EFFECTS OF PROCESSING GRAIN SORGHUM ON FEEDLOT PERFORMANCE AND DIGESTIBILITY WITH LAMBS

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EFFECTS OF PROCESSING GRAIN SORGHUM ON FEEDLOT PERFORMANCE AND DIGESTIBILITY WITH LAMBS

CHAPTER I

INTRODUCTION

The nutritive value of processed feed is measured by its influence on animal performance. This may be expressed in terms of feed consumption and production efficiency. The influence of grain processing on production efficiency depends upon the animal and the changes in chemical and physical aspects of the feed.

It is of interest to note that Henry, in the first edition of Feeds and Feeding copyrighted in 1898 said on grinding grain, "This subject is a difficult one to discuss owing to the great variety of conditions existing as to both grain and animals. Experiments quite generally show increased gains from grinding grain, but in many cases they are not sufficient to pay the cost of grinding." Sixty-nine years later Garrett said in the Proceedings of the Seventh Annual California Cattle Feeders Day Report, "our knowledge concerning the effects of different methods of processing on the feeding value of grains is still quite incomplete. This means we do not completely understand all those factors (physical and physiological) which influence the utilization of grain."

It has been established that lamb feeding has changed since Henry's time. Today lambs gain faster with greater efficiency in a shorter period of time. Much of the progress in lamb feeding can be attributed to genetic improvement of both animals and plants associated with technological advances in nutrition.

There are two basic ways that grain processing can improve animal performance. It can improve palatability and/or digestibility or utilization. This is accomplished by (1) breaking the seed coat and exposing more surface area to bacterial and enzymatic action during the process of digestion, (2) softening the grain permitting more bacterial and enzymatic action during its passage through the gut, (3) increased production of propionates, (4) increased bulk, or (5) various combinations of these factors. Grain processing effects the rations physical form and palatability to animals. A well balanced ration is of no value unless it is readily accepted by the class of animals for which it is balanced.

Grain processing has initiated further investigations of optimum concentrate-roughage rations in lamb rations. Cox (1948) reported superior performance from ground-mixed rations containing 55 percent roughage and 45 percent concentrate. It is assumed that rations must contain a higher concentrate level to get higher energy consumption and improved feedlot performance. Consequently, extensive research has been conducted recently to evaluate the merits of all concentrate rations for growing and finishing lambs.

The objectives of this study were to determine the effect of processing sorghum grain on feedlot performance and digestibility of rations containing 40 percent and 90 percent concentrate. In addition, carcass composition of lambs fed different levels of concentrate were evaluated in respect to grade and yield. Four processing methods evaluated were; dry rolled, steam processed flake, steam processed-fine-ground, and whole sorghum grain.

CHAPTER II

REVIEW OF LITERATURE

Morrison (1959) has reviewed the numerous investigation devoted to the study of the influence of preparing harvested feeds for farm animals. He summarized the results of these investigations by saying:

> "The value of grinding, crushing, or chopping feed depends on the character of the particular feed in question and also on the kind of animals to which it is to be fed."

He further stated that there was no benefit from grinding or crushing most kinds of grain for sheep except for old sheep with poor teeth or young lambs up to 5-8 weeks of age, or perhaps when self feeding fattening lambs.

According to Husted (1966), the milo kernal is coated with a waxy coating that is very resistant to moisture penetration, and the starch portions of the grain takes up water very slowly. The possibility exists that dry rolled milo does not stay in the rumen an adequate length of time to become sufficiently wet to permit maximum digestion by rumen microorganisms and consequently requires some type of processing to obtain maximum utilization.

The degree to which grains are ground appears to be an important factor in their palatability and utilization. According to Hale (1968) fine grinding of milo should result in greater surface area of the grain particles being exposed to digestion in the rumen and thus be superior to dry rolled or coarse ground grain. However, the fine ground grain is more expensive to process than coarser grinding and it is more dusty and less palatable. Fine grinding is not considered desirable for high concentrate rations because of the high percentage fines.

Pope et al. (1960) and Totusek et al. (1964) report that finely ground milo is equal or superior to coarsely ground steam rolled or pelleted milo. Cattle fed finely ground milo ate less feed than those fed coarsely ground milo yet gained as rapidly and were more efficient on a high roughage (40%) ration.

Menzies and Ehardt (1967) revealed lambs fed whole sorghum grain mixed with suncured or dehydrated alfalfa pellets made faster and more efficient gains than a pelleted or ground ration containing the same percentage concentrate.

Shelton (1965) found that whole grain sorghum probably should not be used unless provision can be made to prevent its' separation from the remainder of the feed mixture.

Husted (1968) compared total digestible nutrients (TDN) values for dry rolled and fine ground milo. His results indicated that digestibility of TDN was positively related to milo particle size.

Mehen (1966) showed no advantage in gross energy or digestibility of fine ground milo, however he suggested that the nitrogen free extract (NFE) fraction was more digestible in fine ground than in dry rolled milo.

A feed and preparation study for ewes conducted by Brown and

Caveness (1959) indicated significant difference in feed consumption with different feed preparations. The ewes consumed 94, 90 and 88 percent of feed offered of finely ground, crimped and pelleted rations respectively.

Totusek et al. (1967) have shown that finely-ground grain sorghum was utilized more efficiently by fattening cattle than a coarser ground product. This is in direct contrast to the proposal of Smith et al. (1949).

Kammlade (1955) reports there is little need for special preparation of feeds for most classes of sheep. However, processing can increase consumption and digestibility and may facilitate mixing several grains, which, if fed whole, would not all be consumed in equal proportions. In addition, special grain preparation would be advisable for self feeding fattening lambs.

Hale (1968) of Arizona, Matsushima (1965) of Colorado, Brethour (1969) of Kansas, and Garrett (1968) of California reported that the proper steaming and flaking of milo improved the feeding value of the grain 4 to 12 percent. Steam flaking milo has given more consistent results than either flaking corn or barley. According to Matsushima (1965) steaming corn improved feed efficiency four percent while steaming and flaking milo improved feed efficiency 7.5 percent.

Hale et al. (1965) at the Arizona Station reported that steamed and flaked milo resulted in significantly higher rates of gain than dry rolled milo. Hale's milo was steamed at atmospheric pressure for approximately

25 minutes and rolled into a flake having approximately half the weight per unit volume as original grain. The temperature in the steam chamber averaged 211°F. and the moisture content of the grain leaving the roller was 17.8 percent.

Garrett et al. (1966, 1966a, 1967) and McIlroy et al. (1967) have indicated variable results when feed grains were subjected to various steam treatments before being rolled and fed to cattle. The optimum time-pressure steam treatment was approximately 1.5 minutes at 50 pounds per square inch of steam pressure. In some cases the high steam pressure treatments of milo ($>$60psi) resulted in reduced consumption and insufficient gains even though the feed consumed was utilized.

Lofgreen et al. (1968) labeled palatability responsible for reduced consumption and performance of steers fed gelantinized sorghum grain.

Matsushima et al. (1966) at Colorado heated milo 20-25 minutes in a steam chamber with the temperature in the chamber being approximately 200°F. The moisture content of the grain reached 18-21 percent and the grain is then rolled. If it is necessary to store the grain for any length of time, it is dried to about 13 or 14 percent moisture to avoid heating and spoilage. If the grain reached the rolls with a moisture content of much more than 20 percent it was difficult to get a desirable flake.

According to Phar (1967) the physical properties of flaked grain are much bulkier than regular cracked grain. This may be one of the major advantages of flaked grain particularly for high concentrate rations.

Hale *et al.* (1968) studied the physical properties or gelatinization of the grain to determine if increased performance from flaked milo was due to these properties. Milo flakes were ground and fed as an 80 percent concentrate ration. Feed requirements were increased by 9 percent and steer performance was reduced by .36 pound per day on the ground flake ration indicating the flake should remain intack as much as possible when incorporated in high concentrate fattening rations.

Hale *et al.* (1966) compared bushel weight of milo processed differently and discovered a significant difference. The weights were: dry rolled 45 pounds; pressure cooked 24.5 pounds; steam processed 27 pounds; and fine ground 38 pounds.

A similar study by Matsushima (1967) compared the bushel weight of processed corn and found that dry cracked corn weighed 38 pounds per bushel; flaked 27.2 pounds; cooked and rolled 36.9 pounds; flaked, dried and rolled 34.2 pounds.

According to Armstrong and Blaxter (1957 a, b) and Armstrong *et al.* (1958), the amounts of propionates of volatile fatty acids (VFA) produced during fermentation of feed by rumen microorganisms plays an important role in the energy metabolism of sheep. These end products of digestion (VFA) vary in heat increment (Armstrong and Blaxter, 1957a) and have been credited with providing from 37 percent to 63 percent of the maintenance energy requirement for ruminants (Annison and Lewis, 1959; Stewart *et al.*, 1958; and McCarthy *et al.*, 1957).

According to Newland (1962) feed efficiency may be attributed to the significant decrease in the ratio of acetate to propionate in the rumen. Observation by Armstrong and Blaxter (1957a) indicated that acetic acid, when given alone, causes an increase in nitrogen excertion, whereas propionic acid exerted a marked nitrogen sparing effect. As compared to acetic acid, propionic acid not only has a lower heat increment (Armstrong and Blaxter, 1957a) but is also glucogenic (Deuel et al., 1935).

Phillipson (1952), Balch et al. (1955), Balch and Rowland (1957), Einsor et al. (1959) and Newland et al. (1962) indicated that flaking of corn is a major method of altering volatile fatty acid production or increasing the percentage of propionates in the rumen. This may account for the increased efficiency of gain observed with steam rolled corn in feedlot experiments.

Johnson et al. (1968), found no difference in proportion or total production of volatile fatty acids in the rumen of steers fed flaked grains. Similar studies of completely gelantinized sorghum grain indicates a significant narrowing of the acetate-propionate molar percentages of volatile fatty acids (Colenbrander et al. (1967) and Shaw et al. (1969)).

Newland, (1962) found a decrease in molar percentage of acetate by most forms of heat processed corn in comparison to cracked corn. An increase in the percentage of propionate was more marked than a decrease in acetate. Total volatile fatty acid production favored ground shelled corn. Shaw et al. (1960) found total volatile fatty acid production to be greater in heat processed feeds.

Frederick et al. (1968) and Husted et al. (1968) reported that flat flaking increased in vitro digestion over dry rolled grain, and pressure cooking increased starch digestion. Flat flaking of steam cooked and pressure cooked grain improved digestibility over unflaked and dry flaked grains. It was concluded that concerted efforts of heat, moisture, and pressure was involved in increasing susceptibility of starch in grain to enzyme action. According to Parrot et al. (1969) production of a flat flake did not improve digestibility when compared with dry rolled and steam processed regular flaked barley.

Arnett and Bradley (1961) found increased digestibility of dry matter, crude protein, crude fiber, NFE, and energy of flaked corn when compared with ground and pelleted corn.

Hale et al. (1966) subjected milo grain to low pressure, high moisture in an oversized tempering chamber for 25 minutes at 99^{o}C. prior to rolling a large flat flake containing 17.8 percent moisture. Hale found that the digestibility of NFE and TDN was increased, however protein digestibility was not affected significantly and ether extract was lowered by steam processing. Improvement in the digestibility of NFE of steam processed milo agrees with the findings of Keating et al. (1965).

Buchanan et al. (1968) processed sorghum grain by fine grinding, coarse grinding, rolling and steaming for 20 minutes at atmospheric pressure and 93^{o}C. prior to rolling a flat flake. No differences in digestibility were noted among the various processing treatments for sheep except that the steam processing product depressed ($P < .01$) nitrogen digestibility. Nitrogen retention did not differ significantly.

Johnson et al. (1968) determined digestibility, net energy, and rate of passage of rations composed of 70-80 percent corn processed in the following manners; (1) flaked, (2) cracked, (3) flaked and cracked, and (4) steam cracked. Flaking differs from steam rolling in that the grain is either steamed for a longer period of time or steamed under pressure. Flaked corn as compared to cracked corn resulted in a nine hour faster rate of passage through the alimentary tract, a four to six percent increase in dry matter digestibility, and an increase in energy retention of six to ten percent.

TDN and NFE portions of milo and corn subjected to steaming and flaking was more digestible than dry rolled or ground grain (Hale et al., 1966; Husted et al., 1968; and Arnett and Bradley, 1961). Hayer et al. (1961), and Parrott et al. (1969), found no significant difference in TDN and protein digestibility of steam processed barley when compared to other methods of preparation.

Because of increased starch availability of steam processed grains several workers are concerned with depressed crude fiber digestibility. Johnson et al. (1960) showed inhibition of microbial cellulose digestion in the presence of starch. Inhibition was due primarily to competition for nutrients, and most important being nitrogen. The degree of inhibition and alleviation by urea in both in vitro and in vivo depended on the ratio of starch to cellulose in the ration. High starch ratios could completely inhibit cellulose digestion regardless of additional quantities of nitrogen. Burroughs et al. (1949) showed that certain levels of starch depessed dry matter digestion of inferior roughages but had little effect on high quality roughage.

Hale et al. (1966) and Husted et al. (1968) reported that crude fiber digestibility was significantly lower with pressure cooked sorghum grain when compared to dry rolled or moist heat treated grains.

The possibility of feeding rations that contain no roughage to ruminants has concerned animal scientists for more than a half century. Davenport (1897) and McCandlish (1923) were unsuccessful in attempts to rear calves on rations devoid of roughage and concluded that fiberous material is necessary in the diet of ruminants. Meade and Regan (1931) were the first workers to conclude that roughage or bulk in the ration was unnecessary in the diet for calves. Vitamin A and inadequate minerals seemed to be the limiting factors in this early work. Cox (1948) reported there was a physiological balance factor in determining the efficiency of feed utilization by fattening lambs and the optimum concentrate to roughage ratio for a mixed ration to be 45 percent concentrate and 55 percent roughage.

Glimp, (1969) conducted a study of different concentrate levels in lamb rations. Three hundred twelve ram lambs representing eight breeds were fed rations consisting of 60, 75, and 90 percent concentrate levels for a 63 day feeding period. No significant differences were noted in average daily gain for the various concentrate levels. However, as the TDN level of the ration increased feed efficiency improved. Davis et al. (1963); Oltjen and Davis (1964) and Durham et al. (1964); Pope et al. (1963b);

and Oltjen et al. (1965a) have all reported very good results in fattening cattle when using an all-concentrate ration.

Brethour and Duittsman (1964) observed significantly greater gains with all concentrate rations based on 91 percent rolled barley, corn or milo as compared to rations containing a higher percentage sorghum silage and alfalfa hay.

Ellis (1965) summarized the results of 27 trials involving approximately 3,300 cattle. The following figures for average daily gain, average daily feed intake and feed efficiency, respectively, were; all concentrate - 1.20 kg., 8.67 kg., and 7.24 kg.; part roughage - 1.15 kg., 10.16 kg., and 8.82 kg. In comparing performance on the two types of rations, the general pattern of results indicated that rate of gain was essentially equal, feed consumption was markedly lower on the all concentrate rations, and less feed per unit of gain was required when roughage was excluded. Work reported by Anthony et al. (1960) comparing rations fed to steers containing 30, 10 and 0 percent bermuda-grass hay in a grain mixture showed no difference in either average daily gain or feed efficiency.

Ruttle and Sundt (1968) compared high energy rations to low energy rations with medium-wooled, white faced range lambs. Lambs fed the ration containing 30 percent concentrate and 70 percent roughage had higher average daily gains, were more efficient and had less death loss and digestive disturbances. Menzies and Erhart (1967), and Hanke and Jordan (1964) reported desirable results from limiting concentrate intake when starting lambs on a high concentrate diet. Doane et al. (1961) and Woods (1960) reported no digestive disturbance caused by feeding lambs a high concentrate ration without a "warmup" period. Vetter et al. (1965) reported that lambs on high energy rations had 33 percent higher average daily gains on two percent less feed per lamb per day and were 36 percent more efficient than lambs on low energy rations. Fontenot et al. (1967) studied roughage to concentrate ratios for fattening lambs and found a significant increase in average daily gain as the concentrate level of the ration increased, up to, but not beyond 60 percent. Feed intake increased with the increased concentrate level up to 60 percent. Feed efficiency increased as the concentrate level increased; however, the response was decreased as concentrate level increased.

Thomas and Myers, (1961) fed steam rolled barley to steers receiving an additional 0.91 kg. of 20 percent protein supplement per head daily. During a 140 day feeding period, less feed per unit of gain was required for steers receiving no hay although the steers receiving 0.91 kg. of hay per head daily gained faster. Similar results were reported by Pope et al. (1963b) when they compared all-concentrate rations based on 74 percent steam rolled milo with a conventional fattening ration. Steers fed the all-concentrate ration gained faster on less feed per day.

It is now established (Balch et al., 1955; Shaw et al., 1959; and Reid et al., 1957), that total concentrations and amounts of VFA present in the rumen depend on the diet. High energy diets usually resulted in higher concentrations of total VFA, and higher propionate to acetate ratios than did low energy diets. Changes in VFA ratios in the rumen fluid of ruminants fed high concentrate rations are known to be accompanied by lowered pH values (Matrone et al., 1959). Balch and Rowland (1957) observed that fluctuations in pH varied inversely with the concentrations of VFA. Rhodes and Woods (1962) studied the physical form of rations of rumen environment of lambs and reported that in all cases, rations which narrowed the acetate to propionate ratio also reduced pH.

McDougall (1948); Balch et al. (1955); Matrone et al. (1959) believe the drop in rumen pH resulting from high concentrate or easily fermentable sugars and starches is due to insufficient buffering by saliva.

Reid et al. (1957) and Phillipson (1952) reported lactic acid accumulation in the rumen of animals and believe this leads to lowered rumen pH.

Boman and Huber (1965) studied nutrient utilization of high and low concentrate rations with dairy cattle and found low-hay rations resulted in increased digestibility of protein, ether extract, and nitrogen-free extract.

Menzies et al. (1968) obtained fat probes on early weaned creep fed lambs fed a complex high energy ration and on those fed a standard type ration consisting of 45 percent sorghum grain. The lambs fed a high energy ration had more fat deposited over the 12th rib. Average daily gain was higher and feed conversion was lower for the high energy group of lambs.

Preston et al. (1961) compared carcass composition of lambs fed various forms of corn. Lambs fed steam cracked or cracked corn had more "outside" fat cover; conversely, those fed steam flaked or pelleted corn had a higher percentage of lean and had more "inside" fat. Steam flaked corn appeared to give the most desirable distribution of fat.

Garrett et al. (1967) found the method of grain processing had a significant ($P < .05$) effect on carcass yield. Steers fed rations containing steam rolled grain yielded about one percent more carcass weight. Other measurements were not affected by method of grain processing. When diets containing steam flaked corn were compared to ground corn, Shaw et al. (1960) found an increase in iodine number of visceral and subcutaneous fat. Tove and Matrone (1962) also reported an increase in the percent of unsaturated fatty acids in the depot fat of sheep fed purified diets having a high content of water soluble carbohydrates. Cabezas et al. (1965) reported flaking of corn and pelleting of the diet did not significantly increase the degree of unsaturation of fat when compared to a diet containing ground corn. Weiss et al. (1967) confirmed that increased dressing percentage ($P < .01$) and carcass grade ($P < .05$) was associated with high concentrate diets. Grade, dressing percentage ($P < .01$) and carcass weight ($P < .05$) were negatively correlated with the acetate: propionate ratio.

CHAPTER III

EXPERIMENTAL PROCEDURE AND DESIGN

I. Effect of Processed Grain Sorghum on Feedlot Performance.

The first objective of Experiment I was to compare the effects of different methods of processing sorghum grain on rate of gain and feed utilization in lambs fed *ad libitum* under normal, feedlot conditions. A second objective was to compare 40 percent and 90 percent concentrate rations in respect to yield grade and carcass composition. The third objective was to compare loin eye area, carcass grade, yield grade, and fat thickness with estimates obtained by probing the live lambs and by grader evaluation.

Ninety eight fine-wool, uniform, wethers weighing approximately 65 pounds were purchased in New Mexico. Before the feeding trial all lambs were vaccinated twice with 2 cc Fort Dodge *Clostridium Perfringes* type D toxide, drenched with 2 ounces of Coopa-fine lead arsenic drench, implanted with 3 mg. diethylstibesterol, and sheared. Shipping stress and ecthyma were labeled responsible for a "shrunk out" condition of lambs previous to the feedlot test. On November 30, 1968, the lambs were randomly assigned to fourteen lots of seven each and were fed four different grain sorghum rations at two concentrate levels.

Rations consisted of steam flaked, ground steam flaked, cracked, and whole grain sorghum at 40 percent and 90 percent concentrate levels and were balanced according to NRC requirements. The composition of the rations used throughout the experiment are shown in the following table.

TABLE I. COMPOSITION OF THE 40% AND 90% CONCENTRATE RATION USED THROUGHOUT THE STUDY.

	Pounds Per Ton	
Ingredient	40%	90%
Sorghum grain	778	1,658
Cracked suncured alfalfa pellets	1,200	200
Aurofac 10	2	2
$CaCO_3$	20	20
NaCl		20
Mineral Premix		100
	2,000	2,000

Ground limestone	40.0%
Commercial trace mineral premix ($CaCO_3$)	2.0%
Diethylstibesterol (1 gm./lb.)	2.0%
Vitamin A (280 gm.)	0.6%
Aurofac 10 (760 gm.)	1.6%
Fine ground sorghum grain	53.8%
	100.0%

Sorghum grain was purchased from the Circle E. Ranch, El Dorado, Kansas, and flaked by a high pressure processing system. The whole grain sorghum tested 57 pounds per bu. as compared to a 23 lb. test for flaked grain. Crude protein content of the milo was 8.5 percent. A hammer mill with the screen removed was used to breakup the physical properties of the flake in preparation of the ground steam flaked ration. In preparing the cracked sorghum grain ration, attempts were made to prevent as many fines as possible by only breaking the seed coat of the grain. Cracked suncured alfalfa pellets having a crude protein content of 14 percent was used as a roughage. A trace mineral supplement was added to the high concentrate rations to assure a mineral balance. In addition, blocked salt was fed free choice to all lots. All rations were mixed in the Animal Science and Industry Departmental feed mill, Kansas State University, in sufficient quantities to carry through the duration of the study. Handling the flaked rations was kept to a minimum to keep the flake in tack.

Metal pens at the feeder lamb research unit at Kansas State University were equipped with self feeders and automatic waterers. One-half the pen space was under roof but open on the east and west sides. No bedding was used during the experiment.

The ninety-eight fine-wool wethers were randomly assigned to the seven treatment groups. Treatments were:

A) 40% and 90% levels of whole grain sorghum
B) 40% and 90% levels of cracked grain sorghum
C) 40% and 90% levels of steam flaked grain sorghum
D) 90% level of ground steam flaked grain sorghum

All rations were fed ad libitum. A feed sample was taken periodically and was composited at the termination of the study. Initial and final weights were calculated by averaging the shrunk weights for two consecutive days. Lambs were weighed at 21 day intervals. The study was terminated when the heaviest one-third of all lambs on test reached 110 pounds. Estimates of loin eye area, fat thickness, grade and yield as well as fat probes were completed for the heaviest one-third of the lambs. These lambs were slaughtered to obtain carcass measurements.

A Least Square analysis was used to analyze the data.

II. Effect of Processed Grain Sorghum on Nutrient Digestion.

The first objective of Experiment II was to determine the effect of sorghum grain processing on nutrient availability to lambs. A second was to evaluate the influence of concentrate-roughage ratio on digestibility.

Thirty-five medium weight wethers selected from the group of fine-wool lambs used in Experiment I were used for the digestion study immediately following the termination of the feedlot performance trial. The lambs were fed the same rations as used in Experiment I and each lamb was given one gram per day of chromic oxide (Cr_2O_3) in capsule form during the preliminary and collection periods as an indicator of digestibility.

Experiment II was conducted on the same premises as described in Experiment I with the addition of individual feeding stalls. All lambs were fed *ad libitum* during the seven-day preliminary and six-day collection periods.

Daily feed consumption records were kept by the weigh back system. The feed was sampled daily during the preliminary and collection period and a composite sample made. Water was available *ad libitum*.

A fecal sampling technique employed by Mitchell and Little (1965) was used. Sampling times representing each two hour interval in a 24 hour day were randomly assigned to days of the collection period. Table II shows a typical sampling schedule.

TABLE II. SAMPLING SCHEDULE FOR EXPERIMENT II.

	Time	
Day	a.m.	p.m.
1	8:00	8:00
2	12:00	12:00
3	6:00	6:00
4	10:00	10:00
5	2:00	2:00
6	4:00	4:00

Grab samples containing approximately 15 gm. were taken twice during each 24 hour period and composited at the end of the six day period. All samples were stored in polyethylene bags and refrigerated during collection periods.

A complete proximate analysis was made on the feed sample and the six day composite samples. Least Squares was used to analyze data.

CHAPTER IV

RESULTS AND DISCUSSION

Grain processing to improve utilization can take many forms from a simple grinding or cracking to a complex steam pressure process. Workers from different stations report highly variable results from their grain processing experiments. One reason for the variation in results reported could be a failure to specifically define the grain processing procedure.

A Least Square deviations from the overall mean for feedlot performance are shown in Table III. Methods of processing sorghum grain and concentrate-roughage rations had no significant effects on average daily gains. However, lambs on the 40 percent concentrate rations gained faster per day; .724, .875, .798, as compared to .624, .637, .548, and .798 for the 90 percent concentrate rations. The highest feed conversion was obtained on the 40 percent whole milo, (3.15 pounds of feed per pound of animal gain). The depressed weights for the lambs on the 90 percent concentrate rations during the first weighing period possibly indicate the need for gradually bringing the lambs to a high concentrate level. Less digestive disturbances were observed in lambs on the 40 percent concentrate rations with no death losses due to enterotoxemia or urinary calculi. Six lambs on the 90 percent concentrate ration died from enterotoxemia early in the study and one case of urinary calculi was observed. These results agree with Ruttle and Sundt (1968) who found lambs fed 30 percent concentrate produced higher average daily gains, were more efficient, and had less death loss and digestive disturbances than lambs fed either 60 percent or 90 percent concentrate rations.

Whole or cracked sorghum grain tended to give higher gains than flaked or ground flaked sorghum for lambs, particularly during the first period when cracking approached the $P<.05$ level of significance. Whole, ground flaked, cracked and flaked, respectively, were the rations utilized most efficiently by the lambs. Grinding the sorghum flake reduced performance when compared to mixing the intact flake (.39 vs .55 lb. gain/day). Reduced performance can be in part attributed to reduced feed intake. Adaptation to the ground flake was more difficult when the lambs were initially put on feed. A high percentage of the lambs had diarrhea and four of the six lambs that died from enterotoxemia were from lots containing the 90 percent ground flake. Hale et al. (1968) reported that grinding milo flakes to be used in an 80 percent concentrate ration reduced gain by 0.36 pound daily per steer and increasing feed requirements nine percent.

Colorado, Arizona, and California data indicate increased efficiency by steam flaking milo. The proper rolling of the grain is a major factor in improved performance due to steam processing. Poorly rolled or cracked steam processed grain and overheated grain actually depressed performance. The depressed gain and utilization of the steam flaked grain may be the result of drying the flake to 13 percent moisture for storage through the duration of the study, plus the effects of not processing the grain daily to insure a fresh product. The moisture content of the flake may contribute to the ease of nutrient utilization by the lambs. Factors that apparently effect the performance and utilization of flaked grains are; (1) time of steaming; (2) pressure involved during steaming; (3) moisture content of the grain; (4) thickness of the flakes when rolled after steaming; (5) drying conditions after flaking influences whether the flakes are fed on a wet basis or dried to normal moisture content before feeding; (6) degree of starch gelatinization; (7) changes in protein solubility, and (8) water absorption or affinity for water.

The analysis of variance for the pen location in the barn indicates the lambs on the east side of the barn gained faster (0.759 vs 0.555 lb./day) with less feed (3.05 vs 4.71 lb. feed/ lb. gain) than lambs on the west side. This effect was not significant but approached significance ($P < .05$) during the third period. Table III shows that lambs on the west side gained more slowly and had a higher death loss. Lambs on the west side of the barn were more likely subjected to wind currents, snow, and rain than lambs on the east side. This environmental effect would be the only variable contributing toward this difference in performance and death losses since all treatments were equally represented on both sides of the barn initially.

The value of feed processing and the percentage concentrate is not limited to feedlot performance or digestibility entirely. The product

TABLE III. MEANS AND LEAST SQUARES DEVIATIONS FROM THE MEANS FOR FEEDLOT PERFORMANCE.

	Initial Wt.	Number Observed	ADG 1 lbs.	ADG 2 lbs.	ADG 3 lbs.	Overall ADG lbs.	Feed per lb. gain [1]
Overall Mean	61.31	80	0.658	0.735	0.538	0.657	3.78
		Deviations from Mean					
Treatment							
90% whole		12	-0.053	-0.172	0.204	-0.033	3.29
40% whole		12	0.139	-0.0031	0.067	0.067	3.15
90% cracked		12	-0.185	0.154	-0.036	-0.020	4.86
40% cracked		14	0.427	0.173	-0.023	0.218	3.83
90% flaked		10	-0.386	0.109	-0.020	-0.109	4.46
40% flaked		12	0.298	-0.079	0.239	0.141	4.63
90% gr. flake		8	-0.240	-0.182	-0.431	-0.264	3.30
Barn Effects							
East side		45	0.114	0.065	0.139	0.102	3.05
West side		35	-0.114	-0.065	-0.139	-0.102	4.71
Initial Weight							
Regression Coefficient			0.0068	-0.0034	0.000035	0.0012	

[1]Simple means on group basis and were not analyzed.

produced or the composition of the carcass from a meat animal must be evaluated before the merits of a ration can accurately be measured.

Table IV gives the means and least square deviations from the overall mean for chilled carcass weight, loin eye area, yield grade, kidney fat, carcass grade, and depot fat. The result of this study infers no significant carcass differences for the method of processing, side of barn, or concentrate-roughage ratio. It is interesting to note that the lambs on rations that performed most favorably in the feedlot study were the lambs whose carcasses had higher values than the overall mean for carcass traits. The greatest difference in the carcass traits was observed in the chilled carcass weight with a variation of 29.80 pounds. Lambs on the 40 percent concentrate ration had a heavier chilled carcass weight and a higher grading carcass than did lambs on the 90 percent concentrate ration within the same processing method. Lambs on the 90 percent flake and 90 percent ground flake sorghum rations had lower grading carcasses and a lower yield grade than any other group. Carcasses from the 90 percent ground flake were least desirable for all traits measured. Depot and kidney fat were least affected by nutritional and environmental factors. Lot location favored the east side of the barn for all carcass traits.

Simple correlation coefficients among carcass traits within methods of processing sorghum grain and a pooled correlation over all processing methods are presented in Table V.

Initial lamb weight was most highly correlated with final feedlot weight and chilled carcass weight with a correlation of r = .73 and

TABLE IV. MEANS AND LEAST SQUARES DEVIATION FOR CARCASS TRAITS.

	Initial wt.	Number observed	Chilled carcass wt. lbs.	Loin eye area sq. in.	Yield grade	Kidney fat lbs.	Carcass grade	Depot fat in.
Overall Mean	61.31	80	48.89	2.152	2.78	0.028	5.44	0.147
Treatment								
90% whole		12	2.00	-0.073	0.226	0.0034	0.479	0.011
40% whole		12	3.79	0.200	0.158	-0.0011	0.749	0.016
90% cracked		12	3.32	0.248	-0.013	0.0013	0.352	-0.018
40% cracked		14	12.15	0.439	0.675	0.0046	0.741	0.047
90% flaked		10	-6.84	-0.182	-0.223	-0.0019	-0.938	-0.009
40% flaked		12	3.23	0.111	0.225	0.0017	0.157	0.015
90% gr. flake		8	-17.65	-0.743	-1.048	-0.0080	-1.540	-0.052
Barn Effects								
East side		45	6.04	0.210	0.355	0.0031	0.661	0.022
West side		35	-6.04	-0.210	-0.355	-0.0031	-0.661	-0.022
Initial Weight			0.53	0.018	0.016	0.00018	0.028	0.002

TABLE V. SIMPLE CORRELATIONS AMONG CARCASS TRAITS WITHIN TREATMENTS AND POOLED OVER TREATMENTS.

	90% Whole	40% Whole	90% Cracked	40% Cracked	90% Flaked	40% Flaked	90% Gr. Flake	Pooled Corre-lations
Number Observed	12	12	12	14	10	12	8	80
Initial Wt.								
Ending wt.	.72	.61	.59	.75	.82	.87	.94	.73
Chilled carcass wt.	.81	.74	.83	.83	.60	.83	.67	.74
Depot fat	.31	.42	.60	.24	-.20	.01	.33	.25
Loin eye area	-.19	.11	.09	.43	.55	.59	-.15	.24
Carcass grade	.14	.14	.39	.20	.78	.18	.09	.17
Yield	.38	.40	.48	.28	-.04	.11	.29	.27
Leg conformation	.14	.14	.39	.07	.78	.18	.08	.16
Kidney fat	.13	.12	.08	.26	.36	.47	.07	.19
Ending Wt.								
Chilled carcass wt.	.56	.94	.76	.89	.63	.90	.85	.78
Depot fat	.29	.45	.10	.22	-.18	.53	.32	.20
Loin eye area	-.09	.52	.30	.46	.23	.67	-.04	.37
Carcass grade	-.12	.39	.44	.28	.84	.06	.26	.27
Yield	.37	.36	.07	.27	.06	.16	.25	.22
Leg conformation	-.12	.39	.44	.17	.84	.06	.28	.27
Kidney fat	.06	.09	.08	.30	.55	.56	.01	.20
Depot Fat								
Loin eye area	-.18	.38	-.32	.49	-.39	.04	-.67	.04
Carcass grade	-.01	.15	.28	.63	-.52	-.32	-.33	.00
Yield	.93	.93	.75	.97	.90	.96	.96	.92
Leg conformation	-.01	.15	.28	.61	-.52	-.32	-.27	.02
Kidney	-.29	.09	-.08	.69	.24	.01	-.46	.19
Loin Eye Area								
Carcass grade	-.09	.45	.20	.43	.37	-.04	.69	.27
Yield	-.35	.26	-.12	.42	-.27	.18	-.77	.03
Leg conformation	-.09	.45	.20	.42	.37	-.04	.68	.27
Kidney fat	-.33	.02	.30	.20	.09	.50	-.51	.11
Yield								
Leg conformation	.13	.01	-.08	.63	-.24	-.44	-.40	-.09
Kidney fat	.07	.41	.59	.84	.64	.29	.66	.55

r = .74, respectively. Depot fat, loin eye area, and yield were more highly correlated with initial weight than carcass grade, leg conformation and kidney fat. Loin eye area, depot fat and leg conformation had the most variation due to method of processing. Lambs on the 90 percent cracked ration had carcasses that had a higher correlation between depot fat and initial weight (.60) while the carcasses from the 90 percent flaked ration showed the least correlation (-.20). The highest correlation between initial weight and loin eye area were obtained from lambs fed the 90 percent steam flaked (0.55) and the 40 percent steam flaked (0.59) rations. The smallest correlation was with 90 percent whole (-.19) and 90 percent ground flake (-.15). The 90 percent flake produced carcasses having a high correlation (r = .78) between leg conformation and initial weight. A low correlation was observed in the 40 percent cracked (r = .07). Reasons why such differences in the correlations should occur within these methods of processing are not known.

Final feedlot weight was highly correlated with carcass weight (.78). Leg conformation, carcass grade, and loin eye area had a correlation with ending weight of .27, .27, and .37, respectively, for the pooled correlations. The difference in correlation between treatments for loin eye area and ending weight was -.09 (90% whole) to .67 (40% flaked). Leg conformation and ending weight had correlations ranging from -.12 (90% whole) to .84 (90% flake).

Body depot fat was not highly correlated with any carcass trait measured except yield grade because little variation existed in finish.

This high correlation with yield would be expected since depot fat is the most important single factor influencing yield grade. All other traits were positively correlated with depot fat for the pooled data. Loin eye area, carcass grade, and leg conformation were the least correlated with depot fat. A high correlation (r =.69) and a low correlation (r = -.46) were observed between depot fat and kidney fat on carcasses from lambs fed 40 percent cracked and 90 percent ground flake. Carcass grade was negatively correlated with depot fat for the lambs being fed steam processed grain. According to Hillman (1963) and Matthews (1959) all factors indicating fat in the carcass were positively related with carcass grade and all factors indicating lean were either non-significant or negatively correlated with carcass grade.

Loin eye area was most highly correlated with carcass grade (.27), chilled carcass weight (.37), initial weight (.24), carcass grade (.27) and leg conformation (.27). Yield grade, kidney fat, and depot fat had lower correlations with loin eye area. Carcasses from lambs fed the 90 percent whole grain had a negative correlation between loin eye area and other traits measured.

Yield grade was most highly correlated with body depot fat (.92) and related less to leg conformation (-.09) and kidney fat (.55). Leg conformation correlated with yield varied with methods of processing (-.44, to +.63) and was negative in most cases. One would expect leg conformation to be positively related to yield grade since the preliminary yield grade is adjusted by .05 of a grade for each one-third of a grade that conformation deviates from average choice. There was little difference in leg conformation of the eighty lambs.

Table VI shows the simple correlations of estimated and actual carcass characteristics and the number of observations for each different processing method and pooled over all methods.

TABLE VI. CORRELATION OF ESTIMATED CARCASS TRAITS AND ACTUAL MEASUREMENTS.

Estimator	1	2	3	1 & 2	2 & 3	1 & 3	Actual
Number observed	64	79	9	79	9	0	79
Depot fat	.02	.22	.68	.68	.58	0	
Loin eye area	.28	.29	.51	.73	.84	0	
Carcass grade	.14	.17	0	.56	0	0	
Depot fat probe	.50	.35	.10				.06

The highest correlations obtained from estimated and actual carcass data was between two estimators evaluation of a particular trait. Estimation of loin eye area and actual loin eye area were more highly correlated than estimated depot fat or carcass grade with actual measurements. In most cases the estimates of condition were high and low for loin eye area and carcass grade. A higher correlation was obtained between estimating the condition of an animal than by probing.

Stauffer et al. (1958) and Matthews et al. (1960) reported results from live probing of lambs to obtain backfat thickness, with correlations of .58 and .57 respectively.

Table VII shows the simple correlations among average daily gain (ADG), and weighing periods within treatments and pooled data.

TABLE VII. SIMPLE CORRELATIONS AMONG AVERAGE DAILY GAIN AND WEIGHING PERIODS WITHIN TREATMENTS AND POOLED DATA.

	90% Whole	40% Whole	90% Cracked	40% Cracked	90% Flaked	40% Flaked	90% Gr. Flake	Pooled Data
Number Observed	12	12	12	14	10	12	8	80
Correlation ADG 1 & ADG 2	-.09	-.15	-.08	.17	-.20	.16	-.48	-.12
Correlation ADG 1 & ADG 3	-.22	.41	.29	.03	-.40	-.58	.27	.03
Correlation ADG 1 & Overall ADG	.60	.76	.86	.59	.69	.67	.83	.72
Correlation ADG 2 and ADG 3	-.40	-.22	-.69	-.26	-.62	-.49	-.80	-.44
Correlation ADG 2 & Overall ADG	.09	.36	.08	.51	.11	.65	-.08	.25

Negative correlation existed between the ADG for different weighing periods, but a positive correlation was obtained between the ADG for a single weighing period and the overall ADG. The correlation of ADG for period one and overall ADG was higher (.72) than the relationship of ADG for period two and overall ADG (.25). The health condition of the lambs previous to the feedlot trial, adjustment to the ration, and the amount of fill at the time of intermediate weighings may account for these differences in correlations. The correlation between ADG in the first and third periods was higher than the correlation between ADG in the first and second periods because most of the lambs gained faster during the second weighing period as indicated in Table III. The lowest correlations between weighing periods was observed between period two and three.

Table VIII shows the mean digestible nutrients within the method of processing. A significant difference ($P < .05$) was noted in crude protein digestibility. The 40 percent concentrate rations had a higher digestion coefficient for crude protein than the 90 percent concentrate rations. This may be partially accounted for by the rations not being isonitrogenous. Thus, the lambs fed 40 percent concentrate received more crude protein and utilized a higher percent protein than lambs fed 90 percent concentrate rations. In work conducted by Joyce (1959) and Brent (1960) the protein digestion coefficients decreased as the percentage of roughage decreased. A significant difference due to method of processing was obtained in crude protein digestibility favoring lambs fed 90 percent flaked ration. The flaking process evidently made the crude protein less soluble and resulted in

TABLE VIII. MEANS OF DIGESTIBLE NUTRIENTS WITHIN METHOD OF PROCESSING.

	Crude Protein[1]	Crude Fiber [1]	Crude Fat[1]	Dry Matter[1]	NFE[1]	TDN[1]
90% whole	$.651^{a}$	$.763^{ab}$	$.569^{a}$	$.787^{ab}$	$.449^{ab}$	$.774^{a}$
40% whole	$.800^{b}$	$.456^{bc}$	$.710^{b}$	$.815^{b}$	$.333^{b}$	$.787^{ab}$
90% cracked	$.627^{ac}$	$.496^{bc}$	$.581^{a}$	$.764^{a}$	$.271^{b}$	$.758^{a}$
40% cracked	$.820^{b}$	$.994^{a}$	$.764^{b}$	$.821^{b}$	$.760^{c}$	$.783^{ab}$
90% flaked	$.695^{a}$	$.997^{a}$	$.700^{ab}$	$.828^{b}$	$.684^{ac}$	$.821^{b}$
40% flaked	$.814^{b}$	$.933^{a}$	$.793^{b}$	$.821^{b}$	$.742^{c}$	$.791^{ab}$
90% gr. flake	$.610^{c}$	$.367^{c}$	$.600^{a}$	$.796^{ab}$	$.304^{b}$	$.796^{ab}$

[1]Any mean in the same column with different superscripts is significantly different ($P < .05$).

higher utilization.

Crude fiber digestibility was depressed in the 90 percent ground flake and was significantly lower than digestibility of the 40 percent cracked, 40 percent flaked, and 90 percent flaked rations. Crude fiber digestibility of 40 percent cracked ration was significantly higher than either the 40 percent whole or 90 percent cracked. According to Boman (1965) crude fiber was significantly reduced ($P < .05$) as the percentage hay in the ration decreased. Arnett and Bradley (1961) showed increased crude fiber with rations containing flaked corn. The 40 percent and 90 percent flaked rations approached significance of having a higher digestibility than the 40 percent whole and 90 percent cracked rations. The highest crude fiber digestibilities were 99.4, 97.7 and 93.3 percent for the 40 percent cracked, 90 percent flaked, and 40 percent flaked rations, respectively.

Crude fat digestibility was significantly higher for 40 percent than the 90 percent concentrate rations. The most highly digestible ration for crude fat was the 40 percent flaked ration at 79.3 percent digestibility. Forty percent cracked was significantly higher than 90 percent whole sorghum in crude fat digestibility. These findings were in contrast to Hale et al. (1966) who reported that steam processing depressed ether extract digestibility.

The 90 percent cracked ration had the lowest dry matter digestibility being significantly lower than 90 percent flaked, 40 percent whole, 40 percent flaked, and 40 percent cracked. These results closely agree with work of Arnett and Bradley (1961) and Johnson et al. (1968) in that dry matter digestibility was higher for the steam processed rations.

NFE was significantly higher for the 90 percent flaked, 40 percent flaked, and 40 percent cracked in comparison to 90 percent cracked, 90 percent ground flake and 40 percent whole, since digestibility of crude protein, crude fat, dry matter and crude fiber were high in these rations.

A treatment difference occurred between the 90 percent concentrate rations for TDN values. The 90 percent flaked ration was significantly more digestible than either the 90 percent whole or cracked and approached being significantly more digestible than the 90 percent ground flake. All three rations exposed to steam processing (90 percent flaked, 90 percent ground flaked, and 40 percent flaked) were the highest in TDN values. These results were in full agreement with the findings of Hale et al. (1966), Husted et al. (1968) and Arnett and Bradley (1961).

APPENDIX A MEANS AND STANDARD ERRORS FOR FEEDLOT AND CARCASS CHARACTERISTICS.

	Mean	Standard Error	Number Observed	Maximum	Minimum
Initial Wt.	61.3	.80	80	75.0	42.0
Ending Wt.	98.1	1.17	80	121.0	75.0
Chilled Carcass Wt.	48.9	.55	80	61.0	39.0
Estimator #1 Fat	.21	.008	64	.42	.10
Estimator #2 Fat	.21	.007	79	.40	.10
Estimator #3 Fat	.27	.01	9	.36	.21
Probe	.40	.02	79	.90	.01
Actual Fat	.15	.006	80	.28	.05
Estimator # 1 Loin Eye	1.98	.03	64	2.70	1.50
Estimator # 2 Loin Eye	1.95	.03	79	2.65	1.58
Estimator # 3 Loin Eye	2.01	.07	11	2.35	1.70
Actual Loin Eye	2.18	.04	79	2.93	2.48
Estimator # 1 Carcass Grade	22.3	.27	64	31.00	20.00
Estimator # 2 Carcass Grade	21.6	.12	35	23.00	21.00
Actual Carcass Grade	23.4	.35	80	32.00	21.00
Actual Yield	2.78	.04	80	3.87	2.07
Leg Conformation	23.4	.35	80	32.00	21.00
Kidney Fat	2.78	.07	80	4.60	1.50
Wt. 12/21/68	75.09	1.14	80	99.00	53.00
Wt. 1/ 11/69	90.56	1.17	80	116.00	70.00
Average Daily Gain 1st	.67	.04	79	1.29	.13
Average Daily Gain 2nd	.74	.03	80	1.43	.99
Average Daily Gain 3rd	.56	.04	77	1.21	.78
Average Daily Gain Overall	.66	.02	80	1.43	.13

APPENDIX B SIMPLE CORRELATIONS POOLED OVER SEVEN TREATMENTS - UPPER RIGHT HALF OF MATRIX IS NUMBER OF OBSERVATIONS.

	Initial wt.	Ending wt.	Chilled carcass wt.	Est. #1 fat	Est. #2 fat	Est. #3 fat	Fat probe	Actual probe	Est. #1 loin eye	Est. #2 loin eye	Est. #3 loin eye	Actual loin eye	Est. #1 grade	Est. #2 grade	Actual grade	Actual yield	Leg conformation	Kidney fat
Estimator #1 fat	.43	.48	.47	1.00	63		63	64	64	63		63	64	35	64	64	64	64
Estimator #2 fat	.44	.45	.40	.68	1.00	9	79	79	63	79	11	78	63	35	79	79	79	79
Estimator #3 fat	.65	.08	.62		.58	1.00	9	9		9	9	9			9	9	9	9
Probe	.51	.59	.51	.50	.35	.10	1.00	79	63	79	11	78	63	35	79	79	79	79
Actual fat	.25	.20	.31	.02	.68	.68	.06	1.00	64	79	11	79	64	35	80	80	80	80
Est. #1 loin	.57	.67	.68	.66	.57		.66	.21	1.00	63		63	64	35	64	64	64	64
Est. #2 loin	.45	.59	.56	.50	.47	.45	.40	.18	.73	1.00	11	78	63	35	79	79	79	79
Est. #3 loin	.59	.71	.85		.21	.62	.16	.19		.84	1.00	11			11	11	11	11
Actual loin eye	.24	.37	.44	.26	.11	-.49	.23	.04	.28	.29	.51	1.00	63	34	79	79	79	79
Est. #1 carcass grade	.41	.46	.40	.56	.53		.52	.19	.57	.42		.21	1.00	35	64	64	64	64
Est. #2 carcass grade	.03	.27	.12	.49	.77		.44	-.08	.31	.55		.17	.56	1.00	35	35	35	35
Actual grade	.17	.27	.25	.13	.14	-.13	.36		.24	.17	.02	.27	.14	.17	1.00	80	80	80
Actual yield	.27	.22	.40	.07	.23	.64	.05	.92	.19	.19	.09	.03	.18	-.07	-.09	1.00	80	80
Leg conformation	.16	.27	.25	.12	.13	-.13	.36	.02	.24	.19	.02	.27	.14	.17	.99	-.09	1.00	
Kidney fat	.19	.20	.30	.24	.17	-.06	.07	.18	.11	.15	-.57	.11	.10	.05	-.01	.55		1.00

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LITERATURE CITED

Annison, E. F. and D. Lewis, 1959. Metabolism in the rumen. John Wiley and Sons, Inc., New York, N. Y.

Anthony, W. B., R. R. Harris and J. G. Starling. 1960. High roughage and cottonseed mixtures for fattening calves. J. Animal Sci. 19:1306 (abstr.).

Armstrong, D. G. and K. L. Blaxter. 1957a. The heat increment of steam-volatile fatty acids in fasting sheep. Brit. J. Nutr. 11:413.

Armstrong, D. G. and K. L. Blaxter. 1957b. The utilization of acetic, propionic, and butyric acids by fattening sheep. Brit. J. Nutr. 11:413.

Armstrong, D. G., K. L. Blaxter and N. McG. Graham and F. W. Wainman. 1958. The utilization of the energy of two mixtures of steam-volatile fatty acids by fattening sheep. Brit. J. Nutr. 12:177.

Arnett, D. W. and N. W. Bradley. 1961. Effects of pelleted, flaked, and ground corn and pelleted distillers dried grains with solubles on digestibility of fattening rations and feedlot performance of beef steers. J. Animal Sci. 20:396 (abstr.).

Balch, C. C., D. A. Balch, S. Bartley, Z. D. Hosking, V. W. Johnson, S. J. Rowland and J. Turner. 1955. Studies of the secretion of milk of low fat content by cows on diets low in hay and high in concentrates. V. The importance of the type of concentrate. J. Dairy Res. 22:10.

Balch, C. C. and S. J. Rowland. 1957. Volatile fatty acids and lactic acid in the rumen of dairy cows receiving a variety of diets. Brit. J. Nutr. 11:288.

Boman, R. L. and J. T. Huber. 1965. Effect of a low-hay, high concentrate ration on milk yields and nutrient utilization. J. Animal Sci. 48:798 (abstr.).

Brent, Benny E. 1960. Digestible energy studies on various levels of concentrates in pelleted rations for fattening lambs. A Master's Thesis, Department of Animal Husbandry, Kansas State University, Manhattan, Kansas.

Brethour, John R., Donald G. Ely and W. W. Duitsman. 1969. Different processing methods for sorghum grain for steer fattening rations. Fort Hays Branch Kansas Expt. Sta. 237 Contribution Number.

Brethour, J. R. and W. W. Duitsman. 1964. Use of self-fed all concentrate and high concentrate rations to fattening yearling steers. Kansas Agr. Expt. Sta. 51st Roundup Rpt. Bul. 459.

Brown, C. J. and Jack W. Caveness. 1959. Preference for feed preparation by sheep. J. Animal Sci. 18(3-4) :1158.

Buchanan, J. G., Robert Totusek and A. D. Tillman. 1968. Effect of methods of processing on digestibility and utilization of grain sorghum by cattle and sheep. J. Animal Sci. 27:525.

Burroughs, W., P. Gerlaugh, B. H. Edington and R. M. Bethke. 1949. The influence of corn starch upon roughage digestion in cattle. J. Animal Sci. 8:271.

Cabezas, M. T. 1964. The effect of physical form on nutritive value of ruminant diets. Ph.D. Dissertation. University of Florida.

Cabezas, M. T., J. F. Hentges,Jr., J. E. Moore and J. A. Olson. 1965. Effect of diet on fatty acid composition of body fat in steers. J. Animal Sci. 24:57.

Colenbrander, V. F., E. E. Bartley, J. L. Morrill, C. W. Deyoe and H. B. Pfost. 1967. Effect of feeding expanded grain and finely ground hay on milk composition, yield, and rumen metabolism. J. Dairy Sci. 50:1966.

Cox, R. F. 1948. Physical balance as a factor in determining the efficiency of feed utilization by fattening lambs. Kansas Agr. Exp. Station Tech. Bul. 65.

Davenport, E. 1897. On the importance of the physiological requirements of the animal body; Results of an attempt to grow cattle without coarse feed. Ill. Agr. Exp. Sta. Bul. 46:362.

Davis, R. E., R. R. Oltjen and James Bond. 1963. High concentrate studies with beef cattle. J. Animal Sci. 22:640.

Deuel, H. J., Jr., J. S. Butts, L. F. Hallman and C.H. Cuttler. 1935. Quantitative studies on B-oxidation. Glycogen formation from various fatty acids. J.Biol. Chem. 112:15.

Doane, B. B., E. E. Hatfield, U. S. Garrigus and R. J. Vatthauer. 1961. Is roughage essential in a fattening ration for feeder lambs. Ill. Agr. Exp. Sta. Sheep Day Report.

Durham, R. M., R. Stovell, B. Cude and E. Powitsky. 1964. Ray soybeans, whole cottonseed, and cottonseed meal as supplements for all-concentrate rations. J. Animal Sci. 23:873 (abstr.).

Ellis, G. F. 1965. All concentrate feeding research. Feedstuff 37:50.

Ensor, W. L., J. C. Shaw and H. F. Tellechea. 1959. Special diets for the production of low fat milk and more efficient gains in body weight. J. Dairy Sci. 42:189.

Fontenot, W. H.McClure, F. S. McClaugherty and R. C. Carter. 1967. Effect of physical form and roughage to concentrate ration of rations for fattening lambs. Virginia Polytechnic Inst. Bul. 7.

Frederick, H. M., B. Theurer and W. H. Hale. 1968. Effect of moisture, heat and pressure _in vitro_ starch digestion of milo and barley. J. Animal Sci. 27:1110.

Garrett, W. N. 1967. Steam pressure processing of barley and milo. Proc. 1967 California Feeders' Day.

Garrett, W. N. 1968. Influence of the method of processing on the feeding value of milo and wheat. Proc. 1968 California Feeders' Day.

Garrett, W. N., G. P. Lofgreen and J. L. Hull. 1966a. Steam pressure processing of grain for fattening cattle. Proc. 1966 California Feeders' Day.

Glimp, Hudson. 1969. Lambs don't need high roughage rations. U. S. Meat Animal Research Center. Feedlot 4-69, p.20.

Hale, W. H., Brent Theurer, Bruce Taylor and Herb Essig. 1968. A comparison of 80 and 90 percent concentrate rations fed various lengths of time and the effect of grinding steam-processed milo flakes on performance of fattening cattle. Arizona Feeders Day Rept. Series P-10.

Hale, W.H., Luis Cuitun, W. J. Saba, Bruce Taylor and Brent Theurer. 1966. Effect of steam processing and flaking milo and barley on performance and digestion by steers. J. Animal Sci. 25:392.

Hale, W. H., W. J. Saba, Luis Cuitun, Stephen Mehen, Tom Husted, Wayne Figroid, Bruce Taylor and Brent Theurer. 1965. Digestion of steam-processed milo and barley by cattle. Arizona Feeders Day Rept. Series P-3.

Hanke, H. E. and R. M. Jordon. 1964. Starting lambs on feed. 37th Sheep and Lamb Feeders Day. Minn. Inst. of Agr.

Hayer, W. T., III, R. E. Taylor and F. Hubbert, Jr. 1961. Apparent digestibility and volatile fatty acid studies with all-barley fattening rations for beef cattle. J. Animal Sci. 20:666 (abstr.).

Henry, W. A. 1898. Feeds and Feeding. The Henry Publishing Company. Madison, Wisc.

Hillman, R. M. 1963. Heritability and correlations between carcass and live animal traits in sheep. Master's Thesis, Kansas State University, Manhattan, Kansas.

Husted, W. T., Stephen Mehen, W. H. Hale, Morgan Little and Brent Theurer. 1968. Digestibility of milo processed by different methods. J. Animal Sci. 27:531.

Husted, W. T., W. H. Hale, Brent Theurer. 1966. Digestibility of dry-rolled, steam-processed flaked, steam-processed cut and water-soaked milo by steers. Arizona Cattle Feeders Day Rept.

Johnson, D. E., J. K. Matsushima and K. L. Knox. 1968. Utilization of flaked vs. cracked corn by steers with observations on starch modification. J. Animal Sci. 27:1431.

Johnson, Ronald R., K. dl-Shazly, B. A. Dehority. 1960. Effect of starch on the digestion of cellulose in vitro and in vivo by rumen microorganisms. J. Animal Sci. 19:1268 (abstr.).

Joyce, James A. 1959. Digestion studies on various levels of grain and alfalfa fed nonpelleted, pelleted and pelleted plus hay to lambs. A Master's Thesis, Department of Animal Husbandry, Kansas State University, Manhattan, Kansas.

Kammlade, Sr.,W.G. and W. G. Kammlade, Jr. 1955. Sheep Science. J. B. Lippincott Co., Chicago.

Keating, E. K., W. J. Saba, W. H. Hale and Bruce Taylor. 1965. Further observations on the digestion of milo and barley by steers and lambs. J. Animal Sci. 24:1080.

LeClerg, E. L. 1960. Least-Squares analysis of data with unequal subclass numbers. Agr. Res. Ser. U.S.D.A. ARS - 20-8.

Lofgreen, G. P., V. E. Mendel and D. L. McIlroy. 1968. Effects of kinds of milo, method of processing and level of urea on cattle performance. Proc. 8th Annual California Feeders' Day Rept.

Matrone, G., H. A. Ramsey and G. H. Wise. 1959. Effect of volitile fatty acids, sodium and potassium bicarbonate in purified diets for ruminants. Proc. Soc. Exp. Biol. and Med. 100:8.

Matsushima, J. K., D. E. Johnson, M. W. Heaney and B. A. Weichenthal. 1966. Greater feed efficiency from flaked corn. Feedstuff. Jan. 29, 1966.

Matsushima, J. K. and R. L. Montgomery. 1967. The thick and thin of flaked corn. Colorado Farm and Home Research 17:4.

Matthews, D. J. 1959. Relationship of live lamb measurements to carcass characteristics as affected by different breeding systems. Ph.D. Thesis, Kansas State University, Manhattan, Kansas.

Matthews, D. J., R.A. Merkel, J. D. Wheat, and R. F. Cox. 1960. Technique for measuring the cross-sectional axes of the longissimus dorsi muscle and depth in lambs. J. Animal Sci. 19:803.

McCandlish, A. C. 1923. Studies in the growth and nutrition of dairy calves. V. Milk as the sole ration for calves. J. Dairy Sci. 6:54.

McCarthy, R. D., J. B. Holter, J. C. Shaw, F. G. Heater and J. McCarthy. 1957. Rumen perfusion; A new technique for the ruminologist. Md. Agr. Exp. Sta. Misc. Pub. 291:33.

McDougall, E. I. 1948. Studies on ruminant saliva. I. The composition and output of sheep's saliva. Biochem. J. 43:99.

McIlroy, D. L., V. E. Mendel and W. N. Garrett. 1967. Comparison of commercially prepared, rolled and flaked barley and milo. Proc. 7th Annual Calif. Cattle Feeders' Day Rept.

Mead, S. W. and W. M. Regan. 1931. Deficiencies in rations devoid of roughage for calves. I. The effect of the addition of cod liver oil and alfalfa ash. J. Dairy Sci. 14:283.

Mehen, Stephen, W. H. Hale, Brent Theurer and O. M. Little. 1966. Digestibility of dry rolled, fine ground steam-processed and pressure cooked milo by steers. Arizona Cattle Feeders Day Rept.

Menzies, C. S. and A. B. Erhart. 1967. Lamb feeding experiments (mixtures and pelleted rations). Kansas Exp. Sta., 54th Annual Livestock Feeders Day Bul. 507:22.

Menzies, C. S., Evans Banburg and Clifford Spaeth. 1968. Colby Sheep Exp. Kansas Agr. Exp. Sta. Rept. of Progress 133.

Morrison, F. B. 1959. Feeds and Feeding. Twenty-second edition. The Morrison Publishing Company, Ithaca, New York.

Newland, H. W., W. T. Magee, G. A. Branaman and L. H. Blakeslee. 1962. Effect of heat-processing and pelleting corn for steers and lambs. J. Animal Sci. 21:711.

N.R.C. 1964. Nutrient requirement for farm animals, No. 5. Nutrient requirement for sheep. National Research Council, Washington, D. C.

Oltjen, R. R. and R. E. Davis. 1964. Pellets, DES and MgZn in all concentrate rations. J. Animal Sci. 23:887 (abstr.).

Oltjen, R. R. and R. E. Davis. 1965. Factor affecting the ruminal characteristics of cattle fed all concentrate rations. J. Animal Sci. 24:198.

Oltjen, R. R., R. E. Davis and R. L. Hiner. 1965a. Factors affecting performance and characteristics of cattle fed all-concentrate rations. J. Animal Sci. 24:192.

Parrott, J. C., III, Stephen Mehen, W. H. Hale, Morgan Little and Brent Theurer. 1969. Digestibility of dry rolled and steam processed flaked barley. J. Animal Sci. 28:425.

Phar, P. A. 1967. Grain processing for feedlot rations. Proc. of 1st Kansas Cattle Feeders Nutr. Conf.

Phillipson, A. T. 1952. The fatty acids present in the rumen of lambs fed on a flaked maize ration. Brit. J. Nutr. 6:190.

Pope, L. S., Lowell Walters, George Waller, Jr., and W. D. Campbell. (1960) Effect of pelleting and steam rolling milo, with and without enzymes, for fattening steer calves. Oklahoma 34th Annual Livestock Feeders Day Rept. Misc. Pub. 57.

Pope, L. S., L. E. Walters, G. R. Waller and W. D. Campbell. 1963b. Fattening cattle on all-concentrate rations based on steam rolled milo. Okla. Agr. Exp. Sta. Misc. Pub. 70.

Preston, R. L. and W. H. Pfander. 1961. Performance of fattening lambs fed various forms of corn. J. Animal Sci. 20:947 (abstr.).

Reid, R. L., J. T. Hogan and P. K. Buggs. 1957. The effect of diet on individual volitile fatty acids in the rumen of sheep with particular reference to the effect of low rumen pH and absorption on high-starch diets. Australian J. Agr. Res. 8:691.

Rhodes, R. W. and W. Woods. 1962. Volatile fatty acid measurements on the rumen contents of lambs fed rations of various physical forms. J. Animal Sci. 21:483.

Ruttle, J. L. and C. N. Sundt. 1966. Performance on self-fed lambs on an all-concentrate ration. New Mexico Agr. Exp. Sta. 27th Feeders Day Rept.

Salsburg, R. L., J. A. Hoefer and R. W. Luecke. 1961. Effect of heating starch on its digestion by rumen microorganisms. J. Animal Sci. 20:569.

Shaw, J. C., R. R. Robinson, M. E. Senger, S. Lakshmanan and T. R. Lewis. 1959. Production of low fat milk. J. Nutr. 69:235.

Shaw, J. C., W. L. Ensor, H. F. Tellechea and S. D. Lee. 1960. Relation of diet to rumen volatile fatty acids, digestibility, efficiency of gain and degree of unsaturation of body fat in steers. J. Nutr. 71:203.

Shelton, Maurice. 1965. Effect of physical form of ration on performance of lambs receiving rations composed largely of sorghum grain. Texas A & M Agr. Exp. Sta. PR-2332-2344.

Smith, E. F., D. B. Parrish and A. G. Pickett. 1949. Effect of grinding on the nutritive value of grain sorghums for fattening steer calves. Kansas Agr. Exp. Sta. Cir. 250:37.

Stewart, W.E., D. G. Stewart and L. H. Schultz. 1958. Rates of volatile fatty acid production in the bovine rumen. J. Animal Sci. 17:723.

Stouffer, J. R., D. E. Hogue, D. H. Marden, and G. H. Wellington. 1958. Some relationship between live animal measurements and carcass characteristics of lambs. J. Animal Sci. 17:1151 (abstr.).

Thomas, O. O., and L. L. Myers. 1961. Steam or dry rolled barley in high concentrate rations for fattening beef steers. J. Animal Sci. 20:953 (abstr.).

Totusek, Robert, Dwight Stephens and Lowell Walters. 1964. Improving the utilization of milo for fattening calves; Value of fine grinding and supplemental vitamin. Oklahoma 38th Annual Livestock Feeders Day Rept. Misc. Pub. 74.

Totusek, Robert, Larry Franks, Willie Basler and Robert Renbarger. 1967. Methods of processing milo for cattle. Okla. Agr. Exp. Sta. Misc. Publ. (M. P. 79) :79.

Tove, S. B. and G. Matrone. 1962. Effect of purified diets on the fatty acid composition of sheep tallow. J. Nutr. 76:271.

Vetter, R. L., T. W. Wickersham and Gary Harter. 1965. Comparison of low and high concentrate rations and length of feeding period on feedlot performance of feeder lambs. Iowa State Univ. Agr. Exp. Sta. Sheep Day Rept.

Weiss, R. L., B. R. Baumgardt, G. R. Barr and V. H. Brungardt. 1967. Some influence of rumen volatile fatty acids upon carcass composition and performance in growing and fattening steers. J. Animal Sci. 26:389.

Woods, W., W. Burroughs, N. Raun, R. Cooley and C. Bockhop. 1961. High concentrate, low fiber rations for beef cattle. Feedstuff 33:36.

EFFECTS OF PROCESSING GRAIN SORGHUM ON FEEDLOT PERFORMANCE AND DIGESTIBILITY WITH LAMBS

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ABSTRACT

Processing sorghum grain has become increasingly more popular in the past several years. Advantages which have been associated with processed sorghum grain are increased enzymatic and bacterial action, propionate production, and bulk of the grain.

The first objective was to compare the effects of different methods of processing sorghum grain on rate of gain and feed utilization with lambs fed *ad libitum* under normal, feedlot conditions. A second objective was to compare 40 and 90 percent concentrate rations effects on yield grade and carcass composition. The third objective was to compare loin eye area, carcass, grade, yield grade, and fat thickness with estimates obtained by probing the live animal and by grader evaluation.

Ninety-eight fine-wool wethers were used for the feedlot trial and carcass analysis. Thirty-five of the same lambs were used in the digestion study.

Rations consisted of steam flaked, ground steam flaked, cracked, and whole grain sorghum at 40 and 90 percent concentrate levels. Sun-cured alfalfa pellets were used as roughage. Fecal samples were taken twice during each 24 hour period and composited at the end of the six day collection period for each lamb. A complete proximate analysis was made on the feed sample and the six day composite sample.

The method of processing sorghum grain or concentrate-roughage ratios had no significant effects on average daily gains. Lambs fed the 40 percent concentrate rations had the highest average daily gain. Less digestive disturbances were observed in lambs fed the 40 percent concentrate rations. Feed utilization was highest for whole grain and was reduced in the steam flaked rations. No significant differences existed among the carcass traits of the lambs. Lambs on rations that performed most favorably in the feedlot study were lambs whose carcasses were on the positive side of the overall means for the carcass traits measured. Lambs on the 40 percent concentrate ration had heavier chilled carcass weights and had a higher carcass grade than did lambs on the 90 percent concentrate ration within the same processing method.

Digestibility of crude protein, crude fiber and crude fat was significantly higher for 40 percent concentrate rations when compared to 90 percent rations. A significant difference existed in the method of processing the 90 percent concentrate ration for TDN values favoring the steam flaked grain. Dry matter, ether extract, and nitrogen free extract values were highest for steam processed grains.