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INFLUENCE OF TEMPERING ON THE FEEDING VALUE OF STEAM-FLAKED SORGHUM FOR FEEDLOT CATTLE

J. Salinas, E. G. Alvarez, and R. A. Zinn
Desert Research and Extension Center, University of California, El Centro

ABSTRACT: Two trials were conducted to evaluate the influence of tempering on the feeding value of steam-flaked sorghum (**SFS**) for feedlot cattle. Five dietary treatments were compared: 1) dry rolled sorghum (**DRS**); 2) SFS, no tempering agent; 3) SFS, .275 mg/kg of tempering agent (SarTemp; SarTec, Anoka, MN); 4) SFS, 1.375 mg/kg of tempering agent and 5) SFS, 2.750 mg/kg of tempering agent. Densities of DRS and SFS were .48 and .36 kg/L, respectively. Diets contained (DM basis) 12% sudangrass hay, 71.5% sorghum, 8% molasses, 5% yellow grease, and 3.5% supplement. One hundred fifty crossbred yearling steers (336 kg) were used in a 115-d finishing trial to evaluate treatment effects on performance. Steers were assigned within weight blocks to 25 pens (6 steers/pen). Weight gain averaged 1.49 kg/d, and was not affected (P > .10) by treatments. Steam flaking sorghum reduced (P < .01) DM intake (9%), and enhanced (P < .01) feed/gain (11%), and the NEm and NEg value of the diet (9 and 11%, respectively). Tempering did not influence (P > .20) cattle performance. Given that the NE and NE values of DRS are 2.00 and 1.35 Mcal/kg, respectively (NRC, 1996), the corresponding values for SFS are 2.28 and 1.59 Mcal/kg. Five steers (397 kg) with ruminal and duodenal cannulas were used in a 5×5 Latin square design to evaluate treatment effects on digestive function. Steam flaking sorghum increased (P < .01) ruminal digestion of OM (14%) and starch (16%), flow to the duodenum (P < .01) of nonammonia N (6.3%), feed N (5.5%), and microbial N (9.4%, P < .05), post-ruminal digestion (P < .01) of OM (11%), N (10%), and starch (25%), and total tract digestion (P < .01) of OM (8.3%), N (8.2%), and starch (8.4%). As with the growth performance, the effects of tempering on digestion were small (P > .10). We conclude that steam flaking sorghum increases its NE and NE value (14 and 18%, respectively). Additionally, steam flaking sorghum will enhance the metabolizable protein value of the diet (14%). The use of a tempering agent to enhance the mechanical efficiency of the flaking process may benefit the feeding value of sorghum.

Introduction

Tempering is a chemically facilitated process by which moisture is added to grain prior to further processing. Although increasing moisture content of grain, per se, may not have an important influence on its energy value (Wilson et al., 1973; Zinn, 1990), tempering also softens the grain, thereby reducing the energy cost of rolling. It may also improve the integrity of the kernel as it leaves the rollers, reducing dustiness and fines. The influence of tempering on the feeding value of steam-flaked sorghum (**SFS**) has not been evaluated. Tempering has increased the NE value of both dry rolled and steam-flaked corn (Zinn, 1988). Tempering steam-flaked corn did not influence ruminal or total tract digestion of starch, but increased ruminal microbial efficiency. This beneficial effect may have been related to the sarsaponin surfactants contained in the tempering agent. Grobner et al (1982) and Zinn et al. (1983) noted increased ruminal microbial efficiency with sarsaponin supplementation. The objective of this study was to determine the influence of tempering prior to flaking on the feeding value of sorghum for feedlot cattle.

Experimental Procedures

Trial 1. One hundred fifty crossbred yearling steers (approximately 25% Brahman blood with the remainder represented by Hereford, Angus, Shorthorn and Charolais breeds in various proportions) with an average initial weight of 336 kg were used in a 115-d trial to evaluate the influence of tempering on the feeding value of steam-flaked sorghum. Steers were blocked by weight and randomly assigned within weight groups to 25 pens (six steers per pen). Pens were 43 m^2 with 22 m^2 overhead shade. The trial was initiated May 15, 1997. Five dietary treatments were compared: 1) dry rolled sorghum (**DRS**); 2) SFS, no tempering agent; 3) SFS, .275 mg/kg of tempering agent (SarTemp; SarTec, Anoka, MN); 4) SFS, 1.375 mg/kg of tempering agent and 5) SFS, 2.750 mg/kg of tempering agent. Densities of DRS and SFS were .48 and .36 kg/L, respectively. Water (.075 L/kg sorghum) plus the corresponding amount of tempering agent were sprayed on the sorghum in a continuous flow system, as it was augered into a holding bin located directly above the steam chest. Retention time of sorghum in the holding bin was approximately 30 min. Retention time of sorghum in the steam chest was also 30 minutes. The SFS was prepared as follows. A chest situated directly above the rollers (46 X 61 cm corrugated) was filled to capacity (441 kg) with sorghum and then brought to a constant temperature at atmospheric pressure of 102 C using steam. The sorghum was steamed for approximately 20 min prior to starting the rollers. The first approximately 441 kg of SFS was allowed to pass from the rollers before material was collected for use in the trial. This preliminary period served for warming the rollers and for adjusting the tension of the rollers to provide a flake with the desired density (.36 kg/L). The SFS was allowed to air-dry prior to feeding. Composition of the basal diet is shown in

Table 1. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were allowed ad libitum access to their experimental diets. Fresh feed was provided twice daily. Steers were implanted with Synovex-S® (Fort Dodge Animal Health, Fort Dodge, IA). Energy gain (EG) was calculated by the equation: EG = $ADG^{1.095}$ .0493$W^{.75}$, where EG is the daily energy deposited (Mcal/d), W is the mean shrunk body weight (kg; NRC, 1984). Maintenance energy (EM) was calculated by the equation: EM = .O77$W^{.75}$ (Lofgreen and Garrett, 1968). The NE_m and NE_g value of the diets were obtained by means of the quadratic equation ($x' \frac{\&b \pm \sqrt{b^2 \& 4ac}}{2c}$) where a = -.41EM, b = .877EM + .41DMI + EG, c = -.877DMI, and NE_g = .877NE_m - .41. For calculating steer performance, initial and final full weights were reduced 4% to account for digestive tract fill. Pens were used as experimental units. 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 eye muscle at the twelfth rib; 2) subcutaneous fat over the eye muscle at the twelfth rib taken at a location 3/4 the lateral length from the chine bone end (adjusted by eye for unusual fat distribution); 3) kidney, pelvic and heart fat (KPH) as a percentage of carcass weight; and 4) marbling score (USDA, 1965; using 3.0 as minimum slight, 4.0 as minimum small, etc.). The trial was analyzed as a randomized complete block design experiment.

Trial 2. Five crossbred steers (397 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a replicated 5×5 Latin square experiment to study treatment effects on characteristics of digestion. Treatments were the same as those used in Trial 1 (Table 1), with .40% chromic oxide added as a digesta marker. Steers were maintained in individual pens with access to water at all times. Diets were fed at 0800 and 2000 daily. Dry matter intake was restricted to 6.3 kg/d. Experimental periods were 2 wk, with 10 d for diet adjustment and 4 d for collection. During collection, duodenal and fecal samples were taken 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. Upon completion of the trial, approximately 500 mL of ruminal fluid were obtained from each steer, composited across diets; bacteria were isolated via differential centrifugation (Bergen et al., 1968). The microbial isolates were prepared for analysis by oven drying at 70°C and grinding with mortar and pestle. Feed, duodenal and fecal samples were prepared for analysis by oven drying at 70°C and grinding in a lab mill (Micro-Mill, Bel-Arts Products, Pequannock, NJ). Samples were oven dried at 105°C until no further weight was lost and stored in tightly sealed glass jars. Samples were subjected to all or part of the following analysis: ash, ammonia N, Kjeldahl N (AOAC, 1984); NDF (Goering and Van Soest, 1970; adjusted for insoluble ash), chromic oxide (Hill and Anderson, 1958); purines (Zinn and Owens, 1986); and starch (Zinn, 1990). 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 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 any endogenous additions. This trial was analyzed as a 5×5 Latin square (Hicks, 1973).

Results and Discussion

Treatment effects on feedlot performance and estimated NE value of the diet (Trial 1) are shown in Table 2. Weight gain averaged 1.49 kg/d, and was not affected (P > .10) by treatments. Steam flaking sorghum reduced (P < .01) DMI (9%), and enhanced (P < .01) feed/gain (11%), and the NEm and NEg value of the diet (9 and 11%, respectively). Tempering prior to flaking sorghum did not influence (P > .20) cattle growth performance.

Consistent with the present trial, Zinn (1988) also did not observe an influence of tempering prior to flaking corn on ADG and feed efficiency. However, tempering prior to cold rolling (in absence of steam) corn enhanced ADG (9%), feed efficiency (5%), and dietary NE (3%). In like manner, tempering prior to cold rolling has increased (4%) the NE value of barley (Bradshaw et al., 1996).

Given that the NE_m and NE_g values of DRS are 2.00 and 1.35 Mcal/kg, respectively (NRC, 1996), the corresponding values for SFS are 2.28 and 1.59 Mcal/kg. The NE_m value for SFS is in good agreement with Zinn (1991; 2.34 mcal/kg), but is 4.6% higher then the current tabular value (2.18 Mcal/kg; NRC, 1996). The NRC (1996) has given SFS 92% the value of steam-flaked corn. This relationship is consistent with Zinn (1991). This, plus the observation that the observed NE_m of DRS-based diet was 97% of expected, while that of the SFS-based diet was 101% of expected, leads to the conclusion that the NRC (1996) is overestimating the NE_m value for DRS by 5%. Accordingly, we conclude that the NE_m and NE_g values for DRS are 1.90 and 1.26 Mcal/kg, respectively.

Treatment effects on carcass characteristics is shown in Table 3. There were no treatment effects (P > .10) on carcass weight, dressing percentage, KPH, longissimus area, marbling score and retail yield. Level of tempering agent affected (quadratic component, P < .10) fat thickness and liver abscess. The basis for this is not certain. With corn-based diets, tempering prior to flaking did not affect carcass characteristics. In contrast with cold rolled corn, tempering increase fat thickness (27%; Zinn, 1988). Although, in this latter case, the increase in fat thickness may have been confounded with increased ADG and carcass weight.

Treatment effects on digestive function (Trial 2) are shown in Table 4. Steam flaking sorghum increased (P < .01) ruminal digestion of OM (14%) and starch (16%). Although comparable studies making direct comparisons of the digestibilty of DRS and SFS are not available in the literature, results are consistent with generalized indirect comparisons of DRS and SFS summarized by Theurer (1986) and changes in ruminal digestion with steam flaking corn (Zinn, 1988; Zinn et al., 1998).

Steam flaking sorghum increased (P < .01) flow to the

duodenum (P < .01) of nonammonia N (6.3%), feed N (5.5%), and microbial N (9.4%, P < .05). Similar responses were also observed due to steam flaking corn (Zinn ,1988; Zinn et al., 1998).

Microbial efficiency was affected (quadratic component, P < .05) by tempering. The increase in the ruminal microbial efficiency is most likely a response to the sarsaponin contained in the tempering agent. In previous studies (Grobner et al., 1982; Zinn, 1988; Cheeke, 1998, Zinn et al., 1998), sarsaponin feeding has increased microbial N flow to the small intestine.

Steam flaking sorghum increased (P < .01) post-ruminal digestion (P < .01) of OM (11%), N (10%), and starch (25%), and total tract digestion (P < .01) of OM (8.3%), N (8.2%), and starch (8.4%). Consistent with Zinn (1988) and Zinn et al. (1998), steam flaking increase posruminal and total tract digestion of OM, N and starch. As with the growth performance, the effects of tempering on digestion were small (P > .10).

Treatment effects on ruminal pH and VFA molar proportions are shown in Table 5. Grain processing did not affect (P > .10) ruminal pH or VFA molar proportions. However, level of tempering agent affected (cubic component, P < .10) ruminal pH. In studies with corn, steam flaking did not find ruminal pH or VFA molar proportions (Lee et al., 1982; Zinn et al., 1998), although in others (Zinn, 1987; Zinn et al., 1995) ruminal pH decreased and molar proportions of acetate were increased with steam flaking.

Implications

The NRC (1996) overestimates (5%) the feeding value of steam-flaked sorghum. Steam flaking sorghum will increase its net energy value for maintenance and gain (14 and 18%, respectively). Steam flaking sorghum will enhance the metabolizable protein value of the diet (14%). The use of a tempering agent to enhance the mechanical efficiency of the flaking process may benefit the feeding value of sorghum.

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Table 1. Composition of experimental diets fed to steers (trial 1 and 2) [a].

	Dry	Steam-flaked sorghum			
	rolled	Tempering agent[a], mg/kg			
Item	sorghum	0	.28	1.38	2.75
Ingredient composition, % (DM basis)					
Sudangrass hay	12.00	12.00	12.00	12.00	12.00
Dry rolled sorghum	70.63				
Flaked sorghum		70.63	70.63	70.63	70.63
Cottonseed meal	2.00	2.00	2.00	2.00	2.00
Yellow grease	4.00	4.00	4.00	4.00	4.00
Cane molasses	8.00	8.00	8.00	8.00	8.00
Limestone	1.52	1.52	1.52	1.52	1.52
Urea	1.00	1.00	1.00	1.00	1.00
Ammonium sulfate	.20	.20	.20	.20	.20
Magnesium oxide	.15	.15	.15	.15	.15
Trace mineral salt[c]	.50	.50	.50	.50	.50
Nutrient composition (DM basis)[d]					
NE, Mcal/kg					
Maintenance	2.00	2.19	2.19	2.19	2.19
Gain	1.35	1.51	1.51	1.51	1.51
Crude protein, %	14.5	14.5	14.5	14.5	14.5
Ether extract, %	6.0	6.0	6.0	6.0	6.0
ADF, %	5.0	5.0	5.0	5.0	5.0
Calcium, %	.70	.70	.70	.70	.70
Phosphorus, %	.32	.32	.32	.32	.32
Potassium, %	.86	.86	.86	.86	.86
Magnesium, %	.30	.30	.30	.30	.30
Sulfur, %	.20	.20	.20	.20	.20

[a] Cromic oxide (.40%) was added as digesta marker in trial 2.

[b]SarTemp EXP (Sartec Corporation, Auokova MN) diluted 6:1 with N-propylalcohol.

[c]Trace mineral salt contained: $CoSO_4$, 0.68%; $CuSO_4$, 1.04%; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, .052%; and NaCl, 92.96%.

[d]Based on tabular values for individual feed ingredients (NRC, 1984) with the exception of supplemental fat, wich was assigned NE_m and NE_g values of 6.03 and 4.79, respectively.

Table 2. Influence of tempering before flaking on growth performance of feedlot steers fed sorghum-based finishing diets (Trial 1).

	Dry rolled	Steam flaked sorghum				
		Tempering agent, mg/kg				
Item	sorghum	0	.275	1.375	2.750	SEM
Live weight, kg[a]						
Initial	336	337	337	335	337	2
Final	504	509	503	512	508	7
ADG, kg/d	1.46	1.50	1.44	1.54	1.50	.05
DM intake, kg/d[b]	8.99	8.16	7.93	8.33	8.29	.20
Feed/gain[b]	6.16	5.43	5.50	5.41	5.55	.12
Dietary NE, Mcal/kg						
Maintenance[b]	1.96	2.17	2.16	2.17	2.13	.03
Gain[b]	1.31	1.49	1.49	1.49	1.46	.03
Observed/expected NE						
Maintenance[c]	.97	1.01	1.01	1.01	1.00	.01
Gain[d]	.97	1.01	1.01	1.01	1.00	.02

[a]Initial and final live weights reduced 4% to account for fill.
[b]Dry rolled vs steam-flaked sorghum, P<.01.
[C]Dry rolled vs steam-flaked sorghum, P<.05.
[d]Dry rolled vs steam-flaked sorghum, P<.10.

Table 3. Influence of tempering before flaking on carcass characteristics of steers fed sorghum-based finishing diets (Trial 1).

	Dry rolled	Steam-flaked sorghum				
		Tempering agent, mg/kg				
Item	sorghum	0	.275	1.375	2.750	SEM
Carcass weight, kg	320	324	318	326	325	4
Dressing	63.6	63.3	63.7	64.0	63.6	.4
KPH, %	2.9	2.9	2.9	2.8	2.9	.08
Fat thicness, cm[a]	.84	.88	.80	.90	.71	.06
Ribeye area cm^2	81.3	82.0	81.9	83.1	83.5	.9
Marbling score	3.7	3.7	3.8	3.8	3.9	.1
Retail yield, %	50.9	50.8	51.1	50.9	51.3	.2
Liver abscess, %[b]	16.7	6.7	20.0	13.3	3.3	4.1

[a]Quadratic effect of tempering, P<.10.
[b]Linear effect of tempering, P<.10.

Table 4. Influence of tempering before flaking on characteristics of ruminal and total digestion in steers fed sorghum-based finishing diets (Trial 2).

	Dry	Steam-flaked sorghum				
	rolled	Tempering agent, mg/kg				
Item	sorghum	0	.275	1.375	2.750	SEM
Steers	5	5	5	5	5	
Ruminal digestion, %						
OM[a]	56.17	63.09	66.47	65.67	65.10	.02
NDF	49.82	39.80	47.07	44.50	47.02	.03
Starch[a]	72.49	82.47	88.08	86.58	86.23	.02
Feed-N	52.29	52.11	49.63	49.16	50.48	.01
Microbial	18.14	18.90	17.03	17.15	18.27	.57
N_{eff}[ad]	.99	1.08	1.08	1.08	1.10	.02
Post-ruminal digestion, % duodenal						
OM[a]	54.95	64.00	61.95	61.06	61.35	.01
NDF	6.23	11.37	1.57	4.55	.06	.07
Starch[a]	70.95	95.47	95.36	95.58	92.26	.02
N[ae]	65.38	72.74	73.87	72.20	74.00	.00
Total tract digestion, %						
OM[a]	75.59	82.46	82.96	82.42	82.05	.00
NDF	47.17	47.62	48.95	48.36	47.94	.02
Starch[a]	91.16	99.18	99.51	99.49	98.98	.01
N[ae]	63.95	69.43	70.79	68.85	70.41	.00

[a]Dry rolled vs steam flaked sorghum, P<.01.
[b]Cuadratic effect of tempering level, P<.05.
[c]Microbial N, g/kg OM truly fermented
[d]Nonammonia N leaving the abomasum as a percentage of N intake.
[e]Cubic effect of tempering level, P<.10.

Table 5. Influence of tempering before flaking on ruminal pH and VFA molar proportions in steers fed sorghum-based finishing diets (Trial 2).

	Dry	Steam-flaked sorghum				
	rolled	Tempering agent, mg/kg				
Item	sorghum	0	.275	1.375	2.750	SEM
Ruminal pH[a]	6.04	6.06	6.10	5.89	6.03	.07
Total VFA, mmoles	107	104	96	106	104	6.7
Acetate[bc]	53.80	49.35	52.65	48.92	54.31	.01
Propionate[a]	33.38	36.97	35.94	40.98	34.30	.02
Butyrate	12.81	13.67	11.39	10.09	11.38	.01
Methane[cd]	.44	.39	.41	.34	.43	.02

[a]Cubic effect of tempering level, P < .10.
[b]Linear effect of tempering level, P < .10.
[c]Cubic effect of tempering level, P < .05.

[d]Methane, mol/mol glucose equivalent fermented.