

COMPARATIVE FEEDING VALUE OF STEAM-FLAKED CORN AND SORGHUM IN FINISHING DIETS SUPPLEMENTED WITH OR WITHOUT SODIUM BICARBONATE

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ABSTRACT

A feedlot growth-performance trial involving 64 yearling steers and a metabolism trial involving four steers with cannulas in the rumen, proximal duodenum, and distal ileum were conducted to evaluate the comparative feeding value of steam-flaked corn (SFC, density = .30 kg/liter) and sorghum (SFS, density = .36 kg/liter) in finishing diets supplemented with or without .75% sodium bicarbonate (BICARB). No interactions between BICARB and grain type proved to be significant. Supplemental BICARB increased ADG 5.9% ($P < .10$) and DMI 4.6% ($P < .05$) but did not influence ($P > .10$) the NE value of the diet. Supplemental BICARB increased ruminal pH ($P < .01$) and total tract fiber digestion ($P < .05$). Differences in ruminal and total tract OM, starch, and N digestion were small ($P > .10$). Replacing SFC with SFS decreased ($P < .05$) ADG 6.1% and increased ($P < .01$) DMI/gain 9.7%. Corresponding diet NE_m and NE_g were decreased ($P < .01$) 7.0 and 9.3%, respectively. Ruminal digestion of OM and starch tended to be lower (11.8 and 7.2%, respectively, $P < .10$) for SFS. Ruminal degradation of feed N was 31% lower ($P < .05$) for the SFS diets. Total tract digestibility of OM, N, DE, and ME were 3.3, 10.8, 4.4, and 5.5% lower ($P < .05$), respectively, for the SFS vs SFC diets. In conclusion, 1) SFS had 92% the NE_m of SFC; 2) differences in total tract starch digestibility were small and cannot explain the higher feeding value of SFC; 3) the low ruminal degradation of sorghum N (roughly 20%) should be considered in diet formulation to avoid a deficit in ruminally available N; and 4) .75% BICARB supplementation increased DMI and ADG of cattle fed highly processed grain-based diets.

Key Words: Maize, Sorghum, Buffers, Cattle, Performance, Metabolism

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Introduction

Most studies evaluating steam-flaked sorghum (SFS) have involved comparisons of SFS and other methods of sorghum processing (Hale et al., 1966; Buchanan-Smith et al., 1968; Husted et al., 1968; Lofgreen et al., 1968; Garrett, 1969; McNeil et al., 1971; Potter et al., 1971) or comparisons with wheat (Garrett, 1968; Lofgreen, 1969) or barley (Garrett et al., 1964; Garrett, 1965; McIlroy et al., 1967). Based on NRC (1984), the improvement in ME of sorghum due to flaking is 11%.

This estimate is consistent with some studies (Hale et al., 1966; Buchanan-Smith et al., 1968). However, improvements have been as high as 24% (Husted et al., 1968). These large differences in digestibility of sorghum may not necessarily reflect differences in degree of processing or density of the flake. Several studies (Lofgreen et al., 1968; Garrett, 1969) indicated that feeding value of sorghum was not enhanced by steam rolling, steam flaking, or high-pressure steam flaking (flake densities ranging from .29 to .56 kg/liter). This failure may be a result of an increased potential for acidosis. The objective of the present study was to evaluate the feeding value of steam-flaked corn (SFC) and SFS in diets supplemented with vs without a buffer (.75% sodium bicarbonate).

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TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS FED TO STEERS (TRIALS 1 AND 2)^a

Item	Treatments			
	1	2	3	4
Ingredient composition, % (DM basis)				
Alfalfa hay, midbloom	8.00	8.00	8.00	8.00
Sudangrass hay	4.00	4.00	4.00	4.00
Steam-flaked corn	74.85	—	74.10	—
Steam-flaked sorghum	—	74.85	—	74.10
Blended fat ^b	2.00	2.00	2.00	2.00
Cane molasses, blackstrap	8.00	8.00	8.00	8.00
Limestone	1.65	1.65	1.65	1.65
Urea	1.00	1.00	1.00	1.00
Sodium bicarbonate	—	—	.75	.75
Trace mineral salt ^c	.50	.50	.50	.50
Vitamin A ^d	+	+	+	+
Monensin ^e	+	+	+	+
Nutrient composition (DM basis)				
NE, Mcal/kg ^f				
Maintenance	2.18	2.12	2.17	2.11
Gain	1.51	1.46	1.50	1.45
Crude protein, %	12.1	12.9	12.0	12.8
Ether extract, %	6.4	5.8	6.4	5.8
ADF, %	6.9	9.0	6.9	8.9
Calcium, %	.53	.55	.53	.55
Phosphorus, %	.22	.29	.22	.29

^aDiets in Trial 2 contained an additional .44% chromic oxide as a digesta marker.

^bBlended animal vegetable fat (predominantly soapstock).

^cTrace mineral salt contained: CoSO₄, .068%; CuSO₄, 1.04%; FeSO₄, 3.57%; ZnO, .75%; MnSO₄, 1.07%; KI, .052%; and NaCl, 93.4%.

^d2,200 IU/kg.

^e23 mg/kg.

^fBased on tabular NE values for individual feed ingredients (NRC, 1984) with exception of supplemental fat, which was assigned NE_m and NE_g values of 6.03 and 4.79, respectively (Zinn, 1989).

Experimental Procedures

Trial 1. Sixty-four large-framed crossbred (approximately 25% Brahman and 75% Angus breeding) yearling steers (387 kg) originating from Central California were used. These cattle were received at the Imperial Valley Agricultural Center May 10, 1989. Upon arrival, the steers were treated for internal and external parasites and vaccinated for clostridial infections and infectious bovine rhinotracheitis. Steers were blocked by weight and randomly assigned to 16 pens (four steers/pen) equipped with automatic waterers and fence-line feed bunks. The trial was initiated May 24, 1989. Compositions of diets are shown in Table 1. The SFC was prepared by steaming corn at atmospheric pressure (steam chest set

at 103°C) prior to rolling to a density of .30 kg/liter (23 pounds/bushel). The retention time of corn in the steam chamber was maintained at 34 min. The SFC was allowed to air-dry prior to mixing it into the diet. Steam-flaked sorghum was prepared by steaming sorghum at atmospheric pressure (steam chest set at 103°C) prior to rolling to a density of .36 kg/liter (28 pounds/bushel). A tempering agent (Mycoflake²) was added to the sorghum as it was augured into the holding bin above the steam chest. The retention time of sorghum in the steam chamber was maintained at 45 min. The SFS was allowed to air-dry prior to mixing it into the diet. In vitro enzymatic digestibility of starch as a result of processing was determined using two assays: amyloglucosidase (Zinn, 1990a; except that incubation was for 4 h) and crude diastase (referred to as a diastatic enzyme conversion test³). Diastase reactivity was determined using a modification of the procedure of Walker et al. (1970) as

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follows: 1) place 200 mg of ground sample in a 20-ml screw-cap culture tube along with 20 ml of enzyme buffer (4.845 g anhydrous dibasic sodium phosphate, 4.540 g monobasic potassium phosphate and .500 g α -amylase⁴ [crude, from *Aspergillus oryzae*, 37 units α -amylase activity/mg] in 1 liter H₂O); 2) add 67 units of amyloglucosidase⁴ (1 mg enzyme) and 1 drop of toluene; 3) tightly cap, gently mix, and incubate at 39°C for 4 h in a shaking water bath; 4) transfer 1 ml of starch hydrolyzate solution to a 10-ml centrifuge tube, add 4 ml of trichloroacetic acid (TCA) solution (30 g TCA per liter of H₂O), vortex, and let stand for 5 min; 5) centrifuge at 6,500 \times g for 10 min; 6) transfer 4 ml of *o*-toluidine (solution of 6% *o*-toluidine in glacial acetic acid)⁵ into a separate test tube, add 400 μ l of TCA supernatant solution, cover with a marble, and incubate at 100°C in water bath for 10 min; 7) remove tubes and place in ice bath for 5 min; 8) read absorbance at 630 nm. The primary end-product of α -amylase hydrolysis of starch is maltose, so amyloglucosidase enzyme was added to complete the hydrolysis to glucose. The thickness of the SFC and SFS was determined by breaking the flake approximately in half and measuring the thickness in millimeters (using a micrometer) of the flattest spot near the center of the flake. Estimates of thickness represent an average value for 10 whole flakes randomly selected from the air-dry subsamples. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were fed their respective dietary treatments twice daily (0600 and 1400) at the rate of approximately 110% of appetite. Steers were implanted with Synovex-S⁶ upon initiation of the trial and then again on d 75. Estimates of steer performance were based on pen means. Steers were fasted from feed and water for 16 h prior to obtaining initial and final live weights. Final weights used for calculating steer performance were determined by dividing carcass weight by the average dressing percentage for all steers. Assuming that the primary determinant of energy gain was weight gain, energy gain was calculated by the equation $EG = (.0493 W^{.75})g^{1.097}$, where EG is the daily energy deposited (Mcal/d), g is weight gain (kg/d),

and W is the mean body weight (kg; NRC, 1984). Maintenance energy expended (Mcal/d, EM) was calculated by the equation $EM = .077W^{.75}$ (NRC, 1984). From the derived estimates for energy required for maintenance and gain, the NE for maintenance (NE_m) and gain (NE_g) values of the two diets were obtained by the process of iteration to fit the relationship $NE_g = .877NE_m - .41$ (derived from NRC, 1984). Hot carcass weights were obtained from all steers at time of slaughter. After the carcasses were chilled for 48 h, the following measurements were obtained: 1) longissimus muscle area (ribeye area), taken by direct grid reading of the longissimus muscle at the 12th rib; 2) subcutaneous fat over the eye muscle at the 12th rib taken at a location three-fourths the lateral length from the chine bone end (subjectively adjusted for unusual fat distribution); 3) kidney, pelvic, and heart fat (KPH) as a percentage of carcass weight; and 4) marbling score (USDA, 1965). The trial was analyzed as a randomized complete block design experiment with a 2 \times 2 factorial arrangement of treatments (Hicks, 1973).

Trial 2. Four Holstein steers (106 kg) with "T" cannulas in the rumen, proximal duodenum (6 cm from the pyloric sphincter), and distal ileum (20 cm from the ileal-cecal valve) were used in a 4 \times 4 Latin square design experiment to evaluate treatment effects on characteristics of digestion. Treatments were as indicated for Trial 1. Chromic oxide (.44%) was added to the diets as a digesta marker. Dry matter intake was restricted to 2.73 kg/d (2.6% of initial body weight). Diets were fed at 0800 and 2000 daily. Experimental periods consisted of a 10-d diet adjustment period followed by a 4-d collection period. During the collection period duodenal, ileal, and fecal samples were taken from all steers twice daily as follows: d 1, 0750 and 1350; d 2, 0900 and 1500; d 3, 1050 and 1650; and d 4, 1200 and 1800. Individual samples consisted of approximately 500 ml of duodenal chyme, 250 ml of ileal chyme and 200 g (wet basis) of fecal material. Samples from each steer and within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer approximately 4 h postprandial via the ruminal cannula. Ruminal fluid pH was determined; subsequently, 2 ml of freshly prepared 25% (wt/vol) meta-phosphoric acid was added to 8

⁴Sigma Chemical Co., St. Louis, MO.

⁵Stanbio, San Antonio, TX.

⁶Syntex Corp., Des Moines, IA.

ml of strained ruminal fluid. Samples then were centrifuged ($17,000 \times g$ for 10 min) and the supernatant fluid was stored at -20°C for VFA analysis. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria via differential centrifugation (Bergen et al., 1968). Samples were subjected to all or part of the following analysis: DM (oven drying at 105°C until no further weight was lost; ash, Kjeldahl N, ammonia N (AOAC, 1975); GE (adiabatic bomb calorimeter); purines (Zinn and Owens, 1986); VFA concentrations of ruminal fluid (gas chromatography using 10% SP-1200/1% H_3PO_4 on 80/100 Chromosorb W AW packing in a 183-cm \times 2-mm i.d. glass column with column, inlet, and detector temperatures maintained at 120, 195, and 200°C , respectively, and with carrier gas [N_2] flow rate at 20 ml/min); chromic oxide (Hill and Anderson, 1958), and starch (Zinn, 1990a). Microbial organic matter (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen (OMF) was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia N and MN and, thus, includes endogenous contributions. Methane production was calculated based on the fermentation balance for observed molar distribution of VFA (Wolin, 1960) and OM fermented in the rumen. Endogenous urinary energy loss was estimated as $.63 \text{ W}_{\text{kg}}^{-5}$ (Brouwer, 1965; NRC, 1984). This trial was analyzed as a 4×4 Latin squares design experiment with a 2×2 factorial arrangement of treatments (Hicks, 1973).

Results and Discussion

Characteristics of the corn and sorghum used in this study are shown in Table 2. In making comparisons within or on grain types one is faced with the dilemma of selecting standards for grain processing that will be useful or meaningful. The intent of steam flaking is to enhance digestion. Because starch is the primary constituent of corn and sorghum (Table 2), processing effects that influence the digestibility of starch should be of primary

TABLE 2. CHARACTERISTICS OF CORN AND SORGHUM

Item	Corn	Sorghum
Dry matter, %		
Initial ^a	88.8	90.6
Steam-flaked ^b	85.9	81.4
N, % of DM	1.53	1.65
Ether extract, % of DM	4.7	4.2
Starch, % of DM	71.1	70.0
Density, kg/liter		
Whole grain ^a	.85	.87
Steam-flaked ^b	.35	.42
Flake thickness, mm	1.57	.92
Amyloglucosidase reactive starch, % of total starch ^c		
Whole grain	5.4	5.3
Steam-flaked	17.3	17.5
Crude diastase reactive starch, % of total starch ^c		
Whole grain	4.6	4.5
Steam-flaked	43.2	58.6

^aWhole grain, prior to processing.

^bMeasurement taken on grain as it left the rollers.

^cBoth whole and steam-flaked grains were ground to pass through a 20-mesh screen prior to enzymatic digestion.

concern. Unfortunately, little has been done to establish a practical basis for processing standards for corn or sorghum; consequently, an array of perceived optimums exists among practitioners. In a previous trial (Zinn, 1990a), we observed our optimum response in cattle growth performance with corn flaked to a density of roughly .31 kg/liter (24 pounds/bushel). This was the basis for selecting the flake density for corn in our trial. However, digestibility was improved further by flaking to a density of .26 kg/liter (20 pounds/bushel). Perhaps inclusion of a buffer in the diet might have enabled expression of this increased digestibility in terms of growth and performance. For sorghum, the flake density chosen for this study (.36 kg/liter, or 28 pounds/bushel) is representative of current local practices among established feed mills. Although the SFC vs SFS comparison for this study was intended to be practical, flake densities are somewhat arbitrary. Consequently, caution is warranted in generalizing the results to other flake densities.

No interactions ($P > .10$) between buffer supplementation and grain type were noted for feedlot growth performance or characteristics of digestion. The main effects of SFC vs SFS on growth performance of feedlot steers and carcass merit are shown in Tables 3 and 4. Substituting SFS for SFC decreased ($P < .05$)

TABLE 3. MAIN EFFECTS OF STEAM-FLAKED CORN VERSUS STEAM-FLAKED SORGHUM ON GROWTH PERFORMANCE OF FEEDLOT STEERS AND NE VALUE OF THE DIET (TRIAL 1)^a

Item	Steam-flaked		SD
	Corn	Sorghum	
Days on test	147	147	—
Pen replicates	8	8	—
Live weight, kg			
Initial ^b	387	387	19
Final ^c	625	610	25
Weight gain, kg/d ^d	1.63	1.53	.09
DM intake, kg/d	9.17	9.47	.37
DM intake/gain ^e	5.65	6.20	.24
Diet net energy, Mcal/kg			
Maintenance ^e	2.30	2.14	.07
Gain ^e	1.61	1.46	.06
Obs/expected diet net energy			
Maintenance ^d	1.06	1.01	.03
Gain ^e	1.08	1.01	.04

^aSteam-flaked corn or sorghum made up 74.85% of diet DM.

^bInitial weights were obtained following a 16-h fast without feed or water.

^cCarcass weight divided by .24 (average dressing percentage).

^dMeans differ ($P < .05$).

^eMeans differ ($P < .01$).

ADG 6.1% and increased ($P < .01$) DMI/gain 9.7%. Corresponding diet NE_m and NE_g values were lower ($P < .01$) for SFS than for SFC by 7.0 and 9.3%, respectively. Carcass traits (Table 4) were similar ($P > .10$) for SFS and SFC diets, with the exception of ribeye area, which was larger (7.1%, $P < .05$) for steers fed the SFC-based diets.

Because SFS was substituted for an equal quantity of SFC in the diet (Table 1), we assumed that the NE of SFS is equal to the NE of SFC it replaced (74.47%) plus the change in

NE of diet DM brought about by the replacement. Accordingly, given that SFC has a NE_m of 2.54 Mcal/kg (Zinn, 1987), then SFS has a value of 2.34 Mcal/kg (roughly 92% the value of SFC). This derived value for SFS is in close agreement with the tabular value for SFS (2.30 Mcal/kg) proposed in the NRC (1984). Furthermore, the observed NE for the diets containing SFS were in very close agreement with expected values (Table 3) based on the diet formula and tabular NE values (NRC, 1984).

TABLE 4. MAIN EFFECTS OF STEAM-FLAKED CORN VERSUS STEAM-FLAKED SORGHUM ON CARCASS MERIT (TRIAL 1)^a

Item	Steam-flaked		SD
	Corn	Sorghum	
Carcass weight, kg	390	381	15
Dressing percentage	62.7	62.2	.9
Liver abscess, %	0	3.1	6.2
Retail yield, %	48.5	48.0	.6
Marbling score ^b	4.68	4.63	.55
Rib eye area, cm ^{2c}	89.5	83.6	4.1
Fat thickness, cm	1.82	1.85	.24
KPH fat, % ^d	2.11	2.02	.20

^aSteam-flaked corn or sorghum made up 74.85% of diet DM.

^bCoded: minimum slight = 4, minimum small = 5, etc.

^cMeans differ ($P < .01$).

^dKidney, pelvic, and heart fat as a percentage of carcass weight.

Comparisons of these results with other published values for SFS are limited by differences in processing conditions, type of grain with which it is compared and experimental conditions. Garrett (1965) reported results of two comparative slaughter trials evaluating steam-rolled barley and sorghum (density of steam-rolled sorghum was roughly .50 kg/liter). In the first trial, the NE of steam-rolled sorghum was 20% higher than that of steam-rolled barley. In the second trial, the NE values were similar for the two grains. Perhaps part of this difference could have been a result of differences in degree of processing. However, a subsequent trial (Garrett, 1968) detected no advantage for steam flaking vs steam rolling sorghum. Indeed, more extensive processing, such as prolonged steaming or pressure cooking and flaking, has depressed growth performance (Lofgreen et al., 1968; Garrett, 1969). Notwithstanding, McIlroy et al. (1967) observed a 9% increase in ADG and a 5.2% decrease in DMI/gain with sorghum steam-flaked to a density of .40 vs .50 kg/liter. In the same trial, steam-flaked barley resulted in similar weight gain yet 4% lower DMI/gain compared with SFS. Estimating the NE value of their diets based on live weight, DMI, and ADG, and assuming that their barley had an NE_m of 2.12 Mcal/kg (NRC, 1984), then the corresponding NE_m of SFS was 2.34 Mcal/kg (11% greater than barley). This value for SFS is consistent with our value and lends credence to the current tabular value (2.30 Mcal/kg; NRC, 1984).

In contrast with SFS, observed/expected NE values were higher (5 to 7%, $P < .05$) for SFC. This variance between observed and expected values for SFC is consistent with prior observations (Zinn, 1987) that current tables of feed standards (NRC, 1984) undervalue the improvement in feeding value from steam flaking of corn. Assuming that SFS has a NE_m of 2.30 Mcal/kg (NRC, 1984), then the corresponding replacement value for SFC is 2.51 Mcal/kg. This value is quite close to the value of 2.54 Mcal/kg NE_m obtained for SFC in a previous trial (Zinn, 1987).

The influence of replacing SFC with SFS on characteristics of digestion are shown in Table 5. Ruminal digestion of OM and starch tended to be lower (11.8 and 7.2%, respectively, $P < .10$) for SFS. The estimate of ruminal starch digestibility for SFS (80%) was in good agreement with McNeil et al. (1971) and

Hinman and Johnson (1974), who reported values of 83 and 81%, respectively, for SFS. The ruminal starch digestibility for SFC (86%) is consistent with the summary value of 86% reported by Theurer (1986) and is within the range of 79 to 87% ruminal starch digestibility reported from previous trials at this center (Zinn, 1987, 1990a,b).

The difference between SFC and SFS in ruminal starch digestion was smaller than expected. This result is consistent with the small differences between the two grains for in vitro enzymatic starch digestion based on amyloglucosidase (Table 2). However, results conflict with anticipated differences between the two grains based on starch reactivity to crude diastase. Consequently, caution is warranted when assessing ruminal starch availability based on crude diastase reactivity.

Ruminal degradation of feed N was 31% lower ($P < .05$) for the SFS diets. Assuming that the N in corn has a ruminal degradation of 50% (McDonald, 1954; Cole et al., 1976; Zinn et al., 1981) and the ruminal proteolysis of other ingredients was not different between diets, then by difference the ruminal degradation of N in SFS is estimated to be 20%. This estimate is in reasonably good agreement with a value of 25% obtained for SFS by extrapolation from a trial by Rahnema et al. (1987).

The low ruminal availability of N from SFS would indicate that SFS-based diets should respond to higher levels of NPN supplementation. Consistent with this, Lofgreen et al. (1968) observed a 12.3% increase in ADG and a 14.0% decrease in DMI/gain when urea (at 1.3% of diet DM) replaced cottonseed meal as the source of supplemental N in a SFS-based diets.

Small intestinal digestion of OM, ADF, and starch tended ($P > .10$) to be lower (8.8, 35.5, and 5.0%, respectively) for the SFS diets. Small intestinal digestibility of N was 5.9% lower ($P < .05$) for SFS diets. Total tract N digestibility was 10.8% lower ($P < .01$) for SFS. If the true digestibility (total tract) of N in SFC is 91% (Spicer et al., 1986), then by difference the digestibility of N in SFS was 77%. Lower N digestibility for sorghum vs corn has been well documented, although the magnitude of the difference has ranged from 3% (Spicer et al., 1986) to 20% (Hale, 1973). Degree of processing (dry-rolled vs steam-rolled or flaked) has had little influence on N digestibility of sorghum (Hale et al., 1966;

TABLE 5. MAIN EFFECTS OF STEAM-FLAKED CORN VERSUS STEAM-FLAKED SORGHUM ON CHARACTERISTICS OF DIGESTION (TRIAL 2)^a

Item	Steam-flaked		SD
	Corn	Sorghum	
Steer weight, kg	106	106	—
Replicates	6	8	—
Intake, g/d			
DM	2,733	2,734	—
OM	2,567	2,541	—
ADF	224	272	—
N	53.3	56.2	—
Starch	1,221	1,281	—
Gross energy, Mcal/d	11.96	11.80	—
Flow to the duodenum, g/d			
OM	1,274	1,435	214
ADF ^b	157	198	37
Starch ^b	165	253	74
Non-ammonia N ^b	63.3	71.5	7.2
Microbial N ^b	40.1	37.1	2.8
Feed N ^c	23.2	34.4	6.2
Ruminal digestion, %			
OM ^b , adjusted	65.9	58.1	8.1
ADF	29.5	26.9	14.9
Feed N ^c	56.4	38.8	11.2
Starch ^b	86.5	80.3	5.7
Microbial efficiency ^d	23.8	25.6	4.5
Nitrogen efficiency ^e	1.19	1.27	.13
Flow from the ileum, g/d			
OM ^c	547.8	685.0	89.4
ADF ^c	124.5	170.8	28.4
Starch ^c	16.8	35.3	12.0
N ^f	16.3	21.6	1.1
Small intestinal digestion, %			
OM	56.8	51.8	6.5
ADF	19.0	12.2	15.9
Starch	89.3	84.8	4.9
N ^c	74.0	69.6	3.1
Fecal excretion, g/d			
OM ^b	442.5	504.3	52.3
ADF ^f	117.3	153.1	14.2
Starch ^f	5.3	12.0	3.4
N ^f	16.2	21.3	1.9
Gross energy, Mcal/d ^b	2.58	2.83	.24
Total tract digestion, %			
OM ^c	82.8	80.1	2.0
ADF	47.5	43.3	5.5
Starch ^f	99.6	99.1	.3
N ^f	69.6	62.1	3.5
Energy estimates, Mcal/kg			
DE ^c	3.43	3.28	.09
ME ^c	2.75	2.60	.09

^aSteam-flaked corn or sorghum made up 74.85% of diet DM.

^bMeans differ ($P < .10$).

^cMeans differ, ($P < .05$).

^dGrams microbial N/kg organic matter fermented.

^eNon-ammonia N leaving abomasum/N intake.

^fMeans differ, ($P < .01$).

TABLE 6. MAIN EFFECTS OF STEAM-FLAKED CORN VERSUS STEAM-FLAKED SORGHUM ON RUMINAL pH, VFA MOLAR PROPORTIONS, AND ESTIMATED METHANE PRODUCTION (TRIAL 2)^a

Item	Steam-flaked		SD
	Corn	Sorghum	
pH ^b	5.83	6.31	.22
Ruminal VFA, mol/100 mol			
Acetate	50.5	55.5	6.2
Propionate	35.0	31.0	6.0
Butyrate	14.1	13.4	3.0
Acetate/propionate	1.50	1.92	.60
Methane production ^c	.42	.47	.08

^aSteam-flaked corn or sorghum made up 74.85% of diet DM.

^bMeans differ ($P < .01$).

^cMethane, mol/mol glucose equivalent fermented.

Buchanan-Smith et al., 1968; Husted et al., 1968). Much of this variability presumably is due to varietal differences in tannin content.

Although apparent total tract and small intestinal digestibility of N was lower ($P < .05$) for SFS, ruminal degradation also was lower ($P < .05$). Net absorption of N from the small intestine as a percentage of N intake was very similar for the two diets, averaging 88.4%. Thus, in terms of protein nutrition, the primary concern with a SFS-based diet is to assure that an adequate amount of ruminally degraded N is provided.

Total tract digestibility of OM was 3.3% lower for the SFS than for the SFC diets. Most of this difference was due to decreased ADF and N digestibilities. Total tract starch digestibility was essentially complete for both SFC and SFS. The high total tract digestibility of starch (>99%) for both SFC and SFS is consistent with previous trials (Theurer, 1986; Zinn, 1987, 1990a,b).

Substituting SFS for SFC decreased ($P < .05$) the DE and ME value of the diet 4.4 and 5.5%, respectively. Assuming SFC has DE and ME values of 4.37 and 3.59 (based on NE_m of

TABLE 7. MAIN EFFECTS OF SODIUM BICARBONATE SUPPLEMENTATION (.75%, DM BASIS) ON GROWTH-PERFORMANCE OF FEEDLOT STEERS AND NE VALUE OF THE DIET (TRIAL 1)^a

Item	Sodium bicarbonate		SD
	-	+	
Days on test	147	147	—
Pen replicates	8	8	—
Live weight, kg			
Initial ^b	387	386	19
Final ^c	611	624	25
Weight gain, kg/d ^d	1.53	1.62	.09
DM intake, kg/d ^e	9.11	9.53	.37
DM intake/gain	5.95	5.90	.24
Diet net energy, Mcal/kg			
Maintenance	2.22	2.22	.07
Gain	1.53	1.54	.06
Obs/expected diet net energy			
Maintenance	1.03	1.04	.03
Gain	1.04	1.05	.04

^aSteam-flaked corn or sorghum made up 74.85% of diet DM.

^bInitial weights were obtained following a 16-h fast without feed or water.

^cCarcass weight divided by .624 (average dressing percentage).

^dMeans differ ($P < .10$).

^eMeans differ ($P < .05$).

TABLE 8. MAIN EFFECTS OF SODIUM BICARBONATE SUPPLEMENTATION (.75%, DM, BASIS) ON CARCASS MERIT (TRIAL 1)

Item	Sodium bicarbonate		SD
	-	+	
Carcass weight, kg	381	389	15
Dressing percentage	62.3	62.6	.9
Liver abscess, %	0	3.1	6.2
Retail yield, % ^a	48.7	47.8	.6
Marbling score ^b	4.63	4.67	.55
Ribeye area, cm ²	87.5	85.5	4.1
Fat thickness, cm ^c	1.72	1.94	.24
KPH fat, % ^d	1.99	2.14	.20

^aMeans differ ($P < .05$).

^bCoded: minimum slight = 4, minimum small = 5, etc.

^cMeans differ ($P < .10$).

^dKidney, pelvic, and heart fat as a percentage of carcass weight.

2.56; Zinn, 1987), then the corresponding DE and ME values for SFS are 4.17 and 3.39 Mcal/kg, respectively. These values are in close agreement with tabular DE and ME values for SFS (4.06 and 3.33 Mcal/kg, respectively; NRC, 1984).

The influence of SFC vs SFS on ruminal pH and VFA concentrations is shown in Table 6. Ruminal pH was lower ($P < .01$) for SFC. This lower ruminal pH is consistent with the slightly higher percentage of OM fermented in the rumen for the SFC diets (Table 5). The ruminal acetate:propionate ratio tended to be higher for SFS diets.

The main effects of sodium bicarbonate (BICARB) supplementation (.75% of diet DM) on growth performance are shown in Table 7. Supplemental BICARB increased ADG 5.9% ($P < .10$) and DMI 4.6% ($P < .05$). Feed conversion and diet NE were not affected ($P > .10$). Supplemental BICARB tended to increase (12.8%, $P < .10$) fat thickness and decrease (1.8%, $P < .05$) retail yield (Table 8). The increased carcass fatness with BICARB supplementation probably is a reflection of the increased ADG and higher slaughter weight.

The primary intent of steam flaking is to increase digestibility. However, improvements in digestibility are not always reflected by improved DM conversion (Zinn, 1990a). At times, feedlot growth performance is depressed by increased grain processing (Lofgreen et al., 1968; Garrett, 1969; Zinn, 1990a). This is the basis for buffer supplementation. Supportive research is limited, however, and results have been variable. Few trials have been reported

that evaluate the use of buffers in diets containing highly processed grains.

Nicholson et al. (1963), feeding an all-concentrate diet (86% rolled barley), observed that ADG and DMI were increased by addition of 3% BICARB. As with the present trial, DM/gain was not affected. Brethour et al. (1986) observed an 11.6% increase in ADG and a 5.3% decrease in DMI/gain by the addition of 1.05% BICARB to a finely rolled wheat plus sorghum-based finishing diet. Lofgreen (1976) observed a 7% increase in ADG and an 8% decrease in DMI/gain by the addition of .75% BICARB to a steam-rolled barley-based finishing diet (90% concentrate). The addition of monensin (33 mg/kg) caused a response similar to that of BICARB. However, when both were added together, no further benefit was noted. Across time, the greatest response to monensin was observed during the first third of the trial, whereas the greatest response to BICARB was during the latter third. Stroud et al. (1985), feeding a 76% cracked corn-based diet with or without 1% BICARB, did not detect any effects on ADG or DMI. However, BICARB supplementation improved DM/gain during the final phase of the finishing period. More work is needed to evaluate the relationship between the ionophores and buffer supplementation, particularly with respect to time on feed. Our diets contained monensin (Table 1).

The influence of BICARB supplementation on characteristics of digestion is shown in Tables 9 and 10. Supplemental BICARB did not influence ($P > .10$) ruminal or total tract

TABLE 9. MAIN EFFECTS OF SODIUM BICARBONATE SUPPLEMENTATION
(.75%, DM BASIS) ON CHARACTERISTICS OF DIGESTION (TRIAL 2)

Item	Sodium bicarbonate		SD
	-	+	
Steer weight, kg	106	106	—
Replicates	8	8	—
Intake, g/d			
DM	2,736	2,731	—
OM	2,551	2,557	—
ADF	230	266	—
N	55.7	53.4	—
Starch	1,273	1,229	—
Gross energy, Mcal/d	11.92	11.84	—
Flow to the duodenum, g/d			
OM	1,396	1,315	214
ADF	175	181	37
Starch	225	193	74
Non-ammonia N	69.1	65.6	7.2
Microbial N ^a	40.0	37.1	2.8
Feed N	29.0	28.6	6.2
Ruminal digestion, %			
OM	60.9	63.1	8.1
ADF	24.3	32.2	14.9
Feed N	48.0	47.3	11.2
Starch	82.5	84.3	5.7
Microbial efficiency ^b	26.2	23.1	4.5
Nitrogen efficiency ^c	1.24	1.22	.13
Flow from the ileum, g/d			
OM	610.5	622.4	89.4
ADF	147.6	147.7	28.4
Starch	24.4	27.7	12.0
N	18.8	19.1	1.1
Small intestinal digestion, %			
OM	55.9	52.7	6.5
ADF	12.9	18.3	15.9
Starch	88.9	85.5	4.9
N	72.7	70.9	3.1
Fecal excretion, g/d			
OM	473.3	473.5	52.3
ADF	134.7	135.7	14.2
Starch	8.5	8.8	3.4
N	18.5	18.9	1.9
Gross energy, Mcal/d	2.71	2.70	.24
Total tract digestion, %			
OM	81.4	81.5	2.0
ADF ^d	41.7	49.1	5.5
Starch	99.3	99.3	.3
N	66.8	64.9	3.5
Energy estimates, Mcal/kg			
DE	3.37	3.35	.09
ME	2.71	2.64	.09

^aMeans differ ($P < .10$).

^bGrams microbial N/kg organic matter fermented.

^cNon-ammonia N leaving abomasum/N intake.

^dMeans differ ($P < .05$).

TABLE 10. MAIN EFFECTS OF SODIUM BICARBONATE SUPPLEMENTATION (.75%, DM BASIS) ON RUMINAL pH, VFA MOLAR PROPORTIONS, AND ESTIMATED METHANE PRODUCTION (TRIAL 2)

Item	Sodium bicarbonate		SD
	-	+	
pH ^a	5.87	6.23	.22
Ruminal VFA, mol/100 mol			
Acetate	51.3	55.1	6.2
Propionate ^b	37.0	30.3	6.0
Butyrate	13.0	14.6	3.0
Acetate/propionate	1.49	1.93	.60
Methane production ^c	.41	.48	.08

^aMeans differ ($P < .01$).

^bMeans differ ($P < .10$).

^cMethane, mol/mol glucose equivalent fermented.

digestion of OM, starch, or N. However, total tract digestion of ADF was increased 17.7% ($P < .05$; Table 9). Supplemental BICARB increased ($P < .01$) ruminal pH and tended to decrease the ruminal molar concentration of propionate ($P < .10$).

Boerner et al. (1987a,b) did not observe any influence of 1% BICARB supplementation on ruminal or total tract digestion of OM, starch, or N with a 90% concentrate diet (cracked corn). However, BICARB supplementation increased ruminal and intestinal pH and ruminal molar proportions of propionate. Stroud et al. (1985), feeding a diet similar to that of Boerner et al. (1987a,b), also observed that ruminal pH increased with 1% BICARB supplementation, whereas ruminal VFA, DM, and starch digestion were not affected. Nicholson et al. (1963), feeding an all-concentrate diet (84% rolled barley), observed increased ruminal pH and molar proportions of propionate and a tendency for increased (2.1%) OM digestion with 3% supplemental BICARB. Effects on ruminal pH seem consistent but effects on ruminal propionate are not.

Implications

Steam-flaked sorghum grain had 92% of the feeding value (NE_m) of steam-flaked corn. Differences in starch digestibility were small and cannot explain the lower feeding value of sorghum grain. Low ruminal degradation of sorghum (roughly 20%) should be considered in diet formulation to avoid a deficit in ruminally available N. Addition of .75% sodium bicarbonate increased dry matter intake and average daily gain of cattle fed highly processed grain-based diets.

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