

EFFECT OF SORGHUM GRAIN PROCESSING  
ON BEEF FINISHING PERFORMANCE

by *6408*

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B. S., Panhandle A & M College, 1961  
Goodwell, Oklahoma

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A MASTER'S THESIS

submitted in partial fulfillment of the  
requirements for the degree

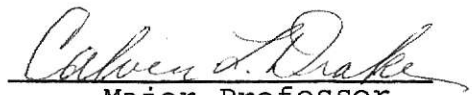
MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1971

Approved by:

  
Major Professor

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# ACKNOWLEDGEMENT

I wish to thank Dr. Calvin Drake, my major professor, for his patience, understanding and assistance in planning and completing this study. Throughout the various stages of this study he has given me his cooperation, advice and constructive criticism which has been most helpful in completing this study.

To Dr. Don Good, Head of the Department, and members of the staff, I wish to express my graditude for their friendship and willingness to offer their services and facilities at all times.

My sincere thanks also goes to my committee members and to other graduate students who have helped with this project. I would like to pay special thanks to Mr. Joe Clemmens of the Herington Tri-County Feedlot, who popped the grain for this project.

I wish to dedicate this work to my wife, Jan, to my two sons, Justin and Brentin, to my daughter, Lesa, and to my parents and parents-in-law who have given me the encouragement and inspiration for academic achievement.

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## Chapter 1

### INTRODUCTION

Grain processing is a major means of improving performance and feed efficiency of cattle finishing rations. Considerable effort is being made to reappraise traditional methods and develop new and more efficient methods of processing. Since most rations contain high grain levels any improvement in grain utilization due to processing will be reflected in overall ration efficiency.

Sorghum grain is the major concentrate being used in the Southwestern United States and some processing is necessary since unprocessed sorghum grain is poorly utilized. Hale and Taylor (1965) and Husted (1966) reported the hard outer layer of sorghum grain is extremely resistant to digestion and must be ruptured. In a typical beef finishing ration of 15-20 years ago, consisting of 40 percent grain, processing other than cracking or coarse grinding appeared to be of little benefit. Many research reports concerning grinding, dry rolling and steam flaking have been published. (Smith and Parish, 1953, Baker et al., 1955, and Pope et al., 1962).

Among methods which have increased feed utilization are steam flaking, dry heat processing (popping) and high moisture and or reconstitution.

Steam flaked sorghum grain involves steam pre-conditioning at atmospheric pressure followed by passage through low tolerance rolls. Hale et al. (1965) and Newson et al. (1968) have reported increased utilization and feed lot performance by feeding steam flaked grain.

Reconstituted sorghum grain improved feed lot performance when compared to dry rolled sorghum grain according to White et al. (1969), McGinty, Breuer and Riggs (1968), Parrett and Riggs (1966) and Buchanan et al. (1968). It involves adding water to dry grain to bring moisture to 28-30% and storing grain for 21 days in air tight structures or trench silos.

Dry heat is being used as a method of grain preparation. Riggs et al. (1970) and Ellis and Tarptan (1966) reported dry heat increased efficiency when compared to dry rolled feed. Garrett (1968) found no difference in utilization when compared with steam flaked sorghum grain.

Most research has compared the newer processing methods to dry rolled or cracked sorghum grain. Limited work has been conducted making direct comparisons of steam processed flaking, reconstituting and dry heat processing (popping) on feed lot performance and digestibility. This study was conducted to determine the effect of these methods of processing on feed lot performance and digestibility of sorghum grain by beef steers.

## Chapter II

### REVIEW OF LITERATURE

#### Physical Properties

The need for physically preparing sorghum grain to improve utilization by cattle has long been recognized. Morrison (1959) has reviewed numerous investigations on the influence of preparing harvested feeds for farm animals. He stated the value of grinding, crushing or chopping feed depends on the characteristics of the feed and the kind of animal to which it is to be fed. During the last 40 years, grinding, dry rolling, steam rolling and steam flaking have been used. According to Husted (1968) the sorghum grain kernel has a waxy coating that is very resistant to moisture penetration, and the starch portion of the grain takes up water very slowly. Dry rolled sorghum grain may not stay in the rumen long enough to become soaked and permit maximum digestion by rumen microorganisms.

Steam Flaked Sorghum. Research has pointed out the importance of physical properties of processed feed grains. Hale et al. (1968) reported that fine grinding sorghum grain should result in the exposure of greater surface area to rumen digestion and thus should be superior to dry rolling or coarse grinding. Later work by Hale (1968) suggested that steam flaked sorghum grain should not be broken up in the processes of feeding;

feed requirements increased 0.36 lbs per day on a flaked and ground ration. Contrasting results were reported by Garrett et al. (1965), who found no difference in grinding or rolling after pressure steaming of grain.

Hale et al. (1966) reported significant differences in bushel weights of processed sorghum grains; dry rolled weighed 45 lbs, steam processed 27 lbs, and finely ground 38 lbs. Matsushima (1967) found dry cracked corn weighed 38 lbs; flaked 27.2 lbs; cooked and rolled 36.9 lbs and flaked, dried and rolled 34.2 lbs per bushel respectively.

Hale et al. (1968) reported steam heat and moisture plus the mechanical pressure in steam flaking are necessary for increased digestibility and utilization. Sorghum grain in this trial was steamed at atmospheric pressure for approximately 25 minutes and rolled into a flake approximately half the weight per unit volume as original grain. The temperature in the steam chamber averaged 211°F and the moisture content of grain off the roller was 18%.

Garrett et al. (1966, 1967) and McIlroy (1967) reported the optimum time and pressure for steam processing and flaking was approximately 1.5 minutes at 50 lbs per square inch of steam pressure.

High Moisture Processing. White and Totusek (1969) reported optimum moisture content of high moisture reconstituted

sorghum grain was 28 to 30%. Hale et al. (1969) reported an increase in utilization of sorghum grain at 22% moisture.

Penic et al. (1968) reported that reconstituted sorghum grain stored in airtight structures should be stored whole and ground prior to feeding. Brethour (1969) suggested that reconstituted sorghum grain stored in trenches be ground or rolled before ensiling to reduce spoilage.

In a direct comparison of grinding vs. rolling reconstituted sorghum grain, White et al. (1969) reported rolling was more efficient. Work by Florence and Riggs (1968) suggested the physical form or particle size of grain affects size of starch granules and availability of starch for digestion. Grinding reconstituted sorghum grain yielded smaller particles than grinding dry sorghum grain. Reconstituted sorghum grain contained more small starch particles than dry rolled. In vitro dry matter disappearance rates were greater for reconstituted sorghum than dry grain.

Dry Heat Processing (Popping). Riggs et al. (1970) found the density of dry heat processed (popped) sorghum grain ranged from 98 gm per liter with 100% popped to 393 gm per liter for 13% popped. The dry heat treatment was at 700 gm per liter. The percent of popped grain was influenced by moisture content, temperature and rate of flow through the machine. As moisture increased from 11.3 to 14.7% the percentage of popped material increased from 27.4 to 43.2.

### Chemical Properties

Steam Flaking. Trei, Hale and Theurer (1966) reported that 30 to 40% gelatinization of starch increased gas production. Gelatinization over 40% did not further increase gas production. At 30 to 40% gelatinization, gas production was highly correlated with dry matter disappearance ( $r = 0.95$ ) and was a good indication of the rate of fermentation in the rumen. Gelatinization is the complete rupture of starch granules brought about by a combination of moisture, heat and pressure (in some instances) mechanical shear.

Osman, Theurer and Haske (1966) noted that in vitro starch digestion with amylolytic pancreatic enzymes was 48% in excellent flaked sorghum grain compared to 17.8% for unprocessed sorghum grain.

Johnson, Matsushima and Knox (1968) reported 25 to 40% starch modification in steam flaked corn. This change in starch molecules was responsible for increased water uptake, lower specific gravity and a more rapid rate of passage.

Anstaett et al. (1969) compared two methods of measuring gelatinization. Methods compared were Congo red stain technique and bata amalyase enzyme hydrolysis (based on ferricyanide). Results of the comparisons showed little correlation between Congo red staining methods and the enzyme hydrolysis method. The Congo red staining method appears not to give results of actual damage to cereal grain starch. The enzyme hydrolysis method based on the ferricyanide determination appears to be



a better method to measure starch gelatinization.

Schake et al. (1970) reported steam flaked sorghum grain was 69.2% gelatinized and yielded 478 mg of maltose per gm upon incultation with B amylase.

Woods (1965) reported a 50% decrease in consumption and a significant decrease in rate of gain resulted from feeding 100% gelatinized corn. The ration contained 68% corn that had been extracted from a die at 400 to 500 psi pressure and 350°F. A further study to explain the decrease in performance revealed a prolonged lowering of rumen pH and high levels of lactic acid 30 minutes after eating.

Wilson and Woods (1966) fed 10% of the ration as 100% gelatinized corn and increased daily gains from 2.42 to 2.70 lbs and increased feed efficiency. Feeding 20 to 30% decreased gains and feed efficiency. Gelatinized corn fed at 2.5 to 5% did not influence gain and efficiency, indicating that low levels of gelatinization have no effect on animal performance.

Hale (1965) reported that steam heating 100% gelatinized sorghum grain fed to beef calves reduced consumption and rate of gain but did not change feed efficiency.

Rooney and Clark (1968) reported temperatures required to gelatinize sorghum grain starch ranged from 67 to 77°C while corn starch gelatinized at 62 to 72°C. Sorghum grain requires a longer cooking time or more thermal energy for processing. Schoch and Maywald (1956) stated the gelatinization temperature

for waxy maize starch was 62.5 to 72.0°C, sorghum starch 68.0 to 75.5°C and waxy sorghum starch 67.5 to 74.0°C.

Anstaett et al. (1969) evaluated hydro-thermal processed grain and reported that a proper combination of steam conditioning and thinness of flake is required to achieve a desirable change in the starch of sorghum grain. They reported 164.3 mg/gm of maltose produced from steamed flaked sorghum grain compared to 27.4 mg/gm for steamed unflaked grain and 43.4 for whole grain.

Walker (1967) reported gelatinization or disruption of the organized structure of starch occurs in the presence of heat and moisture. He noted gelatinization of the starch molecule is beneficial in the hydrolysis of linear starch chains by alfa amylase. Gelatinization destroys the crystallinity of starch and the starch becomes soluble. He indicated starch breakdown is very rapid in highly gelatinized grain.

Erwin (1967) reported water absorption by starch can be influenced by processing. Starch hydrolysis data suggest that steam flaking causes chemical as well as physical changes in starch. He noted that moisture is necessary for gelatinization and heat transfer in the kernel.

High Moisture Reconstitution. Penic et al. (1968) reported the chemical alteration of nutrients in reconstituted sorghum grain are similar to those occurring in germination. Water inhibition of the whole grain starts with the initiation of germination. During the first days of germination the embryo is activated, starch in the endosperm is hydrolyzed and the

aleurone layer secretes hydrolytic enzymes which are responsible for liquifying the starch.

According to Overbeak (1966) seeds of cereal grains are made up of germ (embryo), endosperm tissue (food reserve) and the aleurone layer. In normal germination the starch storage cells are hydrolyzed by B-amylase, secreted by the aleurone layer. The presence of an embryo is necessary for the action of the aleurone layer.

Florence and Riggs (1968) indicated that germination starts and the proteaceous matrix softens when grain is reconstituted. Swelling of the starch itself causes a weakening or destruction of the matrix and cell wall. The result of this action is more free starch granules from damaged endosperm cells. Solubility studies indicate that starch is more digestible in reconstituted sorghum grain and exhibits a faster rate of dry matter disappearance.

Dry Heat Processing (Popping). Walker (1970), observed that during popping, natural moisture in the grain is vaporized by dry heat, creating steam inside the individual cells. The steam disrupts the organized structure of the starch granules, gelatinizing them and making them more digestible.

Microscopic evaluation of popped cereal grain by Reeve and Walker (1969) showed that endosperm cell expansion from popping causes different degrees of starch granule gelatinization. Some starch granules undergo complete gelatinization. Localized cell wall rupturing occurs when the kernels split open. A few intracellular voids or enlarged bubbles occur in the gelatinized

starch as a result of popping explosion. Distribution of horny and floury endosperm and differences in their protein content influences the capacity of cereal grains to expand. Starch in deep endosperm areas was not gelatinized. Germ parts of the kernel do not expand in popping of the grain and popping does not disorganize the structure of the embryo.

Williams and Bauers (1964) suggested that dry heat expansion of cereal grain gelatinized starch and denatured protein. Dry heat temperatures of 370 to 440°F oxidizes fats, and in the presence of starch, forms a complex that is insoluble in ether, causing a low fat determination.

Schake et al. (1970) reported gelatinization values for micronized sorghum grain of 47.6% with 478 mg of maltose produced per gram of sorghum grain. Micronized processed grain is grain subject to dry heat produced by infrared gas fired burners. The end product is partially popped grain which has received exposure to microwaves emitted from the burners during processing.

#### Digestibility

Steam Flaked Grain. Arnett and Bradley (1961) reported increased digestibility of dry matter, crude protein, crude fiber, nitrogen free extract and energy of flaked corn when compared to either ground or pelleted corn.

Hale et al. (1966) reported increases in total digestible nutrients and in digestibility of nitrogen free extract. Dry matter, protein and ether extract digestibility were lowered by steam processing. The grain was subjected to low pressure, high

moisture steam for 25 minutes at 99°C and rolled to a large flat flake containing 17.8% moisture. The decreased ether extract digestibility was due to lower digestibility of pigments and certain oils rather than true fat of sorghum grain.

Keating et al. (1965) reported that cooking sorghum grain for nine hours at 180°F resulted in increased digestibility of nitrogen free extract and a significant decrease in protein digestibility.

Holmes, Drennan and Garrett (1970) found pressure steaming of grain resulted in a more rapid and complete rumen fermentation of starch than atmospheric steaming. Rumen samples from steers and sheep had an overall starch disappearance that averaged 97.3% for atmosphere steamed grain and 97.6% for pressure steamed grain. Starch fermentation in the rumen-reticulum was 90% for steamed grain and 95% for pressure steamed grain ( $P < .05$ ) as determined by abomasal fistulated cattle and slaughter studies with sheep. Overall starch digestion did not differ, however, because of post-ruminal digestion. Twice as much starch reached the duodenum when sorghum grain was processed under atmospheric pressure. Dry matter and organic matter digestibility did not differ for either ration in any part of the gut. Atmospheric steam flaked sorghum grain was subjected to less rumen fermentation and 170 gm more starch was digested by the more efficient processes in the intestines. Starch content of organic matter reaching the abomasum was 25.1% for atmosphere steamed flaked grain and 11.9% for pressure flaked.

Garrett (1969) reported sorghum grain flaked under either atmospheric or additional pressure gave similar efficiencies for maintenance. However, sorghum grain steamed under pressure was used more efficiently for energy storage.

Holmes, Drennan and Garrett (1970) stated that an increase in energy utilization with an equal energy intake must be due to reduced energy loss during fermentation (heat of fermentation), reduced methane production and/or reduced urinary energy loss. Any alteration in the nature of fermentation could result in less energy lost as methane and heat. A large increase in efficiency could be achieved if the steam treatment altered the mean ruminal retention time or otherwise rendered the grain starches less susceptible to the energetically wasteful rumen fermentation process. The grain would undergo intestinal hydrolysis to glucose, which has a lower heat increment than fatty acids (Blaxter, 1962).

In a direct comparison of finely ground, coarsely ground and steam flaked sorghum grain, Buchanan, Totusek and Tillman (1968) reported cattle had a higher digestibility of non-protein organic matter in steam flaked sorghum grain. Sheep had a lower nitrogen digestibility. Nitrogen retention did not differ significantly.

Johnson, Matsushima and Knox (1968) stated that steam flaked corn showed an increase in dry matter digestibility of 4 to 6% and spent nine hours less time in the alimentary tract when compared to either cracked, flaked or steam rolled. Flaking

differs from steam rolling in that the grain is either steamed for a longer period of time or steamed under pressure.

Husted et al. (1968) reported crude fiber digestibility for steam pressure processed flaked sorghum grain was less than that of dry rolled sorghum grain. Earlier work by Husted, Hale and Theurer (1966) showed a lower crude fiber digestibility for moist heat processing of sorghum grain.

Johnson et al. (1960) reported an inhibition of microbial cellulose digestion in the presence of starch. Competition for nutrients, mostly nitrogen was responsible. Dry matter digestion of poor quality roughage was decreased with certain levels of starch (Burroughs et al., 1949). This is not in agreement with earlier work by Arnett and Bradley (1961).

In a comparison of steam pressure flaked and dry sorghum grain, Figroid et al. (1969) reported an increase in total digestible nutrients and digestibility of dry matter, and energy at all steam atmospheric pressures and above. There was a trend for increased protein digestibility as cooking pressure increased from 30 to 70 psi. This does not agree with previous studies which suggest that high cooking pressures lower protein digestibilities. This agrees with early in vitro work by Trei, Hale and Theurer (1966) when atmosphere steam flaked sorghum grain and pressure steam processed sorghum grain at 60 psi gave similar gas production. Gas production increased with starch gelatinization up to 40% gelatinization level (Trei, Hale and Theurer, 1966). This work indicates that proper flaking is

necessary after whole grain has been treated with steam.

Frederick et al. (1967) reported in vitro starch digestion was increased when sorghum grain was pressure steamed at 80 psi and flaked. Nasr (1950) found that starch is hydrolyzed faster in the rumen when granules have been ruptured during flaking. These results are not in agreement with work by Hastings and Mille (1961) who reported a decrease in soluble starch and enzyme susceptibility of steeped and crumbled corn. They also noted that steaming of corn caused a retrogradation of starch during drying.

Salsbury, Hoefer and Luecke (1961) reported that moisture and heat caused a hydration of starch, which speeded up its digestion. However, autoclaving starch or dry heating corn decreased digestion of readily hydrolyzed dry matter.

Karr, Little and Mitchell (1966) suggested that more starch reaches the small intestine than can be digested when ruminants receive a high starch diet. The amount of starch reaching the abomasum ranged from 16 to 38% of that consumed, depending on starch intake. These workers found a combination of moist heat and flaking pressure is needed to reach maximum digestibility and that starch digestion of grain increased with each increase in steam pressure up to 70 psi. They reported an optimum pressure level of 60 psi.

Mehen et al. (1966) fed steers dry rolled, fine ground, steam processed flaked and steam pressure flaked sorghum grain



and found that some moist heat treatment in flaking is necessary to improve digestion over dry rolled. Moist heat treatment increased dry matter, nitrogen free extract and gross energy digestibility. Steam processing and pressure cooking decreased ether extract digestibility. Increased temperatures may reduce protein digestibility.

McNeill, Potter and Riggs (1970) found greater total rumen utilization of starch in steers fed steam flaked and reconstituted grain when compared to micronized and ground grain. Ruminant conversion of feed protein to bacterial protein was significantly greater in steers fed steamed flaked and reconstituted grain. Processing released starch granules from the protein matrix and gave increased carbohydrate utilization. They stated the desirable effects of starch gelatinization may have been offset by lowering the solubility of the protein matrix which incapsulates the starch granules. The intense dry heat of micronization could have denatured the soluble protein in the endosperm and made it less soluble. They suggested that it may not be necessary to destroy the starch granule integrity; only to disrupt the substructure of the kernel and release the starch granules from within the protein matrix.

Wright, Grainger and Marco (1966) studied post ruminal degradation and absorption of carbohydrates in sheep and found 55% of the ration concentrates were in the form of abomasum carbohydrates. Their data indicates very rapid and complete

hydrolysis of starch in the intestine. They suggest that apparent digestion of starch by steers was not a result of microbial degradation of starch in the cecum or colon. Bergman, Kukes, and Yarbough (1924) found amylolytic activity in the small intestine of ruminants.

Conflicting data are reported by Larsen et al. (1956) who revealed no intestinal digestion of starch for the calf.

According to Saba et al. (1964) steam flaked sorghum grain was 13% more digestible than dry rolled. Using the nylon bag technique, steam flaked sorghum grain showed a 19% faster rate of dry matter disappearance when compared to dry rolled sorghum grain. Potter, McNeill and Riggs (1969) found that abomasal protein of steers fed reconstituted and steam flaked sorghum grain was higher in lysine, arginine and glycine but lower in leucine, glutamic acid and alanine than steers fed dry ground grain. Amino acid patterns suggest differences in ruminal conversion of grain to microbial protein.

Trei, Hale and Theurer (1970) reported a significant increase in gas production when sorghum grain is steam flaked with similar gas production for either pressure steam flaked or atmosphere steam flaked sorghum grain. High correlations were found between gas production, dry matter disappearance, total volatile fatty acid production and in vitro starch digestion.

According to Osman, Theurer and Hale (1966), the digestibility of steam flaked sorghum grain pressured at 60 psi is equal

to the digestibility of sorghum flaked by atmospheric pressure. Starch digestion was 173% greater in steam flaked sorghum grain when compared to pressure cooked no flaked sorghum grain.

Colenbrander (1967) reported lower rumen ammonia concentration and more efficient conversion of dietary nitrogen in dairy cattle fed gelatinized grain vs. dry rolled. He also reported 50% greater concentration of rumen bacterial nitrogen in steers receiving heated grain. Pressure flaking increased dry matter and starch digestibility over atmospheric pressure flaking, as measured by both abomasal and fecal sampling (Holmes, Drennan and Garrett, 1969). Gas production was greater for sorghum grain flaked  $\frac{1}{2}$  minute under 3 to 5 kg/cm pressure than for 8 minutes at atmospheric pressure.

McNeill et al. (1969) studied carbohydrate utilization in steers fed steam flaked, reconstituted, micronized and dry ground sorghum grain. Ruminal digestion of starch was greater in steers fed steam flaked, reconstituted, micronized and dry ground sorghum grain. Ruminal digestion of starch was greater in steers fed reconstituted and steam flaked grain. Garrett (1968) reported an increase in digestibility of dry matter for steam pressure flaked when compared to popped and atmospheric pressure steam flaked sorghum grain.

Hentages et al. (1966) fed beef steers ground, pelleted and steam flaked corn. Steam flaked corn produced higher starch and water soluble carbohydrates, and their rate of passage from the rumen. Simple sugars resulting from microbial hydrolysis

of water soluble carbohydrates were found to be highest two hours after feeding then decreased sharply, indicating rapid fermentation.

#### Effect of Processing on Protein Utilization

Dank et al. (1966) using sheep, found autoclaving cottonseed meal for 45 to 75 minutes at 121°C gave maximum nitrogen digestion when compared to no heat and 90 minutes of autoclaving. Unheated meal had a higher digestible protein and extreme heat treatment depressed protein digestibility.

Nitrogen utilization was lowered in sheep fed steam processed flaked sorghum grain according to Buchanan et al. (1968). However, no differences were observed in cattle. Nitrogen retention was increased in all trials involving processed grain.

A reduction in nitrogen solubility and lower ammonia levels in the rumen of sheep fed heat treated plant protein had been reported by Chalmers et al. (1956).

Annison et al. (1959) and Chalmers et al. (1954) reported soluble protein hydrolyzes rapidly causing high rumen ammonia levels, increased apparent protein digestibility and lower nitrogen retention in sheep. Any treatment that reduces protein solubility will reduce rumen ammonia and plasma non-protein nitrogen and cut dietary and urinary nitrogen losses, while causing increased nitrogen retention.

Sherrod and Tillman (1964) reported that autoclaving cottonseed meal and soybean meal at 240°F under 60 psi pressure improved feed efficiency and nitrogen retention. Autoclaving

soybean and cottonseed meal for 45 minutes at 240°F under 15 lbs pressure increased nitrogen retention, rate of gain and feed efficiency. Longer heating increased fecal nitrogen, decreased urinary nitrogen and increased nitrogen retention (Sherrod and Tillman, 1962).

Potter, McNeill and Riggs (1970) studied protein utilization of steam flaked, reconstituted, micronized and ground sorghum grain. Steam flaking and reconstitution enhanced ruminal conversion of sorghum grain protein to bacterial protein. Micronizing sorghum grain decreased ruminal conversion of protein. Steam flaking and reconstitution increased the biological value of grain protein through improved conversion to higher quality bacterial protein in the rumen but micronizing caused a decrease. Abomasal protein from steers fed micronized sorghum grain was lower in lysine, higher in leucine and contained significantly more feed protein and less bacterial protein than that from steers fed reconstituted and steam flaked grain, indicating differences in the extent of ruminal degradation of ration protein. True nitrogen digestion was the same for all treatments with some indication that abomasal protein in steers fed reconstituted grain was slightly more digestible. Total digestion differences of sorghum grain proteins is minimal with respect to processing. This study suggests benefits from steam flaking and reconstitution and possible detrimental effects from micronizing sorghum grain for cattle that have not been observed from total digestion data.

Little and Mitchell (1967) reported an increase in nitrogen retention in steers fed soybean meal (no difference in digestion) and casin when administered into the abomasum compared to oral administration. It was concluded that a loss of rumen ammonia due to rapid degradation and a more favorable amino acid balance in feed than in the microbial protein caused this difference.

Karr et al. (1965) reported nitrogen retention increased 15% and blood urea was lowered in lambs receiving steamed cracked corn. The effect of steamed cracked corn was related to the source of supplemental nitrogen, since soybean meal fed with steamed cracked corn increased nitrogen utilization by 34% while urea supplementation decreased nitrogen utilization by 26%. This suggests that steam treatment of cracked corn may improve the utilization of corn protein and/or total ration nitrogen.

Chalmers et al. (1954) reported lower digestibility of casein given by duodenal fistula when the casein was heat processed.

Hudson et al. (1970) studied the effect of dry heat on soybean protein utilization pre and post abomasally. Heating increased the concentration of dry matter and non protein nitrogen in the abomasum. Protein nitrogen was not affected. Nitrogen, cellulose and dry matter digestibilities were not affected when heated soybean meal was administered posterior to the abomasum.

Glimp et al. (1967) fed dry heated soybean meal (149°C for 4 hours) to lambs and reduced protein solubility from 72 to 35% while increasing nitrogen retention. Decreasing protein solubility by heat resulted in decreased levels of ruminal isovaleric and valeric acids and increased cellulose digestion. These data suggest that the rate of proteolysis was decreased in the rumen, thus resulting in a more efficient utilization of the available nitrogen posterior to the rumen.

Martin et al. (1970) found an increase in feed efficiency and rate of gain when steam flaked and reconstituted sorghum grains were supplemented with high protein levels as compared to low levels. They concluded the need for supplemental protein was not spared by processing to increase utilization of the grain.

High Moisture Reconstituted Sorghum Grain. McGinty, Breuer and Riggs (1966) studied the digestibility of reconstituted and dry rolled sorghum grain. Digestibility for several components of reconstituted grain (dry matter, organic matter and non protein organic matter) were significantly higher than for dry grain. Improvement in all component digestibilities was 29% except protein which was 16%. Starch digestion in the rumen was reported to be greater for reconstituted sorghum grain by McNeill et al. (1969) when compared with micronized and ground sorghum grain.

Abomasal protein from beef steers fed either reconstituted, steam flaked, micronized or dry rolled sorghum grain was evaluated for several amino acids (Potter et al., 1969). Steers

fed reconstituted sorghum had higher levels of lysine, arginine, valine, methionine serine and less leucine phenyalanine, glutamic, alanine and tryosine than steers fed dry ground grain. Amino acid patterns suggest differences in ruminal conversion of grain to microbial protein. Loynackan (1969) reported steers fed reconstituted sorghum grain gained 23% faster and required 14% less feed than those receiving dry rolled grain. He reported a high correlation between dry matter disappearance (nylon bag technique) and in vitro gas production. Optimum conditions for reconstituting sorghum grain were 26 to 30% moisture, 38°C temperature and 21 days storage time.

Buchanan et al. (1968) reported an increase in digestibility of dry matter, organic matter, non protein nitrogen, organic matter and energy in cattle fed reconstituted grain sorghum when compared to dry rolled grain. Physical softening of the endosperm and fermentation changes when water was added gave an apparent increase in levels of reducing sugars and increased the digestibility of reconstituted sorghum grain.

In vitro examination of reconstituted ground and high moisture sorghum grain by Neuhaus and Totusek (1969) revealed an increase in digestibility as moisture level increased. High temperatures at high moisture levels increased digestibility. However, high temperatures had little effect at low moisture levels. At high moisture levels digestibility increased markedly at one day storage and gradually increased to 32 days. Whole reconstituted sorghum grain significantly increased in digesti-



bility but ground reconstituted sorghum grain did not show improvement. Drying whole reconstituted sorghum grain resulted in a total loss of improvement of digestibility due to reconstitution but drying the sorghum grain after grinding resulted in no significant loss. Dry matter loss during storage from reconstituted grain was negligible.

Dry Heat Processed (Popped). Riggs et al. (1970) compared 100% popped, normal run (40% popped), and dry rolled sorghum grain and reported a higher digestibility ( $P < .05$ ) of dry matter, organic matter, non protein organic matter and nitrogen free extract in the dry heat processed grain. Digestibility of ether extract, fiber or protein was not increased by dry heat treatment. They suggested dry heat was responsible for the increased digestibility since popped fractions were not different. Dry matter digestibility of dry heat treated or popped grain is lowered when compared to steam pressure flaked sorghum grain (Garrett, 1968). Dry matter digestibilities of popped and atmospheric pressure, steam flaked sorghum grain were not different.

Volatile Fatty Acids. Volatile fatty acids can account for 37 to 63% of the maintenance energy requirements for ruminants according to Annison and Lewis (1959). Propionic acid has a lower heat increment than acetic. Propionic acid caused a marked nitrogen sparing effect and is glucogenic (Armstrong and Blaxter, 1957; Deuel et al., 1935).

Feed efficiency increased may be attributed to a significant decrease in the ratio of acetate to propionate in the rumen (Newland et al., 1962). The amount of propionate during fermentation of feed by rumen microorganisms plays an important role in the energy metabolism of sheep (Armstrong and Blaxter, 1957). Newland (1962) reported a decrease in molar percent of acetate and an increase in propionate in heat processed corn when compared to cracked corn. Hentages et al. (1966) found a narrower ratio of acetic and propionic when comparing steam flaked corn with pelleted and ground corn.

Colenbrander et al. (1967) reported that completely gelatinized sorghum grain produced a significantly narrower acetate-propionate ratio. According to Cabezas et al. (1964), Phillipson (1952) and Balch and Rowland (1957), steam flaking of corn alters volatile fatty acid production and may account for the increase in efficiency of gain. Johnson et al. (1968) reported volatile fatty acid concentration in the rumen of steers fed flaked corn was not different from dry ground grain.

Theurer, Trei and Hale (1966) indicated that greater volatile fatty acid production was responsible for greater energy in steam flaked sorghum grain. In vitro studies revealed a decrease in volatile fatty acid production with sorghum grain steamed and not flaked and an increase in production when the degree of flatness of flake was increased.

Garrett et al. (1968) fed steam pressure flaked, atmospheric

pressure steam flaked and popped sorghum grain and reported no difference in volatile fatty acid production or ratio of propionic to acetic acid.

Riggs et al. (1970) reported a significant difference in volatile fatty acid production between popped and dry rolled sorghum grain. Significant changes were observed in acetate: propionate ratios.

Dry matter disappeared from the rumen faster for flaked corn than pelleted and dry rolled corn (Hentages et al., 1966 and Johnson et al., 1968).

#### Feedlot Performance

Steam Processed Flaked. Reports have conflicted concerning the voluntary consumption of processed grain. Steam flaked sorghum grain consumption was increased when compared with dry rolled sorghum grain (Hale et al., 1965; Hentages et al., 1966; and Johnson et al., 1968). However, Jordon et al. (1965) reported a decreased intake for sheep fed similar diets.

Garrett et al. (1966) and Figroid et al. (1969) reported a decrease in consumption when cattle were fed steam flaked sorghum grain pressured at 60 psi or more. A quicker and more complete fermentation in the rumen resulting in higher levels of volatile fatty acids was suggested as the causitive factor.

Matsushima and Montgomery (1967) reported that thin flaking corn reduced intake when compared to thick flaking.

Garrett et al. (1968) and Riggs et al. (1970) reported a

significant decrease in consumption of dry heat processed sorghum grain (popped) when compared to atmospheric steam flaked, pressure flaked and dry rolled sorghum grain. However, Schake et al. (1970) reported an increased intake of sorghum grain processed by infrared dry heat compared to steam flaked grain. According to Riggs et al. (1970) adding roughage to the ration helps prevent intake depression.

White et al. (1969 a, b), Brethour (1970) and Newson et al. (1967) reported a decreased intake of reconstituted sorghum grain compared to dry rolled and steam flaked grains, but Hale et al. (1969) reported increased intake on 24% moisture reconstituted sorghum grain compared to dry rolled sorghum grain.

Rate of gain and feed efficiency are considered important measurements of feedlot performance. Hale et al. (1965, 1966) found steam flaking increased average daily gain and increased feed efficiency when compared to dry rolled sorghum grain. Flat flaked sorghum grain required 41 lbs less feed per 100 lb gain compared to dry rolled sorghum grain and an increase of 0.35 lb increase in average daily gain. Newson et al. (1967) reported that steam processed flaked sorghum grain resulted in the fastest rate of gain and greatest feed efficiency when compared to dry rolled, fine grinding, reconstituted rolled and reconstituted ground sorghum grain.

Brethour (1969) compared steam flaked, reconstituted and high moisture sorghum grain and reported a significant increase in feed efficiency for steam flaked sorghum grain

when compared to dry rolled. Wagner, Schneider and Renbarger (1970) noted significant increases in feed efficiency but average daily gain was not different when steam flaked sorghum grain was compared to dry rolled. Sorghum grain was subjected to steam for 15, 25, 35 and 45 minutes and then rolled in an 18 x 24" roller mill with a 0.003 inch cold roller clearance. Improvements in feed efficiency were 10.5, 12.3, 7.0 and 12.3%, respectively.

Garrett et al. (1965) reported increases in average daily gain and feed efficiency when steam pressure processed sorghum grain was compared with atmospheric steam processed. No difference in feed efficiency or average daily gain was observed when comparing atmospheric steam sorghum grain having been steamed for 8 minutes at atmospheric pressure and flaked to dry rolled. Feed efficiency was improved by 8% when comparing steam pressure flaked to dry rolled sorghum grain. Garrett, Lofgreen and Hull (1967) fed beef steers steam pressure and atmospheric flaked sorghum grain and reported no difference in gain. Pressure processed grain was superior to grain either rolled or ground after steaming. Schutt and Lima (1970) found an increase in feed efficiency for steam processed flaked but no difference in rate of gain when steam process flaked sorghum grain and steam rolled sorghum grain were fed to dairy calves.

Feed efficiency was improved by steam pressure processed and flaked sorghum grain when compared to atmosphere steamed

flaked and dry rolled according to Garrett (1969). Increased utilization was related to small increases in digestibility, a more efficient rumen fermentation and less energy waste. Sorghum grain was treated by steam pressures of 50 psi for 1.5 minutes for greatest efficiency and the atmosphere processed sorghum grain was steamed for 8 minutes. Weight gains were similar for the two treatments and should be expected to remain the same if consumption of the pressure processed grain remains 88% or more of the intake of atmospheric pressure flaked grains.

Earlier work by Garrett et al. (1968) revealed no difference in rate of gain or efficiency when comparing sorghum grain steam pressure processed at 60 psi to atmospheric steam processed or popped sorghum grain.

Lofgreen, Mendel and McIlroy (1968) reported a decrease in rate of gain of beef steers fed sorghum grain subjected to steam for 141 minutes and flaked to weigh 21 lbs per bushel.

Jordan (1965) found steam flaked corn did not increase rate of gain in sheep but did produce a small increase in feed efficiency when compared to cracked corn.

Burkhardt et al. (1969) compared feeding dry whole grain, dry rolled, reconstituted and steam flaked corn and found no advantage for flaked compared to unprocessed corn. In contrast, earlier work revealed increased feed efficiency with no change in rate of gain (Hentages et al., 1966; Matsushima and Montgomery, 1967; and Matsushima, Sprague and Johnson, 1966).

Newland et al. (1962) reported steers and lambs receiving corn cooked at 250°F for 30 minutes, rolled into ribbons, dried and broken into flakes increased feed efficiency compared to dry processed, however, rate of gain was not different.

Arnett (1970) fed steam flaked, extruded, high moisture and dry rolled sorghum grain. Average daily gain did not differ significantly and steers fed steam flaked sorghum grain had slightly lower daily gains. High moisture and steam flaked sorghum grain were similar in feed conversion and represented a 9% improvement in ration efficiency over ground grain. Extruded grain was most efficient giving an improvement of almost 15% over ground grain and 5% over flaked and high moisture grain. Cost of gain favored the processed grains. In growing rations, he reported an increase in average daily gain and lower feed consumption for high moisture, steam flaked and extruded sorghum grain when compared with dry rolled sorghum grain. High moisture grain and extruded grain improved efficiency by more than 15% and flaked grain by more than 18% as compared to dry rolled grain. He indicated energy from sorghum grain is utilized much more efficiently when processed by flaking, extruding or stored as high moisture.

High Moisture Reconstituted Grain. High moisture reconstituted sorghum grain increased rate of gain 19.2% when compared to dry rolled and reduced feed required by 14.7% (Hale et al., 1969). White et al. (1969) fed calves high moisture harvested ground, high moisture harvested rolled,

reconstituted ground, reconstituted rolled, coarse rolled, finely ground and very finely ground sorghum grain. Calves fed high moisture harvested rolled and reconstituted rolled gained faster and feed efficiency was increased by 18.8 and 16.9%, respectively over finely ground. Reconstituted ground sorghum grain at 30% moisture gave 11.6% greater gain and 9% greater feed efficiency when compared to fine ground sorghum grain. Ground reconstituted sorghum grain produced 1.8% and 3.5% decrease in gain and efficiency, respectively. In a direct comparison of reconstituted rolled, rolled reconstituted and steam flaked Schake et al. (1969) found no difference in rate of gain among treatments, with the greatest increase in feed efficiency on reconstituted rolled sorghum grain.

Martin et al. (1969) reported an increase of 10% in average daily gain and 23.9% in feed efficiency for steam flaked when compared to high moisture harvested and dry processed sorghum grain. Brethour and Duitsman (1970) found high moisture harvested and reconstituted sorghum grain increased rate of gain and feed efficiency so that 1.15 lbs of dry sorghum grain was replaced by 1 lb of high moisture harvested grain and 1.22 lbs of reconstituted grain. Early work by Brethour, Ely and Duitsman (1969) in comparing reconstituted, steam processed flaked, dry rolled and high moisture harvested sorghum grain revealed cattle fed reconstituted sorghum grain gained significantly less than those receiving high moisture harvested and dry rolled sorghum grain.



According to Wagner and Schneider (1970) sorghum grain reconstituted to 30% moisture and stored 5, 10 and 20 days or steeped in water 48 hours showed improvements in feed efficiency of 3.7, 3.0, 12.0 and 7.2%, respectively, over dry rolled. There was little difference in rate of gain.

In a comparison of ground reconstituted sorghum grain (steeped in water 48 hours, drained and stored in a trench silo), steam flaked and whole reconstituted sorghum grain, the rate of gain and feed efficiency were similar for whole reconstituted and steam flaked sorghum grain. Feed efficiency for steam flaked sorghum grain and whole reconstituted was 17.6 and 15.9% greater when compared to ground reconstituted (Martin et al., 1970).

Marion et al. (1970) compared dry processed, whole reconstituted and ground reconstituted grain stored in trench silos and found a 6% increase in feed efficiency over dry ground grain. Pre-ground reconstituted grain rations were also more efficient increasing feed efficiency 3.9%. Fastest gains were made by steers fed pre-ground reconstituted grains. These data suggest that cattle fed rations of pre-ground reconstituted sorghum grain stored in a trench silo performed as well as those on rations with dry ground grain or post-ground reconstituted grain.

Work by White and Totusek (1969), Penic et al. (1968) and Newson et al. (1968) showed increased feed efficiency with no difference in rate of gain when comparing reconstituted and

dry processed grain.

Work with enzymes and bacteria in reconstituted grain reported by Miller and Harrison (1970) produced a 17.2% increase in rate of gain and 12.95% increase in feed efficiency for treated sorghum grain compared to non treated reconstituted sorghum grain. A greater amount of protein hydrolysis, greater starch break down and lowered maintenance energy needs resulting from the energy sparing effect in hydrolysis of grain has been attributed to an increase in gain and increase in feed efficiency in reconstituted sorghum grain.

Dry Heat Processed (Popped) Grain. Riggs et al. (1970) reported reduced ( $P < .05$ ) feed intake accompanied by an increased efficiency of feed utilization and a non significant decrease in rate of gain, dressing percent and carcass grade in steers fed heat treated (popped) sorghum grain compared to dry rolled. Schake et al. (1970) reported similar rates of gain and feed efficiency in a commercial feedlot evaluation of steam flaked and micronized sorghum grain. Garrett (1968) substantiated this by reporting little difference in rate of gain and feed efficiency when sorghum grain was steam flaked, steam pressure flaked or popped. Endaly and Riggs (1969) in an appraisal of energy utilization in steam flaked, reconstituted, dry rolled and popped sorghum grain found carbohydrate utilization greater in dry heat processed (popped) sorghum grain. Average daily gains were greatest for micronized followed by steam flaking and dry rolled produced least gain. Feed efficiency

was greatest for steam flaked when compared with micronized and dry rolled. Net energy for production was highest for micronized grain.

Durham, Ellis and Cude (1967) reported identical feed efficiencies for dry rolled and steam flaked with daily gains of 1.27 kg on dry rolled, 1.12 kg on steam flaked and 1.23 kg on popped.

Schake et al. (1970) evaluated micronized and steam flaked sorghum grain under feedlot conditions and reported small differences in performance. Steers fed micronized grain went on feed quicker and had faster gains the first 50 days. Steers fed steam flaked grain required .2 lb less feed per pound of gain than steers fed micronized grain rations. Steers fed micronized grain produced heavier carcasses with more finish. Consumption tended to favor micronized grain by 1.5 lbs per day over steers receiving steam flaked sorghum grain. Micronized grain showed possible advantages in case of storage, product stability, bulk density and cost of processing when compared with steam flaking.

Ellis and Carpenter (1966) found steers fed popped sorghum grain gained slightly slower (1.17 kg for popped sorghum grain vs. 1.22 kg for control) but required 16.6% less feed to produce a kg of gain. There were no significant differences in carcass characteristics.

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### Chapter III

#### FEEDLOT PERFORMANCE OF STEERS FED SORGHUM GRAIN PROCESSED BY FOUR METHODS

The high grain content of modern fattening rations and the need for increased feed efficiency has stimulated research in the area of grain processing.

Processing has increased the utilization of grain sorghum by producing a more palatable, efficient product with increased digestibility. Steam flaking sorghum grain, a moist heat preparation, increased average daily gain and feed efficiency compared to dry rolling (Hale et al., 1966, 1965; Brethour, 1969; and Wagner et al., 1970). Garrett et al. (1965) and Mendel and McIlroy (1968) found no difference in average gain and feed efficiency between steam flaked and dry rolled sorghum grain. Burkhardt et al. (1969) and Jordan et al. (1965) reported little difference in average daily gain and feed efficiency when comparing steam flaked and cracked corn. Brethour and Duitsman (1970), Hale et al. (1969), White et al. (1969), Martin et al. (1969) and Wagner and Schneider (1970) reported high moisture sorghum grain (reconstituted) increased average daily gain and feed efficiency when compared to dry processed grain. Schlake et al. (1969) fed steers reconstituted and steam flaked sorghum grain and reported processing method did not influence rate of gain. Brethour and Duitsman (1969) reported average daily gain and feed efficiency were not different when comparing reconstituted and dry rolled sorghum grain.

Dry heat processed (popped) sorghum grain has been reported by Riggs et al. (1970) to increase feed efficiency but average daily gain was not different when compared with dry rolled sorghum grain. Garrett et al. (1968) reported popping of sorghum grain did not improve feedlot performance over steam flaking.

Data comparing dry heat processed, high moisture grain, steam flaked and dry processed grain is very limited. This study was conducted to compare feedlot performance of beef cattle receiving sorghum grain processed by these four methods.

#### Experimental Procedures

Feedlot Cattle. Sixty mixed good to choice yearling steers with an average weight of 322 kg were randomly allotted to twelve lots of five head each. Ten were group fed in two groups of five each and five were individually fed per treatment. The cattle were vaccinated for infectious bovine rhinotracheitis (IBR), blackleg, malignant edema, wormed, and implanted with 30 mg stilbestrol. Automatic waterers were in each pen. The steers were individually weighed and beginning and ending weights were the means of weights on two consecutive days. They were individually weighed at 28 day intervals during the 118 day test. Carcass data were obtained at slaughter. Data were treated by analysis of variance (Snedecor, 1956).

Processing methods compared were; steam flaking under atmospheric pressure, dry heat (popped), reconstituted whole and post ground and coarsely ground sorghum grain.

All cattle received haylage and dry rolled sorghum grain prior to the start of the trial.

Steam Flaked Grain. Steam flaked sorghum grain was processed using procedures outlined by Hale (1965). Sorghum grain was steamed in an oversized steam chamber for 45 minutes at 98.8°C, rolled immediately through a heavy duty Ross 46 x 61 cm roller mill with no tolerance on the rolls. The sorghum grain was flaked to weigh 10.88 kg/bu with 18 to 20% moisture off the rolls. Sorghum grain was flaked daily to provide fresh feed. Cattle were fed twice daily.

High Moisture Reconstituted Grain. Water was metered into conventionally harvested (13.5% moisture) sorghum grain as it entered an air-tight storage facility. The reconstituted grain, containing 28% moisture, was stored three weeks before the trial was started.

Dry Heat (Popped) Grain. Whole sorghum grain was popped in a Cabomatic popper (capacity 3180 kg/hr) with a chamber temperature of 287°C. The popped grain, rolled to a density of 10.65 kg/bu, had water added to increase the moisture from 8.5% (popped grain) to the moisture level of steam flaked grain.

The ration shown in table 1 was fed twice daily. The rations were similar except reconstituted grain was from a different shipment than the other three. Since protein content was different, urea was substituted for sorghum grain to make the four rations isonitrogenous. Origin of the reconstituted grain was from one shipment of grain with the steam flaked, popped and

dry rolled of common origin.

Starch gelatinization was assayed by measuring the rate of starch hydrolysis by B amylase and idometric quantitation of the resulting maltose (Anstaett et al., 1969).

### Results and Discussion

Feedlot and Carcass Data. Feedlot performance and carcass characteristics are shown in table 2. The data are based on 15 head per treatment; 5 head fed individually in sheltered pens and 10 head fed in 2 groups of 5 with no shelter. All pen surfaces were concrete.

Total gain for all treatments was reduced due to high temperatures during July and August. Shades were not available in the group pens and the concrete surface in the pens appeared to increase heat stress and reduce feed consumption. To reduce heat stress, cattle were sprinkled continuously.

Live animal gains were similar among treatments ( $P < .05$ ). However, steers receiving processed sorghum grain gained .09 kg more per day than steers receiving dry rolled sorghum grain.

Steam flaking produced the highest gains followed by popped grain which is in disagreement with Schake et al. (1970) who reported a greater rate of gain for micronized sorghum grain than steam processed flaked grain. Riggs et al. (1970) also reported a lower rate of gain for popped sorghum grain.



when compared with dry rolled. However, it is in agreement with Garrett (1968) who reported no significant difference in steer gain between steam flaked and popped sorghum grain.

Reconstitution and steam flaking did not significantly increase animal gains when compared to dry rolled sorghum grain. This does not agree with Hale et al. (1969) and Brethour et al. (1970) who reported an increase in rate of gain when comparing dry rolled and reconstituted sorghum grain and Hale et al. (1965) and Newsom et al. (1968) in reporting an increase in rate of gain when feeding steam flaked sorghum grain. However, it agrees with work reported by Martin et al. (1969), Schult et al. (1970) and Wagner et al. (1970) who found no difference in rate of gain between dry rolled and steam flaked sorghum grain and Parrett et al. (1966) and Penic et al. (1964) who reported gains of steers receiving reconstituted and dry rolled sorghum grain were not different.

On a dry matter basis steers on dry rolled grain consumed the most feed ( $P < .05$ ), while steam flaked sorghum grain consumption was lowest (table 2). This is in agreement with Riggs et al. (1968) who found consumption of popped grain to be less than dry rolled grain. Consumption of dry rolled sorghum grain was noticeably greater during the first 28 days of the trial since all steers were receiving dry rolled sorghum grain prior to this trial.

The steers consumed more popped than steam flaked sorghum grain, especially during the first 60 days of the test. Schake

TABLE 1. RATION COMPOSITION TO COMPARE FOUR  
PROCESSING METHODS FOR SORGHUM GRAIN  
(WET BASIS)

| Ration<br>Ingredient              | Processing Method           |                                      |
|-----------------------------------|-----------------------------|--------------------------------------|
|                                   | Reconstitution <sup>1</sup> | Dry Rolled<br>Steam Flaked<br>Popped |
|                                   | %                           | %                                    |
| Haylage                           | 10.000                      | 10.000                               |
| Sorghum grain                     | 88.235                      | 88.055                               |
| Salt                              | 0.5                         | 0.5                                  |
| Limestone                         | 0.5                         | 0.5                                  |
| Urea                              | 0.67                        | 0.85                                 |
| Vitamin A <sup>2</sup>            | 0.015                       | 0.015                                |
| Chlorotetracycline <sup>3</sup>   | 0.030                       | 0.030                                |
| Trace mineral premix <sup>4</sup> | <u>0.050</u>                | <u>0.050</u>                         |
| Total                             | 100.000                     | 100.000                              |

<sup>1</sup> Two formulations were necessary to insure isonitrogenous rations, as grain used in reconstitution was different from that used in other rations.

<sup>2</sup> 10,000 IU per gm

<sup>3</sup> 10 gm/lb

<sup>4</sup> Percentages of indicated elements in trace mineral premix: Manganese 4.4%, iron 6.6%, copper 1.32%, cobalt .23%, iodine 30%, zinc 5%, magnesium 20%, sulfur 2.7%.

TABLE 2. PERFORMANCE AND CARCASS DATA OF STEERS FED RATIONS CONTAINING SORGHUM GRAIN PROCESSED BY FOUR METHODS (SUMMER 1970) DRY MATTER BASIS

| Item                              | Processing Method       |                         |                         |                        |
|-----------------------------------|-------------------------|-------------------------|-------------------------|------------------------|
|                                   | Recon-stituted          | Popped                  | Steam Flaked            | Dry Rolled             |
| No. steers                        | 15                      | 15                      | 15                      | 15                     |
| Avg initial wt, kg                | 322.0                   | 323.0                   | 325.0                   | 328.0                  |
| Avg final wt, kg                  | 465.0                   | 466.0                   | 471.0                   | 462.0                  |
| Avg daily gain, kg                | 1.22a±0.13 <sup>d</sup> | 1.22a±0.98              | 1.24a±0.11              | 1.11a±0.1              |
| Avg daily feed intake, kg         | 7.31a                   | 6.91a                   | 6.86a                   | 8.47 <sup>b</sup>      |
| Feed/gain                         | 5.65a±0.25              | 5.75a±0.42              | 5.49a±0.14              | 7.85 <sup>b</sup> ±1.0 |
| <u>Carcass data</u>               |                         |                         |                         |                        |
| Avg hot carcass wt, kg            | 288.0                   | 287.0                   | 288.8                   | 286.0                  |
| Avg rib-eye area, cm <sup>2</sup> | 78.77                   | 80.06                   | 76.13                   | 76.06                  |
| Avg fat 12th rib, cm              | 1.51a±0.14              | 1.21a±0.60              | 1.16 <sup>a</sup> ±0.31 | 1.27 <sup>a</sup> ±0.5 |
| Avg carcass grade <sup>c</sup>    | 9.73a±0.22              | 9.86 <sup>a</sup> ±0.30 | 9.33a±0.27              | 9.80 <sup>a</sup> ±0.4 |
| Avg yield grade                   | 2.88                    | 2.61                    | 2.77                    | 2.82                   |

a,b Means within rows with unlike superscripts are significantly different (P<.05).

c High good = 9; Low choice = 10.

d Standard error.

et al. (1970) and Adam et al. (1968) reported similar results. These data tend to support the theory that cattle receiving popped grain go on feed more rapidly and make greater gains the first 60 days. However, Garrett (1968) reported conflicting data.

There were no significant differences in carcass traits among treatments. Earlier work supports these findings (Penic et al., 1968; White et al., 1969; Parrett et al., 1966).

Feed efficiency was significantly ( $P < .05$ ) increased by each processing method over dry rolling (table 2). Steers receiving processed sorghum grain required an average of .97 kg less feed per kg of gain than steers receiving dry rolled grain. This agrees with work by Hale (1965), Brethour (1969), Wagner et al. (1970), Marion et al. (1970), Penic et al. (1968), Parrett and Riggs (1966) and Brethour and Duitsman (1970) on steam flaked sorghum grain and Endaly and Riggs (1969) and Riggs et al. (1970) on popped sorghum grain. Conflicting data was reported by Durham et al. (1967) and Garrett et al. (1965) who reported feed efficiency of steam flaked and dry rolled sorghum grain was not different.

There was no significant difference in feed efficiency among the three processing methods. However, steam flaked sorghum grain gave the best feed efficiency, and differences between flaking vs. popping and reconstitution approached significance. This trend agrees with Schake et al. (1969, 1970) and Endaly and Riggs (1969). Other workers reported little difference in feed efficiency between popped and steam flaked sorghum grain

(Garrett, 1968, Schake et al. 1970).

#### Summary

This study was conducted to compare feedlot performance and carcass characteristics of steers fed steam flaked, reconstituted, popped and dry rolled sorghum grain. Grain, roughage and supplement were mixed in the bunk twice daily. Popped, flaked and dry rolled grains came from one shipment, while the reconstituted grain came from a second. Urea was used to make the four rations isonitrogenous.

Average daily gain differences between treatments were small and nonsignificant. Fat thickness, loin eye, carcass score, quality grade and yield grade were statistically similar.

Processing (popping, reconstituting or atmospheric steam flaking) increased feed efficiency over dry rolling. These data suggest that steam flaked sorghum grain is more efficiently utilized than popped and reconstituted sorghum grain.

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## Chapter IV

DIGESTIBILITY OF SORGHUM GRAIN PROCESSED  
BY FOUR METHODS FOR STEERS

Sorghum grains provide most of the energy fed to livestock in Kansas. Since large amounts are used, small improvements in digestion are of major economic importance.

Hale et al. (1966) reported TDN and digestibility of nitrogen free extract, and dry matter was increased by steam processed and flaked sorghum grain. Decreased protein digestibility was reported by Keating et al. (1965). However, the digestibility of nitrogen free extract of sorghum grain steam cooked for nine hours at 180°F was increased. Husted et al. (1968) reported a lower crude fiber digestibility in steam processed flaked sorghum grain when compared to dry rolled. Ward and Morrill (1965) and Riley et al. (1965) noted lower crude fiber and protein digestibility from cooked sorghum grain.

Riggs et al. (1970) found dry heat processed (popped) sorghum grain had significantly higher dry matter, organic matter, non-protein nitrogen and nitrogen free extract digestibilities when compared to dry rolled grain. Garrett (1968), however, reported dry matter digestibility of dry heat processed (popped) grain was similar to steam pressure processed flaked sorghum grain.

Reconstitution increased digestibility of dry matter, organic matter and non protein organic matter and protein when compared to dry rolled sorghum grain (McGinty et al. 1966).

The present trial made direct comparisons of four methods of processing sorghum grain. The processing methods studied were dry rolling, steam flaking, reconstitution and dry heat processing (popping).

#### Experimental Procedure

Four Hereford steers that weighed approximately 425.02 kg were used in a 4 x 4 Latin square design. Seven day adjustment and five day collection periods were used throughout. Feed intake was held constant to consumption of the lowest steer (approximately 1% of body weight). Excreta were collected and measured daily and five percent aliquots of feces and urine were retained for chemical analysis. An 80 gram feed sample was taken at each feeding (twice per day) and stored for chemical analysis. Urine was collected under toluene and the composite aliquots were acidified with sulfuric acid. Fecal aliquots were frozen daily and each weekly composite was dried to a constant weight at 60°C. Feed and fecal samples were ground in a Wiley mill and subjected to proximate analysis (A.O.A.C. 1960) and oxygen bomb calorimetry. Urine nitrogen was determined by the Kjeldahl method (A.O.A.C. 1960).

Grain was processed according to Yauk (1971).

The rations were similar, however, two supplements were needed since the reconstituted grain was from a different shipment of grain than the other three. Protein content was different, therefore urea was substituted for sorghum grain to make the four rations isonitrogenous. Alfalfa haylage was used

as roughage (table 1). Supplement for the rations are found in table 2. All steers on digestion trial received one pound of supplement per day.

### Results and Discussion

Apparent digestion coefficients for rations containing sorghum grain processed by four methods are shown in table 3. Coefficients of digestion for protein, crude fiber and ether extract were not different. Nitrogen balance was not significantly altered due to processing method. Steam flaking and popping increased dry matter digestibility over dry rolled. ( $P < .05$ ). Popping did not increase dry matter digestibility when compared with reconstituted but steam flaked sorghum grain yielded an increase in dry matter digestibility. Steam flaked sorghum grain yielded significantly more TDN ( $P < .05$ ) than other processing methods. Energy digestion coefficient was lowest for dry rolled grain ( $P < .05$ ) with no difference between reconstituted grain and popped ( $P < .05$ ). Popped and steam flaked sorghum grain were similar. Mehen et al. (1966), Saba et al. (1964), Buchanan et al. (1968) and Figroid et al. (1969) also reported steam flaking increased dry matter digestibility compared to dry rolled sorghum grain. Garrett et al. (1969) reported no significant difference in dry matter digestibility between popped and steam flaked sorghum grain, however, steam flaking increased digestion of proximate components compared to popped.

Popping of sorghum grain increased ( $P < .05$ ) the nitrogen

TABLE 1. RATION COMPOSITION TO COMPARE FOUR PROCESSING METHODS FOR SORGHUM GRAIN WET BASIS

| Ration<br>Ingredient              | Processing Method           |                                      |
|-----------------------------------|-----------------------------|--------------------------------------|
|                                   | Reconstitution <sup>1</sup> | Dry Rolled<br>Steam Flaked<br>Popped |
|                                   | %                           | %                                    |
| Haylage                           | 10.000                      | 10.000                               |
| Sorghum grain                     | 88.235                      | 88.055                               |
| Salt                              | 0.5                         | 0.5                                  |
| Limestone                         | 0.5                         | 0.5                                  |
| Urea                              | 0.67                        | 0.85                                 |
| Vitamin A <sup>2</sup>            | 0.015                       | 0.015                                |
| Chlorotetracycline <sup>3</sup>   | 0.030                       | 0.030                                |
| Trace mineral premix <sup>4</sup> | <u>0.050</u>                | <u>0.050</u>                         |
| Total                             | 100.000                     | 100.000                              |

<sup>1</sup> Two formulations were necessary to insure isonitrogenous rations, as grain used in reconstitution was different from that used in other rations.

<sup>2</sup> 10,000 IU per gm

<sup>3</sup> 10 gm/lb

<sup>4</sup> Percentages of indicated elements in trace mineral premix: Manganese 4.4, iron 6.6, copper 1.32, cobalt .23, iodine 30, zinc 5, magnesium 20, sulfur 2.7.

TABLE 2. SUPPLEMENT COMPOSITION

| Supplement 1<br>%<br>Composition | Ration<br>Composition          | Supplement 2<br>%<br>Composition |
|----------------------------------|--------------------------------|----------------------------------|
| 54.51                            | sorghum grain                  | 49.82                            |
| 17.2                             | urea (281%)                    | 21.9                             |
| 12.9                             | salt                           | 12.9                             |
| 12.9                             | limestone                      | 12.9                             |
| 1.25                             | trace mineral <sup>1</sup>     | 1.25                             |
| .44                              | Vitamin A <sup>2</sup>         | .44                              |
| <u>.8</u>                        | chlorotetraycline <sup>3</sup> | <u>.79</u>                       |
| 100.00                           |                                | 100.00                           |

<sup>1</sup> Composition, % Mn-4.4, Fe-6.6, Cu-1.32, Co-.23, I-30, Zn-5, Mg-20, S-2.7.

<sup>2</sup> 10,000 IU per gm

<sup>3</sup> 10 gm per lb.

TABLE 3. MEANS AND STANDARD ERRORS OF APPARENT COEFFICIENT OF DIGESTION AND NITROGEN BALANCE OF STEERS FED SORGHUM GRAIN PROCESSED BY FOUR METHODS

| Item                          | Processing Method   |                   |                     |      |                   |      |                   |       |
|-------------------------------|---------------------|-------------------|---------------------|------|-------------------|------|-------------------|-------|
|                               | Recon-stituted      |                   | Popped              |      | Steam Flaked      |      | Dry Rolled        |       |
| No. steers                    | 4                   |                   | 4                   |      | 4                 |      | 4                 |       |
| Dry matter intake kg/day      | 4.2                 |                   | 3.6                 |      | 3.9               |      | 3.9               |       |
| Digestibility <sup>a</sup>    |                     |                   |                     |      |                   |      |                   |       |
| Protein                       | 75.2 <sup>d</sup>   | ±1.2 <sup>c</sup> | 73.7 <sup>d</sup>   | ±3.4 | 72.6 <sup>d</sup> | ±2.2 | 71.3 <sup>d</sup> | ±2.4  |
| Crude fiber                   | 52.0 <sup>d</sup>   | ±5.9              | 47.7 <sup>d</sup>   | ±4.4 | 50.0 <sup>d</sup> | ±2.6 | 52.1 <sup>d</sup> | ±3.5  |
| Ether extract                 | 60.2 <sup>d</sup>   | ±6.3              | 58.4 <sup>d</sup>   | ±7.3 | 62.4 <sup>d</sup> | ±5.8 | 62.0 <sup>d</sup> | ±3.8  |
| Nitrogen free extract         | 87.0 <sup>d</sup>   | ±2.7              | 91.5 <sup>e</sup>   | ±1.3 | 93.0 <sup>e</sup> | ±0.5 | 82.7 <sup>g</sup> | ±2.2  |
| Dry matter                    | 81.9 <sup>d,f</sup> | ±2.4              | 84.3 <sup>e,d</sup> | ±1.9 | 86.2 <sup>e</sup> | ±0.8 | 77.9 <sup>f</sup> | ±2.2  |
| Total digestible nutrients    | 58.5 <sup>d</sup>   | ±1.5              | 61.9 <sup>d</sup>   | ±1.9 | 67.4 <sup>f</sup> | ±0.6 | 61.7 <sup>d</sup> | ±1.9  |
| Gross energy                  | 79.5 <sup>d</sup>   | ±2.6              | 82.1 <sup>e,d</sup> | ±2.4 | 84.0 <sup>e</sup> | ±0.9 | 74.9 <sup>f</sup> | ±2.2  |
| Digestible energy Kcal/gm     | 2.6                 |                   | 2.6                 |      | 2.8               |      | 2.5               |       |
| Nitrogen balance <sup>b</sup> |                     |                   |                     |      |                   |      |                   |       |
| Fecal                         | 24.8                | ±1.2              | 26.3                | ±3.4 | 27.4              | ±2.1 | 28.7              | ±2.4  |
| Urinary                       | 52.4                | ±3.8              | 48.0                | ±3.0 | 60.2              | ±7.0 | 57.4              | ±3.9  |
| Retention                     | 22.8                | ±2.7              | 25.7                | ±4.7 | 12.4              | ±2.6 | 14.0              | ±10.4 |
| Nitrogen retained gm/day      | 27.3                |                   | 29.1                |      | 15.7              |      | 16.3              |       |

<sup>a</sup> Percent of intake, coefficient of digestion (COD) as cited in text.

<sup>b</sup> Percent of intake.

<sup>c</sup> Standard error.

<sup>d,e,f</sup> Any means in the same row with different superscripts is significantly different ( $P < .05$ ).

free extract digestibility compared to reconstituted, however, total digestible nutrients, energy and dry matter digestibilities were not different. This is in disagreement with work by McNeill et al. (1969) who reported reconstitution of sorghum grain increased ruminal digestion of starch compared to dry heat processed. Popping increased ( $P < .05$ ) the digestibility of nitrogen free extract, gross energy and dry matter over dry rolled sorghum grain. Reconstituting sorghum grain significantly increased the digestibility of nitrogen free extract and gross energy, however, total digestible nutrients and dry matter digestibility was not different compared to dry rolled sorghum grain. This is in disagreement with reports by McGinty et al. (1966), Buchanan et al. (1968) and Neuhaus and Totusek (1969) who reported reconstitution increased dry matter digestibility over dry rolled sorghum grain.

Starch alteration (gelatinization) due to processing was evaluated using the enzyme reaction reported by Anstaett et al. (1969). Popped sorghum grain had the largest amount of starch change as indicated by mg maltose produced per gram of sample (table 4). Steam flaked grain weighing 9.9 kg/bu produced 110 mg maltose per gm of sample, reconstituted 25 mg and dry rolled sorghum grain 29.8 mg. This indicates little change in the starch of reconstituted due to processing. Sorghum grain that was steamed and not flaked yielded 20.0 mg of maltose which indicates steaming at atmospheric pressure does not modify the starch. Since steam flaking did alter starch it

TABLE 4. INFLUENCE OF FOUR PROCESSING METHODS ON  
SORGHUM STARCH GELATINIZATION

| Item                     | <u>Maltose</u><br>mg/gm | <u>Gelatinization</u><br>% |
|--------------------------|-------------------------|----------------------------|
| Reconstituted            | 25.0                    | 10.0                       |
| Popped                   | 149.0                   | 62.0                       |
| Steam Flaked - 24 lbs/bu | 87.1                    | 36.0                       |
| Steam Flaked - 22 lbs/bu | 110.0                   | 46.0                       |
| Dry Rolled               | 29.8                    | 12.0                       |
| Steam - not flaked       | 20.0                    | 8.0                        |
| Standard                 | 240.0                   | 100.00                     |



would indicate physical pressure as well as heat is essential for gelatinization.

### Summary

This experiment was conducted to compare the coefficients of digestion (COD) and starch gelatinization due to processing of sorghum grain. The rations (dry rolled, popped, steam flaked and reconstituted) contained approximately 88% sorghum grain and 10% alfalfa haylage plus minerals, vitamins and antibiotics.

COD were determined using a 4 x 4 Latin square design with seven day preliminary and five day total collection periods. The starch gelatinization of sorghum grain was evaluated by enzyme hydrolysis reported by Anstaeht et al. (1969).

There were no significant differences among COD for protein, crude fiber, ether extract or nitrogen balance among treatments. The COD for dry matter, total digestible nutrients and nitrogen free extract was increased ( $P < .05$ ) for steam flaked sorghum grain compared to reconstituted grain. Steam flaked sorghum grain yielded a significantly greater COD for total digestible nutrients, nitrogen free extract, dry matter and energy when compared with dry rolled. There was no significant difference in COD of dry matter, nitrogen free extract or energy when steam flaked sorghum grain was compared to popped.

Popping increased ( $P < .05$ ) the digestibility of nitrogen free extract compared to reconstituted sorghum grain and nitrogen free extract, gross energy and dry matter compared to dry rolled. Reconstituting sorghum grain increased ( $P < .05$ )

the coefficient of digestion for nitrogen free extract and energy over dry rolled but total digestible nutrients and dry matter digestibility was not different.

An enzyme test for gelatinization revealed that popping of sorghum grain yields the highest starch gelatinization. Steam flaked sorghum grain that weighed 9.97 kg/bu was next in amount of gelatinization with little difference among dry rolled, reconstituted and steamed unflaked grain.

These results indicate there were significant differences in COD of the proximate energy fraction in the four different processing methods studied.

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## APPENDIX

APPENDIX TABLE A  
CHEMICAL COMPOSITION OF DIGESTION  
RATIONS CONTAINING SORGHUM GRAIN  
PROCESSED BY FOUR METHODS

| Item                            | Recon-<br>stituted | Popped | Steam<br>Flaked | Dry<br>Rolled |
|---------------------------------|--------------------|--------|-----------------|---------------|
| Digestibility, DM basis, %      |                    |        |                 |               |
| Protein (N x 6.25) <sup>1</sup> | 17.58              | 18.14  | 15.59           | 18.08         |
| Ether extract                   | 2.43               | 2.06   | 2.02            | 2.39          |
| Ash                             | 4.23               | 4.40   | 3.11            | 4.46          |
| Crude fiber                     | 4.70               | 5.02   | 4.43            | 4.90          |
| N-free extract                  | 71.06              | 70.38  | 74.85           | 70.17         |
| Original moisture               | 25.47              | 23.17  | 18.99           | 17.74         |
| Gross energy kcal/gm            | 4.462              | 4.469  | 4.471           | 4.380         |

<sup>1</sup> Protein content was high since one pound protein supplement was fed daily as in feedlot trial, but intake was reduced in digestion stalls.

APPENDIX TABLE B  
CHEMICAL COMPOSITION OF FEEDLOT  
RATIONS CONTAINING SORGHUM GRAIN  
PROCESSED BY FOUR METHODS

| Item                       | Recon-<br>stituted | Popped | Steam<br>Flaked | Dry<br>Rolled |
|----------------------------|--------------------|--------|-----------------|---------------|
| Digestibility, DM basis, % |                    |        |                 |               |
| Protein (N x 6.25)         | 13.09              | 13.66  | 14.89           | 14.08         |
| Ether extract              | 2.92               | 2.62   | 2.43            | 2.81          |
| Ash                        | 2.86               | 2.95   | 2.55            | 2.97          |
| Crude fiber                | 3.93               | 4.37   | 3.98            | 4.49          |
| N-free extract             | 77.22              | 76.39  | 76.15           | 75.65         |
| Original moisture          | 27.39              | 21.97  | 19.28           | 18.50         |
| Gross energy kcal/gm       | 4.338              | 4.286  | 4.378           | 4.329         |

APPENDIX TABLE C  
CHEMICAL COMPOSITION OF HAYLAGE AND SUPPLEMENTS

| Item                     | Haylage | Supplement<br>1 | Supplement<br>2 |
|--------------------------|---------|-----------------|-----------------|
| Composition, DM basis, % |         |                 |                 |
| Protein (N x 6.25)       | 17.62   | 54.41           | 65.38           |
| Ether extract            | 2.63    | 2.36            | 2.78            |
| Ash                      | 7.96    | 21.35           | 23.98           |
| Crude fiber              | 30.15   | 1.72            | 1.41            |
| N-free extract           | 41.64   | 21.16           | 4.95            |
| Original moisture        | 36.90   | 10.97           | 11.92           |
| Gross energy kcal/gm     | 4.354   | 3.191           | 2.888           |



APPENDIX TABLE D  
INFLUENCE OF FOUR PROCESSING METHODS  
ON SORGHUM STARCH GELATINIZATION

| Item                     | <u>Maltose</u><br>mg/gm | <u>Gelatinization</u><br>% |
|--------------------------|-------------------------|----------------------------|
| Reconstituted            | 25.0                    | 10.0                       |
| Popped                   | 149.0                   | 62.0                       |
| Steam Flaked - 24 lbs/bu | 87.1                    | 36.0                       |
| Steam Flaked - 22 lbs/bu | 110.0                   | 46.0                       |
| Dry Rolled               | 29.8                    | 12.0                       |
| Steam - not flaked       | 20.0                    | 8.0                        |
| Standard                 | 240.0                   | 100.00                     |

APPENDIX TABLE E

MEANS AND STANDARD ERRORS OF APPARENT COEFFICIENT OF  
DIGESTION AND NITROGEN BALANCE OF STEERS FED  
SORGHUM GRAIN PROCESSED  
BY FOUR METHODS

| Item                          | Processing Method |                   |                   |       |                   |       |                   |       |
|-------------------------------|-------------------|-------------------|-------------------|-------|-------------------|-------|-------------------|-------|
|                               | Recon-stituted    |                   | Popped            |       | Steam Flaked      |       | Dry Rolled        |       |
| No. steers                    | 4                 |                   | 4                 |       | 4                 |       | 4                 |       |
| Dry matter intake<br>kg/day   | 4.2               |                   | 3.6               |       | 3.9               |       | 3.9               |       |
| Digestibility <sup>a</sup>    |                   |                   |                   |       |                   |       |                   |       |
| Protein                       | 75.2 <sup>d</sup> | ±1.2 <sup>c</sup> | 73.7 <sup>d</sup> | ±3.4  | 72.6 <sup>d</sup> | ±2.2  | 71.3 <sup>d</sup> | ±2.4  |
| Crude Fiber                   | 52.0 <sup>d</sup> | ±5.9              | 47.7 <sup>d</sup> | ±4.4  | 50.0 <sup>d</sup> | ±2.6  | 52.1 <sup>d</sup> | ±3.5  |
| Ether extract                 | 60.2 <sup>d</sup> | ±6.3              | 58.4 <sup>d</sup> | ±7.3  | 62.4 <sup>d</sup> | ±5.8  | 62.0 <sup>d</sup> | ±3.8  |
| Nitrogen free<br>extract      | 87.0 <sup>d</sup> | ±2.7              | 91.5 <sup>e</sup> | ±1.3  | 93.0 <sup>f</sup> | ±0.5  | 82.7 <sup>g</sup> | ±2.2  |
| Dry matter                    | 81.9 <sup>d</sup> | ±2.4              | 84.3 <sup>e</sup> | ±1.9  | 86.2 <sup>e</sup> | ±0.8  | 77.9 <sup>d</sup> | ±2.2  |
| Total digestible<br>nutrients | 58.5 <sup>d</sup> | ±1.5              | 61.9 <sup>d</sup> | ±1.9  | 67.4 <sup>f</sup> | ±0.6  | 61.7 <sup>d</sup> | ±1.9  |
| Gross energy                  | 79.5 <sup>d</sup> | ±2.6              | 82.1 <sup>e</sup> | ±2.4  | 84.0 <sup>e</sup> | ±0.9  | 74.9 <sup>f</sup> | ±2.2  |
| Digestible<br>energy kcal/gm  | 2.6               |                   | 2.6               |       | 2.8               |       | 2.5               |       |
| Nitrogen balance <sup>b</sup> |                   |                   |                   |       |                   |       |                   |       |
| Fecal                         | 24.8              | ±1.2              | 26.3              | ±3.4  | 27.4              | ±2.1  | 28.7              | ±2.4  |
| Urinary                       | 52.4              | ±3.8              | 48.0              | ±3.0  | 60.2              | ±7.0  | 57.4              | ±3.9  |
| Retention                     | 22.8              | ±2.7              | 25.7              | ±4.7  | 12.4              | ±2.6  | 14.0              | ±10.4 |
| Nitrogen retained<br>gm/day   | 27.3              | ±21.6             | 29.1              | ±22.7 | 15.7              | ±27.8 | 16.3              | ±35.2 |

<sup>a</sup> Percent of intake, coefficient of digestion (COD) as cited in text.

<sup>b</sup> Percent of intake.

<sup>c</sup> Standard error.

<sup>d,e,f</sup> Any means in the same row with different superscripts is significantly different ( $P < .05$ ).

APPENDIX TABLE F

PERFORMANCE AND CARCASS DATA OF STEERS FED RATIONS  
CONTAINING SORGHUM GRAIN  
PROCESSED BY FOUR METHODS (SUMMER 1970)

| Item                           | Processing Method                    |                         |                         |                         |
|--------------------------------|--------------------------------------|-------------------------|-------------------------|-------------------------|
|                                | Recon-stituted                       | Popped                  | Steam Flaked            | Dry Rolled              |
| <u>Feedlot data</u>            |                                      |                         |                         |                         |
| No. steers                     | 15                                   | 15                      | 15                      | 15                      |
| Avg initial wt, lbs            | 712.0                                | 714.0                   | 717.0                   | 724.0                   |
| Avg final wt, lbs              | 1026.0                               | 1028.0                  | 1039.0                  | 1021.0                  |
| Avg daily gain lbs             | 2.65 <sup>a</sup> ±0.13 <sup>d</sup> | 2.65 <sup>a</sup> ±0.98 | 2.72 <sup>a</sup> ±0.11 | 2.46 <sup>a</sup> ±0.13 |
| Avg daily feed intake, lbs     | 16.12 <sup>a</sup>                   | 15.24 <sup>a</sup>      | 15.13 <sup>a</sup>      | 18.69 <sup>b</sup>      |
| Avg lbs feed/lb gain           | 6.06                                 | 5.75                    | 5.49 <sup>a</sup>       | 7.85 <sup>b</sup>       |
| <u>Carcass data</u>            |                                      |                         |                         |                         |
| Avg hot carcass wt, lbs        | 634.0                                | 633.0                   | 635.0                   | 632.0                   |
| Avg rib-eye area, sq in        | 12.21                                | 12.41                   | 11.80                   | 11.79                   |
| Avg fat 12th rib, cm           | .57 <sup>a</sup> ±0.14               | .48 <sup>a</sup> ±0.60  | .46 <sup>a</sup> ±0.31  | .50 <sup>a</sup> ±0.57  |
| Avg carcass grade <sup>c</sup> | 9.73 <sup>a</sup> ±0.22              | 9.86 <sup>a</sup> ±1.30 | 9.33 <sup>a</sup> ±0.27 | 9.80 <sup>a</sup> ±0.43 |
| Avg yield grade                | 2.88                                 | 2.61                    | 2.77                    | 2.82                    |

a,b Means within rows with unlike superscripts are significantly different (P<.05).

c High good = 9; Low choice = 10.

d Standard error.

APPENDIX TABLE G  
 PROXIMATE ANALYSIS OF SORGHUM GRAIN  
 PROCESSED BY FOUR METHODS

| Item                     | Processing Method |        |              |            |
|--------------------------|-------------------|--------|--------------|------------|
|                          | Recon-stituted    | Popped | Steam Flaked | Dry Rolled |
| Composition, DM basis, % |                   |        |              |            |
| Protein (N x 6.25)       | 10.62             | 11.39  | 10.08        | 9.79       |
| Ether extract            | 2.50              | 2.76   | 2.56         | 2.73       |
| Ash                      | 1.75              | 1.78   | 1.58         | 1.70       |
| Crude fiber              | 1.89              | 2.40   | 2.08         | 2.07       |
| N-free extract           | 83.24             | 81.67  | 83.70        | 83.71      |
| Original moisture        | 25.80             | 7.11   | 17.92        | 15.09      |
| Gross energy kcal/gm     | 4.408             | 4.396  | 4.430        | 4.364      |

APPENDIX TABLE H  
SUPPLEMENT COMPOSITION

| Supplement 1<br>%<br>Composition | Ration<br>Composition          | Supplement 2<br>%<br>Composition |
|----------------------------------|--------------------------------|----------------------------------|
| 54.51                            | sorghum grain                  | 49.82                            |
| 17.2                             | urea (281%)                    | 21.9                             |
| 12.9                             | salt                           | 12.9                             |
| 12.9                             | limestone                      | 12.9                             |
| 1.25                             | trace mineral <sup>1</sup>     | 1.25                             |
| .44                              | Vitamin A <sup>2</sup>         | .44                              |
| .8                               | chlorotetraycline <sup>3</sup> | .79                              |
| <u>100.00</u>                    |                                | <u>100.00</u>                    |

<sup>1</sup> Composition, % Ca, P, Co.

<sup>2</sup> 10,000 IU per gm

<sup>3</sup> 10 gm per lb.

APPENDIX TABLE I  
 RATION COMPOSITION TO COMPARE FOUR  
 PROCESSING METHODS FOR SORGHUM GRAIN

| Ration<br>Ingredient | Processing Method           |                                      |
|----------------------|-----------------------------|--------------------------------------|
|                      | Reconstitution <sup>1</sup> | Dry Rolled<br>Steam Flaked<br>Popped |
|                      | %                           | %                                    |
| Haylage              | 10.000                      | 10.000                               |
| Sorghum grain        | 88.235                      | 88.055                               |
| Salt                 | 0.5                         | 0.5                                  |
| Limestone            | 0.5                         | 0.5                                  |
| Urea                 | 0.67                        | 0.85                                 |
| Vitamin A            | 0.015                       | 0.015                                |
| Chlorotetracycline   | 0.030                       | 0.030                                |
| Trace mineral        | <u>0.050</u>                | <u>0.050</u>                         |
| Total                | 100.00                      | 100.00                               |

<sup>1</sup> Two rations were necessary to insure isonitrogenous rations as grain used in reconstitution was different from that used in other rations.

EFFECT OF SORGHUM GRAIN PROCESSING  
ON BEEF FINISHING PERFORMANCE

by

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AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of the  
requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1971

This study was conducted to compare feedlot performance and carcass characteristics of steers fed steam flaked, reconstituted, popped and dry rolled sorghum grain. Grain, roughage and supplement were mixed in the bunk twice daily. Popped, flaked and dry rolled grains came from one shipment, while the reconstituted grain came from a second. Urea was used to make the four rations isonitrogenous.

Average daily gain differences between treatments were small and non-significant. Fat thickness, loin eye, carcass score, quality grade and yield grade were statistically similar.

Processing (popping, reconstituting or atmospheric steam flaking) increased feed efficiency over dry rolling. These data suggest that steam flaked sorghum grain is more efficiently utilized than popped and reconstituted sorghum grain.

The coefficients of digestion (COD) and starch gelatinization due to processing of sorghum grain were studied. The rations (dry rolled, popped, steam flaked and reconstituted) contained approximately 88% sorghum grain and 10% alfalfa haylage plus minerals, vitamins and antibiotics.

COD were determined using a 4 x 4 Latin square design with seven day preliminary and five day total collection periods. The starch gelatinization of sorghum grain was evaluated by enzyme hydrolysis reported by Anstætt et al. (1969).

There were no significant differences among COD for protein, crude fiber, ether extract or nitrogen balance among



treatments. The COD for dry matter, total digestible nutrients and nitrogen free extract was increased ( $P < .05$ ) for steam flaked sorghum grain compared to reconstituted grain. Steam flaked sorghum grain yielded a significantly greater COD for total digestible nutrients, nitrogen free extract, dry matter and energy when compared with dry rolled. There was no significant difference in COD of dry matter, nitrogen free extract or energy when steam flaked sorghum grain was compared to popped.

Popping increased ( $P < .05$ ) the digestibility of nitrogen free extract compared to reconstituted sorghum grain and nitrogen free extract, gross energy and dry matter compared to dry rolled. Reconstituting sorghum grain increased ( $P < .05$ ) the coefficient of digestion for nitrogen free extract and energy over dry rolled but total digestible nutrients and dry matter digestibility was not different.

An enzyme test for gelatinization revealed that popping of sorghum grain yields the highest starch gelatinization. Steam flaked sorghum grain that weighed 9970 gm/l was next in amount of gelatinization with little difference among dry rolled, reconstituted and steamed unflaked grain.

These results indicate there were significant differences in COD of the approximate energy fraction in the four different processing methods studied.