EFFECT OF SORGHUM GRAIN PROCESSING ON BEEF FINISHING PERFORMANCE

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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^{o}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 amyolytic 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 inculation 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^{o}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^{o}C while corn starch gelatinized at 62 to 72^{o}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 form 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^{o}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 retrodegradation 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 imporve 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. Ruminal 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