. (1994). When diets contained rolled corn, digestion of starch was similar, while DM and OM digestion was lower at full feed than at 70% ad libitum intake. Burkholder et al. (2004) reported that feeding diets with steam-flaked corn could decrease the output of feces and urine, the nitrogen excretion, and ammonia-nitrogen content. This was due to the increasing of nitrogen digestibility. A similar result was found in our study; with the increase of SFC replacing ratio, the apparent digestibility of dietary crude protein was significantly improved. Steam-flaked corn could also decrease phosphorus excretion and improve dietary P digestibility (Guyton et al., 2003; Chen et al., 2009). The present study agreed with the findings.

Flaking corn had important impacts on energy availability and performance of feedlot cattle (Zinn et al., 2002). Reduced

starch digestibility constitutes the primary basis for the lower feeding value of dry-rolled corn (DRC) versus steam-flaked corn (SFC) in diets for feedlot cattle. Although, ruminal and post-ruminal starch digestion was lower for DRC than for SFC, with differences in post-ruminal starch digestion accounting for most of the variation in total tract starch digestion (Zinn et al., 1995). Karr et al. (1966) suggested that variation in post-ruminal starch digestion may be due to limitations in amylolytic capacity. Because pancreatic amylase secretion and activity were enhanced by increasing the protein supply to the small intestine (Johnson et al., 1968), it was hypothesized (Huntington, 1997) that increasing the dietary protein level may augment post-ruminal starch digestion, because of increased ruminal starch digestion. In the present study, we did not evaluate the effect on starch digestion. However, the increase in ADG may have had a close relationship with starch digestion.

Blood biochemical parameters

Steam-flaked processing for corn could significantly increase starch and feed availability (Owens et al., 1998). Steam-flaked corn tended to increase blood glucose level in the present study. Li et al. (1998) also had the similar result. Increasing of post-ruminal starch could enhance blood glucose concentration. Borg et al. (1987) reported that BUN was an indicator showing the status of dietary crude protein metabolism in the animal and dietary amino acids balance. In the common, BUN had the negative relationship with the apparent digestibility of protein. In the present study, the diet-containing SFC supplied the balance of energy and protein for the rumen microbes, improved the microbial crude protein (MCP) output, and enhanced the dietary nitrogen utilization. Therefore, BUN of steers fed diet with SFC declined.

Conclusions

Steam-flaked corn as a substitute for ordinary cracked corn could improve the growth performance through improving the crude proteins and starch. Under the experiment condition, the optimal replacing ratio was 90%. The average daily weight gain can reach 1.35 kg/d.

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