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PROCESSING METHODS FOR CORN GRAIN FED WITH VARIOUS TYPES, SOURCES AND LEVELS OF ROUGHAGE TO CATTLE

BY

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TYPES, SOURCES AND LEVELS OF ROUGHAGE TO CATTLE

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PROCESSING METHODS FOR CORN GRAIN FED WITH VARIOUS TYPES, SOURCES AND LEVELS OF ROUGHAGE TO CATTLE

Abstract

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Under the supervision of L. B. Embry

Six hundred fifty-six Hereford steers were utilized in a series of experiments to compare the effects of various methods for processing corn grain when fed with various types and levels of roughage. Included in this series of experiments were five feedlot and two digestion trials. Dry and high moisture corn grain fed whole or rolled and steam processed flaked corn grain were the types of grain processing methods studied. However, steam processed flaked corn was used in only one feedlot experiment as the benefits measured by animal performance were similar to that of dry rolled corn. Hay, haylage and corn silage were the various types of roughage compared. Hay and haylage were fed in high roughage growing and low roughage finishing diets with each of the grain treatments. Corn silage was fed at a constant level throughout a growing-finishing study which resulted in a large portion of the diet being corn silage when the cattle were of lighter weights and progressively less as the cattle increased in weight and feed consumption. Parameters used to evaluate these various comparisons included feedlot performance and apparent digestibility data.

Hereford steers were used in all experiments. They were randomly allotted after stratifying on basis of weight and placed in pens paved with concrete but without shade or shelter. The animals were fed once

daily in fence-line feed bunks in amounts to provide available feed at all times.

Reconstituted corn, stored in an oxygen-limiting silo, was used in all experiments as the high moisture corn. The high moisture corn was from the same source as the dry corn within each experiment. Rolling of both the dry and high moisture corn was just prior to feeding. This allowed using the same oxygen-limiting silo for both the whole and rolled high moisture grains. The dry grain was rolled to a medium degree of fineness while the high moisture grain was rolled to produce a flattened kernel with a minimum of fine material. Reconstituted haylage was also from the same source as the dry hay when compared within the same experiment. The hay and haylage were chopped in a similar manner but water was added to the haylage prior to storage in a silo.

The differences between high moisture and dry corn when fed with low levels of roughage (about 10% of diet dry matter) were small and frequently favored dry grain on basis of weight gain. There were also only small differences in feed utilization under these conditions but frequently favored the high moisture corn. At higher levels of roughage, the value of high moisture corn in comparison to dry corn appeared to improve weight gain and feed efficiency.

There seemed to be no consistent difference on basis of rate of gain between whole or rolled dry corn grain with roughage levels up to about 20% of the diet dry matter. Rolled grain was generally consumed at a lower level but with about the same or a slight improvement in feed efficiency in comparison to the whole grain. Apparently, the whole daily in fence-line feed bunks in amounts to provide available feed at all times.

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There seemed to be no consistent difference on basis of rate of gain between whole or rolled dry corn grain with roughage levels up to about 20% of the diet dry matter. Rolled grain was generally consumed at a lower level but with about the same or a slight improvement in feed efficiency in comparison to the whole grain. Apparently, the whole grain was utilized efficiently even though the feces appeared to contain a considerable quantity of apparent whole kernels of grain. Even with roughage levels as much as 60 to 65% of the dry diet, the advantage for rolling dry corn grain was small for steers from weights of 500 to 800 lb.

With high moisture corn and low levels of roughage, there appeared to be little, if any, advantage for rolling the grain in comparison to feeding in the whole form. At higher levels of roughage (20% or more diet dry matter), there appeared to be more advantage for rolling high moisture grain than for rolling dry grain.

Differences in value of dry and high moisture corn were small when fed in diets with limited amounts of corn silage (about 37% of diet dry matter). There was also little difference between whole or rolled corn under these conditions.

Incidence of abscessed livers did not appear to be affected by moisture content of the grain or roughage. However, there was a greater incidence when the corn was rolled. Three hundred eighty-two cattle were examined at slaughter for liver abscesses of which 50% were fed whole corn and 50% fed rolled corn. Fifteen (7.8%) abscessed livers were from cattle fed whole corn and 31 (16.2%) were from cattle fed rolled corn.

Differences in apparent digestibility values for dry or high moisture corn grain were also small in diets containing 7 or 40% roughage. Rolling of either type of corn grain failed to have any large effect. With the lower level of roughage, there was a difference in digestibility in favor of haylage over hay. In feeding trials with low grain was utilized efficiently even though the feces appeared to contain a considerable quantity of apparent whole kernels of grain. Even with roughage levels as much as 60 to 65% of the dry diet, the advantage for rolling dry corn grain was small for steers from weights of 500 to 800 lb.

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INTRODUCTION

Feed processing and storage systems vary widely in requirements for storage facilities and processing equipment and thus in capital outlay and operating costs. Beneficial effects derived from processing and storage must at least equal costs involved to be economical. The total value of any processing or storage system will be added benefits of several factors which should be taken into consideration in deciding how feeds should be harvested, stored and processed for feeding to livestock. These would include cost and time involved in harvesting, storing, processing and feeding; influence on feed consumption and wastage of feed; and effects on weight gains of the animals and feed utilization.

Grains are usually processed for feedlot cattle to increase digestibility, feed intake or for increased use of mechanical equipment. Processing grain may increase digestibility by increasing the surface area exposed to bacterial and enzymatic digestion. Processing grain may also influence rate of passage through the digestive tract because of changes in particle size. A rapid rate of passage would be expected to permit a greater feed intake by the animal; but if passage rate is too rapid, digestibility and thus, efficiency of utilization may be reduced.

Research on feed processing has been rather continuous for the past several years. However, this is necessary because of new developments in machinery and storage structures, introduction of new crops and varieties, new information on nutritional needs and changes in feeding practices. Recent trends in cattle feeding practices have been toward feeding a higher proportion of grain in the diet, feeding of grain in the high moisture state, and feeding of younger animals. Also, a large part of the corn crop is shelled during harvesting and then dried with artificial heat instead of allowing the grain and cob to dry naturally in the field or when cribbed as ear corn. These harvesting changes are true for most of the feed grains and result in an increase in amount and degree of kernel breakage and a possible heat alteration of the grain. All of these factors are interrelated and affect efficiency with which livestock utilize feed. As a result of these changing trends, there is a need for additional research as to the benefits to be derived from grain processing.

The research reported in this thesis involved experiments to determine the value of grain processed by various methods when fed various kinds and ratios of concentrate to roughage to feedlot beef animals of various ages and degree of fatness.

REVIEW OF LITERATURE

There appears to be conflicting recommendations between earlier research concerning the merits of processing methods for various grains being fed to beef feedlot animals and those reported more recently. However, some of the discrepancies appear to have resulted from improper consideration being given to various animal and feed factors which have been shown to affect results obtained from processing grain.

Morrison (1959) states that young animals chew corn more thoroughly than older animals and also have better teeth to masticate feed. Kick et al. (1937) observed on a similar diet that the number of jaw movements by the animal while eating decreased as the age of the animal increased. Shaw and Norton (1906) fed a diet high in whole corn grain to yearling cattle and cows and found 11% and 23%, respectively, whole undigested corn in the feces. With cattle going into feedlots at an earlier age than previously, there may be less need to process whole corn grain.

With increasing daily fixed cost, it is generally more economical to feed a higher proportion of concentrate to obtain higher daily gains. Geasler and Vetter (1972) stated that with a high roughage diet processed corn (rolled, cracked or ground) was more highly utilized than the unprocessed grain. By contrast, with high concentrate diets unprocessed corn grain was utilized more efficiently. Accompanying the increased use of concentrate in cattle diets has been an increase in the use of some grains such as wheat previously not considered a major feed grain. New grains such as triticale have been developed and others such as sorghum grain have been bred to provide increased grain production where previously they had been used primarily for silage production. Also, new varieties have been developed for maximum production and they may differ physically from those previously produced. Therefore, results obtained from various processing methods may differ from earlier results because of these developments.

Another factor, although not biological in nature, which may affect the type of grain processing methods recommended is the number of cattle fed per year at one location. A 2 to 3% reduction in feed required per unit of gain in a large feedlot may be of considerable economic importance; whereas, the same change in a farmer-feeder operation is likely to be of only minor consideration. Therefore, the larger feedlot may be more economically justified in purchasing more expensive equipment for grain processing to obtain small benefits than is the smaller operator. The larger feedlot is able to spread the cost of the equipment over more pounds of feed and therefore reduce the per unit cost. The smaller farmer-feeder may charge a portion of the grain processing cost to the harvesting and storage operation, and therefore, charge part of the cost to the farming operation as well as to cattle feeding.

It is evident that economic considerations play a major role in selection of feed processing systems. However, emphasis with research has been on the animal response in weight gain and feed utilization. These will be given the major emphasis in this literature review since economic benefits can be calculated from weight gain and feed intake data.

Grinding and Rolling

One of the oldest and generally least costly method of processing grain is to break the kernels into smaller particles. This is usually accomplished by the use of various types of grinders or roller mills. The use of roller mills is generally preferred over grinders for most grains. Roller mills have lower power requirements and generally produce a product with more uniformity in particle size. However, the product from a grinder or roller mill could be of similar physical properties if certain precautions are taken.

The process of grinding involves passing grain through a hammer or burr mill. Particle size may vary from a fine powder to coarsely cracked grain depending upon the type of mill and mesh size of the screen. Rolling requires that the grain pass between two rollers. The degree of physical destruction of the intact grain depends upon the clearance between the rollers, kernel size, rate of flow between the rollers and moisture content of the grain. Particle size of the rolled grain may, therefore, vary from fine particles to coarsely cracked. Riggs (1958) concluded from a review of the literature there was little or no difference in nutritional value of grain from the two methods of reducing particle size.

Finely ground grain is generally considered to be digested to a greater extent than is coarsely ground grain or the intact kernel. This is due to a greater exposure of the interior portion of the kernel and allows for more complete digestion. However, finely ground grain is consumed in smaller quantity than whole or coarsely ground grain (Ray and Drake, 1959).

Corn

It is a common practice to grind or roll corn grain because it is thought that much of the material will pass through the digestive tract with little or no digestion if the kernel is not broken. Savings in feed preparation cost could be realized through reduced mechanical power and labor if this processing was not necessary. However, in experiments with calves (Jacobs *et al*., 1940), yearling cattle (Allison, 1917) and two-year-old steers (Mumford, 1905), it was shown that cattle gain faster and more efficiently when corn was rolled or ground as compared to the whole form.

Under the assumptions that cattle are now put into the feedlot at a younger age and that younger animals masticate their food more thoroughly, Goodrich and Meiske (1966) reevaluated the need for grinding and rolling corn grain for feedlot cattle. They reported greater gains, consumption, profits and more efficient utilization of the whole than for rolled corn when fed to yearling steers. Corn comprised about 60% of the total diet with the remainder being corn silage and hay. Meiske, Goodrich and Thorton (1968) repeated this Minnesota research but utilized younger animals. They again found that grinding the corn was unnecessary.

Hixon, Hatfield and Lamb (1969) reported yearling steers self-fed whole corn with supplement gained faster and more efficiently than those fed a similar diet containing cracked corn. Weichenthal and Webb (1969) obtained a 5% faster gain with yearling steers fed dry whole corn with 0 or 10% roughage levels as compared to steers fed ground corn. Whole shelled corn was utilized 7.1% more efficiently than ground corn when no roughage was fed and 6.9% more efficiently at the 10% roughage level. Foster and Woods (1970); Vetter, Burroughs and Wedin (1970) and Perry, Beeson and Mohler (1970) have also shown improved or equal gain and feed efficiency from feeding dry whole corn grain in comparison to the rolled or ground grain in high energy beef cattle diets.

Vance et al. (1971) evaluated the performance of cattle finished on a diet using whole or crimped corn grain with 0, 5, 10, 15, 20 or 25 lb corn silage daily. They concluded that whole corn grain was best utilized in high-concentrate diets and that crimped corn was best utilized in diets containing more roughage.

In reviewing this area of processing corn grain, it was noted that several authors stated that cattle fed whole corn grain were more difficult to keep on-feed as compared to those receiving cracked corn. Kick et al. (1937) reported that steers spent less time masticating shelled corn than did steers receiving the ground grain. They explained this on the basis of more time required for ensalivation of the ground dusty grain than for the whole kernel. This may be related to the problem of cattle going off-feed in that not enough saliva is being secreted, and therefore, causing a more acid rumen resulting in mild cases of acidosis. This would be especially true if feed was not available to the animals at all times. Therefore, when whole corn grain is fed, a higher degree of management ability may be required.

Sorghum Grain

Sorghum grain is a hard, dense grain and is relatively impervious to water. Therefore, the whole grain apparently is resistant to microbial and enzymatic digestion during the period of time it normally remains within the digestive tract. Some method of processing is required for efficient utilization of sorghum grain by beef cattle.

Saba et al. (1964) studied digestibility of whole sorghum grain in nylon bags suspended in the rumen. They found essentially no digestion during a 1-week period. Cadena et al. (1962) conducted similar studies with dry rolled sorghum grain and found the grain to be highly digestible during a 24-hour period.

A series of studies at the Kansas station using various levels of sorghum grain revealed little difference in weight gains of cattle fed finely ground, coarsely ground or dry rolled grain (Smith and Parrish, 1953; Baker et al., 1955). However, animals fed the coarsely ground grain were not as efficient in feed utilization. Pope et al. (1961) at Oklahoma using a 50% concentrate diet showed improved gains and feed requirements for cattle fed finely ground sorghum grain in comparison to dry rolled grain. At Arizona, Hubbert et al. (1962) showed that finely ground as compared to dry rolled sorghum grain reduced feed intake and increased feed requirements when fed with a 65% concentrate diet to yearling steers. Some of these authors suggested that the geographical area in which the grain is fed and the type of diet utilized are reasons for discrepancies reported in the utilization of sorghum grain processed in various ways. In more arid climates, fine grinding of grain results in an extremely dry, dusty feed because of the low humidity. In more humid areas, it is probable that the feed would not be as dusty; and in many of the more humid areas, silage has been frequently used in conjunction with the finely ground grain.

Digestion studies with diets containing 75 to 85% sorghum grain have shown no improvement in digestibility of finely ground grain over coarsely ground grain or dry rolled grain (Husted et al., 1968; Buchanan-Smith, Totusek and Tillman, 1968). However, the level of roughage may influence the digestibility of dry rolled sorghum grain. Studies have shown that the digestibility of dry rolled sorghum grain by steers is much higher on a diet of 50% grain and 50% alfalfa than on a diet containing 98% grain (Keating et al., 1965; Saba et al., 1964). The TDN values, obtained by difference, for the sorghum grain were 86% and 75%, respectively, for the 50% and 98% grain diets. This suggests that the digestibility of dry rolled sorghum grain is higher when fed with high roughage diets than with high concentrate diets.

Other Grains

There has been few recent publications on the benefits of grinding or rolling wheat, barley and oats as compared to the whole grain for beef cattle. Morrison (1959) stated that all of these grains should be fed to beef animals in the ground or rolled form for most efficient utilization. However, these grains have been processed by other means and will be discussed in greater detail later.

Moist Heat Treatment

An increase of propionic acid in the digestive tract of the ruminant animal is generally associated with an increase in growth and fattening. Diets high in grain tend to produce more propionic acid than diets high in roughage. Studies have indicated that heat processed starch and grain results in a greater proportion of propionic acid in comparison to the raw forms (Armstrong and Blaxter, 1957; Shaw et al., 1959).

A measure of the effect of processing upon grains (the degree of disruption of the crystalline structure of starch granules in the endosperm) has been termed gelatinization. The degree of gelatinization in processed grain is measured by the disappearance of birefringence of starch granules and estimated by a beta-amylase digestion technique (Albin, 1971). During moist heat treatment of grain, the grain swells due to water forcing the starch chains apart. To a certain point, the changes caused by swelling are reversible by drying. When these changes become irreversible, the starch is said to be gelatinized. The original starch structure has been made less complex, although not converted to a sugar, and allows for more sites for microbial and enzymatic digestion. However, Mudd and Perry (1969) showed that completely gelatinized corn grain depressed digestibility. Albin (1971) suggested that a level of 30 to 40% gelatinization is desirable for sorghum grain. Experiments conducted by Wilson and Woods (1966) and Mudd and Perry (1969) indicate that this level of 30 to 40% gelatinization is too high for corn grain. Steam rolled, steam processed flaked and pressure cooked flaked are some of the moist heat processing methods that may cause gelatinization.

Steam Rolled, Steam Flaked and Pressure Cooked Flaked

The process of steam rolling grain generally involves subjecting the grain to steam for up to 5 minutes prior to rolling at a temperature near 180 F. Steam processed flaked grain involves a higher temperature (200 F), a longer period of time (20 to 30 minutes) and less tolerance between the rollers. Pressure cooked flaked grain is produced by adding the steam under pressure for a shorter period of time, 1 to 2 minutes. The temperature of the grain at which rolled is about 200 F. Pressure cooked flaked grains are generally less brittle and will not break as readily during the mixing and feeding operation. Also, steaming under pressure would be expected to result in deeper penetration of moisture into the kernel and cause more gelatinization of the starch. Grains processed, as described above, requires some drying before storage as the processing methods raise the moisture content to about 18 to 20%.

Flaking is a method of processing which involves steaming the grain before it is rolled. This method of processing has received considerable attention by researchers. However, a review of the effects of these processing methods is complicated due to a void or incomplete description of the specifications employed in the processing procedure. Also, there has been, when stated, a wide range of specifications between researchers.

Corn. Matsushima and Montgomery (1967) conducted an experiment to determine the effect of varying the space between the rollers of a roller mill used to flake the corn. The thick flakes measured about 1/12th inch in thickness while the thin flakes averaged 1/32nd inch in thickness. Cattle fed the thin flakes gained 4.6% faster and 7.8% more efficiently. This would indicate that quality control is important in grain processing. This may also explain some of the differences noted between researchers at various locations. Differences in results between researchers may have been in the thickness of the flake, and also in the amount of pressure, length of time subjected to heat and to differences in the grain used.

Digestibility studies by Johnson, Matsushima and Knox (1968) with flaked corn compared to dry rolled corn showed an increase in digestibility of dry matter and protein. The application of moist heat to starch or starchy feeds brings about hydration of the starch and hydrated starch is digested more rapidly by rumen microorganisms than untreated starch. However, dry heat resulted in a decrease in the rate of digestion of the readily hydrolyzable dry matter in a study conducted by Salsbury, Hoeffer and Luecke (1961).

Some of the tests with corn by Matsushima et al. (1966) have shown very little advantage in increased weight gain from steam processing. However, an increase of 5 to 10% in efficiency of feed utilization was observed. Similar results were reported by Newland et al. (1962) and Thompson, Bradley and Little (1965).

Garrett, Lofgreen and Hull (1971), in an extensive study of various steam and heat treatments, concluded there was a considerable range in specifications as to steam pressure and temperature treatments satisfactory for processing corn. They also concluded that from a practical standpoint the feeding value of corn is relatively unchanged by steam pressure treatments.

Sorghum Grain. The seed coat of sorghum grain is more dense than most other feed grains and therefore various processing methods which expose the starch portion of the kernel appear more beneficial. Steam rolling of sorghum grain has generally shown little or no improvement in the feeding value when compared to dry rolling or grinding (Pope et al., 1960). This would indicate that processing methods for sorghum grain which break up the outer coat are as effective in improving utilization as the methods involving heat treatment.

There appears to be considerable variation in the type of starch found in different varieties of sorghum grain. Hinders and Eng (1970) compared the effects of pressure cooked flaked and micronized sorghum grain on three different starch types of sorghum grain. By using enzymatic digestion, they found that different sorghum grains responded differently to various processing methods. It was concluded that the color of the outer coat probably had little effect upon the response to processing, but the starch granule and the protein matrix were the principal factors influencing the rate of starch degradation due to processing.

Hale et al. (1966) reported steam flaking significantly increased the digestibility of dry matter, ether extract, nitrogen-free extract and TDN over dry rolled sorghum grain. Husted et al. (1968) observed this same trend when dry rolled or finely ground sorghum grain was compared to the steam flaked or pressure flaked grain. Theurer, Trei and Hale (1967) showed that steam processing and good flaking increases *in vitro* volatile fatty acid production and narrowed the acetate-propionate ratio over poor flakes, steaming alone or untreated grain. Hale (1967) summarized his data at Arizona and reported that steam processed flaked sorghum grain increased gains by approximately 10% and feed requirements were reduced by 5% when compared to dry rolled sorghum grain. Totusek and White (1968) summarized 11 experiments and found close agreement to these values for the benefits from steam processed flaked sorghum grain.

Pressure cooked flaked grains are generally considered to be less brittle and will not break as readily during mixing and feeding operations as compared to steam pressure flaked grains. Pressure cooked flaked grains result in less fine and dusty material in the feedbunk which would be conducive to a greater feed intake. However, this advantage may be offset by usually higher cost of maintenance of the pressure cookers.

Garrett (1970) reported that pressure steamed flaked sorghum grain resulted in more rapid and more complete rumen fermentation of starch as compared to atmospheric, steam flaked grain. Feed intake of beef steers was lower but gross feed efficiency was improved by the steam pressure treatment. Garrett (1970) also stated that previous work has shown a decreased intake of the diet containing steam pressure processed grain sorghum. Net energy for gain values, however, were always as high or higher for the diets containing the steam pressure processed grain even when the depression in feed intake was severe enough to have an adverse influence on animal performance. The type of flake produced is also important to the response obtained from any flaking procedure. Osman _et al_. (1970) observed _in vitro_ that the starch of a thin flake is more rapidly degraded.

Garrett _et al_. (1971), in an extensive study of various processing methods on sorghum grain, found that steam pressure processing of milo resulted in an 8% improvement in feed efficiency and improved the net energy for gain values of high grain diets by 10% when compared to regular steam flaking at atmospheric pressure. These researchers also reported a 3% increase in energy digestibility attributed to the pressure cooking of the grain. Holmes, Drennan and Garrett (1970) compared pressure cooked flaked sorghum grain to grain which had been steamed at atmospheric pressure before rolling. They concluded that pressure cooked flaked sorghum grain resulted in more rapid and more complete fermentation than did grain steamed at atmospheric pressure. They also noted that an adaptation period was required for the pressure cooked grain as evidenced by in vitro results.

McNeill, Potter and Riggs (1971) conducted a study to compare total carbohydrate and starch utilization in the rumen and postruminal tract of steers fed sorghum grain processed by different methods. One of the comparisons involved dry ground versus steaming at atmospheric pressure followed by rolling at minimal tolerance of rollers. They found that total starch digestibility was improved by steam flaking. Also, ruminal starch digestion was greatest in steers fed the steam flaked grain. They suggested that raw starch from sorghum grain is poorly digested in the rumen of cattle fed high concentrate diets. However, when they micronized the grain, and therefore the starch no longer being raw, there was no difference in ruminal starch digestion when compared to the dry ground grain.

Potter, McNeill and Riggs (1971) also studied digestibility of protein in dry ground, steam flaked and micronized sorghum grain. Steam flaking resulted in enhanced ruminal conversion of grain protein to bacterial protein when compared to ground dry grain. However, the use of heat, as in micronization, resulted in decreased ruminal conversion of protein when compared to dry ground sorghum grain. They stated that the effect of heat processing on total digestion of sorghum grain proteins was minimal.

Wheat. The use of heat to process wheat has generally not resulted in any nutritional benefit (Cornett, Sherrod and Albin, 1971; Garrett, 1968). The application of heat to the raw starch of grains generally results in gelatinization. This is thought to aid digestibility of some grains if the amount of gelatinization is not overly severe. Cornett et al. (1971) states and cites other supporting research that raw starch from wheat is already partially gelatinized. In a digestion study they compared dry rolled, steam flaked and micronized rolled wheat. The levels of gelatinization for the treatments were 10.0, 12.5 and 10.0%, respectively. They found that steam flaked wheat had lower digestibility values than dry rolled grain. Garrett et al. (1971) also stated that steam treatment of wheat is not beneficial. One of the problems with flaking wheat is that the flakes are extremely fragile and easily broken which result in a high percentage of fine particles (Cornett et al., 1971; Hale et al., 1969). It was suggested that wheat grain does not absorb moisture as readily as other grains which may account for the less rigid flakes and a larger percentage of fine material.

Hale et al. (1970) found some improvement in performance of cattle fed poorly flaked wheat when compared to flat flaked wheat. This was thought to be primarily due to a reduction in percentage of fines in the poorly flaked wheat.

Embry and O'Connell (1970) recommended that wheat should be coarsely rolled or ground when feeding to beef cattle. Preparation to a powdery material appears to reduce intake and to increase digestive problems. They also stated that results of research have not shown any pronounced and consistent advantage for any processing methods over the dry rolled or coarsely ground grain. Similar recommendations and conclusion are given by Arnett (1971).

Barley. The digestibility of dry rolled barley is high compared to dry rolled sorghum grain (Saba et al., 1964). Garrett (1965) conducted a study comparing steam rolled barley to barley that had been ground. It was found that the acceptability, as measured by voluntary feed intake, was similar for both processing methods. Net energy for production values were also similar for the two processing methods. However, it was stated that benefits from steam rolling over dry rolling may sometimes be obtained.

In two trials in which dry rolled barley was compared with steam processed flaked barley, steam processed barley resulted in increased rates of gain (8%) and increased voluntary feed intake (9%) (Hale et al., 1966). However, there was no improvement in efficiency which would indicate no increase in digestibility from the steam flaking process. They noted that the flaked barley contained less fine material which may be responsible for the increased intake and performance of the cattle receiving the flaked diet.

Results of a study by Parrott et al. (1969) indicated that barley from different sources may vary in utilization and digestibility. They conducted two experiments in which the source of barley differed for each experiment. It appeared that steam processed flaked barley did not improve digestibility of the proximate fractions or the availability of TDN except when the TDN of the barley was low. Garrett et al. (1971) stated that the feeding value of barley was relatively unchanged by processing under steam pressure.

Dry Heat and Mechanical Pressure

More recent developments in methods for processing grains for beef cattle production have utilized dry heat or mechanical pressure. These methods also gelatinize the starch in a similar manner as discussed previously. The main difference is that dry rather than moist heat is used and results in a faster rate of processing with less expense. It is also thought that a more uniform product may be obtained by using dry heat or mechanical pressure. Popping, exploding, micronizing, extruding and roasting are methods which utilize dry heat or mechanical pressure to process feed grains for beef cattle.

Popping, Exploding, Micronizing, Extruding and Roasting

Popping grain is achieved by heating with high temperature air of 700 to 800 F for about 15 to 30 seconds. This grain can then be rolled. The moisture content by the heat treatment is reduced to less than 5%. Therefore, water is usually added to result in typical moisture content of around 12% for palatability purposes. This method results in about 50% of the kernels being popped. More complete popping of the grain may be achieved by subjecting the grain to high pressure steam in a closed chamber followed by a sudden decrease to atmospheric pressure.

This results in a rapid expansion of the grain. This method of popping the grain is called exploding.

Micronization has also been used to pop grain. The grain is passed through a chamber where gas-fired infrared generators supply the heat. The term comes from the fact that micro waves are emitted from infrared burners.

Extruded grain is produced by placing the grain into a tapered housing which contains a spiral screw. This spiral screw crushes the grain and forces it through an orifice. This produces a ribbon-like product and breaks into various shapes.

Roasting consists of passing dry whole grain through an enclosed revolving cylinder. Fins of the cylinder lift the grain through jets of flame that point downward. The roasted corn has a pleasant aroma with an oily, puffed and slightly caramelized appearance.

Corn, Sorghum Grain. Perry et al. (1970) stated that if corn grain is overcooked by steam heat the feeding value and palatability to beef animals are decreased. With this in mind, they investigated the use of dry heat for processing corn grain for finishing beef animals. It was found that animals fed roasted corn gained 12% more rapidly and required 10% less feed per unit of gain than those fed whole corn grain. Burroughs and Saul (1971) reported an improvement of 9% in average daily gain and 8% improvement in feed utilization over whole corn grain when fed in a high concentrate diet to finishing feedlot steers. It was observed in this study there was more benefit of the roasted corn during the early portion of the experiment but little difference in average daily gain in the latter stages of the experiment.

In experiments involving over 1,000 animals, Vetter, Burroughs and Mobley (1971) demonstrated an advantage of roasted corn over whole corn grain in average daily gain and feed efficiency in a 76% corn grain diet. However, cracking the whole corn grain resulted in superior feedlot performance. This could partly be explained on the basis of the age of the cattle, long yearlings or older. They suggested that the high temperature of processing appeared to change or alter the nutrient composition. Heat denaturation of protein with reduced solubility in the rumen could be an important nutrient change. A level of 16% gelatinization occurred by roasting corn grain under conditions of these Iowa experiments. Gelatinization of this degree has been reported to improve utilization of grain. However, best results were obtained with the cracked corn grain diet and no heat treatment or gelatinization had taken place.

An experiment to compare flaked, extruded and whole corn grain was conducted by Chapman and Matsushima (1970). Cattle fed extruded or whole corn gained faster than those fed the flaked grain. However, animals fed whole corn required about 8% more feed per unit of gain. In a digestibility study flaked corn had the highest digestion coefficients with whole corn grain having the lowest values. In a similar study by McLaren _et al_. (1970), cattle fed whole corn gained 5% faster than those fed extruded corn in a 95% concentrate diet. However, cattle fed extruded corn utilized the feed about 4% more efficiently. There was no difference in weight gain or feed efficiency between flaked or extruded corn grain when fed in an 85% concentrate diet.

One of the earlier reports on popping sorghum grain was by Ellis and Carpenter (1966). Dry rolled grain served as the control and 40% of the dry rolled grain was replaced with popped grain in the popped treatment and fed in a high concentrate diet. Popping the grain decreased intake but weight gain was only slightly less, resulting in about a 17% greater feed efficiency for the popped grain treatment. Durham, Ellis and Cude (1967) compared popping to steam processed flaked sorghum grain. They reported that popping the grain increased weight gain but with similar feed efficiency when compared to steam processed flaked sorghum grain.

In a steer feeding study using sorghum grain, Garrett (1968) compared popping to three steam processing methods. All grains were rolled after the various heat treatments. No differences in animal response or carcass value were noted among the treatments. The only major difference was decreased feed consumption for the steers receiving the popped grain.

Dry heat was used by Riggs, Sorenson and Hobgood (1970) to pop sorghum grain. When compared to dry rolled grain, dry heat treated grain showed significantly higher digestibility of dry matter, organic matter, nonprotein organic matter and nitrogen-free extract. There was no significant difference in fat, fiber or protein digestibility between the processing methods. They suggested that the lower intake generally associated with feeding popped grain is partially responsible for the greater efficiency of popped grains.

Exploded grain is similar to popped grain except that a larger percentage of the grain is ruptured. Nylon bag dry matter digestion studies with sorghum grain indicate that this product is highly digestible. Also, a rumen fermentation study performed by Algeo, Brannum and Hibbits (1968) showed that the exploded grain gave a higher level of total volatile fatty acids and a narrower ratio of acetate to propionate than did flaked sorghum grain. In a feedlot trial (Lofgreen and Dunbar, 1970), no differences were noted in nutritive value of sorghum grain processed by explosion or by properly steam processed flaked grain. It has been suggested by some authors that exploded sorghum grain has a decided advantage in quality control (consistency in the degree of processing) as compared to micronized, popped or steam processed flaked grains.

Arnett (1971) has conducted several experiments involving extruded sorghum grain. It was generally found that the response obtained by extrusion was similar to flaked grain. The process resulted in less intake and greater efficiency for the heat processing methods when compared to dry rolled sorghum grain. The extruded sorghum grain tends to have an excessive amount of fine materials which makes the diet less palatable. This was overcome in one experiment by injecting water into the extruding apparatus which resulted in increased consumption of the grain. Cattle fed grain treated in this way gained at a 5% faster rate with a slight improvement in feed efficiency as compared to extruded grain without the added water.

High Moisture Grains

Under certain conditions it may not be desirable or possible to leave the grain in the field until it is dry enough to be stored safely in conventional grain storage facilities. In grain, physiological maturity (the stage at which the grain contains maximum energy) is reached prior to the time the grain is sufficiently low in moisture to prevent spoilage during regular storage. If the grain is left in the field beyond this point, there will be drying provided that favorable climatic conditions exist. However, frequently there will be field losses if the grain is left in the field after physiological maturity is reached. If these field losses are to be avoided, the grain should be harvested and dried artificially or stored in the high moisture state.

With this harvesting advantage in mind, there has been considerable interest in the use of high moisture grains for livestock feeding. Initially, the use of ensiled high moisture grains was considered mainly as a means of utilizing a crop which would be difficult to harvest and store without artificial drying. As research advanced concerning the use of these high moisture grains, this system of storing grain has evolved into an important processing method. Research has been conducted not only with grains harvested with a high moisture content, but with dry grains to which water is added and ensiled. Grains processed in this manner are referred to as reconstituted high moisture grains.

Corn

The use of high moisture grains for beef cattle has been studied for many years. As early as 1904, Kennedy et al. (1904) concluded that soft corn containing 35% moisture was equal to mature corn on a dry basis for finishing steers. McCone et al. (1951) observed a 13% advantage in daily gain for soft ear corn (40% moisture) over mature dry shelled corn when fed to finishing beef steers. Beeson and Perry (1958) reported that fattening two-year-old steers and heifer calves utilized high moisture ground ear corn (32% moisture) from 10 to 15% more efficiently than regular ground ear corn. Cattle fed the high moisture diet also gained slightly faster. Culbertson et al. (1957) reported similar results with fattening beef cattle.

Burroughs et al. (1960) compared high moisture whole and dry rolled corn grain for growing-finishing steers. The steers fed dry or high moisture corn gained at approximately the same rates, but those receiving the high moisture corn were slightly less efficient in feed conversion. It was observed that an average of 21% of the corn kernels escaped digestion in this experiment even though the moisture content (35%) was sufficiently high that the kernels could be mashed between the fingers. These results indicate a need for rolling or grinding high moisture corn before feeding. The need for rolling high moisture corn when fed at 25 to 80% of the diet dry matter was also shown by Jordan, Mitchell and Neuman (1960), Hanke et al. (1967, 1968), and Newland, Klosterman and Johnson (1970).

A 4-year study comparing artificially dried rolled corn to rolled high moisture corn was reported by Self and Hoffman (1972). They reported that feeding ensiled high moisture grain as compared to dry grain to yearling steers as the main source of energy resulted in similar average daily gains when the roughage and protein components were of the same type for the two kinds of grain. For feeding purposes, the value of high moisture grains was greater than artificially dried grains. The increase in feed value was approximately 9%.

Dexheimer, Meiske and Goodrich (1971) reported that the improved feed efficiency for high moisture corn may not be as great as frequently reported because common procedures used to determine moisture may not be accurate for ensiled feeds. Dry matter content of feeds is usually determined by heating a sample of feed in an oven at a temperature below the boiling point of water. The water in the sample is driven off along with some volatile materials and the part of the sample remaining is considered dry matter. Since ensiled high moisture corn contains considerable amounts of volatile materials, dry matter contents of ensiled corn determined by oven drying are generally underestimated. They suggested a chemical determination of water for a more accurate moisture determination. With this in mind, the Minnesota workers conducted a trial to compare the performance of yearling steers fed ensiled high moisture or artificially dried shelled corn. They also studied the influence of these two systems of storing corn on dry matter losses during storage. Average daily gain and feed efficiency were improved 3.2% and 2.7%, respectively, for the cattle fed the high moisture corn. Dry matter losses during storage were 1.85% for dry corn and 2.81% for the ensiled high moisture corn that was stored in an oxygen-limiting silo. They concluded by stating that there was probably little basis for recommending high moisture ensiled corn because of improved energy utilization. However, to avoid drying costs, enable rapid and early harvesting and to save labor, the use of ensiled high moisture shelled corn was recommended.

Reconstitution is a process whereby water is added to dry grain and then ensiled. The result is reconstituted high moisture grain. Embry (1971) and Geasler and Vetter (1972) stated that reconstituted corn gives about the same animal performance as early harvested high moisture grain.

Martin et al. (1971) compared three methods of processing corn in a study conducted at Oklahoma. Cattle fed high moisture harvested corn gained slightly slower than those fed dry ground corn and cattle fed ground reconstituted corn gained slowest. Cattle fed either form of high moisture corn (natural or reconstituted) consumed less feed (12 to 15%) which resulted in improved feed efficiency (6 to 12%) in comparison to cattle fed the dry grain. They stated that these results are similar to previous work at the Oklahoma station. However, it should be noted that the high moisture corn was ground before being ensiled. It has been suggested that this will reduce the response obtained, especially with corn grain.

Baker (1971) conducted four feeding trials in which two involved early harvested high moisture corn or dry rolled grain and reconstituted high moisture or dry rolled grain were compared in the other two. The diet was composed of about 65% corn, 20% roughage and the remainder being supplemental feeds. Cattle fed high moisture corn gained 18% faster, consumed 4% more feed and were 12% more efficient than those cattle receiving rolled dry corn. In comparisons between trials, it appeared that the response obtained by high moisture corn was greatest when reconstituted corn was fed as opposed to the early harvested grain.

Sorghum Grain

Sorghum grain is a major grain source for feeding cattle in the Southwestern United States. The unprocessed grain is poorly utilized by cattle, but seems to be improved by various processing methods as noted earlier. Another method by which the utilization of sorghum grain by cattle can be improved is by high moisture harvesting or reconstitution (McGinty and Riggs, 1967; Parrett and Riggs, 1967; Buchanan-Smith et al., 1968).

Riggs and McGinty (1970) conducted a series of tests comparing the effects of feeding ground moist and ground dry sorghum grain on feedlot performance of beef cattle. In the seven feedlot trials (three of which utilized reconstituted grain), daily gain was similar as for dry ground grain. The grain content of the diets varied between experiments from a low of 21% to a high of 91%. In all experiments, animals fed high moisture grain consumed slightly less feed. This resulted in improved efficiency for the cattle receiving the moist grains. The advantages, calculated as a percent of the efficiency for cattle fed dry grain, amounted to 19% for the grain portion and 11% for the total diet.

Riggs and McGinty (1970) also conducted two digestion trials to compare reconstituted ground and ground dry sorghum grain. The digestibility of all components of reconstituted grain was significantly higher than for dry grain, approximately 16% for protein and 29% for all other components for the first trial. The second trial showed similar trends.

They stated that the improvement in digestibility of grain agrees with the reduction in grain dry matter required per unit of gain observed in the feeding experiments. Riggs and McGinty also stated that reconstituting sorghum grain increased the digestibility of the nonprotein fractions to approximately the same extent as Hale et al. (1966) obtained by steam flaking. McNeill et al. (1971) and Potter et al. (1971) reported that the digestibility of starch and protein from sorghum grain processed by reconstitution or by steam flaking is similar.

The improvement in digestibility may be due to alteration of the starch molecules, but the improvement in digestibility of protein by reconstitution suggests that the protein matrix which encapsulates the starch may also be altered. In dry grain this encapsulation may partially shield the starch molecules from amylolytic enzymes produced by both the microflora and by the animal. Another factor of importance is that moist grain, whether early harvested or reconstituted, tends to grind to a finer particle size than dry grain through the same screens in a hammer mill (Florence, Riggs and Potter, 1968). The more complete physical breakdown coupled with improved digestibility of the protein matrix may contribute additively to the increased digestibility of nonprotein organic matter in ground moist sorghum grains (Riggs and McGinty, 1970).

The Oklahoma station has done considerable work to determine the optimum moisture content of high moisture sorghum grain, the storage period required for improved results and if the grain should be whole or ground prior to reconstitution (White et al., 1969; White and Totusek, 1969; White et al., 1969b; Wagner and Schneider, 1970; Martin et al., 1971). For best results with reconstituted sorghum grain the research indicated that the grain should be reconstituted whole and then ground prior to feeding. However, if early harvested grain is being used it may be ground before being ensiled. The optimum ensiling time and moisture content appears to be at least 20 days and 30%, respectively. Higher moisture is not detrimental nor is longer storage time but shorter time and less water appears to be detrimental. Similar recommendations are given by Hale et al. (1969).

Barley

Research on harvesting, storing and feeding of high moisture barley has been summarized by Krall (1969) and Windels (1971). The advantages for harvesting barley at a high moisture is similar to that of other grains. The earlier harvesting is less affected by advance weather conditions resulting in less field loss, the possibility of less labor being required and better weed control.

From a series of finishing beef cattle feeding trials with yearling steers, Krall (1969) stated that high moisture barley has definite possibilities as a feed grain for fattening cattle but that the advantage does not lie in better weight gains or feed efficiency. However, in these trials there was a slight improvement in rate of gain in favor of the high moisture barley but with similar feed efficiency as for the dry rolled grain. The chief advantage of high moisture barley appeared to be in its high acceptability with animals going on feed faster and resulting in greater gains earlier in the feedlot. The problems associated with dry barley in respect to cattle going off-feed were not encountered with high moisture (either early harvested or reconstituted) barley.

As with sorghum grain, high moisture barley should be rolled prior to feeding. Also when reconstituting barley, the grain should be in the whole form for best results.

Windels (1971) and Krall (1969) also stated that cattle fed rolled high moisture barley tend to grade better when compared to cattle fed dry rolled barley. Generally, feed grain processing methods do not influence the carcass grade unless a pronounced difference is noted in the final weight of the animals. This difference in carcass grade may be due to greater acceptability and gains during the early portion of the feeding period of cattle fed high moisture barley.

Summary of Grain Processing Methods

After reviewing the literature, there appears to be no processing method that is superior for all grains. Of all the feed grains, corn appears to respond to grain processing methods the least. In fact, whole corn grain may be advantageous in high energy diets. This may be due to already high digestibility and palability of corn. All other grains should be processed in some manner for most efficient utilization.

Sorghum grain, with its relatively hard seed coat, appears to respond to the more sophisticated processing methods. Dry rolling or grinding sorghum grain improves the value when compared to the whole grain but the use of heat, such as steam flaking and micronizing generally increases the value over rolling or grinding. High moisture sorghum grain gives about the same response as does the heat treated grains.

Wheat appears to be benefited most by rolling or grinding. Further heat treatment does not appear to be justified when wheat is fed to beef feedlot animals. Barley also does not appear to be benefited by heat treatment. High moisture barley fed cattle tend to present less management problems than when cattle are fed dry barley.

The best method of processing grain for beef cattle would appear to depend upon each individual operation. A farmer-feeder may prefer high moisture grain for the reasons mentioned previously while the large commercial feedlot may be able to justify a more expensive piece of equipment that would steam flake or micronize the grain.

GENERAL PROCEDURES

Considerable interest has been shown concerning the effects from processing grain when fed to beef cattle. Recent research has shown favorable results in many instances from whole corn grain in comparison to corn processed in various ways. Feeding of dry whole corn would appeal to cattle feeders because of the time and expense involved in grain processing. While unprocessed corn grain has been fed with satisfactory results, questions still remain as to the effect various types, sources and levels of roughage may have on feedlot performance when unprocessed grain is fed. This series of experiments was conducted with beef animals to compare the value of unprocessed or rolled dry or high moisture corn grain when fed with various levels of hay, haylage or corn silage.

All experiments were conducted at the Brookings' station of South Dakota State University and utilized Hereford steers as the experimental animals. The cattle were weighed for an initial filled weight and allotted at random to experimental treatments after stratifying on basis of this weight. Initial shrunk weights were taken after withholding feed and water for about 18 hours. Intermediate weights were taken at approximately 4-week intervals during the course of the experiment. Final shrunk weights were taken after feed and water were withheld for about 18 hours. Weight gains for the experiment were calculated on basis of initial and final shrunk weights.

The cattle were fed once daily in fence-line feed bunks in amounts to provide available feed at all times. The pens were paved with concrete but without shade or shelter.

Reconstituted corn, stored in an oxygen-limiting silo, was used in all experiments for the high moisture corn. The high moisture corn was from the same source as the dry corn within each experiment. Rolling of both the dry and high moisture corn was just prior to feeding with that fed whole or rolled coming from the same storage supply. A roller mill having corrugated rollers 10 inches in diameter with about 10 corrugations per inch was used to roll both types of grain. The dry grain was rolled to a medium degree of fineness, while the high moisture grain was rolled to produce a flattened kernel with a minimum of fine material.

Feed samples were taken at regular intervals and used for moisture and other chemical determinations. Dry matter was determined in a forced-air oven at a temperature of about 175 F. All other chemical analyses were performed in accordance with A.O.A.C. (1960) methods. Statistical analyses were conducted by the least-squares method.

Carcass data were collected about 20 hours after slaughter. A government grader placed the conformation, quality and overall carcass grade on each animal along with other additional carcass parameters obtained. Upon slaughter, the livers were examined for abscesses.

Experiment 1--Processing Methods for Dry and Reconstituted High Moisture Corn for Finishing Beef Cattle

One hundred-twenty Hereford yearling steers averaging about 845 lb. were used in this 111-day experiment conducted from September to the end of December. Corn grain was fed in the following forms: 1) dry and unprocessed, 2) dry and rolled, 3) high moisture and unprocessed, 4) high moisture and rolled and 5) steam processed flaked. Each of the 5 treatments was replicated 3 times, giving 15 pens with 8 steers per pen.

A quantity of artificially dried corn (13.9% moisture) sufficient for all treatments was purchased prior to the experiment. Initial quality of the corn and the handling involved resulted in an excessive amount of fine particles. Samples of the corn were dried to a moisture-free basis and put through a series of sieves with shaking until constant weights were obtained on each sieve. The results of the sieving showed that the corn contained about 5% fines (particles passing through a wire mesh opening of 0.157 in) with about another 25% consisting of small or cracked kernels. The test weight of the corn was approximately 52 lb per bushel.

Reconstituted corn was produced by adding water to dry corn grain at several places in a series of augers and then elevated into the oxygen-limiting silo by use of a silage blower. Average moisture as fed was 27.4% which was about the maximum amount of water that could be added without considerable loss at the blower or from the silo. Some grinding occurred from the unloader and the unprocessed high moisture grain contained a considerable quantity of fine material.

The flaked corn was processed at approximately 2-week intervals. The corn grain was exposed to a temperature of 200 to 210 F for 18 to 20 minutes prior to rolling with a roller setting of 0.004 inch. Weight of the flaked grain averaged 27 lb per bushel and moisture content as fed averaged 16.8%.

For the 4-week period before the initiation of the experiment the animals were fed 10 lb rolled corn grain plus alfalfa-brome hay to appetite. All cattle were started on the experiment with 8 lb of the appropriate corn treatment and 10 lb chopped alfalfa-brome hay per animal daily. The hay contained 13% protein with the moisture content averaging 16.2%. The corn was increased 1 lb per head daily for 5 days and then at 0.5 lb increments until feed was available in the bunks at all times after about 8 days. Hay was decreased by 1 lb per head daily until a level of 2 lb per head per day was reached and then maintained at this level during the remainder of the experiment. A 32% protein supplement composed of corn and soybean meal with 5% urea was fed at 2 lb per head daily. Vitamin A and diethylstilbestrol were added to supply 20,000 IU and 10 mg per head daily, respectively.

The experiment was terminated after 111 days with considerable snow and extremely cold weather during the final 3 weeks. Carcass data were collected on all steers at slaughter time.

Experiment 2--Dry and High Moisture Corn Fed Whole or Rolled With Two Levels of Haylage in Cattle Finishing Diets

One hundred twenty-eight Hereford yearling steers were used in this 142-day summer experiment. They were purchased from an auction market and fed a diet composed of 10 lb of alfalfa-brome hay and 5 lb rolled corn grain for a period of 30 days prior to the initiation of the experiment.

Experimental diets were dry and high moisture corn grain fed whole or rolled with 2 or 8 lb of alfalfa-brome haylage (wet basis). Each of the 8 treatments was replicated 2 times with 8 steers per pen. Steam processed flaked corn grain was not included in this experiment due to a lack of response in experiment 1 and also to the time and expense involved in obtaining the product.

Average moisture contents for the dry and high moisture grain were 13.1 and 29.7%, respectively. The high moisture corn was from the same source as the dry corn with water added and stored in an oxygen-limiting silo. The corn was elevated into the structure by use of an auger with water being added at several points. This process of using a single long auger in lieu of a series of augers and a silage blower proved to be a more rapid and easier method of reconstitution for corn grain.

The alfalfa-brome haylage used in this experiment was field chopped. It was cut and swathed on May 31 when in the bud stage. Cool and cloudy weather with some rain prevented chopping and storing for 5 to 6 days. The haylage was stored in a concrete stave silo at an average of 39.4% moisture and it contained 16.6% protein on a dry basis.

The cattle were fed 2 or 8 lb of haylage throughout the experiment. Dry or high moisture grain was fed at 10 or 12 lb, respectively, per head the first day. The grain was increased 1 lb per head daily for 5 days, then 0.5 lb per head daily until the cattle were on full feed.

A 32% protein supplement was fed at 1 lb per head daily with 8 lb of haylage and at 2 lb with 2 lb of haylage. The supplement was a soybean meal-corn-urea type supplement with added minerals and with diethystilbestrol and chlortetracycline to furnish 10 mg and 70 mg, respectively, per head daily. Vitamin A was added to furnish 10,000 or 20,000 IU per head daily for diets with 8 lb or 2 lb of haylage. Urea was included at 6% or 3% in the supplements fed at 1 and 2 lb, respectively, in order to give the same daily intake of urea for all cattle.

The experiment was terminated after 142 days. Data were obtained as for experiment 1 with additional evaluation of certain rumen characteristics.

Experiment 3--Dry and High Moisture Corn Fed Whole or Rolled With Hay or Haylage in Cattle Growing Diets

One hundred twenty-eight steer calves were used in this experiment. The experiment started on February 4 and terminated after 161 days. Experimental diets were dry or high moisture corn grain fed whole or rolled. Each of the four grain treatments was replicated two times with alfalfa-brome hay or reconstituted haylage using eight steer calves per pen.

The dry corn contained an average of 13.8% moisture. The high moisture corn was from the same source with water added resulting in an average moisture content of 28%. The corn was stored in an oxygen-limiting silo and was reconstituted in a manner similar to that described for experiment 2.

The hay (16.2% protein) was a baled alfalfa-brome mixture and chopped with a forage harvester as needed. The average moisture content was 17.4%. Haylage was reconstituted from the same source of baled hay. It was chopped with a forage harvester and blown into an oxygen-limiting silo. Water was added at the forage harvester and at the blower resulting in a final moisture content of 40.8%.

All cattle were fed corn grain at 1% of body weight with an adjustment being made for the high moisture grain so the air-dry matter offered would be the same as for the dry corn. Adjustments in levels offered were made every 4 weeks on basis of average weights for each treatment group.

Hay or haylage was fed to appetite. The levels consumed were considered to furnish an ample amount of protein and no protein supplement was fed. Dicalcium phosphate and trace mineral salt were offered free choice. Vitamin A was fed at 500,000 IU per head once every 28 days in 1 lb of ground corn grain. The steers were implanted with 24 mg of diethystilbestrol at the beginning of the experiment and again with 36 mg after 112 days.

Experiment 4—Dry and High Moisture Corn Grain Fed Whole or Rolled With Hay or Haylage in Cattle Finishing Diets

The one hundred twenty-eight yearling steers used in this experiment were the same animals that were utilized as calves in experiment 3. The experiment was conducted from mid-July to the end of October. Allotment of the cattle to this high energy diet was without regard to the previous growing experiment. They were randomly allotted after stratifying on basis of weight. Experimental diets were dry or high moisture corn grain fed whole or rolled with alfalfa-brome hay or reconstituted haylage. Each of the eight treatments was replicated twice with eight animals per pen.

The dry corn contained an average of 12.0% moisture. The high moisture corn was from the same source with water added, resulting in an average moisture content of 21.9%. The same procedure for reconstitution and storage of the corn was used in this experiment as discussed for experiment 2. This method had been used other times to obtain grain with about 28% moisture. However, the moisture content was less this time.

The hay (15.9% protein) was a baled alfalfa-brome mixture and chopped with a forage chopper. The average moisture content was 13.0%. Haylage was reconstituted from the same source of baled hay. It was chopped in the same manner as the dry hay and stored in an oxygen-limiting silo. Water was added at the forage chopper and at the blower resulting in the moisture content averaging 48.4%.

About 2 weeks were used to change from the previous high roughage diet to the high concentrate diet. After this time all cattle were fed hay or haylage at the rate of about 1.5 lb dry matter per head daily with the appropriate type of corn being fed to appetite. A 32% protein supplement was fed at the rate of 2 lb per head daily. The supplement was a soybean meal-corn-urea type with added chlortetracycline and vitamin A to furnish 70 mg and 20,000 IU, respectively, per head daily. Urea was included at 3% of the supplement. The cattle had been implanted with 36 mg of diethylstilbestrol about 50 days prior to the initiation of this experiment. Therefore, diethylstilbestrol was not fed or implanted during this experiment.

The experiment was terminated after 105 days. Carcass data were obtained and livers and rumens were examined for abnormalities.

Experiment 5--Dry and High Moisture Corn Fed Whole or Rolled With Corn Silage in Cattle Growing-Finishing Diets

One hundred twenty-eight Hereford steer calves were used in this experiment. They were purchased at a livestock auction on December 31. From arrival at Brookings the following day and until the experiment was started 5 days later, they were fed about 10 lb of alfalfa-brome hay per head daily. Experimental treatments were dry or high moisture corn grain fed whole or rolled with a limited amount of corn silage.

The level of corn silage (71.2% moisture stored in a concrete stave silo) was set at 20 lb per head daily for the first 147 days. At this time, the original supply of silage was depleted and the silo was refilled with corn silage that had been stored in a pile without packing or cover. It had undergone extensive heat damage from fermentation and was rather dry (37.7% moisture). The level of this silage was reduced to 10 lb per head daily for the remainder of the experiment. The level of the drier silage resulted in nearly the same dry matter of corn silage intake as from the 20 lb fed the first 147 days.

The dry corn contained an average of 14.1% moisture and the high moisture corn 25.7%. The high moisture corn was stored in an oxygen-limiting silo and was reconstituted in a manner similar to that discussed in experiment 2.

Diethylstilbestrol, chlortetracycline and vitamin A were included in the supplemental protein to furnish 10 mg, 70 mg and 20,000 IU per head daily, respectively. Dicalcium phosphate and trace mineral salt were offered free choice.

The experiment was terminated after 230 days. Data were obtained as for experiment 4.

Experiment 6—Digestibility of Dry and High Moisture Corn Fed Whole or Rolled in a Beef Cattle Growing Diet

Twelve Hereford steers averaging about 775 lb were used in this digestion study. The cattle were kept indoors in individual metabolism crates. Experimental diets were dry and high moisture corn grain fed whole or rolled with reconstituted haylage. Parameters used to measure the effects of reconstitution and rolling corn grain included apparent digestibility of dry matter, gross energy and protein.

Feed consumption (dry matter) was limited to 2.5% of body weight of which 40% was haylage and the remainder being the appropriate corn. The high moisture corn and haylage were reconstituted in a manner similar to that discussed previously. The dry corn, high moisture corn and haylage averaged 13.6, 23.5 and 42.4% moisture content, respectively.

Prior to the experiment all steers were gradually adapted to a 60% concentrate diet. Three steers were then randomly assigned to each of the four grain preparation treatments. A period of 18 days was then allowed to adjust the animals to the diets, which were fed twice daily. Following each collection period, the steers were randomly reallotted without regard to previous treatment.

After each 14-day adjustment period, total fecal collections were made daily for 5 days. Pans were used to collect the fecal material. A 10% sample of the feces was taken at each collection and was frozen until analyses were performed. Dry matter was determined on both the feeds and feces by drying in a forced-air oven at about 175 F. Other chemical analyses of the digestion trials were in accordance with A.O.A.C. (1960) procedures. Statistical analysis of the digestion trials was by the least-squares method.

Experiment 7—Digestibility of Dry and High Moisture Corn Fed Whole or Rolled in Cattle Finishing Diets

Twelve Hereford male animals weighing about 640 lb were used in this digestion trial. In this trial the roughage was limited to 7% of the diet dry matter with the four types of corn grain as discussed in experiment 6 comprising the other 93% of the diet dry matter. Hay was used as the roughage source in 2 periods and reconstituted haylage, from the same source as the dry hay, was used in the other 2 periods. This allowed comparisons between moisture content of the roughage with all corn grain processing methods utilized in the experiment. The moisture content for the dry corn, high moisture corn, hay and haylage averaged 13.4, 22.4, 12.5 and 57.3%, respectively.

In this trial apparent gross energy digestibility was not determined. This was due to similar apparent digestion trends of gross energy and dry matter in experiment 6. Procedures used in this experiment were similar to those employed in the previous digestibility study.

RESULTS

Experiment 1—Processing Methods for Dry and Reconstituted High Moisture Corn for Finishing Beef Cattle

Results of feeding dry and high moisture corn grain either whole or rolled and steam processed flaked corn grain to beef cattle in high energy diets are shown in table 1. Weight gain and feed efficiency data from the experiment indicated some differences between corn processing treatments at 85 days and at 111 days when the experiment was terminated. Since differences in treatment effects at these two times probably can be attributed to cold weather and a considerable amount of wind during the final 3 weeks of the experiment, weight and feed data are shown for the 85-day period as well as for the 111-day experiment. For the 111-day experiment, steers fed the dry corn, either unprocessed or rolled, gained at a faster rate ($P < .05$) than steers fed the high moisture rolled corn. However, at 85 days under more favorable weather, differences in weight gain between dry and high moisture corn were small. It would thus appear that steers fed the high moisture corn were affected more by cold weather than those fed dry corn.

There was no advantage on basis of weight gain for rolling the corn grain. In fact, those animals receiving the unprocessed grain, either dry or high moisture, appeared to gain at a faster rate than did those receiving the rolled grain. Also, steam processed flaked corn had no advantage on basis of weight gains over dry corn, either unprocessed or rolled. Some complaints were received from the flaking processor regarding the quality of the corn and the amount of fines for this type

TABLE 1. PROCESSING METHODS FOR DRY AND RECONSTITUTED HIGH MOISTURE CORN FOR FINISHING BEEF CATTLE

(Sept. 10 to Dec. 30, 1968--111 Days)

	Dry		High Moisture		Steam Processed
	Unprocessed	Rolled	Unprocessed	Rolled	Flaked
Number of steers	24	24	24	24	24
Init shrunk wt, lb	841	844	847	846	841
Final shrunk wt, lb	1136	1128	1117	1098	1118
Avg daily gain, lb					
85 day, filled wt	3.20	3.13	3.17	3.07	3.13
111 day, shrunk wt	2.66	2.55	2.44	2.27	2.49
Avg daily feed, (air-dry), lb					
85 day	22.8	21.9	21.8	21.1	21.6
111 day	23.2	22.0	21.7	21.1	21.5
Feed/100 gain, (air-dry), lb					
85 day, filled wt	714	699	689	689	690
111 day, shrunk wt	874	863	890	929	863
Dressing percent	59.4	59.6	60.5	59.3	59.2
Marbling[b]	5.6	6.4	5.9	5.9	5.7
Carcass grade[c]	19.2	19.5	19.2	19.2	19.5
Fat covering, in	0.70	0.68	0.67	0.63	0.63
Rib-eye area, sq in	12.23	11.49	12.05	11.58	11.47

[a] Stored at about 27.4% moisture in a Harvestore, A. O. Smith Corp.
[b] Modest = 6; Small = 5.
[c] Choice = 20; Low Choice = 19.

of processing. However, the corn was rather typical of that available in the area at the time of the experiment.

Feed consumption data shows a good feed intake from all corn treatments and there were no apparent digestive problems encountered during the experiment. More dry matter was consumed by steers fed dry corn in comparison to high moisture corn, with the steers fed the dry whole corn consuming the greatest amount ($P < .01$). Rolling either the high moisture or dry corn resulted in a slightly lower feed consumption. Steers fed the flaked also had a lower feed intake in comparison to those fed dry corn. Steers fed dry corn showed slightly higher feed intake at 111 days than at the 85-day period. Apparently consumption of the dry corn was affected less by adverse weather conditions.

There were only small differences in feed efficiency between corn processing treatments at the end of the experiment, being slightly higher for the steers fed the rolled high moisture corn. Rate of gain was somewhat higher at 85 days and feed requirements were lower at this time. Gains and feed efficiency at this time were very similar to those of other cattle marketed at about the time of the 85-day period which had been on feed a longer period of time and were heavier and more highly finished. Weight gain and feed efficiency at the 85-day period probably represent more typical performance from the treatments under more favorable environmental conditions than do the values at 111 days. Feed required per unit of gain was similar for all treatment groups at 85 days, being slightly higher for steers fed the unprocessed dry corn. In this instance, the feed requirement was about 3.4% higher than for the other treatments.

The cattle graded low to average Choice, and there was only small differences between treatment groups in dressing percent and carcass grade. Differences for degree of marbling and fat covering were also small.

Results of the experiment indicate that reconstituted high moisture corn grain was similar to dry grain except under conditions of cold weather near the end of the experiment. Rolling or flaking the corn grain showed no advantage in comparison to the unprocessed grain on basis of feedlot performance when the corn grain was full fed with 2 lb of hay. Actually the unprocessed corn grain, either dry or high moisture, appeared to promote faster gains than did the rolled grains.

Experiment 2--Dry and High Moisture Corn Fed Whole or Rolled With Two Levels of Haylage in Cattle Finishing Diets

Results of feeding dry and high moisture corn grain either whole or rolled with 2 or 8 lb of haylage in cattle finishing diets are shown in table 2. Gains appeared to be greater for steers fed dry corn in comparison to the high moisture grain. Grain dry matter consumption and consequently total feed intake was also greater with dry grain. The lower feed intake associated with lower rates of gain for the animals receiving high moisture grain resulted in only small differences in feed efficiency between dry and high moisture corn.

With whole grain, steers fed dry corn appeared to gain at a faster rate than those fed high moisture grain. Gains were reduced by the higher level of haylage by about the same amount for dry and high moisture grain except with rolled high moisture corn. In this instance, the higher level of haylage promoted faster gains than did the low

TABLE 2. DRY AND HIGH MOISTURE CORN FED WHOLE OR ROLLED WITH TWO LEVELS OF HAYLAGE IN CATTLE FINISHING DIETS

(June 10 to October 30, 1969—142 Days)

	Dry Corn				High Moisture Corn[a]			
	Whole		Rolled		Whole		Rolled	
	2 lb Haylage	8 lb Haylage	2 lb Haylage	8 lb Haylage	2 lb Haylage	8 lb Haylage	2 lb Haylage	8 lb Haylage
Number of animals	16	16	16	14	16	16	16	16
Init shrunk wt, lb	652	654	646	646	654	641	644	657
Final shrunk wt, lb	1154	1136	1151	1095	1123	1091	1085	1129
Avg daily gain, lb	3.54	3.39	3.55	3.16	3.30	3.16	3.10	3.33
Avg daily diet (air-dry), lb								
Corn	19.06	17.92	19.48	17.58	17.81	17.16	16.76	16.67
Haylage	1.39	5.54	1.39	5.71	1.39	5.54	1.39	5.54
Supplement	1.89	0.94	1.89	0.97	1.89	0.94	1.89	0.94
Total	22.34	24.40	22.76	24.26	21.09	23.64	20.04	23.15
Feed/100 lb gain (air-dry), lb								
Corn	540	528	549	555	539	535	540	502
Haylage	39	163	39	180	42	174	44	166
Supplement	54	28	53	31	57	30	61	28
Total	633	719	641	766	638	739	646	696
Dressing percent	61.3	61.7	62.1	61.2	62.7	62.5	63.3	62.6
Carcass grade[b]	19.4	19.9	20.1	19.8	19.8	20.0	19.6	20.1
Papillae matting[c]	1.6	1.3	1.6	1.3	2.4	1.6	2.8	1.4
Thickness of rumen wall[c]	1.4	1.3	1.6	1.3	2.1	1.4	2.5	1.6
Hair accumulation[c]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Color[d]	1.2	1.7	1.3	1.5	2.6	2.0	2.2	2.2
Condemned livers	0	1	1	0	2	0	1	2

[a]Stored at about 29.7% moisture in a Harvestore, A. O. Smith Corp.
[b]Good = 17; Choice = 20. Graded to one-third of a grade.
[c]1 = Normal condition. Higher number represents an increase in the characteristic.
[d]Higher number represents a darker color.

level. Grain dry matter consumption was less for the steers fed high moisture corn, with this effect being less for the higher level of haylage.

With rolled grain and 2 lb of haylage, steers fed dry corn tended to gain at a faster rate (14.5%) than those fed high moisture corn, although not significant in this experiment ($P > .05$). With 8 lb of haylage, steers fed high moisture corn appeared to gain at the fastest rate. Grain dry matter consumed was reduced 1.9 lb by the higher level of haylage with dry corn but was essentially unchanged with high moisture corn. This resulted in similar feed efficiency for dry and high moisture corn at 2 lb of haylage, but 10.6% ($P > .05$) less grain was required when feeding high moisture corn with 8 lb of haylage.

Steers fed 8 lb haylage gained at a lower rate than those fed 2 lb haylage except when fed rolled high moisture corn. The higher level of haylage reduced grain dry matter consumption, with the effect being greater for dry corn in comparison to rolled grain. Grain and supplement saved per 100 lb of air-dry haylage amounted to about 31, 11, 23 and 59 lb, respectively, for dry whole, dry rolled, high moisture whole and high moisture rolled grain. These values indicated rather low returns for the higher level of haylage in comparison to the lower level except when fed with high moisture rolled grain.

Dressing percent was higher for the steers fed high moisture grain. Rolling of grain or level of haylage did not appear to have a consistent effect on dressing percent. There also did not appear to be a consistent effect of the treatments on carcass grade.

Upon slaughter, rumens were examined for papillae clumping, thickness of rumen wall, hair accumulation and color. Clumping of papillae, thickness of rumen wall and accumulation of hair were scored from 1 to 4 with 1 representing normal conditions. Color was scored from 1 to 3 with 1 representing a lighter color. While these scores are very subjective, they give some indication of the changes brought about by the diets.

There appeared to be only small differences in the rumen characteristics studied between animals fed rolled and whole corn grain. There were only small differences between dry and high moisture corn with the higher level of haylage. With the lower level of haylage, there was more clumping of rumen papillae and a thickening of the rumen wall with the high moisture grain. Cattle fed high moisture grain also had darker rumens.

As would be expected, cattle fed the higher level of roughage had higher daily feed intake ($P < .05$) and required more feed per unit of gain ($P < .01$). Results also indicated an advantage for dry corn over high moisture corn except when high moisture corn was rolled and fed with 8 lb haylage. This was the only treatment where there appeared to be any benefit by rolling the corn grain.

Experiment 3--Dry and High Moisture Corn Fed Whole or Rolled With Hay or Haylage in Cattle Growing Diets

Results of reconstitution and rolling as compared to dry whole corn grain when fed with about 65% hay or haylage to beef cattle are shown in table 3. Cattle fed high moisture grain gained an average of 0.16 lb (8.2%) more daily ($P < .01$) than those fed dry grain. The highest rate

TABLE 3. DRY AND HIGH MOISTURE CORN GRAIN FED WHOLE OR ROLLED WITH HAY OR HAYLAGE IN CATTLE GROWING DIETS

(February 4 to July 16, 1970—161 Days)

	Dry				High Moisture[a]			
	Whole		Rolled		Whole		Rolled	
	Hay	Haylage	Hay	Haylage	Hay	Haylage	Hay	Haylage
Number of steers	16	16	16	16	16	16	16	16
Init shrunk wt, lb	505	511	508	509	509	508	504	504
Final shrunk wt, lb	803	836	818	835	833	844	836	871
Avg daily gain, lb	1.85	2.01	1.92	2.03	2.01	2.08	2.06	2.28
Avg daily feed (air-dry), lb								
Corn	6.81	7.01	6.96	7.03	7.01	7.05	7.04	7.23
Hay or haylage	11.92	13.19	11.94	13.67	11.68	13.35	11.87	13.80
Total	18.73	20.20	18.90	20.70	18.69	20.40	18.91	21.03
Feed/100 lb gain (air-dry), lb								
Corn	367	349	361	347	348	338	342	317
Hay or haylage	643	656	619	675	581	641	578	605
Total	1010	1005	980	1022	929	979	920	922

[a]Stored at about 28% moisture in a Harvestore, A. O. Smith Corp.

of gain and the greatest advantage for the high moisture grain occurred when the grain was rolled and fed with haylage. Feed consumption on an air-dry basis was about the same for cattle fed dry or high moisture grain. Feed requirements were less for steers fed the high moisture grain ($P < .05$) with the lowest feed requirements being obtained when it was rolled.

When grain was rolled, rate of gain was improved for both dry and high moisture grain ($P < .05$). However, differences were relatively small between rolled and whole grain except for high moisture grain fed with haylage. In this instance, gain was 0.20 lb (9.6%) more daily with 5.8% lower feed requirements.

Steers fed the reconstituted haylage gained at a faster rate in all comparisons ($P < .01$). The average, in favor of haylage, amounted to 0.14 lb (6.6% daily). The greatest advantage in favor of haylage occurred when fed with rolled high moisture grain, (10.7%). More air-dry matter was consumed from haylage than from hay (13.5 vs. 11.8 lb). The difference was significant ($P < .05$) and resulted in 34 and 37% air-dry grain in the diets with haylage and hay.

Feeding of hay or haylage had essentially no influence on feed requirements when the corn grain was fed with rolled high moisture or whole dry grain. However, the requirements were lower with the high moisture grain as compared to the dry grain. The main differences in these instances were lower amounts of grain and higher amounts of forage for haylage diets. In view of similar total feed requirements, the increase in forage in the haylage diets was replacing approximately equal amounts of grain in comparison to the hay diets on basis of feed required per 100 lb of gain. Results were somewhat different when hay or haylage was fed with whole high moisture or rolled dry grain. In these instances, total feed requirements were lower for hay diets. While more forage and less grain were required in haylage diets, the greater forage requirements had less effect on grain requirements than with rolled high moisture and whole dry grain.

In general, the animals receiving this growing diet benefited more from the corn grain processing methods than did animals receiving a higher energy diet in previous experiments. Reconstitution of both the dry grain and hay resulted in consistent improvement in average daily gain. Reconstitution of the grain also improved feed efficiency when compared to the dry grain. Rolling of the dry corn appeared to be less beneficial than rolling high moisture corn when measured by gain and feed efficiency.

Experiment 4--Dry and High Moisture Corn Grain Fed Whole or Rolled With Hay or Haylage in Cattle Finishing Diets

The reconstitution procedure used in this experiment was similar to that utilized in experiments 2, 3 and 5. In these other experiments there was no problem in attaining a moisture content of the corn grain of about 28%. However, for some reason the reconstituted high moisture corn contained only 21.9% moisture in this experiment.

Table 4 shows the results of feeding dry and high moisture corn grain either whole or rolled with limited amounts of hay or haylage to finishing beef cattle. Average daily gain for cattle fed dry corn was about the same as for those fed the high moisture grain. Differences that existed among various forage and grain preparation treatments

TABLE 4. DRY AND HIGH MOISTURE CORN GRAIN FED WHOLE OR ROLLED WITH HAY OR HAYLAGE IN CATTLE FINISHING DIETS

(July 16, to October 29, 1970—105 Days)

	Dry Corn				High Moisture Corn[a]			
	Whole		Rolled		Whole		Rolled	
	Hay	Haylage	Hay	Haylage	Hay	Haylage	Hay	Haylage
Number of animals	16	16	16	16	16	16	16	16
Init shrunk wt, lb	828	818	823	819	829	821	817	818
Final shrunk wt, lb	1109	1087	1094	1111	1105	1103	1096	1107
Avg daily gain, lb	2.66	2.55	2.58	2.78	2.62	2.68	2.65	2.75
Avg daily feed, lb (air-dry)								
Corn	20.12	18.99	18.55	19.14	18.96	18.97	18.62	18.73
Hay or haylage[b]	2.67	2.34	2.64	2.44	2.62	2.35	2.60	2.41
Supplement	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
Total	24.81	23.35	23.21	23.60	23.60	23.34	23.24	23.16
Feed/100 lb gain, lb (air-dry)								
Corn	754	744	718	689	722	706	702	680
Hay or haylage	100	91	102	87	99	91	98	88
Supplement	76	79	78	72	77	75	76	73
Total	930	914	898	848	898	872	876	841
Dressing percent	62.0	63.0	62.6	62.7	62.1	62.7	63.0	62.5
Conformation[c]	21.0	21.0	21.3	21.3	21.1	21.3	21.3	21.2
Marbling[d]	4.9	5.5	5.4	4.8	5.3	5.4	5.2	5.6
Carcass grade[c]	18.7	19.6	19.1	18.6	19.1	19.1	19.0	19.5
Kidney fat, %	2.8	3.2	3.0	2.8	2.9	3.0	2.9	3.4
Color[e]	1.6	3.3	1.5	3.3	1.8	3.5	2.4	3.3
Matting[f]	1.2	1.5	1.2	1.5	1.2	1.3	1.5	1.5
Hair[f]	1.0	1.0	1.0	1.0	1.0	1.4	1.0	1.0
Papillae development[f]	2.9	2.5	2.5	2.8	2.6	2.6	2.5	2.5
Abscessed livers	2	2	6	5	5	1	4	6

[a]Stored at about 21.9% in a Harvestore, A. O. Smith Corp.
[b]Includes hay or haylage required to get animals on higher concentrate diet.
[c]Good = 17; Choice = 20. Graded to one-third of a grade.
[d]Slight, 4; small, 5; modest, 6.
[e]Higher number represents a darker color.
[f]1 = normal conditions. Higher number represents an increase in the characteristics.

with dry or high moisture corn were not large or consistent. Differences in feed efficiency between dry and high moisture corn were also small, but feed requirements were consistently lower for cattle fed high moisture grain.

Only in the case of dry corn fed with haylage was there any appreciable difference in rate of gain between whole and rolled corn (5.8%). Feed requirements were slightly, but consistently, lower for cattle fed rolled corn, amounting to an average of 4.1%. The advantage was primarily from a reduction in corn requirements.

Steers fed the reconstituted haylage gained at a slightly faster rate than did those fed dry hay, except when fed with dry whole corn. Feed requirements were slightly less (3.4%) for cattle fed diets with haylage. This percent change is small, but it represents the improvement in total feed requirements from the haylage which made up only about 10% of the diet dry matter.

An U.S.D.A. beef grader placed the carcass grades on the animals after about an 18-hour chill. There appeared to be no consistent effect on carcass grade between treatments imposed in this experiment. Dressing percentage also did not vary appreciably between treatments.

Also upon slaughter, rumens were examined for papillae matting, thickness of rumen wall and hair accumulation using the same scoring systems as for experiment 2. There appeared to be only small differences in the rumen characteristics studied between animals fed rolled or whole corn grain. Cattle receiving haylage had higher values for color and papillae matting. Animals receiving high moisture grains tended to have darker rumen walls.

Incidence of abscessed livers amounted to 31 or about 24%. Twenty-one of the abscessed livers were from cattle receiving rolled corn. Moisture content of the corn grain or roughage did not appear to influence the incidence of abscessed livers.

This experiment indicated only small and inconsistent differences between dry and high moisture when fed with small amounts of roughage. Only in the case of dry corn fed with haylage was there any appreciable difference in rate of gain between whole or rolled corn. Animals gained faster when the roughage source was haylage as compared to hay except when dry whole corn was fed. In all treatment groups, the animals fed haylage were more efficient in feed conversion.

Experiment 5—Dry and High Moisture Corn Fed Whole or Rolled With Corn Silage in Cattle Growing-Finishing Diets

Average daily gains for all the cattle fed dry or high moisture corn were the same (table 5). When the dry corn was rolled, rate of gain was 0.10 lb less (3.6%) than for steers fed whole corn. Feed consumption was also slightly less for steers fed the rolled dry corn resulting in similar feed efficiency between the whole and rolled dry grain.

Rolling of the high moisture corn did not change the rate of gain in comparison to the whole grain. However, slightly less air-dry matter was consumed with the rolled corn diet, resulting in a small reduction in feed requirements (2.8%) as measured by forced-draft oven moisture determinations.

The lack of response noted in this experiment may have been due to the type of roughage used. Corn silage generally contains 30 to 35%

TABLE 5. DRY AND HIGH MOISTURE CORN GRAIN FED WHOLE OR ROLLED WITH CORN SILAGE

(January 7, 1971 to August 25, 1971—230 Days)

	Dry Corn		High Moisture Corn[a]	
	Whole	Rolled	Whole	Rolled
Number of animals	30[b]	32	32	32
Initial shrunk wt, lb	508	506	508	504
Final shrunk wt, lb	1141	1116	1129	1126
Avg daily gain, lb	2.75	2.65	2.70	2.70
Avg daily feed, lb (air-dry)				
Corn silage	8.26	8.21	8.22	8.23
Corn grain	13.18	12.50	12.41	11.83
Supplement	1.48	1.48	1.48	1.48
Total	22.92	22.19	22.11	21.54
Feed/100 lb gain, lb (air-dry)				
Corn silage	300	310	305	304
Corn grain	478	472	460	437
Supplement	53	56	54	55
Total	831	838	819	796
Dressing percent	63.8	63.7	63.9	64.1
Carcass grade[c]	20.2	20.5	20.4	20.2
Kidney fat, %	2.9	2.7	2.8	2.7
Abscessed livers	2	3	0	3

[a]Stored at about 25.7% moisture in Harvestore, A. O. Smith Harvestore Products, Inc.
[b]Two steers died from pneumonia.
[c]Good = 17; Choice = 20. Graded to one-third of a grade.

corn grain. In this experiment, the corn coming from corn silage would amount to about 3 lb per head daily. This grain is of high moisture content and also a portion of this grain would be cracked. Therefore, the grain in the corn silage may act to buffer the difference between dry and high moisture corn and also between feeding whole or rolled grains.

An U.S.D.A. beef grader placed the carcass grades on the animals after about an 18-hour chill. There appeared to be no consistent effect on carcass grade between treatments imposed in this experiment. Dressing percentage also did not vary between treatments.

Upon slaughter the rumens were examined for abnormalities. Animals receiving high moisture grains tended to have darker rumen walls. Cattle fed rolled corn also appeared to have less free fluid in the rumen than did the cattle receiving whole corn. While the observations are very subjective, they give some indication of the changes brought about by the diets.

Incidence of abscessed livers was quite low in this experiment. Diets contained about 36% corn silage, air-dry basis, and aureomycin was fed at 70 mg per head daily. Under these conditions there were only eight abscessed livers, or about 6%. Six of these were from cattle receiving rolled corn. Moisture content of the grain did not appear to influence the incidence of abscessed livers.

Further processing of dry whole corn grain did not appear to be necessary under the conditions of this experiment. There were only small differences in rate of gain and feed efficiency between the experimental treatments.

Experiment 6--Digestibility of Dry and High Moisture Corn Fed Whole or Rolled in Beef Cattle Growing Diets

Results of this digestion trial comparing dry and high moisture corn grain either rolled or whole with 40% haylage fed to beef cattle are presented in table 6. Dry matter intake was limited to 2.5% of bodyweight. At this level, the 40% roughage and 60% corn grain diet was readily consumed by most animals.

TABLE 6. APPARENT DIGESTIBILITY OF DRY AND HIGH MOISTURE CORN GRAIN FED WHOLE OR ROLLED IN CATTLE GROWING DIETS[1]

	Dry Whole Corn	Dry Rolled Corn	HM Whole Corn	HM Rolled Corn
Number of steers	5	5	4	5
Avg weight lb	787	796	778	760
Avg daily intake lb				
Dry matter	18.28	18.37	17.21	16.69
Protein	2.51	2.52	2.39	2.31
Energy, kcal	36,953	37,160	34,708	33,583
Avg daily excretion lb				
Dry matter	5.48	5.60	5.22	4.66
Protein	.94	1.00	.90	.87
Energy	11,687	12,137	11,326	10,179
Apparent digestion coefficient %				
Dry matter	70.3	69.5	69.4	71.8
Protein	68.6	67.4	67.0	69.7
Energy	63.1	60.4	61.7	62.1

[1]Diets consisted of 60% corn grain and 40% reconstituted haylage on a dry matter basis.

There appeared to be a trend toward a slight increase in apparent digestibility when animals were fed high moisture corn as compared to dry corn. Although not significant, the results are in agreement with feedlot performance data in experiment 3 where steers fed diets with about 65% forage gained at a faster rate when fed high moisture corn.

Rolling of the dry corn tended to depress apparent digestibility for all parameters measured in this study. However, when the high moisture corn grain was rolled there appeared to be an increase in apparent digestibility of all parameters.

A combination of reconstitution and rolling resulted in the highest apparent digestibility of dry matter and protein. Apparent digestibility of gross energy was highest when the dry whole corn was fed. These values were not significant and, therefore, only represent trends that may exist. Although the differences in apparent digestibility seem small, it should be noted that corn grain is already highly digestible and further improvement in digestibility by such mild methods of processing as used in this experiment are likely to be small. Also the differences noted in digestibility are due to only 60% of the diet as the other 40% was haylage and was uniform across the corn grain treatments.

Experiment 7—Digestibility of Dry and High Moisture Corn Fed Whole or Rolled With Low Levels of Roughage in Beef Cattle Diets

Apparent digestibility values for dry or high moisture corn fed whole or rolled with hay or haylage to beef cattle are presented in table 7. Reconstitution of the dry corn appeared to increase the

TABLE 7. APPARENT DIGESTIBILITY OF DRY AND HIGH MOISTURE CORN GRAIN FED WHOLE OR ROLLED WITH LIMITED AMOUNTS OF HAY OR HAYLAGE TO BEEF CATTLE[a]

	DW		DR		HMW		HMR	
	Hay	Haylage	Hay	Haylage	Hay	Haylage	Hay	Haylage
No. of steers	6	6	6	5	6	5	5	6
Avg weight lb	633	644	635	655	658	633	638	634
Avg daily intake lb								
Dry matter	7.68	9.07	7.95	9.38	9.23	9.05	8.92	8.76
Protein	.82	1.03	.86	1.05	1.10	1.08	1.06	1.04
Avg daily excretion lb								
Dry matter	1.51	1.42	1.67	1.57	1.65	1.58	1.44	1.41
Protein	.26	.28	.28	.32	.31	.32	.29	.28
Apparent digestion coefficient %								
Dry matter	80.91	84.36	78.92	83.41	82.05	83.30	82.84	84.29
Protein	68.96	72.69	66.97	70.16	72.22	71.75	72.59	73.66

[a]Diets consisted of 93% corn grain and 7% roughage on a dry matter basis.

apparent digestibility of gross energy and protein. This increase amounted to 1.5 and 4.1%, respectively.

The effect of rolling the corn grain on digestibility was similar in this 93% grain diet as when a 60% grain diet was fed in experiment 6. Animals fed dry whole corn had higher apparent digestibility values than when the dry corn was rolled. When high moisture corn grain was fed rolling tended to increase digestibility. Cattle fed rolled high moisture corn had the highest digestion coefficients and those receiving dry rolled corn had the lowest values.

Also included in this experiment was a comparison of hay and haylage as the roughage source. The roughages were included at 7%, on a dry matter basis, of the total dry diet. Animals receiving the roughage in the form of reconstituted haylage had higher ($P < .05$) apparent digestibility values than when the animals received hay. This difference was most noticeable in those treatments with dry corn than with the high moisture grain. Animals receiving haylage digested the dry matter portion of their diets 3.3% better than those receiving hay. This tends to agree with feedlot data where animals consistently gain faster if fed haylage as compared to hay. This is true in both the growing and finishing phases.

In another portion of the experiment it was decided to determine if the apparent whole kernels observed in the feces of animals fed whole corn were intact or were partially digested. In this study, only whole uncracked were collected in the feed and in the feces. Based on a per kernel basis, dry matter digestibility and gross energy digestibility was 12.28 and 13.40%, respectively. This would indicate that some digestion had taken place in these apparent whole kernels of corn grain appearing in the feces of animals fed dry whole corn.

DISCUSSION

Results of these experiments indicated that cattle fed reconstituted high moisture corn in high concentrate diets were generally more efficient in the utilization of their feed than animals fed dry corn. Animals fed high moisture corn consumed less feed and also gained less. When a limited amount of grain was fed, weight gain and feed efficiency were improved by the reconstitution process with essentially no difference in feed intake.

McNeill et al. (1971) and Potter et al. (1971) reported the process of reconstitution for sorghum grain increased ruminal digestion of both protein and starch over the dry rolled grain. Potter et al. (1971) stated that the poor quality protein of the grain is converted by rumen microbes to higher quality protein with more of the essential amino acids becoming available for absorption. McNeill et al. (1971) reported that both ruminal and post-ruminal breakdown of starch was greater for reconstituted grain than for dry grain. However, due to the difference in the type of protein and starch between corn and sorghum grain it is not known if these results would also apply to corn grain.

The process of fermentation in high moisture feeds is generally thought of as a partial conversion of complex organic matter to more soluble compounds. Some of these more soluble compounds would include acetic, lactic, propionic and butyric acids. These organic acids are similar to those produced in the digestive tract of the ruminant animal. Compounds such as these are a concentrated source of energy for the ruminant animal.

Production of these more soluble compounds such as organic acids also presents a problem in interpreting data because of possible inaccurate dry matter determination when common drying procedures are used. Hood et al. (1971) reported that some drying techniques for ensiled feeds result in a biased estimate of dry matter content and, therefore, dry matter intake. Inappropriately accounting for these more soluble or volatile compounds as a part of the water fraction causes an underestimation of dry matter and energy intakes and would thus lower values for feed efficiency. The method most often used for determination of dry matter is to use dry heat at a temperature below the boiling point of water. This could result in loss of volatile acids and result in a biased dry matter content. However, the problem may not be a critical one under practical conditions. These volatile compounds may vaporize when in the feed bunk prior to consumption during times of high ambient temperature. Therefore, dry matter consumption would not be biased under these conditions and this loss of volatile compounds should be assessed to storage loss. The amount of volatile compounds present is related to moisture content of the feed and to the type of feed. High moisture corn is low in moisture when compared to corn silage and the actual amount of volatile materials lost during drying may be different for corn grain as compared to corn silage. However, corn grain contains a more available source of energy than does corn silage which may also influence the amount of volatile compounds produced during fermentation and subsequently driven off during common drying procedures. Geasler and Vetter (1972) stated that storage losses were 6% for corn silage and 3% for high moisture corn grain when stored in oxygen-limiting silos. Therefore, it would appear that production of volatile compounds may be influenced more by moisture content than type of feed stored and that such losses are low for high moisture corn grain stored in an oxygen-limiting structure.

There appeared to be no consistent difference on basis of rate of gain between whole or rolled dry corn when fed in high concentrate beef cattle diets. Cattle fed dry whole corn generally consumed more grain dry matter than animals receiving rolled corn grain. Benefits from rolling dry corn in relatively high roughage diets were also small. With high moisture corn and low levels of roughage, there appeared to be no advantage on basis of weight gain for rolling the grain. However, rolling high moisture corn generally resulted in more efficient feed utilization as determined by oven drying procedures. At higher levels of roughage (20% or more of diet dry matter), there appeared to be more advantage on basis of animal performance for rolling high moisture grain than for rolling dry grain.

Corn grain, when rolled, is a highly digestible feedstuff. Therefore, whole corn should be as digestible as rolled corn if the cattle masticate the whole corn to the same degree of fineness as the rolled grain. It is known that this is not true due to the appearance of apparent whole corn grain in the feces of cattle fed whole corn. Burroughs <u>et al.</u> (1960) reported when yearling cattle were fed a diet of 65% whole high moisture corn grain with the remainder being hay and supplement that 21% of the whole kernels fed appeared in the feces as whole kernels. When the diet is composed largely of corn grain, whole or rolled, resulting feces are composed largely of undigested corn.

Thus, appearance of whole or large particles of corn kernels in the feces can not be used as an indicator of completeness of total digestibility.

The size of increase in digestibility as a result of rolling corn grain was quite small even though a considerable amount of slightly digested whole corn kernels were visible in the feces when the corn was fed whole. Lack of an increase in digestibility could be due in part to a compensating effect involving starch digestion as influenced by level of starch available for digestion. Less starch was readily available for digestion in the case of the whole corn diet as compared to the rolled corn diet since the starch present in unmasticated kernels is partially protected from digestion by the outer seed coat. The smaller quantity of starch readily available for digestion in the whole corn diet could have resulted in greater starch digestibility than in diets with more readily available starch such as in the rolled corn diet. Thus, the broken kernel starch in the whole corn diet may have been digested more thoroughly than the broken kernel starch in the rolled corn diet due to the lower level of the former when the same quantity of the diet was fed. Karr, Little and Mitchell (1966) present data to substantiate this postulation. These researchers studied starch disappearance when feeding various levels of corn grain and hay to yearling beef steers. They noted that the quantity of starch disappearing and the downward trend in percent of starch digested in the rumen with increasing starch intake indicate that the efficiency of starch digestion in the rumen decreased as the daily starch intake exceeded about 4.5 lb. It was suggested that a considerable amount of starch can be digested in the small intestine. However, it was not of large enough magnitude in their experiment, and efficiency of total starch digestion was less when a higher level of corn grain was fed.

Greater feed intake of animals fed diets composed largely of whole corn grain may also be explained by compensatory starch digestion. The animal apparently consumes whole corn grain until a certain energy level is produced which would come mostly from the masticated kernels. On the other hand, on a limited grain diet rumen fill appears to be a major factor in controlling voluntary intake (Blaxter, Wainman and Wilson, 1961, Montgomery and Baumgardt, 1965).

A compensating effect of more complete digestion of starch would be expected to be quite small in diets containing small amounts of grain due to more complete digestion of the low level of starch present (Karr et al., 1966). Thus, the benefits from rolling grain to eliminate whole corn passage in the feces under limited grain feeding condition should be larger. When limited grain was fed in the feeding trial, processing methods improved rate of gain and feed efficiency over the cattle receiving dry whole corn. Results of the digestion trial indicate similar apparent digestibility coefficients. However, it should be remembered the differences would be due to 60% of the diet as the other 40% was haylage and constant among all treatments.

It appears that rolling corn grain is more beneficial when the grain is in the high moisture state. Even though high moisture grain is not as hard as dry grain, the outer coat may still tend to prevent digestion of the starch contained within the protective exterior. The increased response obtained by rolling the high moisture corn in comparison to dry grain may be due to the difference in amount of mastication required by the animal. High moisture corn may be masticated less thoroughly than dry corn. Dry corn when compared to high moisture corn would need more mastication and salivation to increase the moisture content so that deglutition could occur. With the increased mastication of whole dry corn, more kernels would be broken which would expose more surface area for digestion. The increase salivation required for animal receiving dry whole corn would tend to increase the buffering capacity of the rumen. Increasing the buffering capacity may be beneficial in keeping the animal on feed and might also provide a more optimum environment for rumen microbial digestion.

Vance et al. (1971) reported that dry whole corn, because of its texture, shape and bulkiness, reduced the degree of papillae clumping within the rumen when feeding high concentrate diets. The hard rough edges of corn grain could be acting as a roughness factor to help clean the papillae and prevent clumping. Such reduction in clumping of papillae in the rumen could result in increased nutrient absorption and utilization of the diet. In experiments reported herein where degree of papillae clumping was measured, there appeared to be no difference due to grain processing methods. However, the experiments contained from 6.2% to 23.5% roughage dry matter as hay or haylage. It appeared that level of roughage had a greater influence on papillae matting or clumping than did grain processing methods under conditions of these experiments. Roughage level and degree of clumping appear to be inversely related.

Integrity of the rumen wall has been reported to be associated with incidence of liver abscesses. Although, there was no noticeable difference in rumen parameters, there was about twice as many abscessed livers in cattle fed rolled corn as compared to those fed whole corn. Lack of apparent relationship between rumen integrity and abscessed livers would indicate that either our rumen evaluations were not sensitive enough to pick up the differences or the rumen had regenerated by the time of slaughter.

Level, type and moisture content of the roughage was also studied in this series of experiments. Hay, haylage and corn silage was utilized as the sources of roughage. Increasing levels of roughage when fed with corn grain generally decreased gain and efficiency. The lower rate of gain would be due to a lower energy diet. However, increased gains were noted when a higher level of haylage was fed with rolled high moisture corn. Reconstitution of hay, (adding water and then ensiling), generally resulted in increased rate of gain when compared to similar diets containing hay as the roughage source. The response to reconstitution of hay was not always of significant magnitude but was consistent in all the experiments where hay and haylage were compared except when fed with dry whole corn in the finishing diet. Haylage appeared to be better utilized when fed with rolled high moisture corn. This was true in growing and finishing feedlot studies and also in digestion trials.

Langston et al. (1962) described the process of fermentation of silages as the conversion of carbohydrates to organic acids and gases and the partial breakdown of protein into non-protein and other more soluble compounds. The process of fermentation increases the amount of readily available digestible matter. Therefore, improvement in forage utilization should be obtained by the reconstitution process with a greater response being expected from poor quality roughages.

Cattle receiving haylage consumed more total feed on a dry matter basis than did cattle receiving hay when roughage comprised a large portion of the diet. The increase in total feed intake was due mostly to increased consumption of haylage as corn intake was rather constant among treatments. This may indicate a palatability advantage for the haylage. Hay was chopped in a similar manner as haylage but did not contain water to prevent the material from being dusty which has been shown on numerous occasions to reduce feed consumption.

During the finishing trial where roughage (hay or haylage) was limited to about 10% of the diet dry matter, average daily gain was in favor of the cattle receiving haylage except when dry whole corn was fed. Feed efficiency also favored cattle receiving haylage as the roughage source. This would agree with the high energy digestion trial as diets with haylage had higher apparent digestibility coefficients.

Effects of processing corn grain were less when corn silage was fed. The grain which is in corn silage is already in the high moisture form and a portion of the grain is cracked. Therefore, the effects of grain processing methods employed, rolling and reconstitution, would not be expected to be as large.

SUMMARY

Six hundred fifty-six Hereford beef cattle were utilized in a series of experiments to compare the effects of various methods for processing corn grain when fed with various types and levels of roughage. Included in this series of experiments were five feedlot and two digestion trials. Dry and high moisture corn grain fed whole or rolled and steam processed flaked corn were the types of corn grain processing methods studied. However, steam processed flaked corn was used in only one feedlot experiment as the benefits measured by animal performance was similar to that of dry rolled corn. Hay, haylage and corn silage were the various types of roughage compared. Hay or haylage was fed at levels to comprise both high roughage growing and high energy finishing diets. Corn silage was fed at a constant level throughout a growing-finishing study. Parameters used to evaluate these various comparisons included feedlot performance and apparent digestibility data.

Differences between dry and reconstituted high moisture corn grain when fed with low levels of roughage (about 10% of diet dry matter) were small and frequently favored dry grain on basis of weight gain. There were also only small differences in feed utilization when the diet was comprised mostly of corn grain but frequently favored the high moisture corn. When feeding higher levels of roughage, the value of high moisture corn in comparison to dry corn appeared to improve. Improvement was noticed in both gain and efficiency for animals receiving high moisture grain. During times of extremely cold weather, performance of cattle receiving high moisture corn appeared to be depressed to a greater

extent than for animals receiving dry corn. Although performance in all treatment groups was depressed during cold weather, intake of high moisture grain was reduced with more reduction in weight gain and a larger increase in feed requirements than for animals receiving dry corn during this period.

There appeared to be no consistent difference on basis of weight gain between whole or rolled dry corn grain with roughage levels up to about 20% of the diet dry matter. Rolled grain was generally consumed at a lower level but with about the same or a slight improvement in feed efficiency when compared to whole dry corn grain. Apparently, the whole grain was utilized efficiently in comparison to rolled grain even though the feces appeared to contain a considerable quantity of apparent whole kernels. Even with levels of roughage up to about 65% of the diet dry matter, the advantage for rolling dry corn was small when fed to growing steer calves from weights of about 400 to 800 lb.

Rolling of high moisture corn offered little advantage in weight gain when fed with low levels of roughage. However, animals fed rolled as compared to whole high moisture corn consistently had lower feed requirements. When animals were fed a higher level roughage, there appeared to be more advantage for rolling high moisture grain than for rolling dry grain. Rolling high moisture corn appeared to offer greater benefits when the roughage source was haylage.

Differences in value of dry and high moisture corn were small when fed in diets with limited amounts of corn silage (about 37% of diet dry matter). There were also only small differences between whole or rolled corn under these conditions.

Incidence of abscessed livers did not appear to be affected by moisture content of the grain or roughage. However, there was a greater incidence of abscessed livers when the grain was rolled. Three hundred eighty-two animals were examined at slaughter for liver abscesses of which 50% were fed whole corn and 50% fed rolled corn. Fifteen (7.8%) of the abscessed livers were from cattle fed whole corn and 31 (16.2%) were from cattle fed rolled corn.

In a growing diet where corn grain was limited to 1% of bodyweight, steers fed reconstituted haylage gained at a faster rate than those fed dry chopped hay. Animals receiving haylage also consumed a greater amount of feed on a dry matter basis. Similar results were obtained when a finishing diet was fed. Haylage as compared to hay appeared to offer greater benefits when fed with rolled high moisture corn in both growing and finishing diets.

Differences in apparent digestibility values for dry or high moisture corn grain were small in diets containing 7 or 40% roughage but were generally greater for high moisture corn. Rolling of either type of corn also appeared to be of little advantage. However, rolling high moisture corn increased apparent digestibility to a greater extent than did rolling of dry corn. When hay or haylage was fed at 7% of the diet dry matter there was an increase in digestibility favoring haylage.

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