STUDIES WITH MICRONIZED SORGHUM GRAIN FOR FEEDLOT CATTLE

By

DON C. CROKA

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Oklahoma State University

Stillwater, Oklahoma

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Thesis Approved:

Donald G Wagner
Thesis Adviser

L. J. Bush

Richard R Frahm

N N Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

The processing of cereal grains for beef cattle rations has been widely studied in recent years. Grains are added to the rations of finishing cattle to increase the digestible energy intake. Cereal grain makes up the major portion of today's finishing rations. The grain may supply up to 90 percent of the usable energy of the ration, therefore, any improvement in the efficiency of utilization will be reflected in reduced feed requirement and possibly improved gain.

In recent years sorghum grain has become the most popular feed grain in the southwest. Sorghum grain has been found to have gross energy value comparable to other cereal grains. However, research indicates the feeding value of sorghum grain is less than corn or wheat unless it is processed. Processing causes certain physical and chemical changes which increase nutrient digestibility and change site of digestion.

Until recent years dry heat processing of sorghum grain has not been used. Recent research indicates that micronized sorghum grain results in increased dry matter digestibility along with a decrease in feed requirement. With today's rising cost a slight reduction in the feed requirement is associated with a large savings in grain cost. The purpose of this study was to evaluate the micronizing of sorghum grain for feedlot cattle. The processing method was evaluated by feedlot performance, carcass merit, net energy, and *in vitro* digestibility and *in vitro* gas production.

CHAPTER II

REVIEW OF LITERATURE

Need for Processing

Sorghum grain (milo) is the most readily available and widely used grain for fattening cattle in the Southwest. Since many feedlot rations contain as much as 80 to 90% sorghum grain, the need for physically processing sorghum grain to improve it's utilization has been of great concern for many years. Chemical composition of sorghum grain indicates that it has potential energy comparable to other cereal grains, however, it is not utilized as efficiently as corn or wheat by feedlot cattle, (Totusek *et al.*, 1963 and Hall *et al.*, 1968). As knowledge in the technological area of mechanical equipment has increased so have the methods by which grains are now processed. The use of dry heat for processing grain has received considerable interest in recent years.

The processing of sorghum grain is accomplished by many methods. Hale (1970a) listed the following methods by which sorghum grain may be processed for cattle: (1) ground, (2) dry rolled, (3) soaked, (4) pelleted, (5) steam rolled, (6) steam processed, (7) pressure cooked, (8) reconstituted, (9) early harvested and (10) popped or micronized. All of the methods are an attempt to increase efficiency of grain utilization. It has long been recognized that the efficiency of grain utilization by cattle could be improved by grinding or cracking the grain. Improved feed efficiency and/or increased rate of gain have been observed for cattle fed sorghum grain which had been pelleted, rolled, popped, or steam flaked (Albin, 1971).

Feeding Value of Processed Cereal Grain

The use of hammer or roller mills for processing sorghum grain has been evaluated by Puckett and Daum (1968). If the roughage level is considered, one would expect little difference in the digestion of sorghum grain processed by either grinding or dry rolling (Smith and Parrish, 1953; Baker et al., 1955; Richardson, Smith and Cox, 1955; Smith et al., 1960; Pope et al., 1962; Brethour and Duitsman, 1966; Buchanan - Smith, Totusek and Tillman, 1968; Husted et al., 1968; Hale, 1970). Riggs (1958) concluded that by fattening cattle over eight months old, ground sorghum grain was efficiently utilized than whole grain, and that rolling and crushing offered little or no advantage over grinding. Steevens (1971), however, reported dairy cows fed very finely ground sorghum grain produced more milk and more weight gain than cows fed medium or coarsely ground grain. Alexander (1973) observed no differences in weight gain, but also noted an increase in milk production from cows fed fine or medium ground sorghum grain as compared to coarse ground. In many previous studies with finishing beef cattle, particle size or fineness of grain was not reported.

The most widely used method of commercial processing in recent years has been steam flaking. Hale (1966) compared steam flaked and dry rolled sorghum grain and barley for steers and found increased grain and feed intake on the flaked grains. Feed efficiency was also improved with the steam flaked sorghum grain. Hale (1967) summarized

Arizona data that indicated steam processed flaked sorghum grain increased gains by approximately 10% and reduced feed requirements by 5% compared to dry rolled sorghum grain. In a summary of 11 experiments, Totusek and White (1968) noted that steam flaking of sorghum grain increased rate of gain by 7% over dry rolling and 10% over grinding with an increase of 3 and 7% respectively in feed efficiency.

The process of hot air expansion resulting in popped grain has been described by Rockwell et al., (1968). Air-dry grain at a moisture content of 10 to 14% is popped by heating with high temperature air at 700 to 800° F for 15 to 30 seconds. Moisture content of the popped material is approximately 3%; therefore, remoisturization and rolling are usually essential. Reeve and Walker (1969) reported the effect of popping grain as a disruption of starch granules by using natural moisture in the seed to steam, gelatinize, and expend the starch granules. In a steer feeding study using sorghum grain, Garrett (1968) compared popping to three steam processing methods. No differences in animal response or carcass merit were noted among the four processing methods. The only major difference was decreased feed consumption on the popped treatment, being 15.2 lbs. versus 15.5, 15.7 and 16.3 lbs. on the steamed treatments.

Ellis and Carpenter (1966) reported slightly slower gains but 16.6% less feed required per unit of gain when 40% cracked sorghum grain was replaced with popped sorghum grain in an all-concentrate mixture for yearling steers. Durham, Ellis and Cude (1967) reported daily gains of 1.27, 1.12, and 1.23 kg but almost identical feed conversions for cattle fed cracked, and flaked and popped sorghum grain, respectively, in all concentrate mixtures. Feed intakes were, however, significantly lower on the steam flaked sorghum grain ration.

Cardon (1969) reported favorable results for dry heat processed sorghum grain when compared to steam processed flaked and pressure cooked flaked sorghum grain for finishing cattle. Their popping process involved exposure of raw sorghum grain to an intense gas flame for a short period of time, resulting in approximately 50% popped grain. Their results showed slightly higher feed intake and daily gain on the popped compared to the steam processed grain. Moreover, they observed essentially the same feed requirement per unit of gain and reported that the popped grain ration appeared more palatable, particularly in the early part of the feeding period.

Riggs et al. (1970) compared dry rolling and two methods of dry heat popping sorghum grain for steers. The two heating methods compared were: (1) a machine using an infrared-heated reciprocating steel table and (2) a machine utilizing a gas heated vibrating tray conveyor. They reported significantly lower feed intakes on the dry heat treatments. Slightly lower daily gains were also observed. The lower feed intakes were reflected in increased feed efficiency.

Dry grain which has been heated with gas-fired infrared generators as the grain passes along an oscillating steel plate (table) and dropped into Knorling rolls has been termed micronized grain (Pierce, 1968). The term was coined from the word microwave (microwaves are emitted from the infrared generators) and from the unique type of rollers used. In this process the grain is discharged at the end of the plate at about 300° F. The grain does not pop at the temperatures used. The rolls have a spiral groove which place high diagonal pressure on the grain. The product has an intact, flake-like appearance which resembles some steam flaked grains. Temperature of the grain and density of the final product can be regulated. Densities of micronized grain normally range from 18 to 30 lbs. per bushel.

Schake et al. (1970) evaluated micronized and steam processed flaked sorghum grain under commercial feedlot conditions. They reported live animal gains increased slightly for steers fed the micronized grain, being 2.50 vs. 2.62 lbs. per day on the steam flaked and micronized grain treatments, respectively. Feed intakes on the micronized grain were 22.47 lbs. compared to 20.97 lbs. on the steam flaked grain, and the feed/unit of gain values were 8.60 and 8.40 lbs. on the same rations respectively. These workers noted that steers fed micronized sorghum grain gained more rapidly during the first 50-day interval, suggesting they went on feed more rapidly.

Nature and Gelatinization of Starch

Most cereal grains contain about 70 to 80% starch (Rooney and Clark, 1968; Greenwood, 1970). The endosperm of the cereal grain is primarily starch granules imbedded in a proteinaceous framework (Grasea, 1965; Greenwood, 1970). Leach and Schoch (1961) studied various raw starches and suggested that cereal starches may have a porous granule structure accessible to enzymes, while other starches are less permeable.

A measure of the effect of heat processing upon grains is the degree of disruption of the crystalline structure of the starch granules in the endosperm which has been termed gelatinization. Gelatinization is further defined as damage to the starch granule by pressure, heat, shear or strain and moisture (Anstaett *et al*., 1969; Sandstedt and Mattern, 1960; Sullivan and Johnson, 1964). The degree of gelatinization in processed grains can be measured by the disappearance of birefringence of the starch granules, alpha-amylase digestion (Sandstedt and Mattern, 1960), microscopic structure (Reeve and Walker, 1969), proton magnetic resonance (Jaska, 1971), congo red staining and susceptibility to beta-amylase (Anstaett *et al*., 1969).

During heating and/or moisture treatment of sorghum grain, the grain swells due to water forcing the starch chains apart. To a certain point, the changes caused by swelling are reversible by drying. When the changes become irreversible, the starch is said to be gelatinized; the original starch structure has been destroyed, but the starch has not been converted to a sugar.

In Vitro and *In Vivo* Evaluation of Processing Methods

Upon consumption by cattle, grain is first introduced into the rumen where starch digestion begins. Therefore, any factor which promotes starch digestion by the rumen microorganisms might improve utilization of a high concentrate ration. The rate and amount of starch digestion in the rumen are important in understanding the effect of processing on a cereal grain.

Moist heat treatment of grain has been shown to increase the rate of *in vitro* starch digestion by rumen microbes (Salsburg, Hoefer and Luecker, 1961; Osman *et al*., 1970). Steam or pressure cooking has been reported to increase the rate of *in vitro* starch digestion of both sorghum grain and barley (Osman *et al*., 1970). Moreover, these same workers reported that flaking of steamed or pressure cooked sorghum grain and barley further increased the rate of *in vitro* starch digestion. Rate of starch digestion increased as degree of flaking increased. Trei, Hale and Theurer (1970) reported *in vitro* gas production to be greater for steam flaked sorghum grain and barley than for the untreated grains. Steaming or pelleting of sorghum grain and corn increased *in vitro* gas production when compared to cracked grains (Hastings and Miller, 1961). Moreover, flaking cooked sorghum grain increased gas production, starch digestion and VFA production over cooking (Trei *et al*., 1970), susceptibility to enzmatic attack (Anstaett and Pfost, 1969). Felsman *et al*. (1972) showed that dry roasting corn at temperatures above 127° C resulted in increased *in vitro* dry matter disappearance and glucose release.

Dry heat processing of cereal grains, such as micronizing (Hinders and Eng, 1970; Hinders, 1971) and popping (Walker, Rockwell and Kohler, 1970), has shown to result in increased *in vitro* gas production. Walker *et al*. (1970) reported that popped sorghum grain resulted in higher digestion coefficients and increased total volatile fatty acid production than steam-flaked sorghum grain. Increasing the moisture content of sorghum grain prior to popping increased the percent of the grain which popped and the *in vitro* dry matter digestion (Walker, *et al*., 1970). Ruminal and total starch utilization was greater in steers fed steam flaked and reconstituted sorghum grain compared to those fed dry ground and micronized grain (Potter *et al*., 1969; 1970; McNeill, Potter and Riggs, 1969, 1970). Increases in post ruminal starch digestion of micronized sorghum grain did not completely overcome the lower ruminal starch breakdown.

Hinman (1973) compared sorghum grain which was either dry rolled or micronized to three densities (18, 25, and 32 lbs. per bushel). He observed a significant increase in 12 hour in vitro dry matter disappearance for the micronized treatments. Total volatile fatty acid concentration was lower on the dry rolled treatment than the 18 and 25 lbs. per bushel micronized treatments, and a lower acetate to proportionate ratio was observed on the micronized sorghum grain. Moreover, both intestinal and total starch digestion were significantly higher on the three micronized sorghum grain rations. About 98% of the starch was digested in the total digestive tract on the three micronized sorghum grain rations compared to 81% on the dry rolled ration.

Research would indicate that a desirable degree of gelatinization is about 30-40% in sorghum grain. (Williamson, 1967; Anstaett et al., 1969; Seib, 1970; McNeill et al., 1970). Values near 100% gelatinization have been shown to be undesirable because of low rumen pH values, increasing the proneness to acidosis in feedlot cattle.

CHAPTER III

MICRONIZED SORGHUM GRAIN I. INFLUENCE ON FEEDLOT PERFORMANCE OF CATTLE

Summary

Three feedlot trials involving 64 steers and 30 heifers were conducted to study micronized sorghum grain for finishing cattle. Trials 1 and 2 compared micronized (MS) to dry rolled sorghum (DRS) and trial 3 compared three densities of MS (232, 322 and 412 g/l) to DRS. Evaluation was based on feedlot performance, carcass merit and volatile fatty acid analysis in trials 1 and 2, and included net energy NE_m and NE_g) in trial 3. In trial 1, MS produced an improved feed efficiency (feed/kg gain) ($P < .10$) with no significant differences in gain or feed intake. In trial 2, intake was lower ($P < .10$) on MS with no significant difference in gain or efficiency. No significant differences were observed in trial 3 for intake, gain or feed conversion. In all three trials, the cattle fed MS showed a consistent trend to consume less feed, but gained at the same rate, showing an improved feed efficiency.

No differences existed in carcass characteristics in any of the trials. In trial 3, there were no significant differences in energy values of the feed although energy values tended to favor the MS treatments. Rumen fluid pH values were not different in any of the

trials. In trial 1 and 2 acetic and isovaleric acids were lower and propionic higher, resulting in a narrower acetic:propionic ratio on the MS. No differences were observed in total VFA concentrations in any of the trials.

Introduction

Modern day cattle finishing rations often contain as much as 80% grain. During recent years dry rolling and steam flaking have been the predominant methods of processing sorghum in southwest commercial feedlots.

Several investigations of dry heat processing utilizing popping have indicated lowered intakes with nearly identical daily gains and improved feed efficiencies on popped compared to dry rolled sorghum grain (Ellis and Carpenter, 1966; Durham, Ellis and Cude, 1967; Riggs et al., 1970).

The purpose of this study was to investigate the effect of micronizing sorghum grain in high concentrate feedlot rations since little information is available on this subject.

Experimental Procedure

Three feeding trials involving 64 steers and 30 heifers were conducted to evaluate micronized sorghum (MS) grain for finishing cattle. The equipment used for micronizing the sorghum grain was a reciprocating steel table, 3.96 m X 118 cm X 1.25 cm, activated by a one-half horsepower electric motor. Eight gas-fired infrared generators, each rated at 50,000 BTU per hour and suspended 15 cm above the table, were used to heat the sorghum as it passed across the table. Before heating, the sorghum grain was cleaned with a Clipper cleaner, model 27, to assure an even, free flow. After heating the grain dropped directly through a 21.6 X 76.2 cm roller with spacing of .008 cm. Dry rolled sorghum (DRS) grain, with a geometric mean diameter of 749 microns for trial 1 and 2 and 1366 microns for trial 3, was used as a control. The DRS was cleaned and rolled (not heated) in the same manner as MS. An 80% sorghum (D.M. basis) ration (Table I) was fed ad libitum in all three trials. All animals had access to an opensided shed and outside lot. The feedlot tests were conducted during the following seasons: trial 1 and 2, April to July; trial 3, October to April.

Processing method was evaluated by feedlot performance, carcass merit, volatile fatty acid (VFA) analysis in trials 1 and 2 and included net energy in trial 3. The VFA was separated by gas chromatography (Erwin, Marco and Emery, 1961). Proximate analysis data are presented in Table II.

Trial 1

Sixteen Charolais crossbred feeder steers (297 kg) were used to compare MS to DRS. MS was prepared by adjusting heating time to produce a final product with a density of 322 g/l.

The steers were randomly assigned to four pens with four animals per pen and two pens per treatment. The steers were fed ad libitum from self-feeding bunks which were filled weekly. Diethylstilbesterol (DES) was fed at the rate of 10 mg per head per day. At two separate times during the feeding period rumen samples were obtained from each animal. Ruminal pH values were determined immediately, and a small quantity of rumen fluid, to which mercuric chloride was added, was

TABLE I

RATION COMPOSITION[a]

Ingredient	DRS	MS
Sorghum	80.0	80.0
Cottonseed hulls	5.0	5.0
Alfalfa meal (pelleted)	5.0	5.0
Molasses	4.0	4.0
Soybean meal	4.0	4.0
Urea	0.7	0.7
Salt, T.M.	0.5	0.5
Dicalcium Phosphate	0.4	0.4
Calcium Carbonate	0.4	0.4
Aurofac - 50	225 g	225 g
Vitamin A (30,000 IU/gm)	200 g	200 g

[a]DM basis.

TABLE II

PROXIMATE ANALYSIS OF SORGHUM GRAIN

	Dry Matter	Crude Protein[a,b]	Ash[a]	Ether Extract[a]	CHO[a,c]
Trial 1 and 2					
DRS	87.3	10.66	0.87	3.46	83.97
MS	90.7	11.42	1.68	2.93	84.03
Trial 3					
DRS	86.9	10.04	1.29	2.78	85.89
MS (412)	89.8	10.17	0.97	2.49	86.37
MS (322)	91.4	10.39	0.86	2.49	86.26
MS (232)	92.8	9.83	0.99	1.81	87.37

[a]DM basis.

[b]6.25 x percent Nitrogen.

[c]100-(Sum of figures for crude protein, ash and ether extract).

frozen for VFA analysis. Initial and final weights were taken full with 4% shrink, and the steers slaughtered after 150 days on feed.

Trial 2

Thirty crossbred Angus-Hereford feeder heifers (294 kg) were used to further compare MS and DRS. Heifers were randomly assigned to ten pens with three animals per pen and five pens per treatment. The heifers were fed ad libitum daily. DES was fed (10 mg per head daily). Rumen samples were obtained as in trial 1. Initial and final weights were taken as in trial 1 and the heifers slaughtered after 84 eays.

Trial 3

Forty eight crossbred steers (16 Charolais-X, 16 Hereford X (Angus X Holstein) and 16 Hereford X Angus) averaging 259 kg were used to compare MS of three densities (412, 322 and 232 g/l) to DRS. The three densities of MS were obtained by varying the time of exposure and the intensity of heat from infrared heaters in the micronizing machine. The 49 steers were blocked into three equal groups based on breed and then randomly assigned within block to four pens of four animals each. Within block, treatments were assigned to each pen at random. Thus, there were 12 steers on each treatment in three pens of four steers each. The steers were fed ad libitum daily. Synovex S was implanted at the beginning of the trial. Rumen samples were taken twice during the feeding period as cited previously. Initial weight was taken full with a 4% shrink and final weight after a 16 hour shrink off feed and water. At slaughter, specific gravities were determined on each carcass using the comparative slaughter technique to determine the net energy values of the feed (Garrett, Meyer and Lofgreen, 1959). The initial slaughter group (12 animals) used to estimate initial composition was obtained from a previous trial using cattle of the same general age, weight and condition. Although the initial slaughter group were of Hereford and Angus breeding, and Charolais cattle were used in this study, treatment comparisons are still considered valid. Cattle in the Angus X Hereford block were slaughtered after 179 days on feed and the remainder after 207 days.

In trial 1 and 2 analysis of feed/unit gain and feed intake a model was assumed with the effects of treatment and pens without treatment. Standard error of means were calculated from the variance among pens within treatments. Daily gain and all carcass traits were analyzed with the same model but including the effects of animals within pens which was used as the error term to determine standard error of treatment means. For analysis of pH the effects of time, time by treatment interaction and time by animal within treatment interaction were added to this basic model. The animals within pen variance were used to determine standard error of treatment means. VFA values were analyzed with the same model as pH but included the effects of duplicates.

In trial 3 analysis of feed/unit gain and feed intake a model was assumed with the effects breed, treatment and breed by treatment interaction. There was no pen replication within breed by treatment subclasses, therefore it was assumed that interaction effects were negligible and the interaction term was used to test treatment effects and to calculate standard errors of treatments means. Daily gain, carcass trials, rumen pH and VFA values were analyzed as described above except that breed by treatment interactions were again assumed negligible.

Results and Discussion

Trial 1

Feedlot performance is shown in Table III. Daily feed intakes and gain were 8.37 kg and 1.24 kg, respectively, on the MS compared to 9.28 kg and 1.25 kg on the DRS. Feed efficiency (kg feed/kg live gain), 6.75 for MS vs. 7.42 for DRS, approached significance ($P < .10$). Improved feed efficiency for dry heat treated or popped sorghum grain has been noted by other researchers (Ellis and Carpenter, 1966; Riggs et al. (1970). Increased starch digestion of MS, as shown by Hinman (1973), might account for the improved feed efficiency.

No significant differences were found for carcass characteristics, percent cutability and dressing percent (Table III). Rumen pH values on the MS and DRS, 5.7 and 5.5, respectively, were not significantly different. No differences were noted for total VFA concentration (Table III); however, there was a significant decrease in acetic (A) and iso-valeric acids on the MS treatment. An increase in propionic acid (P) approached significance ($P < .10$), resulting in a narrower A:P ratio for MS. Riggs et al. (1970) noted decreased acetic and increased propionic acid levels in cattle fed popped sorghum grain.

Trial 2

The feedlot performance data are presented in Table IV. As in trial 1 daily gains were similar, while feed efficiency favored MS. As in trial 1, the animals fed MS consumed less feed, with an intake of 8.97 kg, compared to 9.88 kg on DRS, ($P < .10$). Lowered intakes of dry heat treated sorghum grain have been reported previously (Durham, Ellis

TABLE III

TRIAL 1: FEEDLOT PERFORMANCE, CARCASS MERIT AND VFA DATA

	DRS	MS	SE[h]
No. steers	8	8	
Initial live shrunk wt, kg	303	291	
Final live shrunk wt, kg	491	477	
Daily feed, kg[g]	9.28	8.37	± 0.31
Daily gain, kg	1.25	1.24	± 0.07
Feed/kg gain, kg[g]	7.42[a]	6.75[b]	± 0.11
Dressing percent	67.3	66.6	± 0.54
Carcass grade[i]	7.4	7.3	± 0.27
Ribeye area, sq cm	96.3	90.1	± 3.29
Fat thickness, cm	1.3	1.5	± 0.15
Cutability, percent[j]	51.6	51.1	± 0.69
Volatile fatty acids			
Total VFA, umoles/ml	136.8	122.2	±18.32
	------------Molar percent------------		
Acetic	47.7[e]	39.1	± 0.61
Propionic	30.4[a]	38.0	± 1.48
Butyric	12.3	13.5	± 0.53
Isovaleric	2.6[c]	2.0	± 0.15
Valeric	3.7	3.8	± 0.14
pH	5.5	5.6	± 0.09

[a,b]Values with different superscripts differ significantly $(P<.10)$.

[c,d]Values with different superscripts differ significantly $(P<.05)$.

[e,f]Values with different superscripts differ significantly $(P<.01)$.

[g]DM basis.

[h]Standard error of treatment means.

[i]USDA grades converted to following numerical designation: high prime-15, ave. prime-14, low prime-13, high choice-12, ave. choice-11, low choice-10, high good-9, good-8, low good-7.

[j]Percent of boneless trimmed retail cuts on carcass basis = 52.66 - 5.33 (fat thickness) - 0.979 Ipercent kidney fat) + 0.655 (ribeye area) - 0.008 (chilled carcass wt).

and Cude, 1967; Riggs et al., 1970). No differences were observed among the carcass merit data shown in Table IV.

Rumen fluid pH values of the cattle fed MS and DRS were 5.7 and 5.8, respectively. There were no differences in total VFA concentration. Acetic and iso-valeric acid were decreased ($p < .01$) and propionic acid increased on MS. These observations are consistent with those in trial 1.

Trial 3

In trial 3, there were no significant differences observed between treatments for feed intake, gain or feed efficiency (Table V). As previously, daily feed intake tended to be lower on the micronized grain treatments compared to DRS, but there appeared to be no differences among the three densities of MS (MS-412, MS-322, MS-232). Although not significant, gains were slightly higher on all three MS treatments compared to DRS. Schake et al. (1970) reported similar gains for cattle fed micronized and steam flaked grain rations in a commercial feedlot. Although not significant, feed efficiency favored the MS treatments over DRS with little difference among the MS treatments being 7.59, 6.53, 6.14 and 6.49 kg feed/kg gain on the DRS, MS-412, MS-322 and MS-232 treatments, respectively. The tendency for MS to be more efficient than DRS is consistent with observations in the first two trials.

Net energy values for MS and DRS are presented in Table V. Although differences were not significant, there was a trend for higher net energy values for MS supporting the improvements noted in feed/gain ratio. Other data also indicate improved feed efficiency and net energy

TABLE IV

TRIAL 2: FEEDLOT PERFORMANCE, CARCASS MERIT AND VFA DATA

	DRS	MS	SE
No. heifers	15	15	
Initial live shrunk wt, kg	289	299	
Final live shrunk wt, kg	381	388	
Daily feed, kg	9.88[a]	8.97[b]	± 0.28
Daily gain, kg	1.09	1.06	± 0.05
Feed/kg gain, kg	9.06	8.46	± 0.49
Dressing percent	64.4	64.2	± 0.58
Carcass grade	8.5	7.9	± 0.32
Ribeye area, sq cm	70.9	71.6	± 1.87
Fat thickness, cm	1.9	1.8	± 0.10
Cutability, percent	48.9	49.4	± 0.36
Volatile fatty acids			
Total VFA, umoles/ml	93.0	109.4	±10.91
	Molar percent		
Acetic	43.3[c]	36.1[d]	± 1.27
Propionic	33.6[c]	42.6	± 1.19
Butyric	11.9	12.1	± 0.81
Isovaleric	2.7[c]	1.9[d]	± 0.16
Valeric	3.9	3.7	± 0.18
pH	5.7	5.7	± 0.15

[a,b]Values with different superscripts differ significantly (P<.10).

[c,d]Values with different superscripts differ significantly (P<.01).

TABLE V

TRIAL 3: FEEDLOT PERFORMANCE, NET ENERGY, CARCASS MERIT AND VFA DATA

	DRS	MS(412)	MS(322)	MS(232)	SE
No. steers	12	12	12	12	
Initial live shrunk wt, kg	257	259	261	260	
Final live shrunk wt, kg	479	504	496	506	
Daily feed, kg	8.62	8.27	7.43	8.10	± 0.99
Daily gain, kg	1.14	1.26	1.21	1.24	± 0.14
Feed/kg gain, kg	7.59	6.53	6.14	6.49	± 0.28
Initial empty body wt gain (EBW), kg[a]	236	237	239	238	
Final EBW, kg	433	485	472	492	
Daily EBW gain	1.03	1.28	1.20	1.30	± 0.12
Feed/kg EBW gain, kg	7.67	6.77	6.45	6.24	± 0.44
	--------	mcal/kg	--------	--------	--------
NE of total ration[b]	1.26	1.45	1.55	1.43	± 0.07
NE of grain	1.34	1.57	1.69	1.52	± 0.09
NE_m of grain[c]	1.37	1.91	2.12	1.73	± 0.20
NE_g of grain	0.91	1.27	1.41	1.15	± 0.13
Dressing percent	62.7	62.1	61.3	63.2	± 0.49
Carcass grade	9.4	10.1	9.5	10.0	± 0.48
Ribeye area, sq cm	82.8	80.1	81.2	85.8	± 1.83
Fat thickness, cm	1.8	2.2	1.7	2.0	± 0.14
Catability, percent	49.8	44.5	49.7	48.8	± 1.79
Volatile fatty acids					
Total VFA, umoles/ml	73.0	69.2	74.4	70.5	±18.32
	--------	Molar percent	--------	--------	--------
Acetic	38.2	38.5	35.7	37.5	± 0.98
Propionic	39.3	38.3	40.1	41.0	± 1.13
Butyric	11.0	11.3	12.4	10.6	± 0.93
Isovaleric	2.5	2.6	2.2	2.2	± 0.13
Valeric	4.2	4.4	4.6	4.4	± 0.22
pH	5.9	6.1	5.7	6.0	± 0.15

[a] EBW estimated from hot carcass weight (Lofgreen, Hull and Otagahi, 1962).

[b] Energy for gain and maintenance ÷ intake of total ration.

[c] NE X 1.50 = ratio of NE_m to NE_g on basis of average crude fiber content (Lofgreen and Garrett, 1967).

values by dry heat processing grain in both all and high concentrate rations for cattle (Eudaly and Riggs, 1969).

Carcass traits are shown in Table V. There were no treatment differences, for rumen pH. Unlike trials 1 and 2, there were no significant differences or evident trends in total VFA concentration or molar percentages among treatments in this trial (Table V).

Generally there was a consistent trend in all three trials for reduced feed intakes with similar gains and an improved feed/gain ratio on MS versus DRS. In trials 1 and 2 some feed intake and gain depression was noted early in the feeding period with adaptation and compensation occurring thereafter. This conflicts with reports of other researchers who indicated increased palatability in the early part of the feeding period (Cardon, 1969; Schake et al., 1970). Possibly a higher roughage level as used by Schake et al. (1970) would alleviate any intake or gain depression early in the feeding period. In general, this study would suggest that dry heat treatment of sorghum grain, by micronization, may prove beneficial for improving the nutritive value of sorghum for feedlot cattle.

CHAPTER IV

MICRONIZED SORGHUM GRAIN II. INFLUENCE OF PROCESSING METHOD ON *IN VITRO* DIGESTIBILITY, GAS PRODUCTION AND GELATINIZATION

Summary

Studies were conducted to investigate the effects of micronizing sorghum grain on *in vitro* dry matter disappearance (IVDMD), *in vitro* gas production and gelatinization. In trial 1, micronized sorghum (MS) was compared with dry rolled sorghum (DRS). In trial 2, three degrees of MS (412, 322 and 232 g/l) were compared to DRS. In trial 1, MS showed an increased IVDMD over DRS; moreover, as the degree of micronization increased in trial 2 so did the IVDMD. Gas production studies showed an increased rate of gas production from the micronized grain, indicating increased starch availability. Rate of gas production increased with degree of micronization. Gelatinization also increased with increasing degree of micronization.

Introduction

Sorghum grain is processed in an attempt to improve starch availability. Sorghum grain has a starch content nearly comparable to that in other cereal grains, but sorghum appears to have a lower feeding value due to a lower starch availability (Totusek et al., 1963; Hall et al., 1968). Several in vitro dry matter digestion techniques using mixed rumen bacteria have been utilized to evaluate forages (Tilley and Terry, 1963; Johnson, 1966). Their use has been limited, however, in evaluating high energy mixed rations or processed grains. Research evaluating micronized sorghum using in vitro dry techniques is especially limited. The purpose of this study, therefore, was to evaluate the effect of micronizing sorghum grain upon in vitro dry matter disappearance (IVDMD), gas production and degree of gelatinization.

Experimental Procedure

IVDMD

In trial 1, micronized sorghum grain (MS) and dry rolled sorghum grain (DRS) were compared, and in trial 2, three densities or degrees of micronized (412, 322 and 232 g/l) sorghum grain, referred to as MS-412, MS-322 and MS-232, were compared with DRS. The grains were the same as described by Croka and Wagner (1974). IVDMD of the processed grains was determined using a modification of the methods suggested by Tilley and Terry (1963) and Johnson (1969). Fifty ml centrifuge tubes were used to permit fermentation of large numbers of samples concurrently with minimum experimental error. A 0.4 g (DM basis) sample of grain, 15 ml of artificial saliva (McDougal, 1949) and 10 ml of rumen inoculem were incubated in each tube in a pulsating water bath for either 6, 12 or 24 hours incubation periods at 39°C. Rumen fluid was taken six hours after feeding from a fistulated steer receiving 1.5 times its maintainance requirement of a 90% concentrate ration. Rumen fluid was immediately filtered through four and then six layers of cheesecloth. A total of 726 ml of the filtrate was mixed with 2 l of warmed artificial saliva. Carbon dioxide was bubbled through the mixed media until all sample tubes were inoculated. Following inoculation, each tube was immediately flooded with carbon dioxide and stopped with rubber stoppers containing a 2 mm hole to allow gas to escape. The samples were incubated in the dark and stirred three times during the 24 hour incubation. Six tubes with only the saliva-rumen inoculem were carried in each trial as "blanks" to account for dry matter not attributable to the grain samples. After incubation, the tubes were centrifuged at 1390 g for ten minutes, the supernatent decanted, 25 ml of distilled water added and centrifugation repeated. Following decanting, the tubes were dried at 100°C for 24 hours, cooled, weightd, and dry matter disappearance calculated.

Gas Production

The gas production method used was adapted from Sandstedt et al. (1962) as revised by Hinders and Eng (1969). An enzymatic digestion (amyloglucosidase), with yeast being the primary energy utilizer, was used to produce gas from the processed grain sample. The treatments compared in trials 1 and 2 were the same as those in the IVDMD studies. Grain samples were ground through a 20 mesh screen in a laboratory Wiley mill prior to incubation. A 0.8 g grain sample, 0.25 g Fleischman's dry yeast and 10 ml of amyloglucosidase solution (0.25 g of amyloglusidase per 250 ml of water) were added to a 250 ml flask. The flasks were incubated in a pulsating water bath at 39°C for six hours. Each flask was connected in an air-tight manner to an inverted 50 ml burette, filled with .1N HCl containing methylene orange as an indicator, to form a manometric apparatus. Flasks were shaken twice during the incubation period. The quantity of gas produced (ml per g of DM) was measured hourly for six hours by the quantity of liquid displaced.

Gelatinization

The degree of gelatinization of the grains was determined as mg maltose after incubation with beta-amylase (Sung, 1969). The grains were prepared as previously described.

In these trials replication was obtained by doing the laboratory procedure repeatedly on different days (two runs in trial 1 and four runs in trial 2). On each day the feed samples used came from the same initial feed sample so that the only difference between runs was that a different rumen innoculum for IVDMD and enzyme solution for gas production was used each day. This was considered a randomized block design with a factional arrangement of treatments. The model assumed included the effects of treatment, time and their interaction. Standard error of treatment means and mean differences were calculated from the treatment by run interaction error mean square. When run by treatment and run by time were tested with the third order interaction and found to be not significant, these mean squares were pooled and the pooled mean square was used to estimate standard errors. All gelatinization values were determined on the same day. This then was a completely randomized design and was analyzed as such. In trial 1 and 2 analysis of gelatinization a model was assumed with the effects of treatment. Standard error of means and treatment differences were calculated from the variance of duplicates.

Results and Discussion

IVDMD

IVDMD data indicate that the grain processing methods influenced the rate of grain digestion by rumen microorganisms. In trial 1, MS produced a higher IVDMD than DRS in all three incubation periods, 6, 12 and 24 hour (Table VI). In trial 2, the three micronized grains had a greater IVDMD than DRS during all three incubation periods, 6, 12 and 24 hour; moreover, the IVDMD increased with degree of micronization during each incubation period. The higher IVDMD suggests micronization increases starch availability in sorghum as evidenced by the increased rate and extent of *in vitro* digestion. Greater *in vitro* digestibility of sorghum grain which was heat treated by steam flaking or popping has been observed by others (Trei, Hale and Theurer, 1970; Osman *et al.*, 1970). Hinman (1973) noted greater *in vitro* microbial digestion for steam flaked or micronized sorghum grain than for rolled or ground sorghum grain and also more total starch digestion in steers fed either steam flaked or micronized sorghum vs rolled or ground sorghum. Albin, Simnacher and Durham (1966) and Neuhaus (1969) demonstrated a definite relationship between *in vitro* digestibilities of processed grains and feed efficiency of feedlot cattle receiving the same grains and feed efficiency of feedlot cattle receiving the same grains in high concentrate rations. Improved utilization of dry heat treated sorghum grain by finishing cattle has been demonstrated by Riggs, *et al.* (1970) and Ellis and Carpenter (1966).

TABLE VI

IN VITRO DRY MATTER DISAPPEARANCE AND DEGREE OF GELATINIZATION OF PROCESSED SORGHUM GRAIN

Ingredient	IVDMD %			SE[f]	Degree of Gelatinization	
Trial 1	6 hour	12 hour	24 hour		mg maltose /g of grain	
DRS	16.40[a]	26.06[a]	44.92[a]	±0.30	16[a]	±0.47
MS	20.37[b]	33.16[b]	50.72[b]	±0.30	80[b]	±0.47
LSD[e]	2.17	2.17	2.17		28.37	
Trial 2						
DRS	6.33[a]	15.27[a]	30.95[a]	±0.63	15[a]	±0.28
MS-412	13.46[b]	24.23[b]	43.45[b]	±0.63	40[b]	±0.28
MS-322	15.34[c]	25.77[c]	46.02[c]	±0.63	64[c]	±0.28
MS-232	18.24[d]	30.17[d]	48.85[d]	±0.63	105[d]	±0.28
LSD[e]	1.08	1.08	1.08		11.02	

[a,b,c,d]Values in the same column with different superscripts are significantly different ($P<.05$).

[e]Least significant difference

[f]Standard error of treatment means.

Gas Production

Gas production data for trial 1 are shown in Figure 1, and for trial 2 in Figure 2. The gas production data in both trials show an increased rate of enzymatic digestion for MS over DRS. In both trials, significant interactions were present so statistical differences were not concluded, but trends are presented. In trial 1 gas production showed a definite trend to occur at a much faster rate for MS than DRS, particularly during the first four hours (Figure 1). In trial 2, all three MS treatments produced gas at a much faster rate than DRS with the rate of gas production increasing as the degree of micronization increased. Among the three MS treatments the greatest gas production was obtained on the MS-232 treatment and the least on the MS-412 treatment. As in trial 1, the differences in gas production were most apparent during the first four hours of incubation. The gas production data indicated that in sorghum grain micronization increases starch availability, and supports the IVDMD observations presented earlier indicating more rapid microbial digestion. Walker *et al.* (1970) also reported increased *in vitro* enzymatic digestion of popped sorghum grain as the degree of popping increased. The increased starch availability of MS could account for the improved feed efficiency observed with MS in the feedlot (Croka and Wagner, 1974). The interactions noted in the fifth and sixth hours are probably a result of carrying the digestion too long. A lack of substrate or an inhibitory action caused by end product accumulation may have occurred in the fifth and sixth hours.

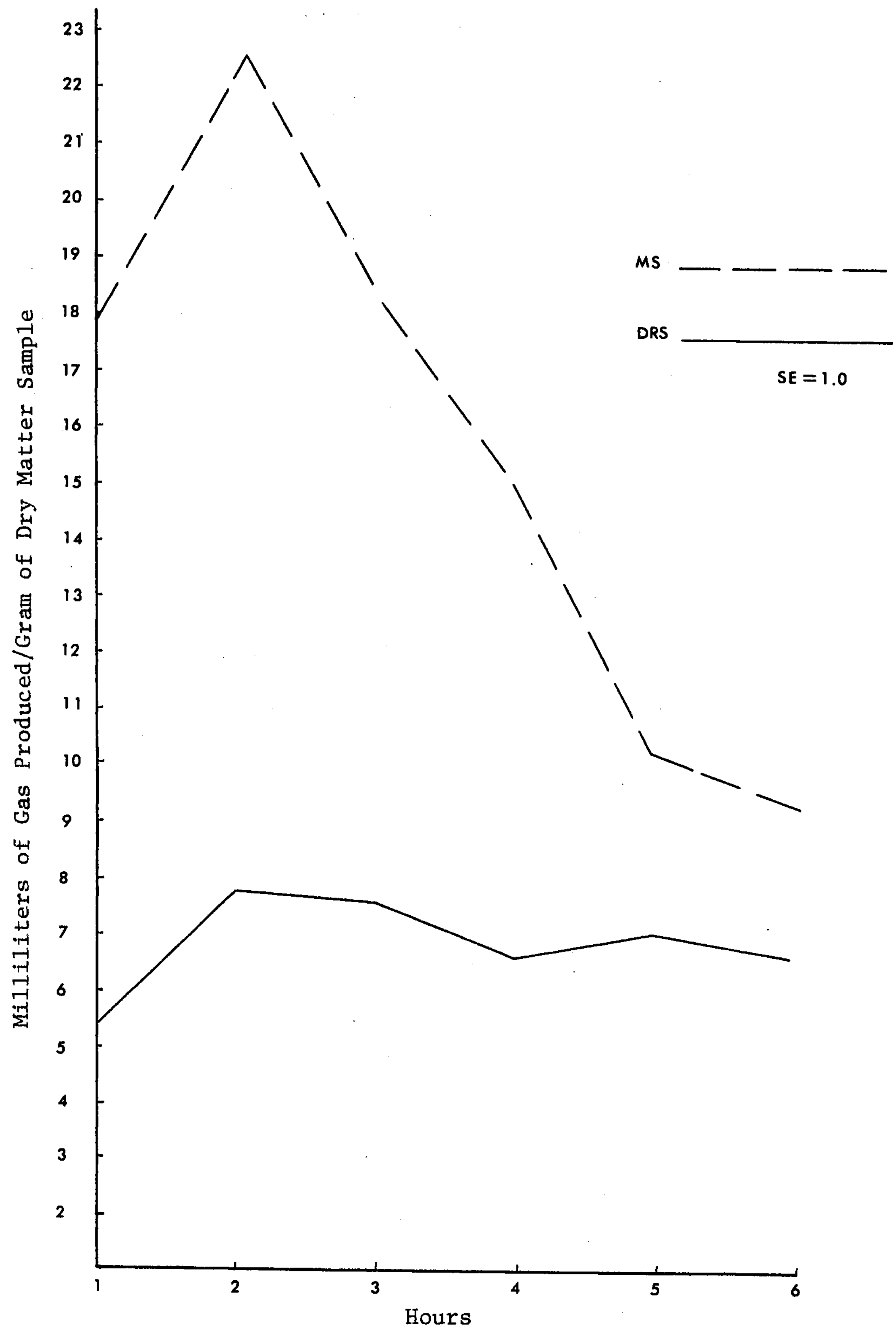

Figure 1. Trial 1: Gas Production From Processed Sorghum Grain.

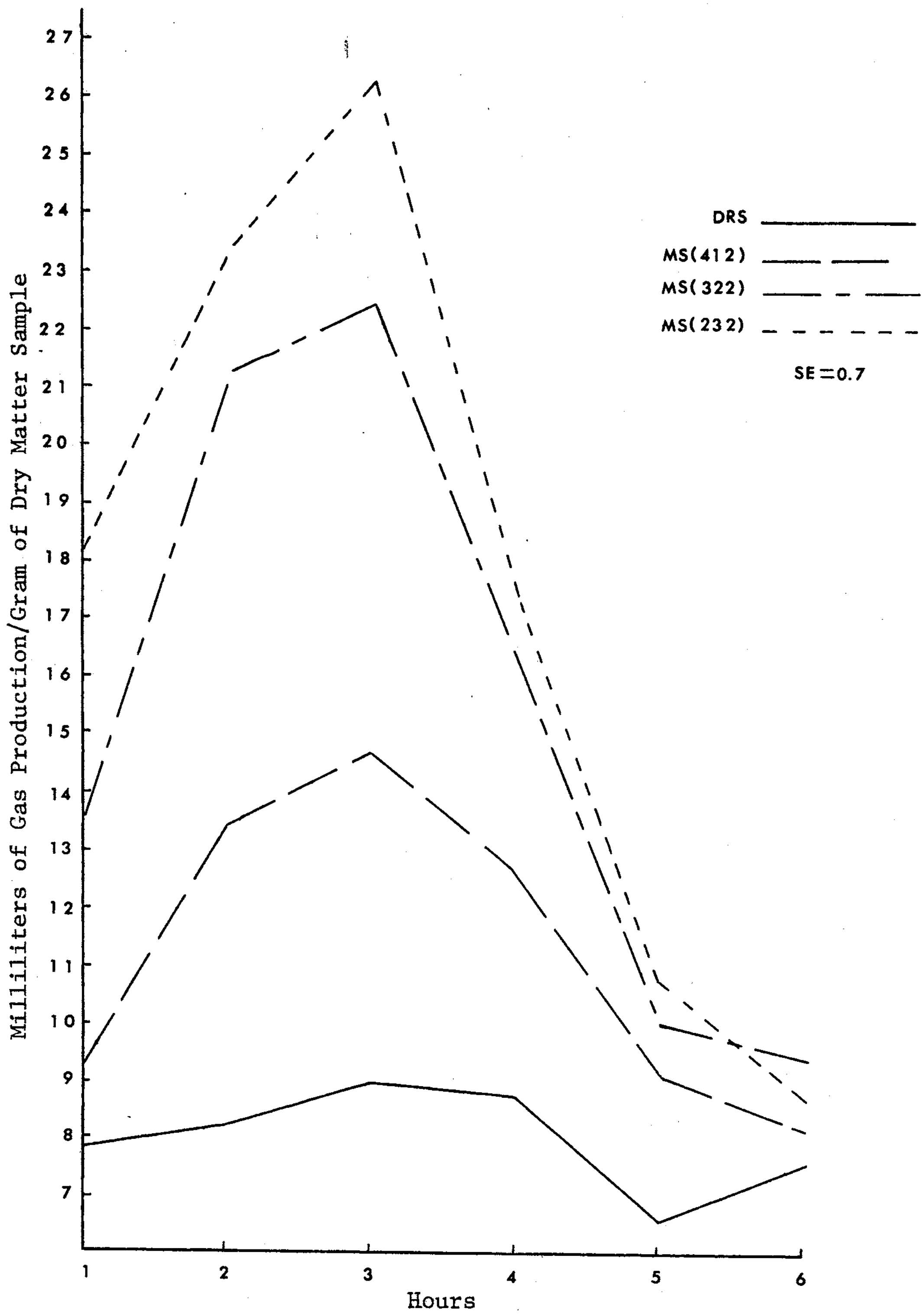

Figure 2. Trial 2: Gas Production From Processed Sorghum Grain.

Gelatinization

The degree of gelatinization (Table VI) indicates the amount of damage occurring to the starch granule during processing. In trial 1, MS resulted in greater enzymatic digestion by beta-amylase than DRS, and in trial 2, as the degree of micronization increased the percent gelatinization increased. Reeve and Walker (1969) showed that a greater amount of the starch in well popped or expanded sorghum grain was gelatinized than in poorly popped sorghum grain. Flaking or rolling of steam heated grain further increases the loss of bifringence (Johnson, Matsushima and Knox, 1968) and *in vitro* enzymatic digestion (Osman *et al.*, 1970).

CHAPTER V

THE EFFICIENCY OF ENERGY UTILIZATION BY BEEF CATTLE FED MICRONIZED SORGHUM GRAIN

Summary

A respiration calorimeter study using twelve feeder steers was conducted to compare the energetic efficiencies of micronized sorghum (MS) and dry rolled sorghum grain (DRS) in high concentrate feedlot rations. After a 60 day feeding period, feces and urine were collected for a seven day period and gaseous exchange measured for two consecutive 24-hour periods, using open circuit respiration calorimetry. MS produced a significantly higher ($P < .01$) dry matter digestibility, resulting in a higher ($P < .01$) digestible energy (DE) content. Protein digestibility was slightly higher on MS, but the difference was not significant. Urine and methane energy losses were approximately the same for both MS and DRS. MS also had a higher metabolizable energy ($P < .01$) and NE_{m+g} ($P < .05$) than DRS, reflecting the higher DE content. Energy gain was greater ($P < .05$) on MS.

Introduction

Sorghum grain has become increasingly important in recent years as an energy source in high concentrate rations for feedlot cattle in the southwest. The need for processing sorghum grain to improve its utilization has been accepted for some time. Processing methods such as grinding, pelleting and rolling have been used for a number of years (Smith and Parrish, 1953; Baker *et al*., 1954; Pope *et al*., 1959). Recently, popping, steam flaking, early-harvesting and reconstituting sorghum grain have shown improvements in feed efficiency (Ellis and Carpenter, 1966; Parrett and Riggs, 1966; Buchanan-Smith, Totusek and Tillman, 1968; Wagner and Schneider, 1970). Methods used for evaluating feedlot rations or processing techniques include feeding trials, digestion trials, *in vitro* studies and the comparative slaughter technique. Respiration calorimetry has been used only sparingly for feed evaluation for finishing beef cattle.

Net energy has become widely accepted in recent years for expressing the value of a ration and the energy requirements for feedlot cattle. Respiration calorimetry along with digestion trials provide a means for partitioning the gross energy of a feed. Micronizing is a relatively new grain processing method on which little information is available. The purpose of this study, therefore, was to investigate the effect of micronizing sorghum on the efficiency of energy utilization, using respiration calorimetry.

Experimental Procedure

Twelve Angus and Hereford feeder steers averaging 352 kg were selected for uniformity in age, condition and weight. The animals were paired on the basis of breed and weight and randomly allotted within pair to either a dry rolled sorghum (DRS) or micronized sorghum (MS) ration, the formula of which is shown in Table VII. The animals were penned in two 9 X 13 m pens equipped with individual feeding stalls and the animals fed twice daily. The animals were pair fed on a dry matter basis.

TABLE VII

RATION COMPOSITION[a]

Ingredient	DRS	MS
Sorghum	80.0	80.0
Cottonseed hulls	5.0	5.0
Alfalfa meal (pelleted)	5.0	5.0
Molasses	4.0	4.0
Soybean meal	4.0	4.0
Urea	0.7	0.7
Salt, T.M.	0.5	0.5
Dicalcium Phosphate	0.4	0.4
Calcium Carbonate	0.4	0.4
Aurofac - 50	225 g	225 g
Vitamin A (30,000 IU/gm)	200 g	200 g

[a]DM basis

The equipment used for micronizing the sorghum grain was a reciprocating steel table, 3.96 m X 118 cm X 1.25 cm, activated by a one-half horsepower electric motor. Eight gas-fired infrared generators, each rated at 50,000 BTU per hour and suspended 15 cm above the table, were used to heat the sorghum as it passed across the table. Before heating, the sorghum grain was cleaned with a Clipper cleaner, model 27, to assure an even, free flow. After heating the grain dropped directly through a 21.6 X 76.2 cm roller with a spacing of .008 cm. The DRS was cleaned and rolled (not heated) in the same manner as MS.

After 50 days the steers were placed in metabolism stalls. Daily feed allowance was reduced to 90¢ of maximum intake achieved previously by each pair and then held constant during the digestion and energy balance trials. Following a 14 day adjustment period in the metabolism stalls, feces and urine were collected for 7 days. Urine and feces were collected and weighted daily and 10% aliquots stored at $4^{o}C$ until completion of the collection period. The daily samples were then mixed, sub-sampled and stored at $0^{o}C$ for future analysis. Urine was acidified with HCl. An additional fecal sample was dried at $60^{o}C$ in a forced air oven, ground through a 1 mm screen in a Wiley mill and stored.

Following the 7 day digestion trial, the steers were randomly placed by pairs in open circuit respiration chambers similar to those described by Flatt _et al._ (1958) for three days, the last two of which included two consecutive 24-hour gas collection periods. The chambers were sealed at least 12 hours prior to the start of gas collection. Outdoor air was pulled into the chambers at a rate of 300 l per minute. The chamber temperature was maintained at approximately 19^{o} C, and air was circulated by a fan. Dry gas meters measured the amount of air passing through the chambers and two spirometers constantly sampled the exhaust gas of each chamber. Beckman IR-315 infrared analyzers were used to measure CO_2 and CH_4. Oxygen was measured by a Beckman para magnetic analyzer.

The gas meters were read and residual chamber air analyzed at the start and end of each 24 hour period. Barometric pressure, room temperature, chamber temperature, humidity and exhaust air wet bulb and dry bulb temperatures were recorded each time for correction of gas volumes to standard temperature and pressure. Heat production was calculated from oxygen consumption, carbon dioxide and methane production and urinary nitrogen excretion using the equation proposed by Brouwer (1958). The net energy for maintenance plus gain (NE_{m+g}) of each ration was determined by respiration calorimetry. Fasting heat production (kcal/$W^{0.75}_{kg/day}$) was considered to be equal to the maintenance energy requirement. Although fasting heat production was not measured in this study, it was assumed to be 77 kcal/$W^{0.75}_{kg/day}$ which has been observed from studies with similar cattle conducted earlier in this laboratory by Kiesling (1973). This value is also in agreement with that reported by Lofgreen and Garrett (1968). Energy available for gain (kcal/$W^{0.75}_{kg/day}$) was calculated by subtracting "on feed" heat production from metabolizable energy (ME) intake (Lofgreen, 1965). The sum of the energy for maintenance and for gain was divided by the dry matter intake (kg/$W^{0.75}_{kg/day}$) to obtain and estimate of NE_{m+g} of each ration (Mcal/kg DM).

Wet fecal samples were analyzed for dry matter and nitrogen by the methods of the A.O.A.C. (1960). Feed, fecal and urine energy were determined by combustion in a Parr adiabatic oxygen bomb calorimeter and carbon was determined in a Leco carbon analyzer as described by Smith *et al*. (A.O.A.C., 1965).

For analyses of variables which were derived from the gas collection period a model was assumed with the effects of block, pair within block, chamber, chamber by block, treatment, block by treatment, day, day by block, pair by day within block, chamber by day, block by chamber by day, treatment by day and block by treatment by day. Standard error of means were calculated from the block by treatment mean square. Analyses of variables from the digestion trial a model was assumed with the effects of pair and treatment. Standard error of means were calculated from the variance of pair by treatment.

Results and Discussion

The proximate analysis, feed intake and digestibility data are presented in Tables VIII, IX and X, respectively. As shown in Table X, grain processing method had a significant effect on ration digestibility. The DRS ration had a 73.89% DM digestibility compared with 81.42% for the MS ration ($P < .01$). Digestible energy (DE) was 68.16% and 80.81% for the DRS and MS rations, respectively ($P < .01$). Protein digestibility was slightly, but not significantly, higher on the MS ration, suggesting that the heat treatment did not produce sufficient protein denaturation in the MS to depress protein digestibility. Potter *et al*. (1971) reported some decrease in ruminal conversion of sorghum protein to microbial protein with micronized grain, but no change in total protein digestion.

Energy losses are shown in Table XI. Fecal energy loss was significantly ($P < .01$) lower for the MS, but urinary energy (UE) and

TABLE VIII

PROXIMATE ANALYSIS OF GRAINS

Ingredient	DRS	MS
Dry matter	87.3	90.7
Crude protein[a,b]	10.66	11.42
Ash[a]	0.87	1.68
Ether extract[a]	3.46	2.93
CHO[a,c]	83.97	94.03

[a]DM basis.

[b]6.25 X percent Nitrogen.

[c]100-(Sum of figures for crude protein, ash and ether extract).

TABLE IX

ANIMAL WEIGHT AND DAILY FEED, ENERGY AND PROTEIN INTAKE DURING ENERGY BALANCE TRIAL

Item	DRS	MS	SE[a]
Mean weight, kg	340.0	363.0	
DM intake, kg/day	4.79	4.78	
GE intake, Mcal/kg DM	4.06	4.74	$\pm$ 0.14
GE intake, Mcal/day	19.50	22.59	$\pm$ 0.59
GE intake, kcal/$W_{kg}^{0.75}$	248.43	276.58	$\pm$12.88
Crude protein of ration, %	14.01	13.74	$\pm$ 0.91
Protein intake, g/day	670.04	657.91	$\pm$ 0.91

[a]Standard error of treatment means.

TABLE X

DIGESTIBILITY OF RATIONS

Item	DRS	MS	SE
Dry matter, %	73.89	***81.42	± 1.15
DE, %	68.15	***80.81	± 1.31
Protein, %	67.90	72.29	± 2.22
Nitrogen absorbed, g[a]	72.74	76.24	± 2.73

[a]N intake - fecal N.

***Significantly different ($P<.01$).

TABLE XI

ENERGY LOSSES

Item	DRS	MS	SE
GE intake, Mcal/day	19.50	22.59	± 0.59
Fecal energy, Mcal/day	6.21	*** 4.32	± 0.31
Fecal energy as % of GE	31.85	***19.19	± 1.31
Urinary energy Mcal/day	0.63	0.61	± 0.03
Urinary energy as % of GE	3.36	** 2.74	± 0.13
CH_4, Mcal/day	0.63	0.71	± 0.06
CH_4, as % of GE	3.11	3.27	± 0.33
Heat production, Mcal/day	6.47	7.38	± 0.35
Heat production as % of GE	32.30	33.52	± 2.36

**Significantly different ($P < .05$).

***Significantly different ($P < .01$).

TABLE XII

ENERGY RETENTION

Item	DRS	MS	SE
Energy gain, Mcal/day	5.55	**9.59	± 0.40
Energy gain as % of GE	28.46	42.45	± 2.37
Energy gain as % of ME	46.16	56.51	± 3.82
Protein, g	159.41	191.24	±21.01
Protein gain, Mcal/day	0.85	1.02	± 0.11
Nitrogen gain as % of N intake	23.13	27.61	± 3.03
Nitrogen gain as % of N absorbed	34.26	38.33	± 3.53
Fat gain, Mcal/day	4.82	8.44	± 0.52

**Significantly different ($P<.05$).

TABLE XIII

ENERGY UTILIZATION

Item	DRS	MS	SE
GE, Mcal/kg DM	4.06	4.74	± 0.14
GE, kcal/kg DM/$W_{kg}^{0.75}$	51.70	57.72	± 2.57
DE, Mcal/kg DM	2.77	*** 3.83	± 0.13
DE, kcal/kg DM/$W_{kg}^{0.75}$	35.27	***46.56	± 2.01
DE as % of GE	68.15	***80.81	± 1.31
ME, Mcal/kg DM	2.51	*** 3.55	± 0.04
ME, kcal/kg DM/$W_{kg}^{0.75}$	31.72	42.65	± 1.13
ME as % of GE	61.69	***74.89	± 0.69
ME as % of DE	90.61	*92.69	± 0.33
NE_{m+g}, Mcal/kg DM	2.43	** 3.35	± 0.09
NE_{m+g} as % of GE	59.85	*70.68	± 1.68
NE_{m+g} as % of ME	96.81	94.37	± 1.81

*Significantly different (P<.10).

**Significantly different (P<.05).

***Significantly different (P<.01).

methane losses showed little difference between treatments. Heat production losses, expressed as mcal/day, were slightly, but not significantly, higher on the MS treatment, reflecting the greater DE intake.

Values for energy retention are shown in Table XII. MS produced a significantly higher ($P < .05$) total energy gain than DRS and a slight, but nonsignificant, increase in nitrogen retention. The greater energy gain is probably due to the slightly greater GE intake and the significantly higher DE content of MS.

Efficiency of energy utilization values are shown in Table XIII. As noted, the MS ration contained a significantly higher DE ($P < .01$), ME ($P < .01$) and NE_{m+g} ($P < .05$) content. The higher ME and NE_{m+g} contents appear to be due largely to an increase in DE content. When ME is expressed as a percent of DE and NE_{m+g} expressed as a percent of ME, little difference was noted in efficiency of energy utilization between DRS and MS. These results suggest, therefore, that processing method had little effect on efficiency of energy utilization beyond digestion.

In general, this study shows that MS had a higher digestibility, resulting in a higher energy value. This is in agreement with the improved feed efficiencies (feed/unit gain) noted in feedlot cattle (Croka and Wagner, 1974a) and the increased *in vitro* dry matter digestibilities and increased *in vitro* gas productions reported on MS (Croka and Wagner, 1974b). Increased dry matter digestibility of popped sorghum has been noted by Riggs *et al*. (1970) and increased starch digestibility of micronized sorghum grain by Hinman (1973).

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VITA

Don C. Croka

Candidate for the Degree of

Master of Science

Thesis: STUDIES WITH MICRONIZED SORGHUM GRAIN FOR FEEDLOT CATTLE

Major Field: Animal Science

Biographical:

Personal Data: Born in Cushing, Oklahoma, July 11, 1947, the son of Ross and Marcia Croka.

Education: Graduated from Cushing High School, Cushing, Oklahoma, in May, 1965. Attended Northeastern Oklahoma A & M College, Miami, Oklahoma. Received a Bachelor of Science degree from Oklahoma State University, with a major in Animal Science, in January, 1970.

Experience: Reared on a livestock farm in central Oklahoma. Feedlot manager at Oklahoma State University Experiment Station, Fort Reno, Oklahoma. Graduate assistant at Oklahoma State University, 1971-1973.

Professional Organizations: Phi Beta Kappa and American Society of Animal Science.