FEEDLOT, *IN VITRO* AND METABOLISM STUDIES
WITH PROCESSED WHEAT AND BARLEY

By

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CHAPTER I

INTRODUCTION

Today feed prices constitute a large portion of the total cost of feedlot gain. The type and amount of grain in a ration depends on price, availability and feeding value. For a feeder to compete in the current price squeeze, he must become a feed processor and not just a feed mixer. Since grain constitutes the major ingredient in cattle rations, a feeder must obtain maximum value from it.

Feed efficiency (feed/gain) and rate of gain are important factors in cost of gain. In some cases feed efficiency can be improved from 10% to 20% by proper processing and feeding prodecures. Rate of gain is more difficult to improve, but a 10% improvement with certain processing procedures may be possible. Until about 10 years ago the only processing techniques that had been investigated to any extent were grinding, dry rolling and steam flaking. Since that time other techniques have been developed in an attempt to improve product utilization. Research studies indicate that some of the newer processing methods appear to improve grain utilization by finishing cattle (Hale, 1973).

Such grains as wheat and barley are available to the livestock feeder for use in feedlot rations. The price of wheat in the past one or two years has been too high to permit extensive use in feedlot rations. But, wheat has been competitive with feed grains at times in recent years and may be again in the future.

Both heat processed and high moisture processed grains have been used by many commercial feedlots. Thus far, very little data are available concerning the effects of dry heat processing of wheat and high moisture processing of barley in feedlot finishing rations. The purpose of these studies was to evaluate 1) micronizing of wheat and 2) high moisture processing of barley in cattle feedlot rations.

CHAPTER II

REVIEW OF LITERATURE

Use of Wheat in Cattle Rations

The tendency in the past has been to not feed all-wheat rations to finishing cattle. Some believe that palability may be a problem and that cattle will tire of wheat after prolonged feeding (Morrison, 1957). Moreover, uncertainly as to proper management required when wheat is fed in finishing rations has also discouraged its use because of concern about increased acidosis, off-feed and the like. Because the carbohydrate portion of wheat appears to be more rapidly fermented in the rumen than in other cereal grains, a greater incidence of abnormal lactic acid levels has been reported (Tremere et. al., 1968).

Feeding Value of Wheat

Wheat sometimes competes with other grains as an energy source in different areas of the nation. In the Midwest wheat competes with corn, in the Northwest with barley and in the Southwest with barley, milo and corn. Studies on the value of wheat in feedlot rations are quite variable and much less numerous than with other grains.

Dunbar et al. (1969) in comparing wheat and barley for feedlot cattle showed that both grains were comparable in feeding value, and that a combination of the two grains may result in better gains, but feed efficiencies were no better. Wheat has been found by Morrison (1957) to give a 9% better feed efficiency over corn and 18% better feed efficiency than barley.

Brethour (1966) reported wheat to have a 9% advantage in feed efficiency over corn and a 15% advantage over milo when each was fed as the only grain. He further reported a 17% advantage over corn and a 24% advantage over milo when wheat and corn were mixed in similar feedlot rations. Oltjen et al. (1966), however, reported a slightly lower value for wheat than for corn. They reported lower gains and more abcessed livers when wheat was fed. Lower gains and feed efficiencies were also reported for wheat than milo (Totusek et al., 1968).

Baker and Baker (1960), in a series of trials with wheat and corn, reported that generally where wheat was substituted for all of the corn, its value was not as great as where it was used to replace one-half of the corn, due to decreased intakes and feed efficiencies. In a summary of 18 feeding trials, Brethour (1970) found that consumption on wheat averaged about 8% less than on barley, but wheat had an advantage of about 10% in feed efficiency. When wheat was fed alone, feed intakes were reduced approximately 16% and rates of gain were 10% less than on sorghum fed alone. Feed efficiencies favored wheat by about 9%. When sorghum and wheat were combined at different levels, decreased feed consumption, decreased gain and increased efficiency have been observed as level of wheat increased (Wagner et al., 1971; Richardson et al., 1967; Brethour, 1966; Brethour and Duitsman, 1961, 1966).

Processing of Wheat

In attempts to improve utilization several different methods of processing wheat have been studied. Wheat has generally not been as responsive to processing as other grains. It is apparent that wheat has anatomical and chemical properties that make it different from other grains (Reeve and Walker, 1969). These workers suggest that the differences may be due to differences in the structural and compositional propertities of the starches, the types of endosperm present and the extent of distribution of an endosperm type.

There has been little difference reported between dry rolled and ground wheat (Baker, 1935; Darlow et al., 1945; Darlow et al., 1946). Bris et al. (1966) and Bris and Dyer (1967) found that feed intake and performance of fattening steers were better on either steam rolled or pelleted wheat than dry rolled wheat, due to excessive fines in the rolled wheat.

Arnett (1971), in evaluating the performance of cattle fed rations containing wheat, looked at several different processing methods, including dry rolling, high moisture harvesting, steam flaking, extruding and feeding whole wheat. In each treatment, wheat comprised 50% of the grain portion in the ration. He observed similar average daily intakes and gains on all treatments, but noted that 13.7% more feed was required per unit of gain on the whole wheat ration.

In a Kansas study (Brethour and Duitsman, 1973) where the grain in feedlot rations consisted of 50% wheat and 50% flaked milo, wheat was processed and fed as either dry rolled, extruded, whole, steam flaked or high moisture harvested. Daily gains were similar on all treatments.

Feed consumption was also similar except on whole wheat, which was consumed at the rate of 1.6 to 1.8 kg more per head daily; whole wheat also displayed a decreased feed efficiency. Carcass data suggested some advantage in both quality and yield grade on dry rolled wheat.

Lofgreen (1970) compared ground and steam rolled wheat to steam rolled milo. Wheat comprised 58% of each treatment. He observed no effect of processing the wheat upon feed consumption, weight gain or feed conversion. In studies by Wagner et al. (1972) and Wagner et al. (1971) the smaller particle sizes produced by fine grinding of wheat in high wheat rations (70%) appeared to cause decreased intakes and gains, with little differences in feed efficiency.

Pressure cooked wheat and sorghum, flaked after cooking, was studied by Eng (1970). Less wheat was consumed than sorghum (8.83 kg vs 9.63 kg) and feed conversion and average daily gains were 6.72, 1.31 kg and 7.19, 1.35 kg, respectively for wheat and sorghum. Hale et al. (1971) found that 50% of the sorghum in a ration could be replaced with steam processed wheat, but weight gains were reduced and feed requirements increased when wheat replaced 75% and 100% of the sorghum.

Dry Heat Processing of Wheat

Dry heat expansion of grains has been studeid by several researchers as a method of processing grains (Ellis and Carpenter, 1966; Durham et al., 1967; Walker et al., 1970). Apparently, exposure of grain to dry heat volatilizes part of the internal moisture in the grain, disrupting the organized structure of the starch granules, causing gelatinization and making them more susceptible to enzymatic attack.

Garrett (1968) in comparing popped wheat with steamed rolled wheat found the acceptability of the popped wheat by feedlot cattle to be satisfactory. Average daily gain on popped wheat was not significantly different from steamed wheat and feed efficiency was slightly better on the popped wheat. Looking at the digestibility of dry rolled, steam flaked and micronized wheats Cornett et al. (1971) found that micronizing did not alter digestibility, but steam flaking tended to decrease digestibility over that of dry rolling. They concluded that steam processing and micronizing hard wheats do not improve their digestiblity.

High Moisture Grains

High moisture harvested grains have been shown to be equal to or better than mature, dry feed grains when used in finishing beef cattle rations. Martin et al. (1969, 1970) reported increased average daily gains and better feed efficiencies by cattle fed either high moisture harvested corn or sorghum than dry corn or sorghum. Improved feed efficiency of about 10% was also noted by Totusek and White (1968) although no improvement in gains were observed when high moisture harvested sorghum grain was fed.

Reconstituting of feed grains in an attempt to improve utilization as noted with high moisture harvested grains has been a relatively common practice in cattle feeding for about the last 10 years. Parrott and Riggs (1966) observed better feed efficiencies in cattle fed reconstituted or high moisture harvested sorghum than in those fed dry sorghum. Reconstituting and high moisture harvesting appeared to produce similar results. A similar improvement in feed efficiency with reconstituted over dry rolled sorghum was also shown by Wagner et al. (1971).

Reconstitution of wheat, on the other hand, has not shown the same improvements as sorghum in cattle performance and feeding value. Brethour and Duitsman (1971) reported no advantage in reconstituting wheat in feeding trials using different levels of wheat. Moreover, Christiansen and Wagner (1974) reported no consistent improvements in feedlot performance by reconstituting wheat over dry rolling wheat, although feed intakes and daily gains were improved some on moist wheat treatments. Less dustiness or more acceptable particle size may have influenced intake and daily gain.

Very little research is present in the literature with regard to the use of high moisture barley in feedlot rations. There are studies of its use in dairy cattle rations. Marx (1973) reported equal milk and fat production by cows receiving 6.8 kg daily of high moisture ensiled barley or dry barley. Moreover, Ingalls _et al._ (1974) found that dry barley and high moisture barley resulted in equal total dry matter intake and production of fat-corrected milk.

Few studies with finishing cattle, however, have been reported. Krall and Thomas (1966) reported that cattle fed high moisture barley are more easily started on feed. They attribute this to reduced digestive disturbances ordinarily seen when starting cattle on high concentrate rations. Increased intakes were observed (Dinusson _et al._, 1964) when high moisture harvested barley was fed to cattle over dry rolled barley. However, gains and feed conversion were not improved.

CHAPTER III

MICRONIZED WHEAT FOR BEEF CATTLE

Summary

Feedlot (two trials involving 65 steers), *in vitro* laboratory and *in vivo* metabolism studies were conducted to evaluate micronized wheat (MW) *vs.* dry rolled wheat (DRW) in 85% wheat rations for finishing cattle. Evaluation was based on feedlot performance, carcass merit, *in vitro* dry matter disappearance (IVDMD), *in vitro* gas production (GP), degree of gelatinization, ration digestibility and ruminal lactate and volatile fatty acid (VFA) concentrations.

Feedlot parameters measured in trial 1 were not significantly different between MW and DRW. In trial 2, average daily feed intake and gain were greater ($P<.01$) on MW. Although not significant ($P>.05$) the same trend existed in trial 1. No differences existed in feed efficiency (kg feed/kg gain). Ruminal pH was higher ($P<.05$) on MW in both feedlot trials. Total VFA concentration was similar on both treatments, although significantly less ($P<.05$) acetate was present on MW in both feedlot trials. In feedlot trial 1, a lower level ($P<.05$) of butyrate was produced by DRW. More propionate ($P<.05$) was present for MW in trial 2.

No significant differences ($P>.05$) between MW and DRW existed for 6 hr. IVDMD in either trial. In both trials, 12 and 24 hr, IVDMD values tended to be lower ($P<.05$ in trial 2) on MW. In both trials, MW

showed a greater ($P < .05$) degree of gelatinization than DRW. GP values were greater ($P<.05$) for MW after 1 and 2 hr. of incubation with amylogucosidase in trial 1 and after 1, 2 and 3 hr. in trial 2 indicating greater starch alteration in MW. _In vivo_ digestibility coefficients were very similar for dry matter, protein and starch in both MW and DRW. Ruminal lactic acid levels were not significantly different ($P>.05$) between the MW and DRW treatments at either 0, 1, 2, 4 or 8 hr. after sampling from rumen fistulated steers. VFA concentrations were similar on MW and DRW at the above sampling times, although favoring less acetate and more propionate 1 and 2 hours post feeding.

Introduction

With grains often constituting nearly 80-90% of feedlot finishing rations cattle feeders are concerned with processing grain to obtain maximum value from it. Several research studies have been conducted to study the effect of dry heat processing of cereal grains, mainly sorghum (Hinman and Johnson, 1974; Croka, 1974; Riggs _et al_., 1970; Schake _et al_. 1970; Garrett, 1968) and corn (Tonroy and Perry, 1974; Felsman _et al_., 1972). In general, these studies have indicated improved feed efficiency.

Hinman and Johnson (1974) reported that total starch digestion was similar for steam flaked and micronized sorghum; however, McNeill _et al_. (1971) found less starch in micronized sorghum was digested in the total digestive tract than in reconstituted or steam flaked sorghum.

Very limited data is available concerning dry heat processing of wheat. In an attempt to evaluate dry heat processing of wheat (_Triticum Aestivum_) for finishing cattle micronized wheat was compared with dry rolled wheat, evaluation being based on feedlot performance, ration digestibility, ruminal volatile fatty acid and lactic formation and in vitro laboratory studies.

Experimental Procedure

Two feedlot finishing trials were conducted to study micronized wheat (MW) vs. dry rolled wheat (DRW) for finishing beef cattle. Prior to processing all wheat was cleaned with a Clipper cleaner to assure an even flow of grain to avoid combustion of fines and charring on the reciprocating steel table (3.96 m x 118 cm x 1.25 cm) used for heating the grain. Above the table (15 cm) eight gas-fired infared generators where suspended and used to heat the wheat as it passed across the table. After heating, the grain dropped directly through rollers with a spacing of .008 cm under 59.1 kg pressure. MW resembled a flaked product. The DRW was cleaned and rolled (not heated) in the same manner as MW. Both the DRW and MW rations (table 1) consisted of 85% wheat (DM basis). The wheat grain was of the Triumph variety, a hard red winter-wheat.

Processing method was evaluated by feedlot performance, carcass merit, volatile fatty acid (VFA) concentrations, total tract digestion of nutrients, ruminal lactic acid, in vitro gas production, in vitro dry matter disappearance (IVDMD) and degree of gelatinization. Proximate analysis data are presented in table 2. Statistical analysis for the feeding trails was conducted according to analysis of variance (AOV) methods outlined by Snedecor and Cochran (1967). Daily gain, pH, carcass parameters and VFAs were analyzed assuming a model with the effects of treatment, pens within treatment and animals within pens. Standard error of treatment means was calculated from the variance among animals

TABLE 1. RATION COMPOSITION (TRIALS 1 AND 2)

Ingredient	International Reference No. (IRN)	% of Ration[1]
Wheat, hard red winter, grain, (4)[2]	4-05-268	85.0
Cotton, seed hulls, (1)	1-01-599	5.0
Alfalfa, aerial part, dehy grnd, mn 17% protein, (1)	1-00-023	5.0
Cotton, seeds w some hulls, solv-extd grnd, mn 41% protein mx 14% fiber mn 0.5% fat, (5)	5-01-621	3.4
Urea		.5
Salt, T.M.		.4
Calcium phosphate, dibasic commercial, (6)	6-01-080	.4
Aurofac-50 mg/kg		250
Vitamin A (30,000 I.U./g), mg/kg		110

[1]D.M. basis.

[2]Dry rolled (DRW) or micronized (MW).

TABLE 2. PROXIMATE ANALYSIS OF WHEAT GRAIN

Item	Dry Matter	Crude Protein[1,2]	Ash[1]	Ether Extract[1]	CHO[1,3]
Trial 1					
DRW	89.4	14.3	2.0	1.8	81.9
MW	92.8	14.8	1.8	1.7	81.7
Trial 2					
DRW	89.6	14.7	2.4	1.1	81.8
MW	94.7	14.0	1.9	1.2	82.9

[1]Values expressed on 100% dry matter basis.

[2]6.25 X percent nitrogen.

[3]100-(sum of figures for crude protein, ash and ether extract).

within pens. Analysis of feed/unit gain and feed intake were analyzed with the same model excluding the effect of animals within pens. Thus, standard error of treatment means was determined from the variance of pens within treatment.

Trial 1. Thirty Angus X Hereford yearling feeder steers (332 kg) were used to compare MW and DRW as evaluated by feedlot performance and carcass merit. The steers were randomly allotted to ten pens with three animals per pen and five pens per treatment. Each ration was fed once daily in an amount sufficient to provide feed availability until the next feeding. The steers were fed for 112 days, July to October. Initial weights were taken as shrunk weights, in which the animals were taken off feed and water for 12 hours prior to weighing. At the conclusion of the feeding trial final weights were taken full (not off feed and water) and then a four percent pencil shrink was taken.

Approximately three-fourths of the way through the trial rumen samples were taken from each animal via stomach tube. On the day prior to sampling, the feed allowance was reduced to make sure that all steers would eat immediately when fed the morning of sampling. Feeding of each pen was staggered so that each pen of steers was sampled 3 to 4 hr. post feeding. Ruminal pH values were determined immediately, and a small aliquot of fluid, with saturated mercuric chloride added, was frozen for VFA analysis by gas chromatography (Erwin, Marco and Emery, 1961). At the end of the feeding trial all animals were slaughtered and carcass and liver data obtained.

Trial 2. Thirty-six Angus X Hereford feeder steers (about 7 months old, 221 kg) were fed to further compare MW and DRW. The steers were randomly allotted to twelve pens with three animals per pen and six pens per treatment. Initial and final weights were taken as shrunk weights (off feed and water for 12 hr. prior to weighing). All steers were fed for 171 days, March to August, and rumen samples were taken as in trial 1. Carcass and liver data were obtained at slaughter.

Laboratory Evaluations. The DRW and MW fed in trials 1 and 2 were evaluated for 6, 12 and 24 hr. *in vitro* dry matter disappearance (IVDMD) using the procedure described by Christiansen and Wagner (1974) and *in vitro* gas production (GP), using a procedure adapted from Sandstedt *et al.* (1962). This system involved incubation of the processed wheat with an amyloglucosidase enzyme solution, using yeast to ferment sugars produced during enzymatic digestion of starch. Gas production was measured each hour during the first six hours of incubation and then again after the 12th and 24th hour of incubation. Degree of gelatinization was determined as mg of maltose released upon incubation with β-amylase as described by Sung (1969). Two runs of each *in vitro* trial (IVDMD and GP) were conducted by repeating the procedures on different days. The values were analyzed by the use of split plot analysis of variance. The model assumed included the effects of run, treatment, time and their interactions. Treatment was considered as main unit and time as sub unit. When run by time was tested with the third order interaction and found to be not significant, these mean squares were pooled and the pooled mean square was used to estimate standard error of treatment means. When a significant F test was present for time, differences between means were tested using a studentized t-test. The standard error of the difference was a combination of the sub plot error and main unit error term.

Digestion Trial. Eight Angus X Hereford yearling steers weighing an average of 375 kg were placed and housed in individual metabolism stalls. All animals were fed twice daily at about 90% of ad libitum intake; the DRW and MW rations were the same as those fed in trial 2. The experiment was a cross over (simple reversal) design as outlined by Brandt (1938). The eight steers were allotted at random, four to each treatment in the first comparison period. Treatment differences were tested for significance using the period by animals in group interaction as the error term. Following adaptation (14 days), feed intake and total fecal output was measured using a 7-day collection period. Treatments were then reversed, and following an adjustment period a second 7-day collection period was conducted. Thus, there were eight observations per treatment.

Total fecal output was measured daily and a 10% aliquot retained. After seven days, the aliquots were composited, dried at 60°C and ground through a 1 mm screen. Feed and fecal samples were analyzed for total dry matter, protein, ether extract, ash and starch. Starch was determined as α-linked glucose polymers by the procedure of MacRae and Armstrong (1968).

Lactic Acid Trial. Five rumen fistulated steers were individually fed twice daily the MW and DRW rations fed in feedlot trial 2. The individuals were randomly allotted to the two treatments, three steers on one treatment and two on the other. After an adaptation period, rumen samples were taken via fistula prior to feeding (0 hr) and then at 1, 2, 4 and 8 hrs. post-feeding. This was done for two consecutive days, from which a mean value was obtained, and then the treatments were reversed. Following a two week adaptation period, rumen samples were again obtained as previously. In this respect a cross over (simple-reversal) design was used (Brandt, 1938) in which there were five animals on each treatment.

Ruminal pH was taken immediately at the time of sampling. The rumen fluid was strained through six layers of cheesecloth and saturated mercuric chloride added. Samples were then frozen for later VFA determination by gas chromatography (Erwin, Marco, and Emery, 1961) and ruminal lactic acid concentrations (Barker and Summerson, 1941).

Results and Discussion

Trial 1. Feedlot performance, carcass merit and VFA data are shown in table 3. Feedlot parameters measured favored MW, although no significant (P>.05) differences existed. Average daily intakes were 9.08 vs. 9.36 kg for the DRW and MW treatments, respectively. Cattle fed the MW gained slightly faster than those fed DRW, 1.65 vs. 1.57 kg/day. Increased intakes and average daily gains have been reported by Cardon (1969) when cattle were fed dry heat processed sorghum grain. On the other hand, feed consumption was found to be similar for steers fed dry rolled or extruded wheat by Brethour and Duitsman (1973). Although not significant (P>.05), feed efficiency (kg feed DM/kg live gain) also tended to be better on MW (5.66 vs. 5.83). Any improvement in feed conversion on MW may be a reflection of the increased daily intakes and gains.

Steers on MW tended to exhibit higher quality carcasses, based on higher conformation scores, increased marbling and higher overall quality grades. Dressing percent was similar (61.2% for MW and 61.2% for DRW). Cutability was slightly better on the DRW treatment because

TABLE 3. FEEDLOT PERFORMANCE, CARCASS MERIT AND VFA DATA FOR CATTLE FED PROCESSED WHEAT IN TRIAL 1 (112 DAYS)

Item	DRW	MW	$S\bar{x}$
No. steers	15	15	
Initial live shrunk wt, kg	333	331	
Final live shrunk wt, kg	508	516	
Daily feed, kg[1]	9.08	9.36	0.26
Daily gain, kg[1]	1.57	1.65	0.10
Feed/kg gain, kg[1]	5.83	5.66	0.16
Dressing percent	61.2	61.2	0.51
Conformation[2]	11.9	12.1	0.37
Marbling[3]	11.7	12.5	0.46
Ribeye area, sq cm[5]	81.1[a]	75.4[b]	0.31
Fat thickness, cm	2.3	2.3	0.04
KHP fat, percent	2.6	2.7	0.14
Carcass grade[2]	8.7	8.9	0.22
Cutability, percent[4]	48.4	47.5	0.37
Abscessed livers	5	4	
Ruminal pH[5]	6.3[a]	6.5[b]	0.05
Volatile fatty acids			
Total VFA, umole/ml	97.8	98.1	13.29
	--------Molar percent--------		
Acetic[5]	41.9[c]	37.1[d]	1.50
Propionic	43.1	45.3	1.65
Isobutyric	1.2	1.1	.23
Butyric[5]	8.6[a]	11.5[b]	1.43
Isovaleric	1.2	1.2	.45
Valeric	3.2	3.1	.40
Caproic	.8	.8	.36

[1]Dry matter basis.

[2]U.S.D.A. grade converted to the following numerical designations: 7=low good, 8=avg good, 9=high good, 10=low choice, 11=avg choice, 12=high choice.

[3]Marbling scores: 11=slight, 14=small, 17=modest.

[4]Percent boneless trimmed retail cuts = 52.66 - 5.33 (fat thickness)-0.979 (percent kidney fat) + 0.665 (ribeye area) - 0.008 (chilled carcass wt).

[5]Values with different superscripts differ significantly: ab: (P<.05), cd: (P<.01).

of a larger ribeye (81.1 vs. 75.4 sq. cm, $P<.05$) and less kidney, heart and pelvic fat. Brethour and Duitsman (1973) also observed that steers fed dry rolled wheat exhibited a better yield grade. Approximately one-third of the cattle on both treatments exhibited evidence of abcessed livers in our study. Since the steers were fed for only 112 days, the incidence of liver abcesses might have been higher had the cattle been fed longer. Oltjen et al. (1966) also noted about one-third of the livers contained abcesses when steers were fed high levels of wheat in rather short feeding periods.

Ruminal pH was significantly higher ($P<.05$) on the MW treatment. Total VFA production, however, was similar for both treatments. Acetate concentration was lower ($P<.01$) and butyrate concentration higher ($P<.05$) on MW. Propionate was slightly lower on MW, although not significant ($P>.05$). Higher concentration of total VFAs, and increased butryic acid levels were observed by Oltjen et al. (1966) when cattle were fed rations containing high levels of wheat.

Trial 2. Feedlot performance, carcass merit and VFA data are presented in table 4. Steers fed MW showed significantly greater daily feed intake (7.81 vs. 7.16 kg, $P<.01$) and gain (1.59 vs. 1.45, $P<.01$) than steers on DRW. DM feed requirements/kg of gain were very good on both treatments, being only 4.92 and 4.95 kg on MW and DRW, respectively. Brethour and Duitsman (1973) reported higher daily gains for cattle fed roasted wheat. However, Lofgreen (1969) reported no differences in gains and feed requirements when wheat was ground through a three-eights inch screen as compared to steam flaked wheat. This is in contrast to work by Martin (1973) in which steam flaked wheat produced increased intakes and gains and improved feed efficiency when compared to dry

TABLE 4. FEEDLOT PERFORMANCE, CARCASS MERIT AND VFA DATA FOR CATTLE FED PROCESSED WHEAT IN TRIAL 2 (171 DAYS)

Item	DRW	MW	$S\bar{x}$
No. steers	18	17	
Initial live shrunk wt, kg	222	220	
Final live shrunk wt, kg	469	491	
Daily feed, kg[1,5]	7.16[c]	7.81[d]	0.18
Daily gain, kg[5]	1.45[c]	1.59[d]	0.07
Feed/kg gain, kg[1]	4.95	4.92	0.08
Dressing percent	61.7	62.3	0.35
Conformation[2,5]	11.5[c]	12.6[d]	0.23
Marbling[3]	12.9	13.3	0.33
Ribeye area, sq cm	78.9	82.5	0.24
Fat thickness, cm	2.3	2.6	0.04
KHP fat, percent	2.5	2.6	0.10
Carcass grade[2]	9.3	9.3	0.12
Cutability, percent[4]	48.4	48.0	0.32
Abcessed livers	12	12	
Ruminal pH[5]	5.7[a]	6.1[b]	0.12
Volatile fatty acids			
Total VFA, umole/ml	116.9	106.0	12.60
	--------Molar percent--------		
Acetic[5]	49.2[a]	44.7[b]	1.75
Propionic[5]	38.5[a]	42.9[b]	1.92
Isobutyric	.9	.9	.11
Butyric	7.3	7.8	.73
Isovaleric	1.0	.7	.20
Valeric	2.6	2.6	.34
Caproic	.5	.4	.11

[1]Dry matter basis.

[2]U.S.D.A. grade converted to the following numerical designations: 7=low good, 8=avg good, 9=high good, 10=low choice, 11=avg choice, 12=high choice.

[3]Marbling scores: 11=slight, 14=small, 17=modest.

[4]Percent boneless trimmed retail cuts = 52.66 - 5.33 (fat thickness)-0.979 (percent kidney fat) = 0.665 (ribeye area) - 0.008 (chilled carcass wt).

[5]Values with different superscripts differ significantly: ab: (P<.05), cd= (P<.01).

rolled wheat. Improvement in feed efficiency was also observed when micronized sorghum grain was fed to cattle compared to dry rolled grain (Croka, 1974).

Carcass parameters followed the same trend as in trial 1. Conformation score was significantly better (P<.01) for cattle on MW. A greater percentage (66%) of the steers showed presence of liver abcesses than in the first trial, with no difference between MW or DRW. This may have been due to the longer feeding period (171 vs. 112 days) in trial 2.

Ruminal pH was higher (P<.05) on MW than DRW (6.1 vs. 5.7). Total VFA concentration tended to be greater on DRW than MW and may have influenced the lower pH noted on DRW. As in trial 1, lower acetic acid (P<.05) and higher propionic acid (P<.05) concentrations were noted on MW. No other large differences in VFA concentrations were observed. A lowered acetic to propionic ratio was also observed by Shaw et al. (1972) when cattle were fed high wheat rations (85%) as compared to rations containing lower levels of wheat. As in trial 1, a much larger particle size was noted for MW (table 5). The increased intakes on MW may have been due to greater particle size and less dustiness. Bris et al. (1966) indicated lower performance of steers fed dry rolled wheat than steam rolled or pelleted wheat, possibly due to excessive fines present. On the other hand, Cornett et al. (1971) found a lower percentage of fine particles in dry rolled wheat than micronized wheat.

Laboratory Evaluations. IVDMD data for the processed wheat fed in the two feedlot trials are presented in table 6 and indicate that micronization did not increase the *in vitro* digestion of wheat by rumen microorganisms. Six-hour IVDMD values were essentially the same for

TABLE 5. PARTICLE SIZE OF PROCESSED WHEAT GRAIN

Item	--Trial 1-- DRW	MW	--Trial 2-- DRW	MW
	% retained on screen			
Screen size (microns)				
4000	2.3	66.8	4.5	66.4
2000	52.4	30.4	76.3	28.2
1000	23.8	0.4	14.6	2.8
500	11.2	0.0	2.1	1.0
250	7.1	0.0	0.4	0.4
125	1.9	1.2	1.2	0.6
Pan	1.3	1.2	0.9	0.6
Geometric mean diameter (microns)[1]	1628	4149	2377	4135
Geometric standard deviation[1]	2.26	1.92	1.78	1.81

[1]Procedure described by Ensor _et al._, 1970.

TABLE 6. *IN VITRO* DRY MATTER DISAPPEARANCE AND DEGREE OF GELATINIZATION OF DRY ROLLED AND MICRONIZED WHEAT

Item	IVDMD[1,3]			Gelatinization
		%		mg maltose/g of grain[2,3]
Trial 1	6 hr.	12 hr.	24 hr.	
DRW	32.23	56.78	77.86	12.3[c]
MW	31.21	50.60	71.51	26.4[d]
$S\bar{x}$	1.33	1.33	1.33	0.54
Trial 2				
DRW	37.88	66.41[a]	78.54[a]	15.8[a]
MW	39.20	57.93[b]	68.76[b]	35.5[b]
$S\bar{x}$	1.90	1.90	1.90	2.62

[1] IVDMD values are means of 12 determinations.

[2] D.M. basis.

[3] Values with different superscripts differ significantly:

ab: ($P<.05$)

cd: ($P<.01$).

MW and DRW in both trials, 1 and 2. IVDMD values for 12-hr. and 24-hr. incubation periods were significantly less ($P<.05$) on MW, however, in trial 2. The same trend was noted in trial 1. In vitro studies with roasted corn have also shown decreased dry matter digestion from heat treatment with longer in vitro incubation times (Tonroy and Perry, 1974). Possibly the effect of high temperature, as with micronization, lowers protein solubility of the grain. Thus, nitrogen may become limiting in an in vitro system at longer times. McNeill et al. (1975) proposed that micronizing sorghum grain with dry-heat may denature the protein in the endosperm, reducing solubility of the protein matrix surrounding the starch granules. The IVDMD values observed for DRW and MW in our studies are quite high as compared to those reported for sorghum grain (Christiansen and Wagner, 1974; Croka, 1974). This tends to indicate that the starch availability for use by microorganisms is much better in wheat than sorghum, even when wheat is conventionally processed such as dry rolled. Christiansen and Wagner (1974) observed similar IVDMD results with dry rolled vs. reconstituted wheat.

Gas production (GP) data for the processed wheat fed in trials 1 and 2 are presented in table 7. GP results indicate that the rate of enzymatic digestion of MW was higher than for DRW during that first hour ($P<.01$) and second hour ($P<.05$) of incubation in trial 1. However, between incubation hours 6 to 12 and 12 to 24 less gas ($P<.05$) was produced on MW, due likely to the much greater GP ($P<.05$) during the first 6-hr. of incubation. Consequently, lower levels of substrate likely were present on MW after 6 hr. More total gas, however, was produced in 24 hr. on MW ($P<.05$). In trial 2 a similar trend as in trial 1 was noted. The rate of digestion of MW was increased during the first,

TABLE 7. *IN VITRO* GAS PRODUCTION[1]

Item	Trial 1 DRW	Trial 1 MW	Trial 1 $S\bar{x}$	Trial 2 DRW	Trial 2 MW	Trial 2 $S\bar{x}$
Hour[2,3]						
1	15.96[c]	34.45[d]	3.46	13.32[c]	35.63[d]	1.79
2	12.93[a]	22.38[b]		11.59[c]	20.52[d]	
3	11.17	16.02		10.42[a]	16.48[b]	
4	10.20	12.17		11.78	13.82	
5	8.36	8.82		8.36	7.11	
6	7.22	6.12		7.89	7.23	
12	29.16[a]	20.32[b]		30.48[a]	23.49[b]	
24	16.05[a]	4.25[b]		26.42[c]	2.58[d]	
Total (1-6 hr.)	65.84[a]	99.96[b]	1.41	63.36[c]	100.79[d]	0.39
Total (1-12 hr.)	95.00	120.28	2.27	93.84[c]	124.28[d]	0.26
Total (1-24 hr.)	111.05[a]	124.53[b]	0.23	120.26	126.86	1.82

[1]Ml gas release/g dry matter.

[2]GP values are means of 4 determinations.

[3]Values with different superscripts differ significantly:
ab: (P<.05)
cd: (P<.01).

second (P<.01) and third hr. (P<.05) of incubation. Again less gas was produced during incubation between hours 6-12 (P<.05) and 12-24 (P<.01) on MW. Total GP during the first 6 hr. and 12 hr. of incubation was greater (P<.01) on MW. The greater gas production during the first few hours of incubation on MW indicates increased starch alteration and susceptibility of the starch molecule to rapid enzymatic attack. Tonroy and Perry (1974) also noted enhanced in vitro digestion of roasted corn at shorter incubation times. Moreover, micronizing of sorghum grain has been shown to increase the rate of in vitro gas production compared to dry rolling (Croka, 1974).

Starch gelatinization values (table 6) were significantly higher on MW (P<.01) in trial 1 and P<.05) in trial 2). Heat treatment by micronization increased susceptibility of the starch granule to β-amylase attack, agreeing with the GP data cited above. In trial 2, the gelatinization values for MW were somewhat higher indicating perhaps somewhat greater heat treatment. Increased gelatinization in micronized sorghum was also noted by Croka (1974). Walker et al. (1970) reported a lower degree of gelatinization, measured by β-amylase attack, in popped wheat than in popped sorghum or barley. Cornett et al. (1971) reported equal gelatinization values for dry rolled and micronized wheats. Possibly wheat does not exhibit as much gelatinization when heat processed as some other cereal grains.

Digestion Trial. Digestibility data for MW and DRW fed in trial 2 are reported in table 8. No significant differences existed between MW and DRW for any of the components measured. As noted, starch digestibility coefficients for MW and DRW were 99.3 and 99.2% respectively. Langlands (1973) reported starch digestibility of 99.3% for wheat. The

TABLE 8. DIGESTIBILITY OF RATIONS

Item	DRW	MW	$S\bar{x}$
No. steers	8	8	
Daily DM intake, kg	6.4	6.3	
Digestibility, total			
Ration, DM basis, %			
Dry matter	81.3	82.9	0.53
Crude protein[1]	79.3	79.8	0.57
Ash	45.2	47.4	2.09
Ether extract	75.0	78.4	3.89
Starch	99.2	99.3	0.04

[1]6.25 x percent nitrogen.

dry matter and starch digestibilities noted on both treatments support the low and nearly identical feed efficiency values obtained for MW and DRW in the feedlot (trial 2), and the in vitro observations cited previously. This is also in agreement with Cornett et al. (1971) in which they found no improvement in digestibility of micronized wheat over dry rolled wheat. Studies with sorghum (Hinman and Johnson, 1974; Hale et al., 1966; Buchanan-Smith et al., 1968; Husted et al., 1968; Riggs et al., 1970), however, have shown improvements in digestibility with several different methods of processing.

Lactic Acid Trial. Ruminal pH values and ruminal lactic acid concentrations determined just prior to feeding (0 hr.) and then at 1, 2, 4 and 8 hrs. post feeding are presented in table 9. No significant differences (P>.05) existed in ruminal pH values at 0, 1, 2 or 4 hrs. between MW and DRW. Although, at 8 hrs. the pH value on MW was significantly higher (P<.05). At 4 hrs. post feeding pH values on both treatments were quite low, 5.07 and 4.87 for MW and DRW, respectively.

No significant differences (P>.05) existed between MW and DRW for ruminal lactic acid concentrations at the various sampling periods. Concentrations were quite low at all times for both treatments, ranging mostly from about 1.6 to 4.2 m moles/liter. Moreover, none of the animals exhibited signs of going off feed. This together with the excellent cattle performance obtained in the two feeding trials would suggest that if proper management practices are used, lactic acidosis may not be a problem when cattle are fed high wheat rations. Varner and Woods (1970) reported higher rumen lactate levels in cattle fed hard than soft wheats. Johnson et al. (1974) observed a greater depression in rumen pH following feeding in cattle fed micronized sorghum

TABLE 9. CHANGES IN RUMINAL pH AND LACTIC ACID LEVELS AFTER FEEDING RATIONS CONTAINING DRY ROLLED OR MICRONIZED WHEAT

		Ruminal pH[1]					Ruminal lactic acid, mM/liter				
		Time (hr) after feeding					Time (hr) after feeding				
Item	No. Steers	0	1	2	4	8	0	1	2	4	8
DRW	5	6.55	6.17	5.38	4.87	5.27[a]	2.89	6.29	2.32	4.15	1.69
MW	5	6.47	5.87	5.16	5.06	5.95[b]	2.50	3.80	3.33	2.04	1.58
$S\bar{x}$		0.13	0.10	0.10	0.06	0.02	0.84	1.36	0.88	1.19	0.14

[1]Values in the same column with different superscripts differ significantly:
ab: $(P<.01)$.

than dry rolled sorghum. They also reported that lactic acid levels were highest two hours after feeding and greatest when micronized sorghum was fed.

Total and molar percentages of ruminal VFAs are presented in table 10. No significant (P>.05) differences existed between MW and DRW at any of the sampling times. There appears to be a tendency for a slightly narrower acetic:propionic ratio at 1 and 2 hours post feeding on MW. This is in agreement with observations in the two feedlot trials.

In general, a trend was present in the feedlot trials for increased intake and gain on MW although no differences were noted for feed/gain between MW or DRW. The feedlot, digestibility and in vitro data indicate that wheat does not respond to processing (is not improved) to the extent noted in other grains, particularly sorghum. Moreover, no digestive disturbances were observed on the high wheat (85%) finishing rations.

TABLE 10. CHANGES IN MOLAR PERCENTAGES OF VFA AFTER FEEDING RATIONS CONTAINING DRY ROLLED OR MICRONIZED WHEAT[1]

Hour	Acid Molar %	DRW	MW	$S\bar{x}$
0	Acetic	47.7	46.2	0.67
	Propionic	31.7	33.1	1.29
	Isobutryic	2.3	1.7	0.17
	Butryic	8.8	9.8	0.25
	Isovaleric	2.8	3.2	0.25
	Valeric	4.7	4.6	0.18
	Caproic	1.9	1.7	0.19
	Total, umole/ml	100.9	101.4	17.04
1	Acetic	44.7	43.4	0.89
	Propionic	36.1	38.0	1.60
	Isobutryic	1.5	1.1	0.07
	Butryic	9.9	10.3	0.67
	Isovaleric	1.8	1.8	0.23
	Valeric	4.5	3.9	0.22
	Caproic	1.5	1.4	0.21
	Total, umole/ml	172.3	178.5	27.30
2	Acetic	41.1	41.4	1.30
	Propionic	38.8	40.1	1.12
	Isobutryic	1.7	1.0	0.41
	Butryic	10.5	10.6	1.03
	Isovaleric	2.2	1.7	0.32
	Valeric	4.6	3.7	0.78
	Caproic	1.1	1.4	0.10
	Total, umole/ml	237.5	181.3	17.05
4	Acetic	40.6	38.8	0.79
	Propionic	43.6	42.2	0.91
	Isobutryic	0.7	0.9	0.06
	Butryic	10.4	11.8	0.55
	Isovaleric	0.9	1.5	0.26
	Valeric	2.9	3.7	0.26
	Caprioc	0.9	1.2	0.12
	Total, umole/ml	303.4	219.6	13.10
8	Acetic	42.0	40.0	1.45
	Propionic	40.6	37.4	1.36
	Isobutryic	1.1	1.7	0.20
	Butryic	9.5	11.1	1.02
	Isovaleric	1.4	2.9	0.22
	Valeric	3.8	5.0	0.41
	Caprioc	1.5	1.9	0.20
	Total, umole/ml	123.7	128.9	8.90

[1]Values are means of 5 observations.

CHAPTER IV

HIGH MOISTURE BARLEY FOR BEEF CATTLE

Summary

High moisture processed barley (high moisture harvested or reconstituted) was compared with dry rolled barley for finishing beef cattle. Evaluation was based upon feedlot performance, _in vitro_ dry matter disappearance (IVDMD), _in vitro_ gas production (amyloglucosidase digestion of starch) and metabolism trials. In trial 1, reconstituted barley (RB) was compared to dry rolled barley (DRB), and in trial 2 DRB, RB and high moisture harvested barley (HMH) were compared. The two feedlot trials involved 84 steers. The barley for reconstitution was raised to 30% moisture and stored for at least 21 days; HMH barley in trial 2 was harvested at 27% moisture.

No significant improvements in feedlot performance were seen with RB or HMH over DRB, although lower dry matter intakes ($P<.01$) were seen in trial 2 by DRB. A tendency for somewhat greater gains on high moisture barley was observed in both trials. Total ruminal volatile fatty acid (VFA) levels were not different ($P>.05$) between DRB and RB, although more ($P<.01$) acetate and less ($P<.01$) propionate was present in trial 1 for RB. No differences ($P>.05$) existed between treatments for IVDMD in either trial 1 or 2.

Gas production values in trial 1 showed no significant ($P>.05$) differences between DRB and RB for either 6, 12 or 24 hr. totals during

enzymatic incubation. However, in trial 2 more ($P<.05$) gas was produced after 6, 12 and 24 hr. on HMH than on RB or DRB. In general no consistent improvements were evident for RB or HMH over DRB.

Introduction

High moisture grain for finishing beef cattle has been studied for years. Both high moisture harvested corn and high moisture harvested sorghum grain have shown increased feed efficiencies over dry rolled or ground grain (Tonroy et al., 1974; Davis et al., 1973; Forsyth et al., 1972; Martin, 1973; Riggs and McGinty, 1970; Totusek and White, 1968). In attempts to recreate the characteristics of high moisture harvested grains, studies involving reconstitution of feed grains have been conducted. Henderson and Geasler (1971) in a review of several studies also noted improved efficiencies with reconstituted corn compared to dry corn and Parrett et al. (1966) noted improved feed efficiency with reconstituted sorghum grain compared to dry rolled sorghum grain. With wheat, on the other hand, reconstituted produced no consistent improvements in feed efficiency for cattle (Christiansen and Wagner, 1974; Brethour and Duitsman, 1971). Most studies with high moisture grains have dealt with corn, sorghum grain and to a lesser extent with wheat. Very little research has been done with high moisture harvested and reconstituted barley fed to feedlot cattle. The purpose of this experiment was to evaluate reconstituted and high moisture harvested barley for feedlot cattle.

Experimental Procedure

Two feeding trials, involving 84 steers, were conducted to compare dry rolled barley (DRB) and reconstituted barley (RB) in trial 1 and DRB, RB and high moisture harvested barley (HMH) in trial 2. The barley (Hordeum Vulgare) used in both trials was of the Will variety. The dry, whole barley used in trial 1 had a density of 546 g/liter and that in trial 2, 457 g/liter. Barley (RB) was reconstituted in the whole form to approximately 30% moisture and stored in an oxygen-limited silo for at least 21 days prior to feeding. The high moisture harvested barley (HMH) in trial 2 was harvested from the same field when containing approximately 27% moisture. The barley in all rations comprised 84% (DM) of the ration (table 11). The DRB, RB and HMH were rolled through a roller mill with a roller spacing of .008 cm. Each ration was fed *ad libitum* once daily in an amount to provide sufficient feed until the next feeding.

Processing methods in trial 1 were evaluated by feedlot performance, ruminal volatile fatty acids (VFA), *in vitro* dry matter disappearance (IVDMD), and *in vitro* gas production (GP). In trial 2, method of processing was evaluated by feedlot performance, IVDMD, GP, and *in vivo* digestion. The proximate analysis data are given in table 12. Statistical analysis for feeding trials was conducted according to analysis of variance (AOV) methods outlined by Snedecor and Cochran (1967). In trial 1 daily gain, pH and VFAs were analyzed assuming a model with the effects of treatment, pens within treatment and animals within pens. Standard error of treatment means was calculated from the variance among animals within pens. This same model was used to analyze daily gain in trial 2. Analysis of feed/unit gain and feed intake for both

TABLE 11. COMPOSITION OF RATIONS[1]

Ingredient	International Reference No. (IRN)	Trial 1 (%)	Trial 2 (%)
Barley, grain, (4)[2]	4-00-549	84.0	84.0
Cotton, seed hulls, (1)	1-01-599	5.0	5.0
Alfalfa, aerial part, dehy grnd, mn 17% protein, (1)	1-00-023	5.0	5.0
Cotton, seeds w some hulls, solv-extd grnd, mn 41% protein mx 14% fiber mn 0.5% fat, (5)	5-01-621	4.2	4.2
Urea		0.6	0.6
Salt, T.M.		0.4	0.4
Calcium phosphate, dibasic, commercial, (6)	6-01-080	0.4	0.4
Calcium carbonate, $CaCO_3$, commercial mn 38% calcium, (6)	6-01-069	0.4	0.4
Aurofac-50, mg/kg		123	99
Vitamin A (30,000 IU/g), mg/kg		220	88
Stilbosol-2, mg/kg			248

[1]Dry matter basis.

[2]Dry rolled (DRB), reconstituted (RB) or high moisture harvested (HMH).

TABLE 12. PROXIMATE ANALYSIS OF BARLEY GRAIN

Item	Dry Matter	Crude Protein[1]	Ash[1]	Ether Extract[1]	CHO[1,2]
Trial 1	----------------	----------------	%	----------------	----------------
DRB	88.5	14.0	3.0	2.0	81.0
RB	71.2	13.1	2.8	2.1	82.1
Trial 2					
DRB	88.8	14.0	3.5	2.8	79.8
RB	72.3	13.9	2.9	2.2	81.1
HMH	72.7	14.2	1.9	2.5	81.4

[1]100% dry matter basis.

[2]100-(sum of figures for crude protein, ash and ether extract).

trials were analyzed with the same model excluding the effect of animals within pens. Thus, standard error of treatment means was determined from the variance of pens within treatment. Tests of significance among treatment means were conducted by the use of LSD protected by a preliminary F test.

Trial 1. Forty-eight Angus, Hereford and Angus X Hereford steers (306 kg) were used to compare RB and DRB. The steers were randomly allotted to twelve pens with four animals per pen and six pens per treatment. All individuals were fed for 110 days, August to December. Initial and final weights were taken as shrunk weights, off feed and water for 12 hours prior to weighing.

Approximately three-fourths of the way through the trial rumen samples were taken from each animal via stomach tube. On the day prior to sampling, the feed allowance was reduced somewhat to insure that all animals would eat at the same time when fed on the morning of sampling. Feeding of each pen was timed so that each pen of steers was sampled 3 to 4 hours post feeding. Ruminal pH values were determined immediately after sampling; saturated mercuric chloride was added to a sub-sample to stop fermentation, and the fluid was frozen for VFA analysis (Erwin, Marco and Emery, 1961).

Trial 2. Thirty-six Angus, Hereford and Angus X Hereford steers were used to compare: 1) DRB, 2) RB and 3) HMH. The steers averaged 283 kg and were randomly allotted to twelve pens with three individuals per pen and four pens per treatment. All steers were fed for 88 days, July to October. The cattle were not completely fed out to slaughter due to a shortage of high moisture feed. Initial weights were taken full (not off feed and water) with a 4% pencil shrink and final weights were taken as shrunk weights (off feed and water for 12 hours prior to weighing).

Laboratory Evaluation. The processed grains used in the feeding trials were evaluated by IVDMD using procedures described by Christiansen and Wagner (1974). GP studies (amyloglucosidase digestion of starch and yeast fermentation of released sugars) were conducted to further evaluate the treatments fed, using a method adapted from Sandstedt et al. (1962). GP readings were taken hourly for the first six hours and then after the 12th and 24th hour of incubation. Two runs of each in vitro trial (IVDMD and GP) were conducted by repeating the procedures on different days. The values were analyzed by the use of split plot analysis of variance. The model assumed included the effects of run, treatment, time and their interactions. Treatment was considered as main unit and time as sub unit. When run by time was tested with the third order interaction and found to be not significant, these mean squares were pooled and the pooled mean square was used to estimate standard error of treatment means. When a significant F test was present for time, differences among means were tested using a studentized t-test. The standard error of the difference was a combination of the sub plot error and main unit error term.

Digestion Trial. In the second feeding trial, a digestion trial involving 5 steers housed in metabolism stalls was conducted. The steers were fed one of three treatments: DRB, RB and HMH. Ration compositions were the same as fed in trial 2 and were run concurrently with the feeding trial.

Total daily intakes and fecal collections were recorded after a two week adjustment period prior to starting and between each period.

The collection period was over a 7 day period at which time feed and fecal samples from each steer were composited. Because it became apparent that a shortage of HMH would occur, all five steers (initially six, but one steer became injured) were fed HMH in the first period, two were fed DRB and three RB in the second period and two RB and three DRB in the third period. Consequently, it is such that not all of the treatments were fed in each comparison period. Means and standard error of the means were thus reported. Fecal samples were dried at 60°C and ground through a 1mm screen in a Wiley mill. Starch determinations were conducted on the feed and fecal samples by the procedure of McRae and Armstrong (1968). Total tract digestibility of dry matter, crude protein and starch was determined.

Results and Discussion

Trial 1. Feedlot performance and VFA data are presented in table 13. No significant (P>.05) differences existed in any of the feedlot parameters measured. Average daily DM intakes, gains and feed efficiency were very similar on both treatments with intake being 8.05 vs. 8.24 kg, gain 1.43 vs. 1.47 and feed per unit gain 5.64 vs. 5.62 on DRB and RB, respectively. Krall (1969) indicated no differences in intake, gain or feed efficiency between reconstituted and dry processed barley for fattening cattle.

Ruminal pH values were not different (P>.05) between treatments. Total VFA production was similar for both treatments, although a lower (P<.01) concentration of acetate and higher concentration (P<.01) of propionate was observed for DRB. The acetate:propionate ratio appeared quite high on both treatments considering the rations contained 84% (DM)

TABLE 13. TRIAL 1: FEEDLOT PERFORMANCE AND VFA DATA (110 DAYS)

	DRB	RB	$S\bar{x}$
No. steers	24	24	
Initial live shrunk wt, kg	307	304	
Final live shrunk wt, kg	465	466	
Daily feed, kg[1]	8.05	8.24	0.31
Daily gain, kg	1.43	1.47	0.11
Feed/kg gain, kg[1]	5.64	5.62	0.11
Ruminal pH	6.3	6.3	0.11
Volatile fatty acids			
Total VFA, umole/ml	94.6	99.0	8.45
	-------Molar percent-------		
Acetic[2]	55.1[a]	61.0[b]	1.50
Propionic[2]	32.2[a]	23.9[b]	2.16
Isobutyric	1.3	1.3	0.14
Butyric	7.9	9.8	1.03
Isovaleric	0.8	1.4	0.30
Valeric	1.9	1.8	0.19
Caproic	0.8	0.8	0.24

[1]Dry matter basis.

[2]Values with different superscripts differ significantly: ab: ($P<.01$).

barley. Galyean (1975) also observed a wide acetate:propionate ratio when high moisture corn was fed in a digestion study. In a study where dry barley and high moisture barley made up 60% of the concentrate mixture for dairy cattle Ingalls et al. (1974) reported acetic:propionic ratios of about 2.5:1. In our studies no differences were evident (P>.05) for other individual acids measured.

Particle size data is shown in table 15. A smaller percentage of fine particles was present for RB than DRB. This may be due to the softening effect of reconstitution, thus lessening shattering of the kernel during rolling as in dry grain.

Trial 2. Performance data are present in table 14. Average daily intake on the DRB (8.11 kg) treatment was significantly less (P<.01) than on either RB (9.63 kg) or HMH (9.08 kg). The increased intakes noted may have been due to increased acceptability of RB and HMH due to the smaller particle size (table 15) or perhaps increased dustiness of DRB. No significant differences (P>.05) existed, however, for average daily gain, although gain tended to be greater on RB (1.46 kg) and HMH (1.47 kg) than on DRB (1.32). No difference (P>.05) existed in the amount of feed required per unit of gain between any of the treatments. Dinusson et al. (1965) and Krall (1969) found high moisture harvested barley to be equal to dry rolled barley. These workers indicated equal consumption (DM) and similar feed efficiencies when the barley was fed to beef cattle. However, they observed that cattle fed high moisture barley tended to go on feed faster.

Laboratory Evaluations. IVDMD data for the barley in trial 1 and trial 2 are shown in table 16. No differences (P>.05) in IVDMD were noted between DRB and RB in trial 1 or DRB, RB and HMH in trial 2 at

TABLE 14. TRIAL 2: FEEDLOT PERFORMANCE (88 DAYS)

	DRB	RB	HMH	$S\bar{x}$
No. steers	12	12	12	
Initial live shrunk wt, kg	281	284	284	
Final live shrunk wt, kg	399	413	413	
Daily feed, kg[1,2]	8.11[a]	9.63[b]	9.08[b]	0.31
Daily gain, kg	1.32	1.46	1.47	0.17
Feed/kg gain, kg[1]	6.14	6.40	6.22	0.19

[1]Dry matter basis.

[2]Values with different superscripts differ significantly: ab: ($P<.01$).

TABLE 15. PHYSICAL CHARACTERISTICS OF BARLEY GRAIN

Item	--Trial 1--		------Trial 2-----		
	DRB	RB	DRB	RB	HMH
	% retained on screen				
Screen Size (Microns)					
4000	49.1	88.4	70.0	92.7	93.7
2000	29.4	9.6	17.3	5.6	5.6
1000	14.5	0.1	8.2	1.1	0.0
500	4.1	0.5	2.3	0.4	0.2
250	2.2	0.6	0.8	0.1	0.1
125	0.7	0.7	0.8	0.1	0.4
Pan	0.0	0.1	0.6	0.0	0.0
Geometric mean diameter (microns)[1]	3208	4998	3956	5280	5330
Geometric standard deviation[1]	2.06	1.57	2.00	1.33	1.35

[1]Procedure described by Ensor _et al._, 1970.

TABLE 16. *IN VITRO* DRY MATTER DISAPPEARANCE

Item		IVDMD[1]	
		%	
Trial 1	6 hr.	12 hr.	24 hr.
DRB	34.06	58.43	68.66
RB	38.45	56.92	60.82
$S\bar{x}$	3.20	3.20	3.20
Trial 2			
DRB	34.41	52.77	64.22
RB	32.68	50.04	59.73
HMH	33.49	50.47	62.47
$S\bar{x}$	3.67	3.67	3.67

[1]IVDMD values are means of 12 determinations.

either 6, 12 or 24 hr. incubation times. There was a trend, however, in both trials for the IVDMD to be slightly higher for DRB after 12 and 24 hr. of incubation. The similar IVDMD values agreed with the nearly identical feed efficiencies noted in the two feeding trials. Reconstituted and high moisture harvested sorghum grain (Neuhaus and Totusek, 1971; Schneider, 1971 and Martin, 1973) have shown increased IVDMD over dry rolled sorghum. Reconstituted wheat, on the other hand, has shown little or no improvement in IVDMD over dry rolled wheat (Christiansen and Wagner, 1974).

Further evaluation by GP is presented in table 17 for trials 1 and 2. After 1 hr. of incubation with amyloglucosidase more gas was produced ($P<.01$) by RB in trial 1. No other significant differences were observed until between the 12th and 24th hr. of incubation when a greater amount ($P<.05$) of gas was produced by DRB. This was likely due to higher substrate levels being available on DRB after 12 hr. of incubation since RB was more rapidly digested in the early hours of incubation. No significant differences existed in trial 1 for 6, 12 or 24 hr. total gas production between DRB and RB.

In trial 2 less gas was produced ($P<.05$) by DRB during the third hour of enzymatic incubation than by HMH, with RB being intermediate between DRB and HMH. Likewise, the HMH treatment tended to produce the most gas during the first, second and fourth hour of incubation. Between 12 and 24 hr. less ($P<.05$) gas was produced by RB and HMH than DRB. This is in agreement with trial 1 in which DRB produced more gas between the 12th and 24th hour of incubation time than did RB. The total gas produced was greater on HMH than on DRB or RB during 6 hr. ($P<.01$) and also 12 and 24 hr. ($P<.05$) of incubation. It appears that,

TABLE 17. *IN VITRO* GAS PRODUCTION[1]

Item	Trial 1 DRB	Trial 1 RB	Trial 1 $S\bar{x}$	Trial 2 DRB	Trial 2 RB	Trial 2 HMH	Trial 2 $S\bar{x}$
Hour[2,3]							
1	18.55[c]	29.01[d]	1.48	13.44	11.67	15.31	1.84
2	11.76	15.53		9.22	10.20	13.50	
3	9.21	12.53		9.22[a]	9.68[a,b]	14.54[b]	
4	6.86	8.10		8.94	12.80	13.76	
5	6.12	6.73		5.63	7.27	7.22	
6	5.59	5.82		6.55	6.40	7.23	
6-12	20.86	20.26		24.90	26.88	26.92	
12-24	13.35[a]	4.21[b]		19.07[a]	12.36[b]	13.50[b]	
Total (1-6 hr.)	58.08	77.69	2.22	52.98[a,c]	58.01[a]	71.54[b,d]	1.24
Total (1-12 hr.)	78.93	97.95	1.35	77.88[a]	84.89[a]	98.46[b]	1.69
Total (1-24 hr.)	92.30	102.19	2.04	96.97[a]	97.26[a]	111.98[b]	1.52

[1]ML gas release/g dry matter.

[2]GP values are means of 4 determinations.

[3]Values with different superscripts differ significantly:
ab: ($P<.05$)
cd: ($P<.01$).

initially (first 3 hrs), the high moisture treatments may be more susceptible to enzymatic attack possibly due to a softening of the protein matrix of the endosperm (Sullins et al., 1971). Moreover, Martin (1973) reported increased gas production by high moisture harvested sorghum grain over dry rolled grain.

The IVDMD values noted in our studies for barley are much higher than those commonly seen for sorghum grain and, in fact, appear reasonably similar to those observed with wheat (Croka, 1974; Christiansen and Wagner, 1974). Trei et al. (1970) also reported greater in vitro dry matter digestibility and increased gas production from barley as compared with sorghum grain. Possibly, the starch in ground or rolled barley is more digestible than in sorghum and, therefore, does not respond to processing to the extent that sorghum does.

Digestion Trial. Total in vivo digestion of dry matter, crude protein and starch for DRB, RB and HMH fed in trial 2 are shown in table 18. Ration digestibility was very similar among the processed barley treatments as indicated by average digestion coefficients for dry matter of 79.4, 78.9 and 78.7%, protein 80.9, 79.1 and 78.4% and starch 99.2, 99.0 and 99.1% on the DRB, RB and HMH barley treatments respectively. This is contrast to the higher digestibilities reported for high moisture processed sorghum over dry sorghum (Riggs and McGinty, 1970 and Buchanan-Smith et al., 1968). Ahmed et al. (1974) reported increased digestibility of crude protein and starch when rolled, acid treated high moisture barley was fed to steers as compared to whole moist barley fed whole.

The digestibility data reported in this study agrees with the feedlot performance data observed when these same rations were fed in the feedlot. The results of these studies suggest that dry rolled barley

TABLE 18. EFFECT OF PROCESSING METHOD UPON DIGESTIBILITY OF BARLEY RATIONS BY CATTLE

Item	DRB	RB	HMH
No. steers	5	5	5
Daily DM intake, kg	5.7	6.4	5.5
Digestibility, total[1]			
Ration, DM basis %			
Dry matter	79.4±0.66	78.9±0.25	78.7±1.03
Crude protein	80.9±1.08	79.1±0.49	78.4±0.82
Starch	99.2±0.03	99.0±0.13	99.1±0.15

[1]Means ± standard error.

has a more digestible endosperm than sorghum, and thus, high moisture processing may have less value for barley than sorghum. This is similar to results obtained with wheat which was reconstituted (Christiansen and Wagner, 1974).

LITERATURE CITED

Ahmed, F. A., J. H. Topps and D. G. Dempster. 1974. The digestibility by friesian steers of dry and acid-treated moist barley offered either whole or rolled in diets containing roughage. Nutr. Abstr. and Rev. 44:662.

Arnett, D. W. 1971. Effect of method of processing wheat for finishing steers. J. Anim. Sci. 33:275.

Baker, G. N. and M. L. Baker. 1960. Wheat for fattening yearling steers. Nebr. Agr. Exp. Sta. Bull. 454.

Baker, M. L. 1935. The use of wheat and rye for fattening calves. Nebr. Agr. Exp. Sta. Bull. 295.

Barker, S. B. and W. H. Summerson. 1941. The colorimetric determination of lactic acid in biological materials. J. Biol. Chem. 138: 535.

Brandt, A. E. 1938. Tests of significance in reversal or switchback trials. Iowa Agr. Exp. Sta. Res. Bull. 234:69.

Brethour, J. R. 1966. Feeding wheat to beef cattle. Kans. Agr. Exp. Sta. Bull. 487.

Brethour, J. R. 1970. The use and value of wheat in beef cattle feeding. Proc. of an International Symposium. Okla. State Univ., Stillwater, Okla. p. 177.

Brethour, J. R. 1971. Different wheat varieties in beef rations. J. Anim. Sci. 33:276. (Abstr.).

Brethour, J. R. and W. W. Duitsman. 1959. Use of wheat in a fattening ration for yearling steers. Beef cattle feeding investigation, 1958-59. Kans. Agr. Exp. Sta. Circ. 363.

Brethour, J. R. and W. W. Duitsman. 1961. Substitution of wheat for sorghum grain and cottonseed meal in a fattening ration for yearling steers. Beef cattle investigation, 1960-61. Kans. Agr. Exp. Sta. Circ. 382.

Brethour, J. R. and W. W. Duitsman. 1966. Fifty percent wheat in all concentrate rations for yearling steers. Beef cattle investigations, 1965-66. Kans. Agr. Exp. Sta. Bull. 492.

Brethour, J. R. and W. W. Duitsman. 1971. 58th Roundup Report 1970-71. Kans. Agr. Exp. Sta. Bull. 545.

Brethour, J. R. and W. W. Duitsman. 1973. High-moisture milo cut at two moisture levels and ground or treated with propionic acid pre-ensiling. Kans. Agr. Exp. Sta. Bull. 569.

Bris, E. G. and I. A. Dyer. 1967. New varieties of wheat for bovine finishing rations. Wash. Agr. Exp. Sta. Bull. 682.

Bris, E. J., I. A. Dyer and D. Howes. 1966. Wheat as a grain for fattening cattle. Proc. Amer. Soc. Anim. Sci. W. Sec. 17:301.

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

Burkhardt, J. D. and L. B. Embry. 1971. Dry and high moisture barley fed whole or rolled with corn silage in cattle growing-finishing diets. So. Dakota Agr. Exp. Sta. A. S. Series 71-21.

Burkhardt, J. D., L. B. Embry and R. M. Luther. 1970. Dry and high-moisture corn fed whole or rolled with hay or haylage in growing-finishing rations. Beef Cattle Field Day, So. Dakota State Univ. A. S. Series 69-4.

Cardon, B. P. 1969. Dry heat processing of grain. Arizona Feeds, Tucson. AF No. 137.

Christiansen, R. R. and D. G. Wagner. 1974. Reconstituted wheat. I. Influence on feedlot performance of cattle. J. Anim. Sci. 38:456.

Christiansen, R. R. and D. G. Wagner. 1974. Reconstituted wheat. II. Influence of physical form on in vitro digestibility. J. Anim. Sci. 38:463.

Cornett, C. D., L. B. Sherrod and R. C. Albin. 1971. Effects of methods of processing upon digestibility of a new wheat by sheep and cattle. J. Anim. Sci. 32:716.

Croka, D. C. 1974. Studies with micronized sorghum grain for feedlot cattle. M. S. Thesis, Okla. State Univ.

Darlow, A. E., W. D. Campbell, R. B. Cross, V. G. Heller and H. M. Briggs. 1945. Dried sweet potatoes and ground wheat as a substitute for corn in rations for fattening steer calves. Okla. Agr. Exp. Sta. Memeo. Circ. 136.

Darlow, A. E., W. D. Campbell, F. B. Cross, V. G. Heller and H. M. Briggs. 1946. A comparison of dried sweet potatoes, wheat and corn for fattening steer calves. Okla. Agr. Exp. Sta. Bull. 296.

Davis, G. V., D. W. Arnett and A. B. Eurhart. 1973. Nutritive value of flaked, extruded, high moisture reconstituted and dry rolled milo. Kans. Agr. Exp. Sta. Bull. 571:9.

Dinusson, W. E., D. O. Erickson, C. N. Haugse, D. W. Bolin and M. L. Buchanan. 1965. High moisture barley for fattening cattle. No. Dakota Farm Res. Vol. 24. No. 1. P. 9.

Dunbar, J. R., G. P. Lofgreen and D. G. Addis. 1969. Wheat as a replacement for barley in high energy rations. 9th Ann. Calif. Feeder's Day. p. 12.

Durham, R. M., G. F. Ellis and B. Cude. 1967. A comparison of flaked, popped and cracked milo in all-concentrate rations. J. Anim. Sci. 26:220. (Abstr.).

Ellis, G. F., Jr. and J. A. Carpenter. 1966. Popped milo in fattening rations for beef cattle. J. Anim. Sci. 25:594. (Abstr.).

Eng, K. S. 1970. Nutritional value of wheat. Calf News. 8:32.

Erwin, E. S., G. J. Marco and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.

Felsman, R. J., R. W. Harvey and E. R. Burrick. 1972. Effect of roasting corn on grain characteristics and cattle performance. J. Anim. Sci. 34:358. (Abstr.).

Forsyth, J. G., D. N. Mowat and J. B. Stone. 1972. Feeding value for beef and dairy cattle of high moisture corn preserved with propionic acid. Can. J. Anim. Sci. 52:73.

Galyean, M. L. 1975. Influence of processing method on the digestion of corn starch by steers. M. S. Thesis, Okla. State Univ.

Garrett, W. N. 1968. Influence of the method of processing on the feeding of milo and wheat. 8th Ann. Calif. Feeder's Day. p. 36.

Hale, W. H. 1973. Influence of processing on the utilization of grains (starch) by ruminants. J. Anim. Sci. 37:1075.

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

Hale, W. H., B. Theurer, J. A. Marchello, B. Taylor and J. Sullivan. 1971. Various levels of short stemmed wheat grain in high concentrate steer fattening rations. Ariz. Agr. Exp. Sta. Series, P-23: 3-1.

Henderson, H. E. and M. R. Geasler. 1971. Physical preparation of corn grain for feedlot cattle. Mich. St. Univ. Coop. Ext. Serv. Bull. AH-BC-71.

Hinders, R. and K. Eng. 1970. Effect of grain sorghum type on starch degradation due to pressure cooking and micronization. Feedstuffs. 42:20.

Hinman, D. D. and R. R. Johnson. 1974. Influence of processing methods on digestion of sorghum starch in high concentrate beef cattle rations. J. Anim. Sci. 39:417.

Hinman, D. D. and R. R. Johnson. 1974. Influence of degree of micronization on the site and extent of sorghum starch digestion in beef cattle fed high concentrate rations. J. Anim. Sci. 39:958.

Huebner, R. R. 1970. Comparative studies on glutenine from different classes of wheat. J. Agr. Food Chem. 18:256.

Husted, W. T., S. Mehen, W. H. Hale, M. Little and B. Theuer. 1968. Digestibility of milo processed by different methods. J. Anim. Sci. 27:531.

Ingalls, J. R., K. W. Clark and H. R. Sharma. 1974. Acid-treated high moisture barley for dairy cows. Can. J. Anim. Sci. 54:205.

Johnson, R. R., E. T. Clemens, D. D. Hinman, N. A. Cole and D. Williams. 1974. Influence of grain processing on development of subclinical acidosis in beef cattle. Okla. Agr. Exp. Sta. MP92:107.

Krall, J. L. 1969. High moisture barley. Feeding high moisture barley to fattening cattle. Mont. Agr. Exp. Sta. Bull. 625:25.

Krall, J. L. and O. O. Thomas. 1966. High moisture grains. 10th Cattle Feeder's Day. Mont. State Univ.

Langlands, J. P. 1973. Wheat as a survival ration for sheep. I. The digestion of wheat and formaldehyde treated wheat. Australian J. Exp. Agr. and Anim. Husbandry. 13:341.

Lofgreen, G. P. 1970. Comparative net energy values of rations containing wheat and other grains for beef cattle. Proc. of an International Symposium. Okla. State Univ. Stillwater, Okla. p. 191.

MacRae, J. C. and D. G. Armstrong. 1968. Enzyme method for determination of α-linked glucose polymers in biological materials. J. Sci. Food Agr. 19:578.

Martin, T. S. 1973. Feedlot and in vitro studies with processed sorghum and wheat. M. S. Thesis, Okla. State Univ.

Martin, J., R. Peck, M. England, J. Alexander and R. Totusek. 1969. Methods of harvesting and processing the sorghum and corn plants for finishing cattle. Okla. Agr. Exp. Sta. MP82:33.

Martin, J., R. Peck, M. England, J. Alexander and R. Totusek. 1970. Methods of utilizing the sorghum and corn plants for finishing cattle. Okla. Agr. Exp. Sta. MP84:47.

Martin, J., R. Peck, M. England, J. Alexander and R. Totusek. 1971. A comparison of corn processing methods, several levels of corn silage, and sorghum stover silage versus corn silage for finishing steers. Okla. Agr. Exp. Sta. MP85:45.

Martin, T. and D. G. Wagner. 1974. Effect of various processing techniques on sorghum utilization. Okla. Agr. Exp. Sta. MP92:98.

Marx, G. D. 1973. Harvesting, storing and feeding high moisture barley to lactating cows. J. Dairy Sci. 56:677. (Abstr.).

McNeill, J. W., G. D. Potter and J. K. Riggs. 1970. Factors influencing utilization of processed sorghum grain by steers. Tex. Agr. Exp. Sta. Consolidated PR-2775-2800. No. 2778. p. 18.

McNeill, J. W., G. D. Potter and J. K. Riggs. 1971. Ruminal and post-ruminal carbohydrate utilization in steers fed processed sorghum grain. J. Anim. Sci. 33:1371.

McNeill, J. W., G. D. Potter, J. K. Riggs and L. W. Rooney. 1975. Chemical and physical properties of processed sorghum grain carbohydrates. J. Anim. Sci. 40:335.

Morrison, F. B. 1957. Feeds and feeding. Morrison Publ. Co., Ithaca, New York.

Neuhaus, V. and R. Totusek. 1971. Factors affecting the in vitro digestibility of high moisture sorghum grain. J. Anim. Sci. 33:1321.

Oltjen, R. R., P. A. Putman, E. E. Williams, Jr. and R. E. Davis. 1966. Wheat versus corn in all-concentrate cattle rations. J. Anim. Sci. 25:1000.

Parrett, N. A. and J. K. Riggs. 1966. Dry, reconstituted and early harvested grain sorghum for finishing cattle. Tex. Agr. Exp. Sta. Cons. Prog. Rpt. No. 2423.

Reeve, R. M. and H. G. Walker, Jr. 1969. The microscopic structure of popped cereals. Cereal Chem. 46:227.

Richardson, D., E. F. Smith, B. E. Brent and F. G. Clary. 1967. The value of sorghum grain, corn and wheat fed individually and in varying combinations in beef cattle finishing rations. Kans. Agr. Exp. Sta. Bull. 507:12.

Riggs, J. K. and D. D. McGinty. 1970. Early harvested and reconstituted sorghum grain for cattle. J. Anim. Sci. 31:991.

Riggs, J. K., J. W. Sorenson, Jr., J. L. Adame and L. M. Schake. 1970. Popped sorghum grain for finishing beef cattle. J. Anim. Sci. 30:634.

Sandstedt, R. M., D. Straham, S. Veda and R. C. Abbot. 1962. The digestibility of high amylose corn starches. The apparent effect of the Ae-gene on susceptibility to amylase action. Cereal Chem. 29:123.

Schake, L. M., E. T. Garnett, J. K. Riggs and O. D. Butler. 1970. Commercial feedlot evaluation of micronized and steam-flaked grain sorghum rations. Tex. Agr. Exp. Sta. Consolidated PR-2775-2800. No. 2780. p. 25.

Schneider, W. W. 1971. In vivo and in vitro evaluation of high moisture processing of milo and milo-wheat combinations. M. S. Thesis, Okla. State Univ.

Shaw, F. D. and W. J. Pryor. 1972. Feeding wheat to cattle. II. The effect of level of wheat and sodium bicarbonate on ruminal characteristics. Australian Vet. J. 48:504.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. 6th edition. The Iowa State University Press, Ames.

Sullins, R. D., L. W. Rooney and J. K. Riggs. 1971. Physical changes in the kernel during reconstitution of sorghum grain. Cereal Chem. 48:567.

Sung, An-Chein. 1969. Enzymatic evaluation of changes in processed grains. Feedstuffs 41:19.

Tilley, J. M. A. and R. A. Terry. 1963. A two stage technique for in vitro digestion of forage crops. J. Brit. Grassland Soc. 18:104.

Tonroy, B. R. and T. W. Perry. 1974. In vitro digestion of raw, roasted, and pressure-flaked corn. J. Dairy Sci. 57:1508.

Tonroy, B. R., T. W. Perry and W. M. Beeson. 1974. Dry, ensiled high-moisture, ensiled reconstituted high-moisture and volatile fatty acid treated high moisture corn for growing-finishing beef cattle. J. Anim. Sci. 39:931.

Totusek, R., L. Franks, J. R. Newsom and E. C. Nelson. 1968. Milo vs. wheat for fattening cattle. Okla. Agr. Exp. Sta. MP80:64.

Totusek, R. and D. White. 1968. Methods of processing milo for cattle. Proc. Tex. Nutr. Conf. p. 50.

Tremere, A. W., W. G. Merrill and J. K. Loosli. 1968. Adaptation to high concentrate feeding as related to acidosis and digestive disturbances in dairy heifers. J. Dairy Sci. 51:1065.

Trei, J., W. H. Hale and B. Theurer. 1970. Effect of grain processing on *in vitro* gas production. J. Anim. Sci. 30:825.

Varner, L. and Walter Woods. 1970. Influence of wheat upon *in vitro* and *in vivo* lactic acid levels. J. Anim. Sci. 31:257. (Abstr.).

Varner, Larry and Walter Woods. 1971. Wheat in Cattle Rations. 1971. Nebr. Beef Cattle Rep. EC71-218. Univ. of Nebr.

Wagner, D. G., R. Christiansen and W. Holloway. 1971. Influence of storage time and moisture level on feeding value of whole reconstituted milo for fattening cattle. Okla. Agr. Exp. Sta. MP85:64.

Wagner, D. G., R. Christiansen, W. Holloway and R. Renbarger. 1971. Influence of level of wheat and method of processing wheat on the performance of fattening beef cattle. Okla. Agr. Exp. Sta. Misc. Pub. No. 85. p. 59.

Wagner, D. G., R. Christiansen and D. F. Stephens. 1972. Dry processing of wheat for finishing beef cattle. Okla. Agr. Exp. Misc. Pub. No. 87. p. 87.

Walker, H. G., Bet Lai, W. C. Rockwell and G. O. Kohler. 1970. Preparation and evaluation of popped grains for feed use. Cereal Chem. 47:513.

TABLE 19. AOV FOR FEEDLOT TRIALS: ADG, CARCASS AND pH DATA (WHEAT)

Source	df	MS									
		ADG	DP	Conf	Marb	REA	BF	KHP	Grade	Cutab	pH
(Trial 1)											
Total	29										
Trt	1	.2657	.0000	.3000	4.8000	5.8609	.0000	.2083	.3000	5.1207	.2430
Pen/trt	8	.1863	.0003	1.3333	3.0000	.7919	.0257	.1917	.7333	1.4972	.0907
Residual	20	.1478	.0004	2.1000	3.2333	1.4201	.0287	.2917	.7000	2.1074	.0407
(Trial 2)											
Total	34										
Trt	1	.8805	3.2821	11.1111	1.7778	3.8874	.0721	.1111	.0000	1.8678	1.2100
Pen/trt	10	.0932	3.0713	4.0111	5.7778	1.2264	.0670	.2278	.7333	3.0997	.4739
Residual	23	.0995	1.7821	.9445	2.0000	1.0683	.0314	.1875	.2778	1.8878	.2531

TABLE 20. AOV FOR FEEDLOT TRIALS:
ADC AND F/G DATA (WHEAT)

Source	df	MS	
		ADC	F/G
(Trial 1)			
Total	9		
Trt	1	.9000	.0722
Residual	8	.3482	.1331
(Trial 2)			
Total	11		
Trt	1	6.0209	.0027
Residual	10	.1986	.0378

TABLE 21. AOV FOR FEEDLOT TRIALS:
ADG AND pH DATA (BARLEY)

Source	df	MS	
		ADG	pH
(Trial 1)			
Total	47		
Trt	1	.0867	.0169
Pen/trt	10	.2436	.5505
Residual	36	.2672	.2716
(Trial 2)			
Total	35		
Trt	2	.3671	-----
Pen/trt	9	.2086	-----
Residual	24	.3548	-----

TABLE 22. AOV FOR FEEDLOT TRIALS:
ADC AND F/G DATA (BARLEY)

Source	df	MS	
		ADC	F/G
(Trial 1)			
Total	11		
Trt	1	.4962	.0019
Residual	10	.5820	.0721
(Trial 2)			
Total	11		
Trt	2	8.3277	.0728
Residual	9	.3771	.1445

TABLE 23. AOV FOR IVDMD DATA

Source	df		MS	
(Wheat)			(Trial 1)	(Trial 2)
Total	11			
Main plot	3			
Run	1		2.2188	10.1568
Trt	1		61.2009	95.5417
Run X Trt	1		7.6161	.8008
Sub plot	8			
Hour	2		1846.0950	1282.1155
Hour X Trt	2		9.1514	36.7885
Residual	4		3.5551	7.2584
(Barley	(Trial 1)	(Trial 2)		
Total	11	17		
Main Plot	3	5		
Run	1	1	28.5209	73.3261
Trt	1	2	8.2337	13.3906
Run X Trt	1	2	18.2532	3.8278
Sub Plot	8	12		
Hour	2	2	880.2503	1249.3613
Hour X Trt	2	4	37.4388	1.3309
Residual	4	6	20.5060	26.9176

TABLE 24. AOV FOR *IN VITRO* GAS PRODUCTION DATA

Source	df		MS	
(Wheat)			(Trial 1)	(Trial 2)
Total		31		
Main plot		3		
Run		1	10.3627	2.6450
Trt		1	22.7307	5.4285
Run X Trt		1	.0131	.8257
Sub plot		28		
Hour		7	203.4094	199.2245
Hour X Trt		7	93.5132	176.0748
Residual		14	23.9653	6.3832
(Barley)	(Trial 1)	(Trial 2)		
Total	31	47		
Main plot	3	5		
Run	1	1	4.6132	.0027
Trt	1	2	12.1894	18.3949
Run X Trt	1	2	1.0404	.5742
Sub plot	28	42		
Hour	7	7	181.3200	228.5841
Hour X Trt	7	14	29.7490	8.4558
Residual	14	21	4.3948	6.7694

TABLE 25. AOV FOR DIGESTION DATA (WHEAT)

Source	df	MS				
		DM	Protein	Starch	Ash	EE
Total	15					
Period	1	.2139	3.0363	.0001	24.1573	176.0929
Animals in groups	6	6.6999	1.9723	.0610	243.1050	255.3452
Group	1	4.2333	9.0450	.0000	35.2836	7.3984
Trt	1	9.5636	.9168	.0121	20.0704	45.5625
Residual	6	2.2665	2.5857	.0159	35.0938	121.2835

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Master of Science

Thesis: FEEDLOT, IN VITRO AND METABOLISM STUDIES WITH PROCESSED WHEAT AND BARLEY

Major Field: Animal Science

Biographical:

Personal Data: Born in Powell, Wyoming, January 1, 1951, the son of Mr. and Mrs. Marion Aimone and married Melissa Morland, October 6, 1974.

Education: Graduated from Mountain View High School, Mountain View, Wyoming in May, 1969. Received Associate of Science degree from Northwest Community College, Powell, Wyoming in May, 1971. Received the Bachelor of Science degree from the University of Wyoming in Laramie, Wyoming, in May, 1973, with a major in Animal Science.

Experience: Reared on a beef cattle and sheep ranch in Southwestern Wyoming. Livestock and meats judging team member at Northwest Community College (1970-71) and University of Wyoming, 1971-1973. Meat laboratory assistant at the University of Wyoming, 1972-73. Graduate assistant at Oklahoma State University, 1973-75.

Organizations: Member of American Society of Animal Science and Alpha Zeta.