Effect of corn processing on growth performance, carcass characteristics, and plasma glucose-dependent insulinotropic polypeptide and metabolite concentrations in feedlot cattle[1]

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ABSTRACT: The objectives of this trial were to evaluate the association between corn processing, glucose-dependent insulinotropic polypeptide (GIP) concentration, and intramuscular (IM) fat deposition. We hypothesized that steers fed whole shelled corn (WSC) would have a greater IM fat deposition than steers fed cracked corn (CC) due to an increase in plasma GIP concentration. Backgrounded, Angus-cross cattle (initial body weight [BW] = 279 ± 9.8 kg) were used in a randomized complete block design in a feedlot setting for an average of 230 d. Cattle were allotted in 12 pens (6 pens per treatment with 8 animals per pen). There were three blocks: heifers (n = 32, initial BW = 265 ± 1.3 kg), small steers (n = 32, initial BW = 262 ± 1.3 kg), and large steers (n = 32, initial BW = 310 ± 1.4 kg). Two pens within each block were randomly assigned to one of the following treatments: 1) CC or 2) WSC. Animal growth performance, carcass characteristics, and plasma hormone and metabolite concentrations were analyzed using the MIXED procedure of SAS, including the fixed effects of treatment, or treatment, time, and their interaction. Pen and block were included as random effects. Carcass yield and quality grade distributions were compared using the GLIMMIX procedure of SAS. including the fixed effects of treatment and time with pen and block as random effects. Linear regression was used to evaluate the association of plasma GIP concentration and IM fat content. Average daily gain (P = 0.57) and final BW (P = 0.34) were similar, regardless of treatment. Cattle fed CC had reduced (P < 0.01) dry matter intake (DMI) when compared with those fed WSC. This lesser DMI resulted in improved gain:feed ratio (P < 0.01) for cattle fed CC compared with cattle fed WSC. There was no effect (P ≤ 0.33) of corn processing on plasma glucose, plasma GIP concentrations, hot carcass weight, dressing percentage, or marbling score. There was a positive linear relationship (P = 0.03) between IM fat concentration and plasma GIP concentration. In conclusion, feeding CC increased gain:feed ratio compared with WSC, but there was no difference in plasma GIP concentration, whereas plasma GIP concentration appears to be related to IM fat deposition.

Key words: gastric inhibitory polypeptide, glucose absorption, incretin, lipogenesis, marbling, starch

INTRODUCTION

Regulation of marbling has been studied for a long time. Intramuscular (IM) fat deposition affects the meat quality and carcass value; therefore, producers are incentivized to produce cattle with greater IM fat concentrations. Corn processing changes the digestion site of corn (Owens et al., 1986). While cracked or ground corn is fermented in the rumen with very little starch passing to the small intestine, cattle fed whole shelled corn (WSC) has much more starch that reaches the small intestine (Owens et al., 1986). It is known that diet, and its interactions with the site of absorption, affect how and where adipose tissue grows (Smith and Crouse, 1984). For example, feeding cracked corn (CC) or WSC in the first half of the finishing period and CC on the second half of the finishing period to cattle has been reported to increase IM fat deposition when compared with feeding cattle diets based on WSC for the entire finishing period (Gorocica-Buenfil and Loerch, 2005). Using isoenergetic infusions of starch in the rumen, starch in the abomasum, and glucose in the abomasum, Baldwin et al. (2007) have shown differences in glucose incorporation into fatty acids into difference adipose tissue depos. However, what regulates the dietary effect on each adipogenic site is not known. The glucose-dependent insulinotropic polypeptide (GIP) hormone has been studied for more than four decades in humans and other species (Cataland et al., 1974; Brown et al., 1975; Andersen et al., 1978). Considerably less is known about the secretion and actions of GIP in ruminants, specifically the influence of GIP on lipid metabolism and the effect of GIP on IM fat deposition in beef cattle.

Glucose-dependent insulinotropic polypeptide is released from the small intestine with multiple functions, such as being able to stimulate insulin secretion, inhibit apoptosis, and promote the proliferation of the pancreatic beta cells. The main functions of GIP are to stimulate insulin secretion and fat accumulation (Beck, 1989; Miyawaki et al., 2002; Martin and Faulkner, 1994). In sheep, infusions of GIP decreased lipolysis in subcutaneous adipose tissue (Martin et al., 1993b). Relling and Reynolds (2008) reported that abomasal infusion of starch increased plasma GIP concentration in dairy cows. Dawson et al. (1999) described an increase in plasma GIP concentration when beef cattle were fed grass silage compared with grass hay. However, there are no studies evaluating the effects of diet on plasma GIP concentration in feedlot cattle. Furthermore, there are no studies directly linking plasma GIP concentration and fat deposition in feedlot cattle.

We hypothesized that feeding CC, compared with WSC, to feedlot cattle would increase IM fat deposition due to an increase in plasma GIP concentration. Thus, the objectives of this trial were to determine the effect of corn processing on plasma GIP concentration and IM fat deposition.

MATERIALS AND METHODS

All animal procedures were approved by the Ohio State University Institute of Animal Care and Use Committee (#2016A00000002) and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Federation of Animal Science Societies, 2010).

Animals, Experimental Design, and Treatments

Backgrounded, Angus-cross heifers and steers (initial body weight [BW] = 279 ± 9.8 kg) were used in a randomized complete block design and housed in a confinement barn at the Eastern Research Experimental Station at Caldwell, OH. The blocking criteria was one block of heifers ($n = 32$, 4 pens, initial BW = 265 ± 1.3 kg), light steers ($n = 32$, 4 pens, initial BW = 262 ± 1.3 kg), and heavy steers ($n = 32$, 4 pens, initial BW 310 ± 1.4 kg). Cattle within each block were randomly allotted in pens. Pens (six pens per treatment with eight animals per pen) within each block were then randomly assigned and equally distributed to one of the following treatments: 1) cattle fed CC-based diets or 2) cattle fed WSC-based diets. Diets contained 70%

of the experimental treatment corn on a dry matter (DM) basis. The same lot of corn was used for the WSC and CC diets. To crack the corn, a dual pair roller (Roskamp Champion, Watterloo, IA) was used, with an average particle size of 0.7 mm. The remainder of the diets were 15% dried distillers grains with solubles, 7% grass hay, and 8% supplement (DM basis; Table 1). The experimental diets met the nutrient requirement for finishing cattle (NRC, 2000), both diets had the same composition, and the corn processing was the only difference.

From weaning (6.5 ± 0.85 mo) until the experiment started, the animals were backgrounded for 5 mo on a fescue-based pasture. Three months before the trial started, cattle were offered ad libitum hay and a supplement containing 60% WSC, 10% soybean meal, 28% soybean hulls, and 2% animal-vegetable blend fat. The soybean meal, the soybean hulls, and the animal-vegetable blend fat were mixed and pelleted and then mixed with the WSC. The amount of supplement increased monthly such

Table 1. Composition of dietary treatments and nutrient composition of finishing diets containing CC or WSC on a DM basis

Ingredient, %	CC	WSC
WSC	—	70
CC	70	—
DDGS[a]	15	15
Grass hay	7	7
Supplement[b]	8	8
Ground corn	37.059	37.059
Soybean meal	28.08	28.08
Limestone	12.22	12.22
Salt	6.11	6.11
Vitamin A-30	0.09	0.09
Vitamin D-3	0.09	0.09
Vitamin E	0.27	0.27
$CaSO_4$	8.55	8.55
Selenium	0.46	0.46
Rumensin 90	0.24	0.24
Potassium chloride	3.66	3.66
$CuSO_4$	0.07	0.07
$ZnSO_4$	0.24	0.24
$MnSO_4$	0.12	0.12
Cobalt carbonate	0.001	0.001
Animal-vegetable blend oil	2.74	2.74
Analyzed composition[c], %		
Neutral detergent fiber	13.35	12.87
Acid detergent fiber	7.98	7.80
Crude protein	13.98	13.73
Ether-extractable lipid	4.19	4.38

[a]DDGS = dried distillers grains plus solubles.

[b]Ingredients in the supplement represent a 100 % of the supplement

[c]Nutrient analysis performed on all ingredients. NDF.

that when the experiment started, cattle were consuming 3 kg of supplement per animal daily (DM basis).

The transition from the backgrounding diet started upon feedlot entry and was considered day 1 of the experiment. At that time, and based on the intake of the animals, it was estimated that the diet was 48% concentrate and 52% hay with a total intake of 6.25 kg/head each day based on the backgrounding diet of 3 kg consumption of pellets and WSC with ad libitum hay. The transition to the feedlot diet occurred using a two-ration blend. From day 1 to 3, cattle were fed 75% of the backgrounding concentrate and 25% of the finishing concentrate. From day 3 to 5, cattle were fed a 50:50 blend of the two rations and, from day 5 to 7, cattle were fed 25% of the backgrounding concentrate and 75% of the finishing concentrate. After being adapted to the finishing concentrate, forage inclusion was gradually reduced. The ratio of concentrate and hay was changed by increasing concentrate and decreasing hay by 3% of the total diet each day from day 8 to 22 to achieve the final diet of 93% concentrate and 7% hay. During the transition, DM intake (DMI) was fixed at 6.25 kg. After the diet transition period, feed offered was gradually increased. Bunks were observed daily and feed offered was increased 5% (DM basis) if bunks were clean 2 d in a row. From all the animals, a heifer on the WSC and a steer (light steers block) on the CC diet did not adapt to the feeding system and were removed from the experiment within the adaptation period. A steer (light steers block) on the CC diet died due to causes not related to the diet on day 159 of the experiment; its performance data has been included in the analysis. One steer (heavy steers block) on the CC diet was not loaded for carcass data due to knee problems.

Sampling, Carcass Characteristics, and Analysis

Weekly feed samples were composited and dried to 105 °C DM to adjust feed delivery (on a DM basis) and allow the determination of DMI. Composite feed samples taken every 28 d were dried in a forced-air oven at 55 °C and stored for future analysis.

Steers were individually weighed on days 0, 14, 28, and 56 and, then, every 28 d during the trial until the last day of the trial (days 230, 240, and 225 ± 4 for the heifers, light steers, and heavy steers, respectively). Weight was measured 1 h prior to the normal feeding time, and cattle were not withheld from feed or water. When animals had a round/

full brisket by visual appraisal (Phillips et al., 2002; Felix and Loerch, 2011), they were weighed off test and harvested at a commercial abattoir. Half of the animals in each pen within each block were sent to slaughter at the same time such that both dietary treatments were represented in each off-test day.

On day 28 and at the end of the trial, 10 mL of blood was taken from the jugular vein. Blood samples were collected in syringes and immediately transferred to 15-mL polypropylene tubes (Sarstedt, Nümbrecht, Germany) containing solutions of disodium Ethylenediaminetetraacetic acid and Benzamidine HCl (1.6 and 4.7 mg/mL blood, respectively) and placed on ice. After centrifugation for 30 min ($1,800 \times g$ and 4° C), plasma was aliquoted into individual polypropylene 1.5-mL microcentrifuge tubes (VWR International, Radnor, PA) and stored at −80 °C until analyzed.

Hot carcass weight (HCW) was recorded on the day of slaughter and dressing percentage (DP) was calculated using the off-test weight of the cattle. Carcasses were chilled for 48 h at −4 °C and ribbed between the 12th and 13th ribs and subcutaneous backfat thickness at the 12th rib (BF), *Longissimus dorsi* muscle area (LMA), marbling score, kidney, pelvic and heart fat (KPH), and United State Department of Agriculture (USDA) Quality Grade (USDA, 1997) were collected by a certified USDA grader. The LMA from the 11th to 12th rib was removed from the left side of each carcass, trimmed of external fat, ground (Hobart model #4822, Hobart Co., Troy, OH) three times, and subsampled for determination ether-extractable (EE) lipid (AOCS, 2005) in the *L. dorsi* muscle as a measurement of IM fat deposition.

Composited feed samples were analyzed for DM (100 °C for 24 h), acid detergent fiber, and neutral detergent fiber (Ankom Technology method 5 and 6, respectively; Ankom Technology, 2014), crude protein (method 990.03; Association of Official Analytical Chemists, 2000), EE lipid (AOCS, 2005), and total ash (600 °C for 12 h).

Plasma GIP concentration was run as described in Relling et al. (2014). The GIP intraassay coefficient of variation was 7.8%. The sensitivity (minimum detection limit) of the GIP assay was 0.025 pmol/tube. Plasma glucose concentration was measured using an enzymatic assay (#1070 Glucose Trinder, Stanbio Laboratory, TX). Plasma nonesterified fatty acids (NEFA) concentration was measured using an enzymatic assay (Wako Chemicals USA, Inc., Richmond, VA) as described by Johnson and Peters (1993). Interassay and intraassay coefficients of variation were <6% for glucose and NEFA assays.

Statistical Analysis

The experimental design was a randomized complete block design. Animal growth performance, carcass characteristics, and plasma glucose, NEFA, and GIP concentrations were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model for animal performance included the fixed effect of treatment. Pen and block were included in the model as random effects. For plasma glucose, NEFA, and GIP concentrations, the model included time and their interaction as fixed effects. The repeated measure statement was used to test effects over time on plasma glucose, NEFA, and GIP concentrations with the compound symmetry covariance structure because it yielded the smaller Akaike information criterion for small sample sizes or AICC. Carcass characteristics were analyzed with a similar model but without time and its interaction. Carcass yield and quality grade distributions were compared using the GLIMMIX procedure of SAS, including the fixed effects of treatment and time with pen and block as random effects. Data are presented as least squares means. Because there was not a time by treatment interaction for plasma glucose, NEFA, and GIP concentrations, data represent only the main effect of treatments. A simple linear regression was used to evaluate the association between plasma GIP concentration and IM deposition. Differences were declared significant at $P \leq 0.05$. Trends, where discussed, were declared at $P \leq 0.10$.

RESULTS AND DISCUSSION

Growth Performance

Cattle fed CC or WSC had similar ($P = 0.57$; Table 2) average daily gain (ADG) and, thus, did not differ ($P = 0.34$; Table 2) in final BW. DMI was reduced ($P < 0.01$; Table 2) when cattle were fed CC compared with WSC. This reduction in DMI resulted in better feed efficiency ($P = 0.01$; Table 2) for cattle fed CC when compared with cattle fed WSC. The decrease in DMI in CC-fed cattle compared with WSC-fed cattle has been previously reported (Zinn, et al., 2011). As described previously, DMI regulation is multifactorial (Forbes, 2003). Some of the factors that may be regulating DMI might be increase in rumen propionate production, increase in net energy (NE), or changes in rumen pH in the CC diet compared with the WSC diet. It is believed that the reduction in DMI when cattle fed CC compared with those fed WSC could

be due to a greater flux of propionate to the liver during meals. The rapid metabolization and hepatic oxidation of propionate would send a signal to terminate meals (Allen et al., 2009).

Corn processing increases the NE of the diet (Owens et al., 1997; Zinn et al., 2011; Owens and Balsam, 2013). Therefore, animals may have to consume less CC to achieve similar NE intake than WSC (Conrad et al., 1964). This shift often improves feed efficiency (Owens and Balsam, 2013), similar to the results of the current study. Consistent with the idea of better feed efficiency when processing grains, Owens et al. (1997) reviewed corn processing and stated that feeding either steam-rolled or flaked corn, milo, and wheat decreased DMI without decreasing ADG when compared with feeding those same grains that were dry rolled. However, the feed to gain ratio was not always improved simply by grinding or rolling corn for cattle (Owens et al., 1997; Corona et al., 2005). In fact, the efficiency of cattle fed WSC diets was greater than cattle fed diets containing dry-rolled corn (Owens et al., 1997; Owens and Balsam, 2013). This feed efficiency advantage for WSC over CC diets may occur because often less roughage is included in diets for cattle fed WSC than for cattle fed processed corn

grain (Owens et al., 1997). Digestibility of WSC could be influenced by numerous factors. These would include forage source and level, age of the animal, protein source, dietary protein concentration, and pH of the rumen (Gorocica-Buenfil and Loerch, 2005) In addition, agronomic attributes of the grain (kernel hardness, kernel moisture, and concentration of foreign matter) may also affect digestibility (Corona et al., 2006). Although digestibility was not determined in the current trial, cattle age and forage level seem likely to be among the most important factors influencing WSC digestibility and performance of cattle fed diets based on WSC. In the current trial, cattle were all of similar ages, and forage level remained equal across treatments.

Increasing rumen fermentation of corn due to processing increases the likelihood of acid production in the rumen and the development of subclinical acidosis (Fulton et al., 1979). Subclinical acidosis decreases overall DMI as a consequence of a greater day-to-day DMI variation (Stock et al., 1995). In the current study, we did not evaluate rumen pH and there were not liver abscesses at harvest; therefore, we cannot state that the decrease in DMI in CC-fed cattle compared with WSC is due to changes in ruminal pH.

Plasma Hormone and Metabolite Concentrations

We hypothesized that feeding WSC to beef steers would increase plasma glucose concentration; however, there was no effect ($P = 0.38$; Table 3) of corn processing treatment on plasma glucose concentrations. Similarly, there was no effect ($P = 0.77$; Table 3) of corn processing on plasma GIP concentration.

One possible explanation for the lack of difference in plasma glucose and GIP in the current experiment would be that ruminant and nonruminant animals have different mechanisms for the stimulation of GIP release. Glucose-dependent insulinotropic polypeptide is released in nonruminants

Table 2. BW, ADG, DMI, and gain:feed ratio of beef steers fed CC or WSC in their diets during the finishing phase in a feedlot[a]

Items	CC	WSC	SEM	P-value
Pens (animals)	6 (47)	6 (47)		
Initial BW, kg	278.4	279.5	1.15	0.52
Final BW, kg	537	541	2.9	0.34
ADG, kg/d	1.32	1.34	0.016	0.57
DMI, kg/d	8.51	9.12	0.113	< 0.01
Gain:feed ratio	0.145	0.128	0.003	< 0.01

[a]Backgrounded cattle were divided into three blocks of heifers ($n = 32$, 4 pens), light steers ($n = 32$, 4 pens), and heavy steers ($n = 32$, 4 pens). Diets contained 70% of corn (experimental treatment), 15% dried distillers grains with solubles, 7% grass hay, and 8% supplement on a DM basis. Cattle were fed for 230, 240, and 225 ± 4 d for the heifers, light steers, and heavy steers blocks, respectively.

Table 3. Plasma concentrations of glucose, NEFA, and GIP in beef cattle fed CC or WSC in their diets during the finishing phase in a feedlot[a]

Items	CC	WSC	SEM	P-value Treatment	Time	Treat. × Time
Pens (animals)	6 (47)	6 (47)				
Glucose, mg/dL	91.22	89.03	1.730	0.38	< 0.01	0.61
NEFA, μM	238.1	173.1	15.72	< 0.01	< 0.01	0.40
GIP, pmol/mL	1.21	1.16	0.109	0.77	< 0.01	0.82

[a]Backgrounded cattle were blood sampled to collect plasma on day 28 and at the end (days 225–240) of the trial.

in response to the absorption of glucose and fat (Cataland et al, 1974; Brown et al., 1975). In humans and other nonruminant animals, the secretion of GIP into the circulation is due to glucose absorption mainly, and it enhances the pancreatic response to hyperglycemia by increasing the secretion of insulin (Morgan et al., 1988). However, plasma GIP and plasma insulin concentrations were inversely correlated when cattle were fed grass silage or dried forages, suggesting that GIP was not insulinotropic in ruminants (Dawson et al., 1999). In addition, Faulkner and Martin (1999) reported that the insulinotropic response depends on the plasma glucose concentrations, and there is a threshold (120 mg/dL) that most of the times is not reached in cattle fed forage-based diets. It could be that cattle fed CC generate a greater proportion of propionate in the rumen compared with cattle fed WSC. The conversion of propionate to glucose in the liver could lead to similar amounts of glucose absorbed on both treatments and explain the lack of difference in plasma glucose concentrations (Table 3). However, volatile fatty acids (VFAs) production and absorption were not measured in the current study.

Some authors suggest dietary fatty acids are a more important stimulus for GIP secretion than glucose in ruminants when compared with nonruminants (Martin et al., 1993a; Martin and Faulkner, 1994; Dawson et al., 1999). Working with preruminant goats, Martin et al. (1993a) concluded that carbohydrate absorption did not elicit GIP secretion. Martin et al.'s (1993a) data suggested instead that fat is the major nutrient to stimulate GIP secretion in ruminants (even preruminant animals). However, in adult ruminants, which tend to have diets with low lipid concentration, or dietary components other than glucose and fatty acids may be important in eliciting GIP secretion. Relling and Reynolds (2008) conducted a study where they infused the abomasum of lactating dairy cows with corn starch, casein, or soybean oil and evaluated plasma GIP concentrations. After infusion, plasma GIP concentration increased on day 1 when oil or casein was infused and tended to increase when starch was infused compared with control. On day 7 of the same study, starch and casein increased plasma GIP concentration, but cows infused with oil were not different from the control group. Thus, there may be fundamental differences between ruminants and nonruminants in the secretion of gut hormones that require additional research.

The only blood metabolite that was altered in the current study was plasma NEFA concentrations. Plasma NEFA concentrations were increased ($P < 0.01$) in cattle fed CC compared with cattle fed WSC (Table 3). Plasma NEFA concentration is normally associated with lipid mobilization from the adipose tissue and due to an increase in fat content in the diet (Gagliostro and Chilliard, 1991). In vitro studies of adipose tissue metabolism showed that GIP has the capacity to increase both the rate of fatty acid synthesis (Oben et al., 1991) and incorporation of fatty acids into adipose tissue (Beck and Max, 1987; Haji Baba and Buttery, 1991). In the current experiment, both groups of cattle had similar changes in BW; therefore, the cattle fed CC were not in a negative energy balance compared with the cattle fed WSC. Both diets also contain similar lipid concentration. Therefore, the current data do not explain the increase in plasma NEFA concentration. In dairy cattle, Stefańska et al. (2017) have shown a negative association between rumen pH and plasma NEFA concentration. As stated previously, we did not measure rumen pH; however, the association of plasma NEFA concentration and rumen pH should be studied in beef cattle as a simple marker of rumen health.

Carcass Characteristics

Consistent with BW results, there was no effect of corn processing on HCW ($P = 0.70$) or dressing percentage ($P = 0.33$; Table 4). Corona et al. (2005) evaluated the effect of corn processing on beef cattle carcass characteristics and reported feeding WSC reduced dressing percentage of cattle when compared with feeding dry-rolled corn or ground corn. The authors mentioned that the difference may have reflected treatment effects on ruminal fill because the NE value of the diets for BW maintenance and gain were similar.

Evaluating diets in the current study, more indigested starch should pass to the small intestine in cattle fed the WSC (Owens et al., 1997). In the small intestine, starch digestion provides glucose for absorption, whereas, in the rumen, starch digestion provides VFA for absorption. Of the VFA produced in the rumen, only the absorbed propionate fraction contributes to net glucose synthesis in the liver (Armstrong et al., 1960; Tyrrell and Moe, 1974). It is also known that IM fat uses mainly glucose as a precursor for fatty acid synthesis, whereas subcutaneous fat uses acetate as a precursor (Smith and Crouse, 1984). Previous data suggest that glucose absorption increases GIP concentration (Relling and Reynolds, 2008), which could stimulate lipogenesis and inhibit lipolysis (Andersen et al., 1978; Martin et al., 1993b; Wachters-Hagedoorn et al.,

Table 4. Carcass characteristics of backgrounded beef cattle fed CC or WSC in their diets during the finishing phase in a feedlot[a]

	CC	WSC	SEM	*P*-value
Pens (animals)	6 (45)	6 (47)		
HCW, kg	346	348	3.6	0.70
Dressing, %[b]	60.2	59.9	0.24	0.33
Back fat, cm	1.36	1.34	0.10	0.92
KPH, %	2.14	2.28	0.06	0.15
LMA, cm²	90.34	86.95	1.258	0.06
Marbling score[c]	697	724	15.9	0.24
IM fat[d], %	7.81	8.30	0.379	0.36
% USDA Quality grade[e]				
Choice	52.98	48.65	12.60	0.72
Prime	18.09	25.54	7.14	0.39
% USDA Yield Grade[f]				
YG 1–3	94.98	86.43	5.56	0.14
YG 4	5.02	13.57	5.57	0.14

[a]Backgrounded cattle were divided into three blocks of heifers (*n* = 32, 4 pens), light steers (*n* = 32, 4 pens), and heavy steers (*n* = 32, 4 pens). Diets contained 70% of corn (experimental treatment), 15% dried distillers grains with solubles, 7% grass hay, and 8% supplement on a DM basis. Cattle were fed for 230, 240, and 225 ± 4 d for the heifers, light steers, and heavy steers blocks, respectively.

[b]Dressing percentage was calculated by dividing hot carcass weight by final BW.

[c]For marbling score: 600–699 = moderate; 700–799 = slightly abundant.

[d]IM fat = ether-extractable intramuscular fat.

[e]Three heifers, one in CC diet and two on WSH were grade as cutter. Two steers on the CC diet were grade select.

[f]Carcass Yield Grade was calculated (USDA, 1997): YG = 2.50 + 6.35 × fat thickness (cm) – 2.06 × LM area (cm²) + 0.2 × KPH (%) + 0.0017 × HCW (kg). YG 1–3 represent cattle graded 1 to 3; YG4 represent cattle graded 4. No cattle grade 5.

2006). We had hypothesized that feeding WSC to beef steers would increase marbling in the carcass because more starch would bypass the rumen and, thus, more glucose would be present in the bloodstream of cattle fed WSC compared with cattle fed CC. However, there was no effect of treatment ($P \geq 0.14$) on back fat, KPH, marbling score, EE IM fat concentrations, Quality Grade, or Yield Grade (Table 4). The lack of treatment difference in plasma GIP concentrations may explain the lack of difference in back fat, KPH, or marbling score.

Longissimus dorsi muscle area tended to be greater ($P = 0.06$; Table 4) in cattle fed CC compared with cattle fed WSC. Increased efficiency in cattle fed CC may have allowed more energy to be partitioned to muscle growth. Yield Grade, an important estimate of carcass cutability or percentage of retail product, is calculated from back fat, KPH, HCW, and LMA.

The challenge in quality beef production is producing greater marbling deposition while maintaining a minimum level of undesirable subcutaneous fat and visceral fat. Gorocica-Buenfil and Loerch (2005) reported that forage level and corn processing affected carcass characteristics, including marbling score. However, those researchers fed younger steers that were not backgrounded prior to the test. In contrast, cattle on the current study were heavier, older, and backgrounded prior to entering the feedlot, which might explain in part the lack of difference in marbling when treatments were compared. Relevant to the current study, Gorocica-Buenfil and Loerch (2005) concluded that cracking corn might not always provide additional benefits to the carcass value of the animal, despite the advantages frequently seen in performance and carcass characteristics in beef cattle fed more processed grain.

Although corn processing treatments failed to illicit changes in plasma GIP concentration, there was a linear association ($P = 0.03$) between plasma GIP concentration and IM fat concentration. This relationship is represented by the following equation:

$$y = 7.32 + 0.35 \quad x$$

where y = plasma GIP concentration (pmol/mL) and x = IM fat concentration (%). The intercept of the equation is 7.32 ($P = 0.01$). The SEMs associated with the intercept and the slope are 0.806 and 0.160, respectively.

In conclusion, feeding CC decreases DMI, without affecting ADG, and, therefore, increases gain:feed ratio compared with WSC. Also feeding CC increases LMA compared with WSC. Feeding CC increased plasm NEFA concentration compared with WSC. However, corn processing did not affect plasma GIP concentration. There is a positive association between plasma GIP concentration and IM fat deposition. These data do not confirm that GIP increases marbling accretion or decreases IM fat lipolysis as it does in the subcutaneous adipose tissue (Martin et al., 1993b). However, more research is needed to evaluate the dietary effects on plasma GIP concentration and its association with marbling.

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