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THE INFLUENCE OF GELATINIZED CORN AND NITROGEN SOURCE ON ANIMAL PERFORMANCE AND RUMEN FERMENTATION IN BEEF CATTLE

by

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THE INFLUENCE OF GELATINIZED CORN AND NITROGEN SOURCE ON

ANIMAL PERFORMANCE AND RUMEN FERMENTATION IN BEEF CATTLE

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INTRODUCTION

The beef industry today faces the challenge of producing greater quantities of edible products more economically and efficiently. One of the more critical problem areas which must be overcome is the apparent inefficiency of feed conversion into body weight gains. This is particularly true in the finishing phase of producing beef, where it has been estimated that 15% to 25% of the ingested grain is excreted undigested in the feces. Thus, the ultimate goal of many research efforts in ruminant nutrition has been to improve the efficiency of feed utilization. These investigations have covered a broad spectrum of activities; such as improving nutrient digestibility, increasing feed intake, altering rumen fermentation or altering tissue metabolism of the animal.

Since cereal grains represent the major portion of the feed consumed during the finishing phase, it is not surprising to find considerable emphasis placed on the nutrient combinations, feed additives, management and processing techniques that would enhance the utilization of grains. Steam processing of cereal grains has been an attempt to improve the utilization of these grains by cattle. A combination of heat, moisture, pressure and mechanical shear causes a rupture of the starch granule and is defined as gelatinization (Smith, 1959). Gelatinized starch has been shown to cause alterations in the rumen microbial fermentation pattern be-

cause of increased susceptibility of the starch granule to enzymatic attack. The differences in the degree and severity of gelatinization which governs the rate, extent and end products of digestion may be the reason for the inconsistency of the animal performance data in the literature.

Generally, there is a rapid increase in lactic acid concentration and shifts in the proportions of volatile fatty acids in the rumen when gelatinized starch is fed to ruminants. These changes indicate either a change in the rate or pattern of microbial fermentation. Often times however, feed consumption is reduced and body weight gains are depressed, indicating that the quality control on the degree of gelatinization may be important in processing.

Sufficient data have been reported which indicates an interrelationship between protein and energy components in the ration. The degree to which the observed altered rumen fermentation arising from feeding gelatinized corn may influence nitrogen utilization is not fully known at the present time. Data have been reported which would indicate that nitrogen utilization is influenced by the presence of lactic acid in the rumen. It is also possible that data reported in the past may have been influenced by feeding methods as well as nutrient combinations.

Before the value of feeding gelatinized corn to ruminants can accurately be assessed, it is necessary to determine if the source of supplemental protein influences animal per-

REVIEW OF LITERATURE

Influence of Processed Grains on Animal Performance and Rumen Fermentation

Cereal grains have been subjected to various types and degrees of processing throughout the years. The processing of cereal grains has employed mechanical reshaping, heat, moisture and pressure both singularly and in various combinations. The ultimate goal of these efforts has been to improve the efficiency of feed conversion, live weight gains or both. In general the improvement obtained by processing grains would appear to lie in any one or a combination of the following three areas; (1) increasing the digestibility of the nutrients in the grains, (2) altering microbial fermentation to obtain more efficient feedstuff degradation and an end product that is more efficiently utilized at the tissue level, and (3) increasing feed consumption and acceptability. The possibility that method of processing may cause depressed animal performance by altering the above mentioned factors must also be considered.

Influence of Processed Grains on Animal Performance

The initial work concerning the influence of heat processed grain on animal performance was reported by Phillipson (1952). Body weight gains were similar and the efficiency of feed conversion by lambs was improved by feeding flaked maize. More recently, Newland *et al*. (1962) reported the effects of

four kinds of processed corn (pelleted, flaked, crumbled and a commercially heated source of corn) for both sheep and cattle. Body weight gains were not significantly improved by any of the processing methods. However, the efficiency of feed conversion was improved by 8%, 12%, 7% and 16% by the pelleted, flaked, crumbled and commercially heated corn, respectively.

Little *et al*. (1962) reported that steers receiving flaked grain were 7% more efficient than steers receiving ground grain although average daily gain was only slightly improved. Similar results were reported by Matsushima *et al*. (1965) which demonstrated that the efficiency of feed utilization was improved 10% and feed consumption depressed 6% for the steers fed flaked corn as compared to dry rolled grain. Average daily gain was similar for both groups of cattle.

Hentges *et al*. (1962) reported that feeding steam rolled corn resulted in a 7% improvement in average daily gain and increased the efficiency of feed conversion by 14% as compared to cracked and ground corn. This agrees with the earlier work reported by Shaw *et al*. (1960) in which cattle fed pelleted hay and steam flaked corn gained .2 kg. more per day and required 77.7 kg. less feed per hundred kg. of body weight gains as compared to animals fed long hay and ground corn.

Preston and Pfander (1961) fed lambs either steam flaked, steam cracked, cracked or pelleted corn in a finishing ration. Feeding the steam cracked corn resulted in an increased average daily gain and improved the efficiency of feed utilization. This agrees with later work reported by Karr *et al.* (1963) in which regular cracked, steam cracked and water soaked corn were compared when fed to suckling lambs. The lambs receiving soaked corn gained significantly more than those fed regular cracked corn. However, the efficiency of feed conversion favored the lambs fed steam cracked corn. In a 54 day acceptability study, lambs consumed 12.8 times more steam cracked corn than regular cracked corn.

Arnett and Bradley (1960) reported increased gains and improved feed conversion when steers were fed flaked corn. More recently, Osman (1966) and Matshushima and Montgomery (1967) reported that *in vitro* digestion and animal performance, respectively, were improved by the quality of the flake produced. The thinner flakes produced the most improvement in the parameters measured. Haenlein *et al.* (1962) reported the results of a comparison between pelleting the complete ration, expanding the grain mixture (50% yellow corn and 50% raw soybeans) and feeding the grain mixture in ground form to Guernsey heifers. Daily weight gains in kg. were .76, .67, and .54 respectively, for the animals receiving rations containing expanded corn, ground corn and a complete pelleted ration. Also *ad libitum* feed

consumption rates in kg. were 4.16, 3.93 and 2.96 respectively, for the cattle fed the three types of rations.

In contrast to these reports, Thompson _et al_. (1964) reported little or no improvement in animal performance when steers were fed steam processed corn. DeBie (1964) and Wilson (1967) reported that feeding a finishing ration containing gelatinized corn resulted in a significant reduction in body weight gains, efficiency of feed utilization and feed consumption by cattle.

Hayer _et al_. (1961) and Ralston _et al_. (1963) reported no improvement in average daily gain or efficiency of feed conversion from feeding cattle steam rolled barley as compared to dry rolled barley. In contrast, Thomas and Myers (1961) reported an increase in average daily gain when finishing steers were fed steam rolled barley. More recently Hale _et al_. (1964) reported that steam rolled barley increased the daily gain and efficiency of feed conversion of cattle by 9% and 11%, respectively over dry rolled barley. These workers also reported that feed consumption was similar for cattle fed both rations. Parrott _et al_. (1967) reported that the digestibility of the proximate fractions of barley was not improved by steam processing and flaking. These workers also reported that nitrogen-free extract digestibility was improved by steam flaking milo prior to feeding.

Pope _et al_. (1961, 1962) reported no significant improvement in animal performance by feeding steam rolled

milo versus ground milo. Drake et al. (1967) fed graded levels of gelatinized sorghum grain to either individually or group fed steers. Little variation in feed consumption was observed between the treatments. Daily gain and efficiency of feed utilization were inconsistent. There appeared to be no improvement in animal performance by including any level of gelatinized sorghum in the ration. Menzier et al. (1963-64a, 1963-64b), reported that rations containing 55% alfalfa and 35% sorghum grain which had been subjected to various sizes of grind, heating temperatures and fed to lambs in various physical forms resulted in no differences in either body weight gains or efficiency of feed conversion. Improvement in body weight gains, efficiency of feed utilization or both for steers fed steam processed milo have been reported by Hale and Taylor (1965), Hale et al. (1965, 1966) and Parrott et al. (1967).

Influence of Processed Grains on Rumen Fermentation

The initial work concerning the influence of processed grains on rumen fermentation was reported by Phillipson (1952). Flaked grain was observed to reduce the concentration of acetate and increase the concentration of propionate in the rumen. These results were later confirmed by Shaw et al. (1960), Newland et al. (1962) and Wilson (1967). Phillipson (1952) also reported that flaked maize resulted in an elevated lactic acid concentration in the rumen. Similar

results have more recently been reported by DeBie (1964) and Wilson (1967).

Rhodes and Woods (1961) reported that feeding lambs a pelleted ration (composed of 67% concentrate) as compared to a meal form resulted in a narrowed ruminal acetate to propionate ratio. Total volatile fatty acid levels and rumen pH were not consistently influenced by treatment. The data also indicated that fistulated lambs did not exhibit as pronounced a response from treatment as did the intact lambs. Luther and Trenkle (1963) also demonstrated that pelleting the concentrate portion of the ration resulted in a narrowed acetate to propionate ratio, regardless of concentrate level. This was in contrast to the work reported earlier by Woods and Luther (1962) which did not demonstrate any alteration in the pattern of rumen fermentation. Wilson (1967) reported a narrower acetate to propionate ratio when gelatinized corn was included in the ration. Higher concentrations of butyrate were found in the rumen contents from animals receiving gelatinized corn. The ruminal lactic acid levels were reported to be high in the steers fed gelatinized corn and it was observed that these levels were dependent on the level of gelatinized corn fed. It was also noted that coarse gelatinized corn resulted in higher ruminal lactate levels than fine gelatinized corn. In vitro fermentation data did not substantiate these findings, however.

In contrast however, Johnson *et al*. (1968) were unable to demonstrate any difference in molar percent of the volatile fatty acids in the rumen contents of steers fed flaked corn and cracked corn. Little *et al*. (1962) reported a wider acetate to propionate ratio in the ruminal contents as a result of feeding flaked corn as compared to the ground corn. No differences because of the type of corn fed were noted in butyrate levels. These results were confirmed in a later experiment reported by Little *et al*. (1963). It was observed that steers fed steam rolled corn had a significantly larger molar percentage of ruminal acetate than steers fed either pelleted or dry flaked corn. The molar percentage of ruminal propionate and the total concentration of volatile fatty acids did not appear to be influenced by the type of corn fed. The proportion of butyrate was significantly larger in the rumen contents of animals fed pelleted corn, as compared to the ground, flaked or steam rolled. DeBie (1964) reported the results of *in vivo* rumen fermentation trials which indicated that gelatinized corn caused a marked increase in ruminal lactic acid levels. A decrease in the molar percent propionate was also observed in the rumen contents of steers fed the gelatinized corn. Thompson *et al*. (1964) reported that the rumen contents of steers fed flaked corn contained significantly less total volatile fatty acids than steers fed ground corn rations.

Garrett *et al*. (1966) and Garrett *et al*. (1967) have reported that steam pressure processing of milo improved efficiency of feed utilization by 8%. It was demonstrated however that there is an optimum time - pressure relationship for the cooking of barley, corn and milo. Their data suggests that higher or lower time - pressure relationships are less advantageous than the optimum and causes a depression of body weight gains and reduces the efficiency of feed conversion. Thus, differences in the gelatinization of the starch granules may explain the diversity of results obtained with heat processed grains. Smith (1959) defined gelatinization of starch as the rupture of the starch granules brought about by a combination of moisture, heat, pressure and mechanical shear. He also reported gelatinization values from 11% to 49% for pelleted corn, depending on the conditions while pelleting. Hastings and Miller (1961) reported that pelleted corn, which had previously been steam conditioned, had a higher concentration of soluble sugars and produced more gas when subjected to B-amylase than untreated grain. Erwin (1966) measured the utilization of cooked cereal grains by rumen microorganisms *in vitro* and found the degree of gelatinization to influences the rate of carbohydrate utilization. Trei *et al*. (1966) reported that steam flaking increased gas production *in vitro*. It was observed, however, that if the degree of gelatinization exceeded 30% to 40%, gas production was not increased. Woods

(1968) has suggested that both the proportion of starch granules ruptured and the severity of rupture caused by heat processing may influence animal performance and rumen fermentation.

The results of feeding heat processed cereal grains to ruminants has been rather variable. In certain studies heat processed grains have improved body weight gains and the efficiency of feed utilization. Other studies have been unable to demonstrate any beneficial effect on animal performance as a result of feeding heat processed grain. In some cases, feeding heat processed grain resulted in depressed animal performance. The influence of heat processed grains on ration digestibility and rumen fermentation has also been quite variable. A comparison of the results reported by different workers is complicated by the different types of heat processing methods employed, the time subjected to the process, the differences in the resulting products and their subsequent effect on animal performance and rumen fermentation. It would appear that the variability of results may be due to differences in the degree and severity of starch gelatinization, which is obtained under various processing methods.

The Influence of Lactic Acid on the Nutrition and Metabolism of Ruminants

It is well documented that the rumen microbial population produces volatile fatty acids, as well as other end products, and intermediates during the course of carbohydrate fermentation. Lactic acid has also been shown to accumulate in the rumen contents following the ingestion of various feedstuffs, especially those that promote a rapid rate of fermentation. Feeding processed grains has been shown to alter rumen microbial fermentation and often times lactic acid has been shown to accumulate in the rumen ingesta. The influence of an accumulation of lactic acid in the rumen and the subsequent effects on rumen fermentation and animal performance has therefore been considered relevant to the investigations concerning processed grains.

Lactic Acid Production in the Rumen

Woodman and Evans (1938) reported a transitory accumulation of lactic acid during the *in vitro* fermentation of glucose by sheep rumen microorganisms. The experiments also suggested that lactate was further converted to volatile fatty acids and gaseous products in the rumen. This work was later confirmed by Phillipson and McAnally (1942). In addition to glucose, these workers reported that fructose and cane sugar caused an accumulation of lactic acid in the rumen of sheep. However, the fermentation of maltose, lactose and galactose

did not result in lactic acid accumulation in the rumen. The authors suggested that the sugars which supported rapid rumen fermentation produced lactic acid and eventually volatile fatty acids. These workers also reported that occurrence of lactic acid in the rumen was transitory and under conditions of high concentration, small amounts appeared in the abomasum.

Elsden (1945) noted a substantial increase in ruminal lactic acid levels when glucose was fermented. He also reported that lactic acid levels decreased and disappeared approximately three hours after the last detectable amounts of glucose disappeared.

Earlier work reported by Phillipson (1942) indicated that when sheep were fed mangolds and cabbage, lactic acid accumulated in the rumen ingesta. The author suggested that the rate of rumen fermentation was dependent on the ration consumed. The most rapid fermentation was observed when mangolds and cabbage were fed with roughage. When bran and oats constituted the concentrate portion of the ration, rumen fermentation was less rapid and roughage alone was observed to be the least rapid. The rumen pH was lowered abruptly with the production and accumulation of lactic acid. Later investigations by Phillipson (1952) demonstrated that lambs fed flaked maize had an exceptionally low rumen pH associated with an accumulation of lactic acid. Balch and Rowland (1957) reported lactate levels of 90-270 mg./100 ml. in the rumen fluid of cows fed high concentrate rations containing

50% flaked maize, whereas, only a negligible amount was observed when cows were fed the unprocessed grain. Similar results have been reported by Bruno and Moore (1962) utilizing *in vitro* fermentation studies. Autoclaving alfalfa meal greatly increased the *in vitro* production of lactic acid as compared to untreated alfalfa meal.

Waldo and Schultz (1956) reported that feeding silage to cattle resulted in greater ruminal lactic acid concentrations than could be accounted for by the lactic acid content of the silage. They also reported that whole grain caused a slight increase in rumen lactic acid levels of cattle when added to a hay ration. The peak concentration of lactic acid was observed one half to one hour after feeding while the addition of whole grain to an all hay ration caused the peak concentration of lactic acid to appear earlier after feeding. Starch and cellulose were considered as the major precursers of the volatile fatty acids in the rumen ingesta only after they had been subjected to rumen fermentation for several hours. They also reported that lactic acid infused via a rumen fistula disappeared more slowly than the lactic acid formed from the ingestion of silage. The total experiment as reported demonstrates that the rate of fermentation, the microbial metabolic end products of rumen fermentation and the disappearance of these products from the rumen are dependent on the ration consumed. Similar results have been reported by Briggs *et al*. (1957). In these experiments lambs

were fed a ration of chaffed wheat and lucerne hay. A high proportion of either wheat starch or molasses was added to the ration before high concentrations of ruminal lactate appeared. After including a small amount of starch in the ration for a few weeks, larger amounts of starch than originally used were needed to obtain the higher concentrations of ruminal lactic acid. Thus, these workers demonstrated the ability of the microorganisms to adapt to the ration being fed. Chow and Walker (1964) reported that sheep fed wheat starch had higher ruminal lactic acid levels and a lower rumen pH than sheep fed lucerne hay. The concentrations of total nitrogen, protein nitrogen and total volatile fatty acids in the rumen contents were higher and associated with the rations causing higher concentrations of lactic acid.

Reid _et al_. (1957) fed wheat starch to sheep and reported high concentrations of ruminal lactic acid each day after feeding. Feed intake was voluntarily reduced to a level which prevented lactic acid accumulation in the rumen. When rumen pH dropped below 5.0-5.5, the molar percent of propionic and butyric acids declined rapidly to as low as 8% and 5%, respectively. Sheep fed a continuously high level of wheat starch for four weeks exhibited a marked increase in molar percent of propionic acid while butyric acid levels remained constant. Infusion of a 10% solution of sodium carbonate after ingestion of the starch ration maintained ruminal pH at 5.8 or above and prevented any accumulation of lactic acid in the rumen contents.

The Influence of Lactic Acid on Feed Intake

Thomas et al. (1961) reported that 288 grams of lactic acid, partially neutralized to pH 5.0, introduced into the rumen of cattle prior to feeding did not alter feed intake. However, 576 grams of lactic acid in combination with 252 grams of acetic acid decreased the intake of hay by 20%. An additional 100 grams of propionic acid caused a reduction in feed intake by 30%. Emery et al. (1961) observed a reduction in the voluntary intake of dry matter as the amount of lactic acid ingested with the feed increased. This result was not obtained, however, when either the calcium or sodium salts of lactic acid were used. Similar results have been reported by Montgomery et al. (1963). Lactic acid was infused into the rumen of cows at a rate of 340 grams per 681 kg. body weight. Voluntary intake of hay (the only feed) was reduced slightly under these conditions. When the acid was partially neutralized to pH 5.0 prior to infusion or if the sodium salt was infused, no change in voluntary feed intake was observed. Senel and Owen (1966) reported that sodium and calcium lactates supplemented to provide the equivalent of 9% lactic acid on a dry matter basis resulted in an increased dry matter intake. In contrast, Johnson et al. (1962) reported that the addition of 8% lactic acid to a purified ration for steers decreased dry matter consumption. When hay, silage and hay rations were supplemented with 9.8% lactic acid, feed intake

was not significantly different from the unsupplemented basal ration (Ekern and Reid, 1963). DeBie (1964) and Wilson (1967) reported marked reductions in feed intake associated with excessively high ruminal lactic acid conditions when cattle were fed gelatinized corn.

The Influence of Lactic Acid on Animal Performance and Rumen Fermentation

Klosterman et al. (1961) reported that the addition of 0.5% ground limestone to corn silage at ensiling time resulted in a 78% increase in lactic acid content of the silage. Cattle receiving the treated silage gained faster and exhibited an improved efficiency of feed utilization. Additional investigation on the influence of adding 1% ground limestone and 6% water to 40.6% moisture ear corn at ensiling time showed a 125% increase in lactic acid content above that of the untreated silage. These data tend to indicate that the increased lactic acid content of the silage resulted in improved animal performance, thus, indicating an increased caloric efficiency of the silage containing higher levels of lactic acid.

Johnson et al. (1962) observed that a purified ration containing 8.6% added lactic acid resulted in increased body weight gains and improved the efficiency of feed utilization as compared to the basal ration. The feed replacement value of the added lactate was calculated to be 2.88 times that of

the basal purified ration. However, when 4.3% lactate was added to the ration an increased feed utilization was not observed. Lactate supplementation also increased ration digestibility. This agrees with earlier work reported by Bentley et al. (1956) which indicated that corn steep-water (containing 25% lactic acid on a dry matter basis) improved ration digestibility. It was also reported that for the promotion of weight gains, lactic acid was superior to corn on an isocaloric basis, while a mixture of acetic and propionic acids was not superior to corn.

Emery et al. (1961) reported that lactic acid additions to grain rations for growing dairy heifers depressed body weight gains and feed intake. The efficiency of feed utilization was improved and directly related to the amount of lactic acid consumed. Ration digestibility did not appear to be adversely affected by lactate supplementation with the exception of protein. A slight, but non-significant improvement in body weight gains and efficiency of dry matter utilization was reported by Senel and Owen (1966) when they supplemented a sorghum silage - beet pulp ration with 9% lactic acid on a dry matter basis. The lactic acid supplementation resulted in a narrower ruminal acetate to propionate ratio.

Ekern and Reid (1963) investigated the energy utilization and ruminal volatile fatty acid patterns of steers fed hay, silage or hay supplemented with lactic acid. There appeared to be no differences among animals in regard to the amount