Effect of feed processing upon barley utilization
by Robert H Anderson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Animal Science
Montana State University

Abstract:
A feeding trial and a digestion trial were conducted to evaluate the effect of steam-rolling on the utilization of barley. Thirty-six Charolais cross steers weighing 268 kg were divided into six lots of six head each according to sire and weight. Three lots were fed in outside pens with a covered feed bunk and slotted floors. The three other lots were fed in completely enclosed pens inside a building on slotted floors. The three treatments used in the feeding trial were as follows: (1) whole barley and supplement; (2) steam-rolled barley and supplement; and (3) steam-rolled barley, beet pulp and hay plus supplement. Following a 56-day wintering period, all steers were implanted with 36 mg of RALGRO for the 157-day fattening phase. Treatment number, daily gains and feed required per kg of gain were as follows: (1), 1.12, 9.3; (2), 1.28, 6.9; and (3), 1.23, 7.7. Net return of $22.48 per head favored the steers fed the steam-rolled barley followed closely by the stefers fed the complete ration at $22.35 per head, whereas the steers fed whole barley produced a net loss of $16.72 per head.

The steers fed inside gained 1.14 kg per day and required 8.0 kg of feed per kg of gain whereas the steers fed outside gained 1.28 kg per day and required 7.9 kg of feed per kg of gain. The net returns per head were as follows: $14.88 and $3.87 for the steers fed outside and steers fed inside, respectively.

Digestion coefficients for dry matter, protein and digestible energy of whole or steam-rolled barley, respectively, were as follows: 73.6%, 81.5%; 67.0%, 72.9%; and 73.5%, 80.8%.

Grains recovered from the feces weighed 12% less than the grain as fed. The as-fed grain had a germination rate of 99%, whereas 5% of the grain recovered from the feces germinated.

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Signature Robert H. Anderson

Date May 18, 1973

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A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

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Animal Science

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June, 1973

ACKNOWLEDGEMENTS

My gratitude and appreciation are expressed to Dr. O. O. Thomas for his sincere and understanding guidance throughout my graduate program, in organization and conduction of the experiments, and his invaluable suggestions in the preparation of this manuscript. I also express my appreciation to Dr. B. R. Moss and Dr. P. J. Burfening for their advice and suggestions with the manuscript; to Dr. E. P. Smith for his assistance with the statistical analyses of this data; and to Dr. R. L. Blackwell for his encouragement.

I wish to express sincere gratitude to my wife and family for their help, understanding and encouragement during my graduate work.

Appreciation is expressed to LaVerne Hellyer and the student help at the Nutrition Center for their aid in collecting the experimental data. I also express appreciation to Mrs. Susan Bradley for her assistance with the laboratory work.

An acknowledgement of indebtedness is made to Mrs. Frankie Larson for typing the manuscript.

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ABSTRACT

A feeding trial and a digestion trial were conducted to evaluate the effect of steam-rolling on the utilization of barley. Thirty-six Charolais cross steers weighing 268 kg were divided into six lots of six head each according to sire and weight. Three lots were fed in outside pens with a covered feed bunk and slotted floors. The three other lots were fed in completely enclosed pens inside a building on slotted floors. The three treatments used in the feeding trial were as follows: (1) whole barley and supplement; (2) steam-rolled barley and supplement; and (3) steam-rolled barley, beet pulp and hay plus supplement. Following a 56-day wintering period, all steers were implanted with 36 mg of RALGRO for the 157-day fattening phase. Treatment number, daily gains and feed required per kg of gain were as follows: (1), 1.12, 9.3; (2), 1.28, 6.9; and (3), 1.23, 7.7. Net return of $22.48 per head favored the steers fed the steam-rolled barley followed closely by the steers fed the complete ration at $22.35 per head, whereas the steers fed whole barley produced a net loss of $16.72 per head.

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Digestion coefficients for dry matter, protein and digestible energy of whole or steam-rolled barley, respectively, were as follows: 73.6%, 81.5%; 67.0%, 72.9%; and 73.5%, 80.8%.

Grains recovered from the feces weighed 12% less than the grain as fed. The as-fed grain had a germination rate of 99%, whereas 5% of the grain recovered from the feces germinated.

INTRODUCTION

Barley is the major grain crop of Montana. One method of marketing this grain is feeding it to beef cattle. Because processing has an effect on the cost of grain fed to livestock, it may, therefore, be economically feasible to feed whole, unprocessed grains. Studies were undertaken at Montana State University to determine the value of processing barley by comparing the feeding of whole barley with steam-rolled barley for the growing and fattening of beef cattle.

The problems to be evaluated were as follows:

1. What is the digestibility of whole barley as compared to steam-rolled barley?
2. How do cattle fed whole barley perform when compared to those fed steam-rolled barley?
3. Can barley be fed without any additional roughage?

Feeding trials were designed to compare whole barley with steam-rolled barley for fattening cattle. A complete ration of steam-rolled barley, supplement, hay and beet pulp were fed as a control ration. Metabolism trials were conducted to evaluate the effect of processing on the digestibility of barley.

There is considerable interest in total confinement feeding of beef cattle. However, little is known of the effects of total confinement in a controlled environment upon fattening beef cattle. In order to add to this knowledge, the feeding trial was divided into two replications, one being fed outside and the other being fed in total confinement with controlled environment inside the MSU Nutrition Center Building.

LITERATURE REVIEW

Processing Methods

Grains added to cattle fattening rations are subjected to a wide variety of treatments. The utilization of grains, in general, improved with processing. To improve the digestibility of grains, processing in some form is recommended for all grains, with the possible exception of corn.

The many processing methods that have been or are being used on grain are described by Hale and Theurer (1972) as follows:

Processing methods can be roughly divided into two categories: 1) Dry processing and 2) Wet processing.

Methods of Dry Processing	Methods of Wet Processing
Whole grain	Soaking
Grinding	Steam flaking
Dry rolling or cracking	Steam rolling
Popping	Pressure cooking
Extruding	Exploding
Micronizing	Reconstituting
Roasting	Early harvesting
Pelleting	Silage

Dry Processing

Whole grain: Whole grains are fed in the form in which they are stored following harvest as mature dry grain. Corn is the only grain which can be successfully fed in this form. All the other grains benefit substantially from processing.

Grinding: Grinding is probably the least expensive and simplest processing method available. The texture of ground grains varies from fine to coarse, depending upon the mesh of the screens used in the mill.

Hammermills, which are the most popular means of grinding grains, consist of a series of hammers which swing around an axle and pound the grains through the screens.

Dry rolled or cracked: Dry rolling or cracking is the most popular method for processing grains. The processing is accomplished by passing the grains through a roller mill. The texture of the rolled grain is affected by the tolerance between the two rollers and can vary from the cracked grain to a finely ground consistency.

Popping: Popping is an effective method of processing grain sorghum. Passing the grain through heated, dry air results in expansion of the grain rupturing the endosperm and starch granules of the grain.

Micronizing: Micronizing pops the grains with microwaves generated by a gas-fired infrared heater.

Roasting: Roasted grains are augered through a chamber heated by a gas flame, which raises the temperature of the grain to about 300°F. The moisture content of the grain is reduced to less than 5%, and in the process the kernel is expanded.

Extruding: Extruded grains are augered through a cylinder and forced out through dies, producing a ribbon-like product which breaks into flakes. The friction of the grain moving through the cylinder produces heat which reaches about 200°F at the extruding dies.

Pelleting: In pelleting, like extruding, the grain is forced through dies, except that the grains are ground and can be a mixture of feeds.

Wet processing

Soaking: Soaking grains in water for 12 to 24 hours softens the endosperm and waxy coating and produces a highly palatable product. Soaked grains can be fed either whole or rolled.

Steam rolling: In steam rolling, the grain is treated with live steam for about 3 to 5 minutes before being rolled. The rolling process is similar to that of dry rolling. The initial purpose of the steam treatment was to kill weed seeds.

Steam flaking: Steam flaking is a modification of the steam rolling process, in which treatment specifications and quality control are more closely followed. The moisture content of the grain is raised to 18 to 20% and the temperature before flaking is about that of boiling water.

Pressure cooking: Pressure cooking is a further modification of the steam rolling process wherein the grain is treated to 50 psi for about one and one-half minutes. However, the grain must be cooled to about 200°F before flaking or rolling.

Exploding: Grains to be exploded are subjected to high pressure steam in a closed chamber, followed by a sudden decrease in pressure. This treatment results in a rapid expansion of the grain kernel. Grain sorghum is the only grain treated by this method.

Reconstituted grains: Reconstituting grains is a variation of soaking where moisture is added to mature grains at harvest and stored in air-tight storage. Moisture is raised to 25 to 30%. This process is still in the experimental stage and length of satisfactory storage is not yet known. However, it is felt that this process holds great promise for feeding grain sorghums.

Early harvesting: (High moisture grains). Grains are harvested while the moisture content is still 20-35% and are stored in silos. Grains thus treated are usually rolled before feeding and are highly palatable and digestible.

Silages: Grain silages are usually the entire head of the grain which is harvested early and made into silage. Because of the higher crude fiber content, grain head silages have the potential to be an excellent cattle feed.

Utilization of Grains as Affected by Processing

The common recommendation when feeding corn to fatten cattle, especially when the ration is 80% or more concentrates, is to feed whole, shelled corn. This recommendation stems from the idea that, although ground corn produces faster gains and better feed efficiency, the improvement in gains and efficiency do not pay the milling cost.

There is conflicting data concerning the consumption of whole, shelled corn when compared to ground corn. Ohio and Minnesota workers indicated that a greater amount of whole, shelled corn was consumed per pound of gain, whereas Texas and Indiana workers indicated that up to 10% less corn was consumed and that the reduced gains were due to reduced feed consumption.

Increased feed consumption, when the whole grain is fed, may be due to cattle's preference for the whole or coarse preparations. Otis (1904) found that growing dairy calves preferred shelled corn to corn-chop and also that better gains were made by cattle fed the shelled corn. He also noted less problem with scours when shelled corn was fed.

McCandlish (1923) found that young calves preferred whole corn or oats to the ground form. He also reported that calves fed at a self-feeder consistently consumed a ration much narrower in nutritive ratio than recommended, but as the calves aged, the nutritive ratio widened. As calves became older, the amount of hay or roughage consumed was increased.

Ray and Drake (1959) reported that when calves were given a choice between whole, coarsely ground, finely ground, pellets or ground pellets of corn, milo or oats, they consistently chose the coarser preparation. When given a choice between grains, no consistent preference was shown. Finely ground grains were consumed in significantly lesser amounts than the coarse preparations. Pellets were preferable to ground pellets.

Utilization of feeds by the ruminant animal is dependent upon the physical form of the feed. Shaw and Norton (1906) recovered unmasticated corn and oats from feces of calves, heifers, or mature cows and reported that recovered grain had about the same chemical analyses as the grain before feeding. Table 1 shows the percentage of the fed grains recovered from the feces in the unmasticated form. Not much nutritive value was derived from these grains which passed through the digestive tract unmasticated. However, the bacteria and enzymes affected the germinating power of the grain by reducing it from over 90% to under 10%.

TABLE 1. PERCENTAGE OF FED GRAINS RECOVERED FROM FECES IN UNMASTICATED FORM

	Whole corn	Whole oats	Whole corn and oats
	%	%	%
Mature cows	22.75	12.06	26.40
Heifer-yearling	10.77	5.48	17.50
Calves	6.28	2.98	5.78

Allison (1917) reported a study which evaluated 5 different preparations of corn on average daily gain and net returns. Cattle fed ground, shelled corn yielded highest average daily gains followed closely by those fed whole, shelled corn. The greatest net return was produced by feeding ear corn, followed again by whole, shelled corn. Thus, feeding whole, shelled corn appeared to be the most efficient and profitable way to feed corn.

Peters (1931a) compared ground barley, whole barley, and whole, shelled corn for fattening cattle. He found that cattle fed whole, shelled corn produced the best gains, whereas those fed whole barley gained the least. Ground barley tended to be unpalatable and resulted in reduced consumption. The poor gains produced by the whole barley were reported to be due to the kernels passing through the gastrointestinal tract and thus were of no nutritive value.

In other work, Peters (1931b) reported that grinding corn and alfalfa increased daily consumption and daily gains, but he felt that the increased gains did not pay for the added cost of grinding.

When a grain mixture in two forms, ground and unground, was used to raise calves to six months of age, Hilton, Wilbur and Hienton (1933) reported that calves consumed approximately one-fourth pound more per day of the ground mixture. Although more feed was consumed, there was no difference in daily gain.

Darnell and Copeland (1936) reported that dairy cows consumed more of a concentrate mixture in ground form than when the mixture consisted of 50 to 75% whole grain. The cows showed a preference for whole corn and milo over barley and oats. Greater milk production was obtained from cows consuming the ground grain mixture; most of the increased milk production was attributed to the greater consumption of grain. It was also reported that a wide variation existed among cows in the amount of mastication of the whole grains. More corn than milo was masticated, indicating a size relationship to amount of mastication of grains.

Reduced rumination time was noted in work by Kick _et al._ (1937), along with an increase in work required for mastication of ground corn. Grinding of roughages or grains resulted in no conservation of metabolizable energy. The time spent masticating and ruminating was affected by the roughage:concentration ratio of the ration.

In work with milo, Atkison and Beek (1942) reported that more grain was wasted when the whole or coarsely ground grain was fed. Atkison recovered 42% of the whole grain, 4.8% of the coarsely ground, and 1.5% of the finely ground grain from the feces. The small size and hardness of the kernel of the milo grain indicated that some sort of processing was necessary.

Calovos and Keener (1954) reported results of a trial comparing palatability and digestibility of coarsely ground versus finely ground grain. The finer grind proved to be more digestible than the coarser grind with no difference noted in consumption. This latter observation is contrary to the findings of Ray et al. (1959), who noted that cattle preferred the coarser preparations.

Cullison (1961) reported that calves consumed 32% more pelleted hay and 24.8% more ground hay than long hay and that gains of cattle fed these hays were 99% and 52%, respectively, faster than cattle fed the long hay. A preference was shown for the pelleted hay. In another trial, steers receiving their entire ration in the pelleted form consumed less feed and gained slower than when the ration was fed in either the ground or in the conventional form. It was further noted that the addition of one and one-half pounds of straw per head per day resulted in a 26% increase in consumption and a 37% improvement in gains over the pelleted ration without straw. When the pelleted or ground rations were fed, normal rumination and cud chewing were markedly decreased and an abnormal rumen condition developed. This latter condition was corrected by feeding straw. A decreased secretion of saliva was observed when the pelleted ration was fed, resulting in a significantly lowered pH.

Myers (1962) reported that steers fed an all concentrate ration consumed less feed and were more efficient than steers that received barley plus hay. Average daily gains were about the same. Myers further reported no differences between steers fed steam-rolled barley and dry-rolled barley in terms of feed consumption and feed efficiency.

In a feeding trial comparing full-fed rations of 50% ground alfalfa and 50% ground shelled corn, or 50% ground alfalfa and 50% rolled shelled corn, Goodrich, Whetzal and Embry (1962) reported that there were no differences in rate of gain, feed efficiency, or digestibility of cattle fed these rations.

Keating et al. (1965) reported results of digestion trials of barley and milo with steers and lambs. With 50% roughage, digestion coefficients of the grain components were similar, except that the TDN for milo was higher. When the concentrate levels were increased to 85%, the digestibility of the protein and NFE of barley was significantly ($P < .05$) higher than that of the milo. Cooking the milo with 2 parts water significantly decreased ($P < .05$) protein digestibility. Contrary to the results with cattle, the digestibility of NFE and gross energy were significantly greater ($P < .05$) for barley when fed to lambs.

In work by Clanton and Woods (1966) comparing pelleted or coarsely ground alfalfa hay mixed with either cracked or pelleted corn fed to fattening steers, the weight gains improved as levels of cracked corn in the diet increased from 0 to 75% of the ration. Carcass grade, dressing percentage, and fat thickness increased as the level of corn increased in the ration. The steers did not perform as well when the corn portion of the ration was pelleted instead of cracked. Increasing cracked corn in the ration narrowed the acetate:proponiate ratio in the rumen, but the pelleted corn had no effect. Similar results were noted when the long hay replaced the pelleted hay. The physical form of the hay did not significantly influence the animals' performance when fed with high levels of cracked corn.

Using *in vivo* bag technique, Evans and Colburn (1967) reported that grinding corn, oats, rye, sorghum, soybeans, and wheat increased rumen digestion coefficients and TDN values when compared to the unground form of these grains. The protein digestion coefficients for soybeans and dried corn increased less than for the other grains. The hardness and moisture content of the grain affected the digestibility of corn more than the other grains. The *in vivo* bag technique offered a method of comparing digestibility of grains.

Buchanan-Smith, Totusek, and Tillman (1968) reported work evaluating the digestibility of dry matter, organic matter, nonprotein organic matter, energy and nitrogen retention of diets containing steam-processed -rolled, reconstituted-rolled, coarsely or finely ground grain sorghum. The digestibility of the dry matter, organic matter, nonprotein organic matter and energy was greater in the diets containing the reconstituted-rolled grain than in the finely or coarsely ground grain.

Burkhardt et al. (1969) reported no advantage from rolling or flaking corn, when compared to the unprocessed grain, upon weight gains or feed efficiency when corn was fed with two pounds of hay per day. Similarly, reconstituted high-moisture corn showed no advantage over dry corn.

Using a comparative slaughter feeding trial technique, Garrett, Lofgreen and Hull (1971) reported no consistent improvement in the feeding value and energy utilization of wheat, corn, or barley when treated by various combinations of steam, pressure and time. However, steam pressure processing of milo resulted in a 10% improvement in net energy utilization.

Feeding All Concentrate Rations to Beef Cattle

Finishing beef cattle efficiently is facilitated by feeding a ration containing high levels of energy. An all-grain ration would contain high levels of energy; however, problems arise from the feeding of all-grain rations. Normal rumen activity is encouraged by bulk in the diet, which prevents compaction and stimulates microbial action.

When feeding ruminants, attention must be given to the amount of roughage in the diet. Several forms of roughage have been used. These include polyethylene (rough tabs) and oyster shells which are supposed to remain in the rumen. Hay or straw have also been used in rations. More recently, grains (barley and oats) with relatively high levels of crude fiber have been used. The shape of the whole corn kernel is thought to serve as roughage, thus the reason for the performance of whole, shelled corn.

In the earliest report on all-concentrate rations, Geurin et al. (1959) compared rolled barley with ground ear corn. The supplemented, rolled barley produced the best gains, most efficient use of feed, and promoted normal rumination. This work indicated that properly supplemented barley can effectively serve as both concentrate and roughage in a fattening ration for beef cattle.

In a paper reviewing the works of several investigators, evaluating all-concentration rations for beef cattle, Wise et al. (1968) concluded that all-concentrate feeding has many attributes which might be attractive to cattle feeders. Comparisons of grain rations with and without roughage indicated that feed consumption was lower and feed per unit of gain was less with all-concentrate rations. Another point is that the amount of grain per unit of gain was about equal in rations both with and without roughage. All concentrate rations need to be supplemented with minerals that would normally be included in the roughage. The literature cited by Wise (1968) implied that buffering may be valuable in all-concentrate rations but no clear-cut conclusions can be made from data presented. Rumen parakeratosis, liver abscesses, reduced feed intake, founder and bloat are among the attendant problems with all concentrate rations and can be alleviated by the addition of 10 to 15% roughage in the diet.

In a similar review work, Meiske et al. (1970) concluded that although all-concentrate rations are feasible, best gains are obtained with a ration containing about 5 to 10% roughage. Some success was reported with roughage substitutes in the form of polyethylene products, oyster shells, or silicates. Some of these have been effective in reducing the incidence of rumen parakeratosis. Feeding whole, shelled corn effectively reduces liver abscesses and rumen parakeratosis, primarily because of the shape of the kernel. However, feeding whole, shelled corn often did not produce faster gains and improved feed efficiency.

Richardson et al. (1961) reported that the highest rate of gain was obtained from a ration having a roughage:concentrate ratio of 1:5. Digestion coefficients were highest when the roughage:concentrate ratio was between 1:3 and 1:5.

Wise et al. (1961) reported acceptable gains with supplemented ground shelled corn for fattening beef cattle. No problems were encountered with diarrhea, bloat, or stiffness. Addition of either ground or long hay had no effect on the performance of the cattle.

Calves are able to perform satisfactorily on all-concentrate diets for extended periods, provided that the ration is adequately supplemented with the essential nutrients according to Wise et al. (1961). The buffering ability of the rumen is important to this performance.

Thomas et al. (1961) reported satisfactory gains with steam-rolled barley rations fed without roughage to heifers and steers. Including Dynafac in the ration increased gains and feed efficiency.

Myers (1962) in a feeding trial comparing steam-rolled barley and dry-rolled barley with molasses, all fed with 0, 2, or 6 pounds of hay, reported that best gains were produced with steam-rolled barley plus 2 pounds of hay daily. Steam-rolled barley included in the wintering ration produced the best results.

Harper et al. (1962) indicated that all-barley rations require fortification with trace minerals to produce the desired effect.

Parrott, Loughead and Hale (1968) reported that digestible energy intake increased as grain replaced hay from 0 to 60% of the ration, then decreased as the grain levels increased from 60 to 90% of the ration. In another trial, digestible energy intakes were markedly reduced when the ration was 100% grain as compared to rations of 90% and 95% concentrates.

Hironaka and Bailey (1968) compared rations approximately equal in digestible energy content but of varying rations of barley and hay. The rate of gain increased and the amount of digestible energy per unit of gain decreased as the amount of barley in the ration increased.

It is suggested that the nature of the digestion products accounts for this difference.

In a study comparing whole, shelled corn, ground corn, and steam-flaked corn fed without roughage, with 10% corn cobs or with 4% perlite, Vance et al. (1970) reported that feedlot performance was unaffected by any of the treatments. Net energy values were highest for the steam-flaked corn. The addition of corn cobs reduced rumen wall damage. The addition of perlite was less effective than corn cobs for reducing damage to rumen walls.

Wiktorsson (1971), in work with dairy cows, showed that cows digested concentrates to the same extent, regardless of the quantity consumed. As long as the cows had adapted to the ration, there is no reason to assume lower digestibility at higher consumption of concentrates.

Barley for Fattening Cattle

The first choice of grains to fatten cattle is, without a doubt, corn. Corn produces the most efficient and problem-free gains in whatever form it is fed. Other grains will effectively finish cattle but may require more attention to management details than does corn. Wheat, for example, is equal to corn in energy value, but if more than 50% of the ration is wheat, digestive problems arise. No digestive problems are reported with grain sorghums, but best utilization requires that they be processed; even so the energy value is less than corn.

Barley has the attributes of an excellent cattle feed; when compared with corn, barley is somewhat lower in energy, higher in protein, and about 3 times higher in crude fiber. A problem with barley is that it can produce bloat, and in some forms, cattle find barley unpalatable.

Dinusson et al. (1960) reported that barley was equal to corn in a cattle fattening trial. He also reported that rolled barley fed with some hay produced cheapest gains.

Myers (1962) reported satisfactory performance from steers fed either steam-rolled barley or dry-rolled barley. No difference in feed consumption or feed efficiency were noted between the two processes.

Oregon trials (1961) indicated that rolled and pelleted barley gave equal results during the early part of the feeding trial; however, during the last 2 months of the trial, rolled barley produced faster and cheaper gains than the pelleted barley.

Dinusson et al. (1962a) reported that supplements containing more than 17% protein were of no real benefit when fed with dry-rolled barley containing 12% protein for fattening steers. Supplements based on alfalfa meal or malt sprouts were superior to those based on distillers' products and beet pulp or no supplements. Carcass characteristics were not affected by the various supplements, with the exception that conformation and finish were improved with the added protein.

In another study, Dinusson et al. (1962b) reported no differences between steam- and dry-rolled barley. Increasing the protein level was of no value in these rations based on barley containing about 12% protein.

Results of work reported by Harper et al. (1962) emphasized the need to fortify all-barley rations with trace minerals or feeds rich in trace-element content.

Dinusson et al. (1964) reported that the addition of beet pulp, malt sprouts, and alfalfa to dry-rolled barley rations showed no advantage over dry-rolled barley plus a supplement. No added benefits were noted from pelleting the complete ration.

Geurin et al. (1959) reported that the barley hulls supply adequate roughage to permit normal rumination by the cattle and yet provide sufficient energy for rapid gains and rapid finishing.

South Dakota workers (1967) reported results of several trials studying the value of adding hay and/or molasses to all-barley rations. Also, a trial was conducted to evaluate the need for protein supplementation to barley rations. Best rate of gain with cattle was obtained when 5% molasses and 15% hay was fed with the barley. Feed consumption, however, was increased and more feed was required per pound of gain. Barley plus 5% molasses produced a pound of gain with the least amount of feed, but the average daily gain was 0.25 pounds per day less than the barley, 5% molasses, and 15% hay diet. It was believed that the hay in the diet aided in getting the cattle on feed without digestive problems and thereby produced better gains earlier. Increased feed consumption was noted when 5% molasses was added to the barley or the barley and hay rations. Further work with the amount of hay to be fed with barley indicated that about 10% added hay yielded the best results in terms of barley saved per pound of gain. Little or no protein supplement was deemed necessary with barley rations, but mineral supplements containing calcium and trace minerals were beneficial.

Hironaka and Bailey (1968) reported that gains from rations increased as the amount of barley increased in relation to the hay. These diets were approximately equal in digestible energy (DE). It was noted that, as the barley in the diet increased, less DE was required per pound of gain. This suggests a difference in DE utilization between barley and hay.

Confinement Housing for Beef Cattle

The most efficient use of labor and facilities for feeding cattle occurs when the cattle are concentrated in one area. Problems encountered with a concentration of cattle are related to the weather and accumulation of manure. These problems are largely solved by use of building over and/or around the pens and slotted floors over a manure pit. The minimum amount of space required by a beef animal to perform at an optimum level is dependent upon several factors and may well be undetermined; however, about 20 square feet per head for total confinement inside on slotted floors is recommended.

Henderson, Newland and Esmay (1965); Henderson and Newland (1966);

Henderson, Geasler and Hawkins (1967) reported that cattle performance tended to decrease as allotted space decreased. Further, feed per hundred weight gain increased as space decreased. The trials were conducted in experimental manure pack lots open to the south with a roof covering the entire lot area. Recommendations arising from the Michigan work are that about 2 to 3 square feet are needed per 100 pounds of body weight for bedded or concrete floors. Some reduction in space can be allowed in winter and an increase during the summer months should be considered.

In a summary of three years' work, Meiske _et al_. (1970); Meiske _et al_. (1971); Meiske _et al_. (1972) reported comparisons of five housing systems. The systems evaluated were as follows:

1. Conventional open shed with outside concrete lot.
2. Manure pack confinement.
3. Cold slat confinement.
4. Warm slat confinement.
5. Open lot with dirt mound and wind break.

Contrary to the Michigan State workers' observations, the rate of gain decreased as the allotted space increased; there was no observed difference in feed per hundred weight gain in the manure pack confinement pens. The best rate of gain was obtained from the warm slat pens at either 17 square feet or 25 square feet per head, followed closely by the manure pack test and the warm slat at 14 square feet per head.

Similar to observations of the Michigan State workers concerning manure pack confinement pens, the Minnesota workers noted that the average daily gains of cattle on both cold slat confinement and conventional open shed decreased as the density increased.

In contradicting reports comparing inside housing with open or outside pens, Meiske et al. (1972) reported more favorable results from the inside pens. Henderson et al (1965) reported that whether or not the floors were slatted or solid concrete, rate of gain and feed efficiency favored the open housing.

Ingalls and Seale (1967) reported comparing heated housing with open housing for feeding both steers and bulls. The heated housing treatment animals consumed less feed and required slightly less feed per pound of gain with no difference in rate of gain over the open housing treatment. During the fall feeding period, (October-December), the outside animals gained 13.6% faster on an 18.5% higher feed intake. However, during the winter period, (December-March), the outside animals consumed 11.6% more feed, with 6.8% lower gains and 20% lower feed efficiency than the animals inside. Small differences were noted during the spring period (March-May). This data tends to indicate no real benefit is derived from heated housing except perhaps during the winter months.

Givens et al. (1967) reported satisfactory winter results from both concrete and dirt corrals when the allotted space per animal was 312 to 355 square feet. Also, animals with sheltered pens on slatted floors and 58 square feet per head did equally as well as the open corrals. Individual stalls for beef animals were of no benefit and in some cases proved detrimental.

Hoffman and Self (1970) reported that shelter significantly increased ($P<.05$) the rate of gain in both winter and summer, with the greatest effect in the winter. Shelter had no effect on feed consumption but did significantly improve ($P<.05$) winter feed efficiency with a trend toward improved feed efficiency in the summer. The surface of the feeding pens had no effect on any of the parameters.

When a conventional drylot with a dirt mound and natural windbreak was compared with a confinement facility open to the south over an oxidation ditch, Vetter, Mobley and Gay (1970) reported that no consistent results were obtained from two trials. However, the cattle in confinement in general, out performed those in the drylot.

McCarrick and Drennan (1972) compared the effect of winter environment on live weight gains of Hereford-Shorthorn steers. Groups of 9-month-old steers were housed in cubicles either roofless or indoors with no significant difference between treatments. No difference was noted on subsequent gains on pasture.

METHODS AND PROCEDURE

Trial 1 - Feeding Trial

A feeding trial was conducted at the Montana State University Agricultural Experiment Station Nutrition Center, Bozeman, Montana, using thirty-six (36) steers from the U. S. Range Livestock Experiment Station at Miles City, Montana. The steers were artificially sired by two Charolais bulls bred to Hereford-Angus cross cows. The steers were one-half Charolais one-fourth Hereford one-fourth Angus. After arriving at the MSU feedlot in October 1971, the steers were vaccinated and treated for internal and external parasites and placed on a preconditioning regime, until the beginning of the feeding trial in December, 1971.

The steers used on the feeding trial were selected for uniformity from the forty-two (42) head orginally received. The 36 head used were randomly placed into six groups which were uniform in size and weight and with each sire represented in each group. Each group was randomly assigned to one of six pens (3 outside and 3 inside). Three treatments were randomly assigned to three pens outside and the three pens inside.

The three pens outside were located partially under an open shed with fenceline feed bunks. One-half of the pens had slotted floors over an anaerobic manure pit; the other half of the floors were solid concrete. Water was provided *ad libitum* from thermostatically heated waterers. Salt was provided *ad libitum*. The pen size was 5.5 x 7.5 meters, allowing approximately seven square meters per head.

The three inside pens were 3.7 x 4.0 meters square, allowing approximately 2.5 square meters per head with slotted floors over anaerobic pits. Feed bunks are 3 meters long and movable. Water and salt were provided *ad libitum*. The temperature of the room containing the pens was maintained at 60 to 70^{o}F for the entire feeding period.

The three treatments were as follows:

1. Whole grain barley and 0.45 kg of supplement daily.
2. Steam-rolled barley and 0.45 kg of supplement daily.
3. Steam-rolled barley, 0.9 kg of pelleted beet pulp, 0.9 kg of hay and 0.45 kg of supplement daily.

For the first 56 days (wintering period) of the 213-day feeding period, all treatments were fed chopped hay, *ad libitum*, in addition to the prescribed feed regime for that treatment.

The hay was removed, except as noted for treatment 3, for the 157-day fattening period. At the beginning of this period, a shrunk weight was taken and the cattle were implanted with 36 mg of RALGRO. Barley, either whole or steam-rolled, was full-fed for the fattening period. The feeding schedule called for twice daily feeding; one-half of the daily ration was provided at each feeding.

The feeding regime and ration for the three treatments inside was similar to the outside treatments.

The supplement fed was designed to balance of calcium:phosphorus ratio of the total ration by providing adequate calcium to bring the calcium:phosphorus ratio to 1:1 to 2:1. The supplement also provided nonprotein nitrogen in the form of urea and biuret, trace minerals, vitamins A and D, and chlortetracycline.

TABLE 2. SPECIFICATIONS OF SUPPLEMENT

MSU No. 713	
Ingredients	Percent of Ration %
Barley	23.50
Soybean meal	3.65
Linseed meal	5.00
Urea (281)	1.45
Biuret (230)	0.85
Wheat millrun	30.00
Dehydrated alfalfa meal	20.00
Molasses, cane	20.00
Trace minerals	0.05
Limestone (38)	9.25
Vitamins and antibiotics[a]	x

[a] Vitamin A added to provide 88,000 IU/kg; vitamin D added to provide 44,000 IU/kg; chlortetracycline added to provide 145 mg/kg.

At the termination of the fattening trial, the steers were held off feed and water overnight, with final weights taken in the morning. The steers were slaughtered at Pierce Packing Company, Billings, Montana. Hot carcass weights were recorded at the time of slaughter.

Carcass data were collected after one and one-half days in the cooler. Rib eye tracings and fat cover measurements were taken. Conformation grade, marbling and maturity scores, kidney fat estimate, quality grade and yield grade were determined by a USDA Meat Grader. Average daily gains and carcass data were analyzed for statistical significance by the least square method as detailed by Steel and Torrie (1960). Differences among three or more means were tested for significance by Duncan's (1955) multiple range test.

Trial II - Digestion Trial

Three steers of the same source as those in trial I were used for a digestion study of the feeds. After adaptation to each of the seven feeds or feed combinations, a seven day collection period of feces and urine followed. The procedure described by Clanton (1961) was followed for collection of feces and urine, with the exception that seven individual samples were kept, rather than a composite sample. Individual metabolism stalls, in which the urine and feces can be collected separately, were used. The steers were fed twice a day, with one-half of the daily ration each time. Water was provided free-choice in an automatic cup.

Urine and feces were collected daily before the afternoon feeding during the 7-day collection period. Both were weighed at the time of collection. Five percent of the urine was acidified and frozen for storage and 10% of the feces were frozen. The feeds were sampled at the time of feeding and stored in a cool, dry place until analyses were conducted.

The individual fecal samples were analyzed in the following manner: The frozen sample was thawed at room temperature overnight and mixed by kneading in the plastic bag in which it was stored. One 3-gram sample was weighed for protein analysis, two 10-gram samples weighed and placed in a 100°C oven overnight for dry matter determination, and a fourth sample of approximately 25 g was set out to air dry for gross energy determination. One of the dried samples was ashed in a muffle oven overnight at 600°C. The second dried sample was ground in a micromill and approximately 2 g weighed and placed in an envelope made of 15 cm diamter circles of filter paper. Nine such samples were placed in a Soxhlet apparatus for the ether extraction process. The extraction process was allowed to proceed for 16 hours. After this time, the samples were aired to remove the ether, and dried in a 100°C oven overnight and weighed. The ether extract was assumed to be the difference in weights from before and after the extraction process.

The seven extracted samples from each animal from each fecal collection period were mixed together in one composite sample. This sample was submitted to the Montana State University Chemistry Station for crude fiber determination.

The protein content of the fecal samples were determined on the 3 g of wet samples by the Kjeldahl method following the procedure described by Harris (1970), with the exception that a commercially available prepared catalyst pack (Kelpack powder No.2; Harshaw Scientific) was used instead of the chemical mixture detailed in the procedure. Protein content was calculated by multiplying the percentage of nitrogen in the sample by 6.25.

The gross energy content of each fecal sample was determined by using a Parr Oxygen Bomb Calorimeter. A 1-gram sample of the air dry feces was weighed and packed tightly into a dried, preweighed bomb cup. The prepared sample was moistened with a drop of distilled water and burned in 20 atmospheres of oxygen in the calorimeter. At the same time, a sample was weighed for dry matter determination. This permitted calculating the calories per gram of feces on a dry-matter basis.

Urinary energy was determined by measuring the nitrogen content of the urine sample. Five ml of urine were measured into a styrene flame cup and weighed and the nitrogen content determined by the Kjeldahl method previously described. Urinary energy was calculated by the formula $UE_{kcal/gm} = 0.022 + 0.118$ (UN%) set forth by street, butcher and Harris (1964).

Feeds were analyzed by the same procedures as were the feces, with the exception of quantities used, (1 g instead of 3 g for the Kjeldahl).

The crude fiber content of the feeds were determined at the MSU Nutrition Center Laboratory from the ether extracted samples. The procedure followed is described by Harris (1970).

In addition to the proximate analysis and gross energy determinations, a whole barley grain sample obtained before feeding and a sample recovered from the feces were also compared by comparative germination and weights. One hundred kernels of each barley were placed in germination trays on moist blotter paper and incubated at room temperature for one week.

At the same time, 100 kernels of each grain were counted, placed in a 100^{o}C oven overnight and weighed, thus giving a value for the relative bulk densities of barley as fed and as recovered from the feces.

RESULTS

Trial I - Feeding Trial

The results of the wintering phase are shown in table 3. The average beginning weight was 265 kg, and the average gain was 57.4 kg. The steers fed steam-rolled barley gained 1.12 kg per day followed closely by the steers fed the complete ration treatment of 1.09 kg per day. The steers fed whole barley gained 0.86 kg per day or 24% less than the steers fed steam-rolled barley. Steers fed steam-rolled barley consumed an average of 7.8 kg of feed per day, compared to 8.4 kg per day and 8.7 kg per day, respectively, for steers fed the complete ration and whole barley. Steers in both the steam-rolled barley treatment required 7.8 kg of feed per kg of gain, whereas the steers fed the whole barley ration required 38% or 2.9 kg more feed per day. Although steers fed the steam-rolled barley gained slightly faster than those fed the complete ration, the cost of feed per 100 kg of gain favored the complete ration treatment at $38.79 versus $39.21. The feed cost per 100 kg of gain for the steers fed the whole barley ration was $50.63 or 31% more than for steers fed the complete ration.

Table 4 shows the results of the wintering phase of trial 1 by treatment and environment. The greatest total gain of 71 kg and the largest average daily gain of 1.25 kg were made by the steers fed steam-rolled barley inside the MSU Nutrition Center Building. The steers inside, fed either whole barley or steam-rolled barley, gained faster than their counterparts fed outside. Steers in the three

TABLE 3. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE WINTERING PHASE (December 17, 1971 to February 12, 1972)

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, kg				
Initial	267.1	268.5	259.5	
Final	314.9	331.9	320.5	
Gain	47.9	63.4	61.0	
Daily gain	0.86	1.12	1.09	± .09
Average daily ration, kg				
Supplement	0.45	0.45	0.45	
Barley	4.59	4.30	3.62	
Roughage	3.62	3.04	3.19	
Beet pulp	--	--	0.70	
Average daily feed, kg	8.66	7.79	8.36	
Feed/kg gain, kg	10.69	7.75	7.75	
Feed cost/100 kg gain, $	50.63	39.21	38.79	

treatments fed inside consumed less feed daily than did the corresponding treatment fed outside. Although the steers fed steam-rolled barley inside gained faster on the least amount of feed per kg of gain (7.3 kg), steers fed the complete ration inside consumed the least amount of feed daily (7.5 kg) and produced gains at the least cost ($35.71 per 100 kg of gain). The feed required to produce a kg of gain ranged from 7.3 kg to 12.7 kg, with the steers fed whole barley outside requiring the most feed. Gains of steers fed whole barley outside were the most costly at $59.66 per 100 kg of gain.

TABLE 4. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE WINTERING PHASE (December 17, 1971 to February 12, 1972)

	Whole barley		Steam-rolled barley		Complete barley		Standard error
	Outside	Inside	Outside	Inside	Outside	Inside	
No. animals	6	6	6	6	6	6	
Average weights, kg							
Initial	278.5	255.8	280.8	256.3	261.7	257.2	
Final	319.3	310.7	337.0	327.0	323.4	317.5	
Gain	40.8	54.9	56.2	70.8	61.7	60.3	
Daily gain	0.73	0.98	1.00	1.25	1.10	1.08	± .12
Average daily ration, kg							
Supplement	0.45	0.45	0.45	0.45	0.45	0.45	
Barley	4.63	4.58	4.13	4.49	3.76	3.49	
Roughage	3.76	3.49	3.36	2.72	3.45	2.95	
Beet pulp	--	--	--	--	0.73	0.63	
Average daily feed, kg	8.84	8.52	7.94	7.66	8.39	7.53	
Feed/kg gain, kg	12.65	8.74	8.19	7.31	7.61	7.89	
Feed cost/100 kg gain, $	59.66	41.60	40.74	37.70	37.72	35.71	

Table 5 shows the results of the fattening phase of trial 1. Steers fed steam-rolled barley gained slightly faster than steers fed the complete ration (1.34 kg versus 1.27 kg). Steers fed steam-rolled barley gained more efficiently than steers fed whole barley, requiring 6.9 kg of feed per kg of gain. Steers fed whole barley consumed 10.2 kg, 21% more whole barley per day than did those fed steam-rolled barley. Steers fed the complete ration required 7.7 kg of feed per kg of gain, followed by steers fed whole barley at 9.1 kg feed per kg of gain. The feed cost per 100 kg of gain favored steers fed steam-rolled barley at \$41.45 per 100 kg gain, followed by the complete ration treatment at \$43.50 per kg gain. Whole barley fed to steers produced the most costly gains at \$50.70 per 100 kg gain.

TABLE 5. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE FATTENING PHASE February 12, 1972 to July 18, 1972).

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, kg				
Initial	314.9	331.9	320.5	
Final	505.3	541.0	521.5	
Gain	190.4	209.1	201.0	
Daily gain	1.20[b]	1.34[b]	1.27	± .03
Average daily ration				
Supplement	0.45	0.45	0.45	
Barley	10.18	8.43	7.12	
Roughage[a]	0.23	0.23	1.42	
Beet pulp	--	--	0.83	
Average daily feed	10.87	9.12	9.83	
Feed/kg gain, kg	9.08	6.90	7.73	
Feed cost/100 kg gain, \$	50.70	41.45	43.50	

[a] Roughage only fed 14 days at start of trial.
[b] ($P < .01$)

Results by treatment and environment for the fattening portion of trial 1 are shown in table 6. Average daily gains of animals fed outside were generally better than those fed inside. The three outside treatments and average daily gains were as follows: Steam-rolled barley

1.46 kg; complete ration, 1.42 kg; and whole barley, 1.29 kg. Average daily gains of steers fed inside were as follows: 1.23 kg, 1.12 kg, and 1.12 kg for steers fed steam-rolled barley, complete ration and whole barley, respectively.

TABLE 6. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE FATTENING PHASE (February 12, 1972 to July 18, 1972).

	Whole barley		Steam-rolled barley		Complete barley		Standard error
	Outside	Inside	Outside	Inside	Outside	Inside	
No. animals	6	6	6	6	6	6	
Average weights, kg							
Initial	319.3	310.3	337.0	327.0	323.4	317.5	
Final	524.8	485.8	566.1	516.2	547.0	495.8	
Gain	205.5	175.1	299.1	189.2	223.6	178.3	
Daily gain	1.29	1.12	1.46	1.23	1.42	1.12	± .05
Average daily ration, kg							
Supplement	0.45	0.45	0.45	0.45	0.45	0.45	
Barley	10.39	9.98	9.18	7.76	8.16	6.08	
Roughage[a]	0.23	0.23	0.23	0.23	1.41	1.41	
Beet pulp	--	--	--	--	0.91	0.77	
Average daily feed, kg	11.07	10.66	9.86	8.44	10.93	8.71	
Feed/kg gain, kg	8.54	9.63	6.77	7.04	7.75	7.70	
Feed cost/100 kg gain, $	47.66	53.75	40.63	42.26	43.92	43.10	

[a] Roughage only fed 14 days at start of trial.

The steam-rolled barley-fed steers penned outside showed an 11% improvement in gains when compared to the outside pen of whole barley-fed steers; this improvement can be attributed to the processing of the barley. Likewise, an 8% improvement was noted between these two treatments fed inside. Steers fed steam-rolled barley outside made the most economical gains ($40.36 per 100 kg) on the least amount of feed per kg of gain (6.8 kg feed per kg gain), followed closely by steers fed steam-rolled barley inside ($42.26 per 100 kg gain) and required 7.0 kg feed per kg of gain. Steers fed the whole barley treatment generally performed poorer than the other two treatments, with those fed inside being the least efficient and economical.

Table 7 shows the consolidated results for trial 1, including a summary of the financial outcome. The average beginning weight was 265 kg with an average cost of $244.22 per head, and the average gain for the trial was 258 kg.

Steers fed the steam-rolled barley produced 272.5 kg of gain at the rate of 1.29 kg per day requiring 6.9 kg of feed per kg of gain, at a cost of $40.17 per 100 kg of gain, and yielded a net return over costs of $22.48 per head. Steers fed the complete ration performed quite similarly to the steers in the steam-rolled barley treatment. Steers in both of these treatments gained significantly faster ($P<.05$ for the complete ration and $P<.01$ for steam-rolled barley) than steers on the whole barley treatment.

The rate of gain, feed per kg of gain, feed cost per 100 kg of gain, and net return per head over costs for steers fed whole barley were as follows: 1.11 kg per day, 9.3 kg, $49.96 and -$16.72, respectively.

TABLE 7. WEIGHT GAINS, FEED EFFICIENCY AND FINANCIAL OUTCOME OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION FOR THE ENTIRE FEEDING TRIAL (December 17, 1971 to July 18, 1972)

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, kg				
Initial	267.1	268.5	259.5	
Final	505.3	541.0	521.5	
Gain	238.2	272.5	262.0	
Daily gain	1.11[ab]	1.29[b]	1.22[a]	± .04
Average daily ration, kg				
Supplement	0.45	0.45	0.45	
Barley	8.71	7.35	6.20	
Roughage	1.13	0.97	1.89	
Beet pulp	--	--	0.85	
Average daily feed, kg	10.29	8.77	9.39	
Feed/kg gain, kg	9.29	6.94	7.67	
Feed cost/100 kg gain, $	49.96	40.17	42.06	
Initial value[c], $	246.10	247.42	239.13	
Final value[d], $	362.54	392.87	386.18	
Feed cost/steer[e], $	118.25	108.06	109.79	
Other costs[f], $	14.91	14.91	14.91	
Net return, $	-16.72	22.48	22.35	

a ($P < .05$)
b ($P < .01$)
c Initial weight x $0.92/kg.
d Average carcass value/kg x carcass weight. Steers sold on carcass grades of $1.27/kg, Choice; $1.17kg, good.
e Feed prices: Barley, whole, $5.51/100 kg; barley, rolled, $5.95/100 kg.
f Yardage: 7¢/head/day.

Table 8 shows the results of the entire feeding period of trial 1, including all treatments and environments.

The steers fed outside, both the steam-rolled barley and the complete ration, gained 285 kg, with an average daily gain of 1.34 kg per day. Average daily gains of steers in descending order were as follows: 1.23, 1.14, 1.11 and 1.08 for the steam-rolled barley inside, whole barley outside, complete ration inside, and the whole barley inside, respectively.

The feed required per kg of gain slightly favored the steam-rolled barley inside treatment over the steam-rolled barley outside (6.9 kg versus 7.0 kg). Feed cost per 100 kg of gain also slightly favored steam-rolled barley inside versus outside ($39.99 versus $40.34).

The steers fed the complete ration performed in a similar manner; that is, the inside treatment required slightly less feed per kg of gain (7.6 kg versus 7.7 kg) at slightly less cost ($41.64 versus $42.46). However, the whole barley treatment steers reversed this trend with the outside treatment being the more efficient of the two treatments (9.1 kg versus 9.4 kg and $49.27 versus $50.64).

Net returns favored the outside treatments over their counterpart fed inside. Steers fed steam-rolled barley outside yielded the highest net return at $30.23 per head, with steers fed the complete ration outside returning $25.78 per head, whereas steers fed whole barley outside yielded a net loss of $11.36 per head. The treatments fed inside returned $18.93, $14.74, and $-22.07 per head for the complete ration, steam-rolled barley, and whole barley, respectively.

TABLE 8. WEIGHT GAINS, FEED EFFICIENCY AND FINANCIAL OUTCOME OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION FOR THE ENTIRE FEEDING TRIAL (December 17, 1971 to July 18, 1972)

	Whole barley		Steam-rolled barley		Complete barley		Standard error
	Outside	Inside	Outside	Inside	Outside	Inside	
No. animals	6	6	6	6	6	6	
Average weights, kg							
Initial	278.5	255.8	280.8	256.3	261.7	257.2	
Final	524.3	485.8	566.1	516.2	547.0	482.2	
Gain	246.3	230.0	284.9	259.9	285.3	238.6	
Daily gain	1.14	1.08	1.34	1.23	1.34	1.11	± .05
Average daily ration, kg							
Supplement	0.45	0.45	0.45	0.45	0.45	0.45	
Barley	8.89	8.57	7.80	6.89	6.99	5.40	
Roughage	1.18	1.09	1.04	0.81	1.95	1.81	
Beet pulp	--	--	--	--	0.86	0.86	
Average daily feed, kg	10.52	10.11	9.29	8.25	10.25	8.52	
Feed/kg gain, kg	9.14	9.37	6.99	6.90	7.71	7.63	
Feed cost/100 kg gain, $	49.27	50.64	40.34	39.99	42.46	41.64	
Initial value[a], $	256.65	235.54	258.88	235.96	241.19	237.08	
Final value[b], $	380.59	344.50	418.41	367.34	402.29	370.07	
Feed cost/steer[c], $	120.39	116.12	114.39	101.73	120.41	99.16	
Other costs[d], $	14.91	14.91	14.91	14.91	14.91	14.91	
Net return, $	-11.36	-22.07	30.23	14.74	25.78	18.93	

a Initial weight x $0.92/kg.

b Average carcass value/kg x carcass weight. Steers sold on carcass grades of $1.27/kg, choice; $1.17kg, good.

c Feed prices: Barley, whole, $5.51/100 kg; barley, rolled, $5.95/100 kg.

d Yardage: 7¢/head/day.

Carcass data collected from steers in trial 1 are shown in table 9. Steers fed steam-rolled barley produced dressed carcasses weighing an average of 323.4 kg, which was significantly higher ($P < .01$) than the average carcass weight of 295.7 kg produced by steers fed whole barley. Average carcass weight of steers fed the complete ration was 313.9 kg, which was significantly heavier ($P < .05$) than those of steers fed whole barley.

Although the steers fed steam-rolled barley brought the least amount of money per kg ($1.21), they yielded the greatest net return of $22.48 per head, which was primarily due to their production of the largest carcasses. Steers fed the complete ration sold for the most money per kg ($1.24) but yielded a net return of $22.35 per head that was slightly less than the return of steers fed steam-rolled barley; this difference was due to the size of carcass produced.

Steers fed whole barley produced the smallest carcasses, 296 kg, and sold for more money ($1.22/kg) than the steers fed steam-rolled barley ($1.21/kg), but yielded a net loss of $16.72 per head. Average quality grade of all treatments was low choice, and although there was a significant difference ($P < .01$) among yield grades, the differences did not result in a discount of the price paid for the carcasses. The yield grade is influenced by the estimated amount of kidney fat in the carcass, of which no differences were noted, and also by the fat covering which was significantly less ($P < .05$) for steers fed the whole barley. The conformation grade of steers fed whole barley was significantly lower (P<.01) than that of steers fed steam-rolled barley and significantly lower (P<.05) than that of steers fed the complete ration. No differences were noted between the other carcass characteristics of all treatments. Because of the similarity of steers in the trail, the differences of the carcass characteristics noted among treatments can be attributed to the treatment.

TABLE 9. CARCASS DATA OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, kg				
Live weight	503.0	540.2	522.5	± 10.4
Hot carcass weight	295.7[ab]	323.4[b]	313.9[a]	± 5.9
Dressing percentage,%	58.8	59.9	60.1	± .44
Conformation grade[c]	12.5[ab]	13.8[b]	13.5[a]	± .31
Maturity score	14.8	14.7	14.4	± .13
Degree of marbling[d]	4.9	4.9	5.2	± .27
Fat cover, cm	4.1[a]	5.3[a]	5.3[a]	± .33
Rib eye area, cm^2	70.3	70.3	70.3	± .13
Kidney fat, %	2.8	2.8	2.9	± .22
Quality grade[c]	11.7	11.8	12.1	± .19
Yield grade	1.8[b]	2.2[b]	2.6[a]	± .19
Price, $/kg	1.22	1.21	1.24	

a (P<.05)
b (P<.01)
c 11=high good; 12=low choice; 13=average choice.
d 4=slight; 5=small

Table 10 summarizes the carcass data of steers in trial 1, showing treatment and environmental influence. The largest carcasses were produced by steers fed outside, and the weights were as follows: 343 kg, 328 kg, and 305 kg for steers fed steam-rolled barley, complete ration and whole barley, respectively. All treatments fed outside graded low choice, as did steers fed the complete ration inside, whereas steers fed steam-rolled barley and whole barley inside graded high good. Average carcass weights of steers fed inside were as follows: 304 kg, 300 kg, and 286 kg for steers fed steam-rolled barley, the complete ration and whole barley, respectively. The conformation grade of steers fed outside was higher than that of the corresponding treatment fed inside, suggesting that environment had an effect on that trait. The conformation grade of steers fed steam-rolled barley and the complete ration outside was high choice, whereas conformation grade of steers receiving the steam-rolled barley and complete ration inside were average choice. Steers fed whole barley outside produced carcasses with a conformation grade of average choice, compared to low choice for those fed inside. The maturity score of all steers in all treatments were similar, as were the rib eye areas. The average marbling score for all steers was 5.0. Steers fed steam-rolled barley and complete ration outside had 5.6 cm fat cover, whereas steers fed whole barley outside had 3.8 cm of fat cover. Steers fed steam-rolled barley, the complete ration and whole barley inside had 5.1 cm, 4.8 cm and 4.3 cm of fat cover, respectively. Estimated kidney fat was

TABLE 10. CARCASS DATA OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION

	Whole barley		Steam-rolled barley		Complete barley		Standard
	Outside	Inside	Outside	Inside	Outside	Inside	error
No. animals	6	6	6	6	6	6	
Average weights, kg							
Live weight	520.7	485.8	565.6	514.8	547.0	498.1	± 14.5
Hot carcass weight	305.3	286.2	343.4	303.5	328.0	300.3	± 8.6
Dressing percentage,%	58.6	58.9	60.6	59.1	59.9	60.3	± .62
Conformation grade[a]	12.8	12.3	14.7	13.0	14.5	12.5	± .43
Maturity score	15.0	14.7	15.0	14.4	14.3	14.5	± .19
Degree of marbling[b]	4.8	4.9	5.2	4.6	5.4	5.0	± .38
Fat cover, cm	3.8	4.3	5.6	5.1	5.6	4.8	± .48
Rib eye area, cm^2	70.3	69.7	70.3	70.3	70.3	69.7	± .19
Kidney fat, %	2.8	2.7	2.9	2.7	3.3	2.5	± .32
Quality grade[a]	12.0	11.3	12.3	11.2	12.3	11.8	± .40
Yield grade	1.7	1.8	2.3	2.1	3.2	2.1	± .26
Price, $/kg	1.24	1.20	1.22	1.20	1.23	1.24	

a 11=high good; 12=low choice; 13=average choice; 14=high choice.
b 4=slight; 5=small.

greatest (3.3%) for steers fed the complete ration outside, followed by steers fed steam-rolled barley outside with 2.9% kidney fat. Estimates of kidney fat were as follows: 2.8%, 2.7%, 2.7%, and 2.5% for steers fed whole barley outside, whole barley inside, steam-rolled barley inside and the complete ration inside, respectively. Both fat cover and kidney fat influence the yield grade of carcasses. Steers fed the complete ration outside had an average yield grade of 3, whereas the balance of the steers in the trial were yield grade 2. Yield grade 3 suggests that the carcasses were somewhat fatter and wastier than those which were yield grade 2.

The results of trial I considering feeding inside versus outside covering the phases of wintering, fattening, and the entire feeding trial are shown in tables 11, 12, and 13, respectively.

During the wintering period (table 11), the average daily gain was 1.11 kg for the steers fed inside, a gain which was 0.17 kg or 15% per day faster than steers fed outside. Steers fed inside required 7.7 kg of feed per kg of gain, whereas those fed outside required 9.5 kg of feed per kg of gain; this difference was 1.8 kg or 23% less feed per kg of gain in favor of the inside treatment. Cost of feed per 100 kg of gain was $7.69 less, again in favor of steers inside.

The trend was reversed for the fattening phase (table 12), as the steers fed outside gained significantly faster ($P<.01$) than those fed inside (1.40 kg versus 1.15 kg per day). Feed per kg of gain (7.7 kg) and feed cost per 100 kg of gain ($44.07) was also less for steers fed outside.

For the entire feeding trial (table 13), steers outside gained significantly faster ($P<.01$) than those fed inside (1.28 kg versus 1.14 kg). Cost of feed per 100 kg of gain and the feed required per kg of gain were about about the same (7.9 kg versus 8.0 kg).

Despite the fact that steers fed outside cost $16.00 more each and required $13.00 more feed than those fed inside, they yielded $11.00 more per head than steers fed inside. The primary reason for this is that the steers fed outside (table 14) graded significantly higher ($P<.05$), low choice, than those fed inside which graded high good. The difference in grade in this case accounted for 4½¢/lb less for steers fed inside.

TABLE 11. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED EITHER INSIDE OR OUTSIDE DURING THE WINTERING PHASE (December 17, 1971 to February 12, 1972)

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, kg			
Initial	273.5	256.3	
Final	326.6	318.4	
Gain	53.1	62.1	
Daily gain	0.94	1.11	± .07
Average daily ration, kg			
Supplement	0.45	0.45	
Barley	4.2	4.2	
Roughage	3.5	3.0	
Beet pulp	0.2	0.2	
Average daily feed, kg	8.4	7.9	
Feed/kg gain, kg	9.5	7.5	
Feed cost/100 kg gain, $	46.03	38.34	

TABLE 12. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED EITHER INSIDE OR OUTSIDE DURING THE FATTENING PHASE (February 12, 1972 to July 18, 1972)

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, kg			
Initial	326.6	318.4	
Final	546.1	499.4	
Gain	219.5	181.0	
Daily gain	1.40[b]	1.15[b]	± .03
Average daily ration, kg			
Supplement	0.45	0.45	
Barley	9.2	7.9	
Roughage[a]	0.6	0.6	
Beet pulp	0.3	0.3	
Average daily feed, kg	10.6	9.3	
Feed/kg gain, kg	7.7	8.1	
Feed cost/100 kg gain, $	44.07	46.36	

a Roughage only fed 14 days at start of trial.
b ($P < .01$)

TABLE 13. WEIGHT GAINS, FEED EFFICIENCY AND FINANCIAL OUTCOME OF STEERS FED EITHER INSIDE OR OUTSIDE DURING THE ENTIRE FEEDING TRIAL (December 17, 1971 to July 18, 1972)

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, kg			
Initial	273.5	256.3	
Final	546.1	499.0	
Gain	272.2	243.1	
Daily gain	1.28[a]	1.14[a]	± .03
Average daily ration, kg			
Supplement	0.45	0.45	
Barley	7.9	6.9	
Roughage	1.4	1.3	
Beet pulp	0.3	0.3	
Average daily feed, kg	10.0	8.9	
Feed/kg gain, kg	7.9	8.0	
Feed cost/100 kg gain, $	44.03	44.09	
Financial returs, $			
Initial value[b]	252.24	236.19	
Final value[c]	400.43	360.64	
Feed cost/steer[d]	118.40	105.67	
Other costs[e]	14.91	14.91	
Net return	14.88	3.87	

a (P<.01)
b Initial weight x $0.92/kg.
c Average carcass value/kg x carcass weight. Steers sold on carcass grades of $1.27/kg, choice; $1.17kg, good.
d Feed prices: Barley, whole, $5.51/100 kg; barley, rolled, $5.95/100 kg.
e Yardage: 7¢/head/day.

TABLE 14. CARCASS DATA OF STEERS FED EITHER INSIDE OR OUTSIDE

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, kg			
Live weight	544.3[b]	499.1[b]	± 8.6
Hot carcass weight	325.7	296.7	± 5.0
Dressing percentage, %	59.7	59.4	± .36
Conformation grade[c]	14.0	12.6	± .25
Maturity score	14.8	14.5	± .11
Degree of marbling[d]	5.2	4.8	± .22
Fat cover, cm	5.1	4.8	± .28
Rib eye area, cm^2	70.3[a]	69.7[a]	± .13
Kidney fat, %	3.0	2.6	± .18
Quality grade[c]	12.2[a]	11.5[a]	± .24
Yield grade	2.4	2.0	± .15
Price, $/kg	1.23	1.22	

a ($P < .05$)
b ($P < .01$)
c 11=high good; 12=low choice; 13=average choice; 14=high choice.
d 4=slight; 5=small.

Live weight of steers fed outside were significantly heavier ($P < .01$) than those fed inside (544.3 kg versus 499.1 kg, respectively). The dressing percentages were similar, as were maturity scores, marbling score, and fat cover. Even though steers were of similar breeding, were from the same source, and were subjected to similar feeding programs, the conformation grades were significantly different ($P < .05$). The conformation grade of the steers fed outside was high choice, whereas that of steers fed inside was low choice. The rib eye area was also significantly greater ($P < .05$) for steers fed outside; however, this difference was only 0.65 cm square. Steers fed outside had a somewhat greater estimate of kidney fat (3% versus 2.6%) and yield grades (2.4 versus 2.0), indicating that the steers outside were slightly fatter.

Trial II - Digestion Trial

The apparent digestibilities, proximate analyses of the rations, and the ingredients of the rations are shown in tables 15 and 16. The apparent digestibility (table 15), of all analyses of the whole barley were increased by steam-rolling with the exception that the digestibility of crude fiber decreased. Protein, nitrogen-free extract, and digestible energy digestibilities increased from 67%, 79%, and 74%, respectively, for the whole barley, to 73%, 81%, and 81%, respectively, for the steam-rolled barley. The digestibility of ether extract increased 92% from 25% for the whole barley to 48% for steam-rolled barley.

The apparent digestibility of steam-rolled barley plus supplement was the highest of the three rations, followed by the complete ration, with whole barley plus supplement having the lowest digestibility coefficients. The digestibilities of protein, nitrogen-free extract, and digestible energy for the whole barley plus supplement ration were as follows: 64%, 72%, and 66%, respectively, and showed increases of 26%, 27%, and 27%, respectively, when the barley was steam-rolled.

Steam-rolled barley plus supplement ration showed a substantial increase (12.6% to 62.7%) in the digestibility of the ether extract fraction when compared to whole barley plus supplement ration. Although analytical data appear to be accurate, no other plausible explanation can be offered for this inconsistently high increase.

The digestibility of crude fiber shows a decrease (19.2% to 17.7%) from the whole barley plus supplement ration to the steam-rolled barley plus supplement ration. This decrease appears to be contrary to the logical improvement expected; however, it is not inconsistent with digestibility change noted between whole barley and steam-rolled barley which also decreased from 33% to 0.

One hundred whole barley kernels from feed samples and 100 whole barley kernels recovered from the feces were dried and weighed. Grain recovered from the feces weighed 12% less than for the barley as fed. Weight of the 100 kernels were 3.7827 g and 3.3392 g for the barley as fed and the barley recovered from the feces, respectively. Gross visual examination of the recovered barley kernels shows some eroding of the outer coating of the kernel.

Two other sets of 100 kernels were placed in germination trays on moist blotter paper. Results are shown in figures 1, 2 and 3. After one week, 99 barley grains of the before feeding samples sprouted, whereas only 5 of those recovered from the feces sprouted. Although the kernels appeared to be only slightly affected, the passage through the gastrointestinal tract had a substantial effect upon the grain.

TABLE 15. APPARENT DIGESTIBILITIES OF THE FEEDS AND RATIONS FED TO STEERS

	Dry matter	Protein	Ether extract	Crude fiber	Nitrogen-free extract	DE	TDN
Grass hay	65.0	60.7	17.4	62.9	73.5	64.8	63.3
Whole barley	73.6	67.0	25.1	33.1	79.4	73.5	73.2
Steam-rolled barley	81.6	72.9	48.1	--	91.0	80.8	83.3
MSU 713	64.6	81.0	57.3	57.3	83.0	36.1	68.1
Whole barley MSU 713	66.2	63.5	12.6	19.2	72.4	66.1	73.0
Steam-rolled barley MSU 713	84.7	79.7	62.7	17.7	92.1	84.0	82.1
Complete ration	76.6	72.9	41.2	40.6	85.6	75.9	76.8

TABLE 16. PROXIMATE ANALYSIS OF FEED INGREDIENTS USED IN RATIONS FED TO STEERS

	Grass hay	Whole barley	Steam-rolled barley	MSU 713	Beet pulp
Dry matter	94.9	91.7	90.6	93.3	93.7
Protein	8.9	12.4	12.8	25.8	11.3
Crude fiber	37.4	4.9	4.4	11.6	18.4
Ether extract	3.0	2.3	2.8	4.3	1.4
Nitrogen-free extract	45.1	78.1	78.0	45.3	61.1
Ash	5.6	2.4	2.0	13.0	7.9
Gross energy (mcal/kg)	4.37	4.41	4.41	3.99	4.10

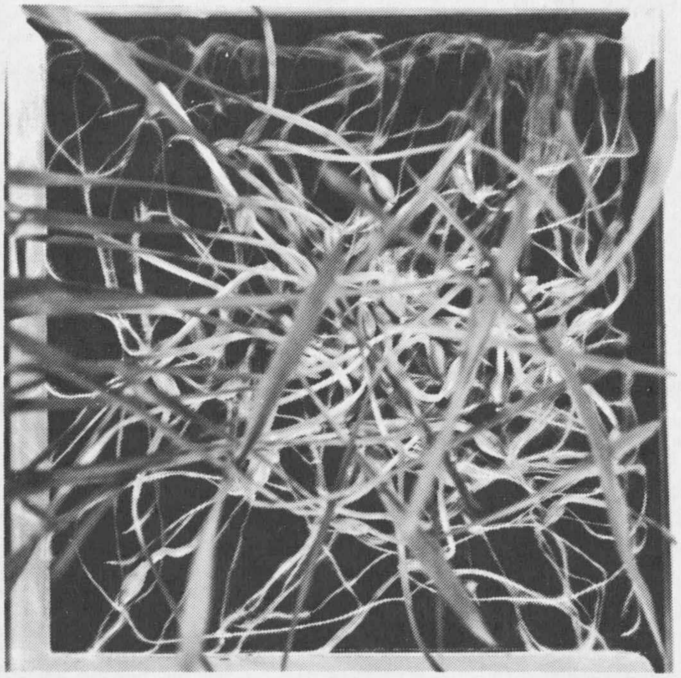

Figure 1. Growth produced by 50 kernels of barley before feeding.

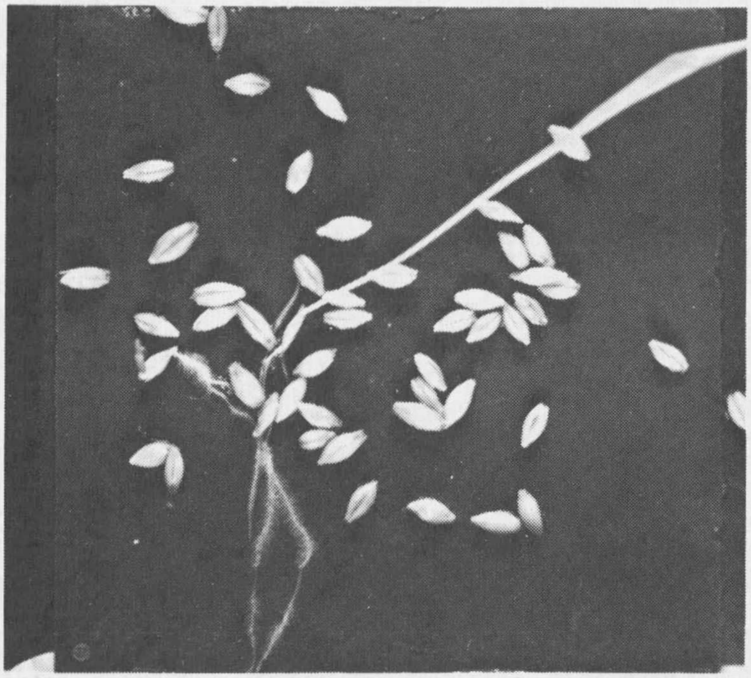

Figure 2. Growth produced by 50 kernels of barley recovered from the feces.

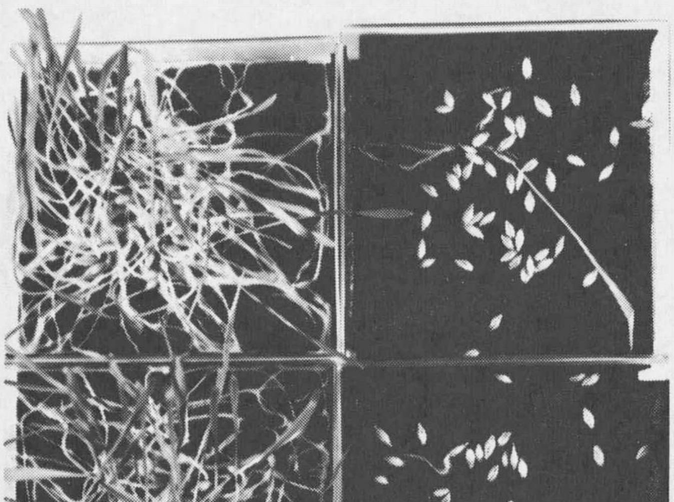

Figure 3. Comparative growth of 100 kernels each of barley before feeding (left) and barley recovered from feces (right).

A comparison of the proximate analysis of whole barley before feeding with barley recovered from the feces is shown in table 17. Very little difference is noted among all analyses with the exception of crude fiber which increased from 4.87% in the barley before feeding to 8.10% in the barley recovered from the feces. This noted increase in crude fiber content of the grain recovered from the feces may have been due to an error in laboratory procedure.

TABLE 17. PROXIMATE ANALYSIS OF BARLEY AS FED AND BARLEY RECOVERED FROM FECES

	Before feeding whole barley	From feces whole barley
Dry matter	91.65	91.91
Protein	12.43	12.62
Crude fiber	4.87	8.10
Ether extract	2.25	2.14
Ash	2.35	1.88
Nitrogen-free extract	78.10	75.26
Gross energy (mcal/kg)	4.41	4.34

DISCUSSION

Morrison (1956) recommended that for best utilization of a grain, it should be ground or subjected to some form of processing, making digestion easier. The whole idea of processing grains is to improve the digestibility and utilization of the grains. Processing exposes more surface area to the digestive system, thus improving the utilization of a grain by the animal. The amount of improvement in digestibility of a grain is dependent upon the grain. Grains such as wheat, barley and milo, which have relatively hard outer shells, tend to resist digestive action and, therefore, show greater response to processing than does, for example, corn, which has a comparatively soft outer shell.

Whole barley utilization and feed efficiency is less than that of steam-rolled barley, unlike the similar feed efficiency between whole, shelled corn and rolled, shelled corn as reported by Foster and Woods (1970). In a metabolism trial (trial II), steam-rolled barley was found to be more digestible than the whole barley and rations containing steam-rolled barley were more digestible than rations containing whole barley. Substantial improvement in digestibility of all nutrients was noted when steam-rolled barley was compared with whole barley.

In trial I, both the steers fed steam-rolled barley and the complete ration gained faster, more efficiently, and produced higher quality carcasses than the steers fed whole barley. Similar results were reported by Peters (1931) who found that whole, shelled corn produced better gains than ground barley, which, in turn, was better than whole barley.

Like the work reported here, steers also consumed more whole barley with a large amount passing unmasticated in the feces, as shown in observations of trial I.

Unmasticated grain in the feces appeared to be completely intact, and when the manure containing these grains were spread in the field, the resulting growth tends to confirm this observation. The chemical analyses of the grains recovered from the feces were similar to that of the grain before feeding (table 17), further confirming that the grain was still intact. However, close examination of the grain shows erosion of the outer shell of the kernel. When the bulk density of the grains was compared, the grain recovered from the feces was found to be lighter than the grain as fed; so perhaps the grain does not pass through the gastrointestinal tract without being somewhat affected. The results of a germination trial, (trial II), closely parallels work done by Shaw and Norton (1906), who found that grains recovered from feces had a germination rate of less than 10%, thus suggesting that the digestive system does, in fact, affect whole grain kernels. The growth of grain in manure containing unmasticated grain was due primarily to the concentration of grain spread with the manure.

Wise (1968) concluded that steers fed an all-concentrate ration finished lighter, had improved dressing percentages, and gained comparably to steers fed complete rations. However, in the work reported herein, the steers fed an all-concentrate ration of steam-rolled barley finished heavier, had higher dressing percentages and gained slightly faster than steers fed whole barley. The steers fed the complete ration gained nearly as fast and the carcasses were slightly better than those of the steam-rolled barley treatment. Work reported by Myers (1962) tends to confirm the need for some hay in a barley ration. Myers noted that 2 pounds of hay per day produced the best results when compared to 0, 4, and 6 pounds of hay per day fed with a high barley ration.

The advantage of adding hay to the ration is the reduction of possible digestive problems which are inherent to all-concentrate rations. Those problems which are reduced by feeding a small amount of roughage, include rumen parakeratosis, liver abscesses, founder and bloat. The hay in the ration also stimulates salivation which has a buffering action in the rumen, thus reducing the possible incidence of bloat and other digestive problems. Holding the rumen pH constant provides an optimum environment for the rumen microbial population to function corresponding in part with work reported by Cullison (1961).

The results of feeding trial I, comparing inside and outside confinement, are contrary to those reported by Minnesota workers comparing warm slat confinement housing with other types of confinement for cattle. Meiske et al. (1972) reported the best rate of gain from the warm slat confinement when the cattle had about 25 square feet of space per head, in a comparison with other types of confinement, including cold slat confinement and conventional confinement. However, when warm slat confinement inside the MSU Nutrition Center Building was compared with outside partially covered pens, the rate of gain and feed efficiency favored steers in the outside pens. The cattle in the warm slat confinement were allowed approximately 25 square feet per head as suggested by the Minnesota workers.

During the wintering phase, the steers fed inside gained faster and more efficiently than steers fed outside. This corresponds with the work reported by Ingalls and Seale (1967), who noted that for the December to March feeding period, steers fed outside required 12% more feed daily, gained 7% slower and had a 20% lower feed efficiency than those fed inside. Ingalls, however, noted little difference between the inside and outside treatments during the subsequent March to May feeding period, whereas in the fattening phase of trial I, steers fed outside consumed 14% more feed daily, gained 21% faster and required 5% less feed per unit of gain than did steers fed inside.

During the wintering phase, the steers fed inside had the advantage of not having to cope with the changing weather conditions which affected outside steers. Young (1973 personal communication) indicated that the performance of cattle shows the greatest effect during the first change in weather; after that they become adapted and can tolerate the same weather without any drastic effect on performance. Gains of steers outside were slowed because of weather changes. Later as the winter progressed, these steers became acclimated to the weather and made normal gains.

When looking at the financial results of the feeding trial, steers fed outside netted a greater return per head than those inside. Returns for steers inside should have been even less than was indicated by the data presented here because the cost of maintaining the building was not properly charged to these animals. A yardage charge of 7¢ per head per day was charged to all animals whether inside or out. Cost of maintaining a heated facility would cost more than 7¢ per head per day. If this additional cost of maintaining the heated facility had been charged to the steers inside, a net loss would have resulted. Perhaps in climates where the weather is far more variable, where it is harder for the animals to become adapted, the performance of the animals would improve sufficiently to pay the additional cost of a building.

SUMMARY

The effect of steam-rolling on the utilization of barley was studied. All-barley rations were fed to steers in the feedlot in either the whole or the steam-rolled form. A third ration of steam-rolled barley, hay and beet pulp was fed as a control ration. All rations were fed with the same supplement. The parameters evaluated were average daily gain, feed consumption, feed efficiency and carcass grade. Also incorporated into the trial was an evaluation of inside versus outside feeding of steers. A metabolism study (trial II) was conducted to compare the digestibility of whole barley with steam-rolled barley.

In trial I, 36 head of steers averaging 268 kg, were randomly divided into 6 groups of 6 head each and placed into 3 pens inside and 3 pens outside. Three lots were fed in pens with a covered feed bunk and the other three lots were fed inside a building on slotted floors. The three treatments used in the trials were as follows: (1) whole barley and supplement; (2) steam-rolled barley and supplement; and (3) steam-rolled barley, beet pulp and hay plus supplement. All steers were implanted with 36 mg RALGRO.

The average daily gain of the steers fed steam-rolled barley was significantly greater ($P<.01$) than that of the steers fed whole barley (1.28 vs. 1.12 kg). The steers fed whole barley consumed more feed daily, required more feed per unit of gain and at a greater cost per unit gain than did steers fed steam-rolled barley. The average carcass grade of both treatments was high good. Because of the larger gain at a lower

cost per unit of gain, the steers fed steam-rolled barley produced a net return of $22.48 per head, whereas the steers fed whole barley produced a net loss of $16.72 per head. The steers fed the complete ration performed similarly to the steers fed steam-rolled barley with the exception of carcass grade. The carcasses of the steers fed the complete ration graded low choice compared to the high good carcasses of the steers fed steam-rolled barley.

The overall performance of steers in the feedlot would tend to favor the complete ration. The steers fed the complete ration had less digestive problems and produced better grading carcasses than the other treatments.

The average daily gain of the steers fed outside was significantly greater (P .01) than that of the steers fed inside (1.28 kg versus 1.14 kg). Although the daily feed consumed, feed per unit gain and cost of feed per unit of gain were similar, the net return per steer favored the steers fed outside ($14.88 versus $3.87). The steers fed outside graded low choice, whereas the steers fed inside graded high good, accounting for the difference in net return.

Three steers of the same source and breeding as those in trial I were placed on metabolism crates for the metabolism study (trial II). The apparent digestibility of dry matter, protein, ether extract, nitrogen-free extract (NFE) and total digestible nutrients (TDN) of whole barley increased from 74%, 67%, 25%, 79% and 73%, respectively, to 82%, 73%, 48%, 91% and 83%, respectively, when the barley was steam-rolled. The all-barley plus supplement rations also showed similar increases in digestibility when whole barley was compared with steam-rolled barley.

APPENDIX

APPENDIX TABLE 1. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE WINTERING PHASE (December 17, 1971 to Februrary 12, 1972)

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, lb				
Initial	589	529	572	
Final	694	732	707	
Gain	106	140	134	
Daily gain	1.89	2.48	2.40	± .19
Average daily ration, lb				
Supplement	1	1	1	
Barley	10.1	9.5	8.0	
Roughage	8.0	6.7	7.0	
Beet pulp	--	--	1.5	
Average daily feed, lb	19.1	17.2	17.5	
Feed/lb gain, lb	10.7	7.75	7.37	
Feed cost/100 lb gain, $	22.96	17.79	16.66	

APPENDIX TABLE 2. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE WINTERING PHASE (December 17, 1971 to February 12, 1972)

	Whole barley		Steam-rolled barley		Complete ration		Standard
	Outside	Inside	Outside	Inside	Outside	Inside	error
No. animals	6	6	6	6	6	6	
Average weights, lb							
Initial	614	564	619	565	577	567	
Final	704	685	743	721	713	700	
Gain	90	121	124	156	136	133	
Daily gain	1.61	2.17	2.21	2.76	2.43	2.38	± .26
Average daily ration							
Supplement	1.0	1.0	1.0	1.0	1.0	1.0	
Barley	10.2	10.1	9.1	9.9	8.3	7.7	
Roughage	8.3	7.7	7.4	6.0	7.6	6.5	
Beet pulp	--	--	--	--	1.6	1.4	
Average daily feed, lb	19.5	18.7	17.4	16.9	18.5	16.6	
Feed/lb gain, lb	12.65	8.74	8.19	7.31	7.61	7.12	
Feed cost/100 lb gain, $	27.06	18.87	18.48	17.10	17.11	16.20	

APPENDIX TABLE 3. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE FATTENING PHASE (February 12, 1972 to July 18, 1972)

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, lb				
Initial	695	732	707	
Final	1114	1193	1150	
Gain	420	461	443	
Daily gain	2.65[b]	2.96[b]	2.81	± .07
Average daily ration, lb				
Supplement	1	1	1	
Barley	22.4	18.6	15.7	
Roughage[a]	0.5	0.5	3.1	
Beet pulp	--	--	1.8	
Average daily feed, lb	24.0	20.1	21.7	
Feed/lb gain, lb	9.1	6.9	7.7	
Feed cost/100 lb gain, $	23.00	18.80	19.73	

a Roughage only fed 14 days at start of trial.
b ($P < .01$)

APPENDIX TABLE 4. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION DURING THE FATTENING PHASE (February 12, 1972 to July 18, 1972)

	Whole barley		Steam-rolled barley		Complete ration		Standard error
	Outside	Inside	Outside	Inside	Outside	Inside	
No. animals	6	6	6	6	6	6	
Average weights, lb							
Initial	704	684	743	721	713	700	
Final	1157	1071	1248	1138	1206	1093	
Gain	453	386	505	417	493	393	
Daily gain	2.84	2.46	3.21	2.71	3.14	2.48	± .10
Average daily ration, lb							
Supplement	1.0	1.0	1.0	1.0	1.0	1.0	
Barley	22.9	22.0	20.1	17.1	18.0	13.4	
Roughage[a]	0.5	0.5	0.5	0.5	3.1	3.1	
Beet pulp	--	--	--	--	2.0	1.7	
Average daily feed, lb	24.4	23.5	21.6	18.6	24.1	19.2	
Feed/lb gain, lb	8.54	9.63	6.77	7.04	7.75	7.70	
Feed cost/100 lb gain, $	21.62	24.38	18.43	19.17	19.92	19.55	

a Roughage only fed 14 days at start of trial.

APPENDIX TABLE 5. WEIGHT GAINS, FEED EFFICIENCY AND FINANCIAL OUTCOME OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION FOR THE ENTIRE FEEDING TRIAL (December 17, 1971 to July 18, 1972)

	Whole barley	Steam-rolled barley	Complete barley	Standard error
No. animals	12	12	12	
Average weights, lb				
Initial	589	592	572	
Final	1114	1193	1150	
Gain	525	601	578	
Daily gain	2.45^{ab}	2.84^{b}	2.70^{a}	± .08
Average daily ration, lb				
Supplement	1	1	1	
Barley	19.2	16.2	13.7	
Roughage	2.5	2.1	4.2	
Beet pulp	--	--	1.9	
Average daily feed, lb	22.7	19.3	20.7	
Feed/lb gain, lb	9.3	6.9	7.7	
Feed cost/100 lb gain, $	22.66	18.22	19.08	
Initial value[c], $	246.10	247.42	239.13	
Final value[d], $	362.54	392.87	386.18	
Feed cost/steer[e], $	118.25	108.06	109.79	
Other costs[f]	14.91	14.91	14.91	
Net return, $	-16.72	22.48	22.35	

a ($P < .05$)
b ($P < .01$)
c Initial weight x $41.80 cwt.
d Average carcass value/lb x carcass weight.
e Feed: Barley, whole, $50/ton; barley steam-rolled, $54/ton.
f Yardage: 7¢/head/day.

APPENDIX TABLE 6. WEIGHT GAINS, FEED EFFICIENCY AND FINANCIAL OUTCOME OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION FOR THE ENTIRE FEEDING TRIAL (December 17, 1971 to July 18, 1972)

	Whole barley		Steam-rolled barley		Complete ration		Standard error
	Outside	Inside	Outside	Inside	Outside	Inside	
No. animals	6	6	6	6	6	6	
Average weights, lb							
Initial	614	564	619	565	577	567	
Final	1157	1071	1248	1138	1206	1063	
Gain	543	507	628	573	629	526	
Daily gain	2.51	2.38	2.95	2.72	2.95	2.45	± .11
Average daily ration, lb							
Supplement	1.0	1.0	1.0	1.0	1.0	1.0	
Barley	19.6	18.9	17.2	15.2	15.4	11.9	
Roughage	2.6	2.4	2.3	2.0	4.3	4.0	
Beet pulp	--	--	--	--	1.9	1.9	
Average daily feed, lb	23.1	22.3	20.5	18.2	22.6	18.8	
Feed/lb gain, lb	9.14	9.37	6.99	6.90	7.71	7.63	
Feed cost/100 lb gain, $	22.35	22.97	18.30	18.14	19.26	18.89	
Initial value[a], $	256.65	235.54	258.88	235.96	241.19	237.08	
Final value[b], $	380.59	344.50	418.41	367.34	402.29	370.07	
Feed cost/steer[c], $	120.39	116.12	114.39	101.73	120.41	99.16	
Other costs[d], $	14.91	14.91	14.91	14.91	14.91	14.91	
Net return, $	-11.36	-22.07	30.23	14.74	25.78	18.93	

a Initial weight x $41.80/cwt.
b Average carcass value/lb x carcass weight. Steers sold on carcass grade of $57.50, choice; $53.00, good.
c Feed prices: Barley, whole, $50/ton; barley, rolled, $54/ton.
d Yardage: 7¢/head/day.

APPENDIX TABLE 7. CARCASS DATA OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION

	Whole barley	Steam-rolled barley	Complete ration	Standard error
No. animals	12	12	12	
Average weights, lb				
Live weight	1109	1191	1152	± 32
Hot carcass weight	652[ab]	713[b]	692[a]	± 13
Dressing percentage, %	58.8	59.9	60.1	± .44
Conformation grade[c]	12.5[ab]	13.8[b]	13.5[a]	± .31
Maturity score	14.8	14.7	14.4	± .13
Degree of marbling[d]	4.9	4.9	5.2	± .27
Fat cover, in	1.6[a]	2.1[a]	2.1[a]	± .13
Rib eye area, in^2	10.9	10.9	10.9	± .02
Kidney fat, %	2.8	2.8	2.9	± .22
Quality grade[c]	11.7	11.8	12.1	± .29
Yield grade	1.8[b]	2.2[b]	2.6[b]	± .19
Price, $/lb	.55	.55	.56	

a (P<.05)
b (P<.01)
c 11=high good; 12=low choice; 13=average choice.
d 4=slight; 5=small.

APPENDIX TABLE 8. CARCASS DATA OF STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION

	Whole barley		Steam-rolled barley		Complete ration		Standard
	Outside	Inside	Outside	Inside	Outside	Inside	error
No. animals	6	6	6	6	6	6	
Average weights, lb							
Live weight	1148	1071	1247	1135	1206	1098	± 32
Hot carcass weight	673	631	757	669	723	662	± 19
Dressing percentage, %	58.6	58.9	60.6	59.1	59.9	60.3	± .62
Conformation grade[a]	12.8	12.3	14.7	13.0	14.5	12.5	± .43
Maturity score	15.0	14.7	15.0	14.4	14.3	14.5	± .19
Degree of marbling[b]	4.8	4.9	5.2	4.6	5.4	5.0	± .38
Fat cover, in	1.5	1.7	2.2	2.0	2.2	1.9	± .19
Rib eye area, in^2	10.9	10.8	10.9	10.9	10.9	10.8	± .03
Kidney fat, %	2.8	2.7	2.9	2.7	3.3	2.5	± .32
Quality grade[a]	12.0	11.3	12.3	11.2	12.3	11.8	± .40
Yield grade	1.7	1.8	2.3	2.1	3.2	2.1	± .26
Price, $/lb	.56	.55	.55	.54	.56	.56	

a 11=high good; 12=low choice; 13=average choice; 14=high choice.
b 4=slight; 5=small.

APPENDIX TABLE 9. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED EITHER INSIDE OR OUTSIDE DURING THE WINTERING PHASE (December 17, 1971 to February 12, 1972)

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, lb			
Initial	603	565	
Final	720	702	
Gain	117	137	
Daily gain	2.08	2.44	± .16
Average daily ration, lb			
Supplement	1	1	
Barley	9.2	9.2	
Roughage	7.7	6.7	
Beet pulp	0.5	0.5	
Average daily feed, lb	18.5	17.4	
Feed/lb gain, lb	9.5	7.7	
Feed cost/cwt gain, $	20.88	17.39	

APPENDIX TABLE 10. WEIGHT GAINS AND FEED EFFICIENCY OF STEERS FED EITHER INSIDE OR OUTSIDE DURING THE FATTENING PHASE (February 12, 1972 to July 18, 1972)

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, lb			
Initial	720	702	
Final	1204	1101	
Gain	484	399	
Daily gain	3.08[b]	2.54[b]	± .06
Average daily ration, lb			
Supplement	1	1	
Barley	20.3	17.5	
Roughage[a]	1.4	1.4	
Beet pulp	0.7	0.6	
Average daily feed, lb	23.4	20.5	
Feed/lb gain, lb	7.7	8.1	
Feed cost/cwt gain, $	19.99	21.03	

a Roughage only fed 14 days at start of trial.
b $(P<.01)$

APPENDIX TABLE 11. WEIGHT GAINS, FEED EFFICIENCY AND FINANCIAL OUTCOME OF STEERS FED EITHER INSIDE OR OUTSIDE DURING THE ENTIRE FEEDING TRIAL (December 17, 1971 to July 18, 1972)

	Outside	Inside		Standard error
No. animals	18	18		
Average weights, lb:				
Initial	603	565		
Final	1204	1100		
Gain	600	536		
Daily gain	2.82[a]	2.51[a]	±	.06
Average daily ration, lb				
Supplement	1	1		
Barley	17.4	15.3		
Roughage	3.1	2.8		
Beet pulp	0.6	0.6		
Average daily feed, lb	22.1	19.7		
Feed/lb gain, lb	7.9	8.0		
Feed cost/100 lb gain, $	19.97	20.00		
Initial value[b], $	252.24	236.19		
Final value[c], $	400.43	360.64		
Feed cost/steer[d], $	118.40	105.67		
Other costs[e], $	14.91	14.91		
Net return, $	14.88	3.87		

a (P .01)
b Initial weight x $41.80/cwt.
c Average carcass value/lb x carcass weight. Steers sold on carcass grades of $57.50, choice; $53.00, good.
d Feed prices: Barley, whole, $50/ton; barley, rolled, $54/ton.
e Yardage: 7¢/head/day.

APPENDIX TABLE 12. CARCASS DATA OF STEERS FED EITHER INSIDE OR OUTSIDE

	Outside	Inside	Standard error
No. animals	18	18	
Average weights, lb			
Live weight	1200[b]	1101[b]	± 19
Hot carcass, lb	718[b]	654[b]	± 11
Dressing percentage, %	59.7	59.4	± .36
Conformation grade[c]	14.0[b]	12.6[b]	± .25
Maturity score	14.8	14.5	± .11
Degree of marbling[d]	5.2	4.8	± .22
Fat cover, in	2.0	1.9	± .11
Rib eye area, in^2	10.9[a]	10.8[a]	± .02
Kidney fat, %	3.0	2.6	± .18
Quality grade[c]	12.2[a]	11.5[a]	± .24
Yield grade	2.4	2.0	± .15
Price, $/lb	.56	.55	

a ($P<.05$)
b ($P<.01$)
c 11=high good; 12=low choice; 13=average choice; 14=high choice.
d 4=slight; 5=small.

APPENDIX TABLE 13. INITIAL AND FINAL WEIGHTS OF INDIVIDUAL STEERS FED WHOLE, STEAM-ROLLED BARLEY OR A COMPLETE RATION FOR THE WINTERING PHASE (December 17, 1971 to February 12, 1972) AND THE FATTENING PHASE (February 12, 1972 to July 17, 1972)

Steer No.	Initial Wt.	Final Wintering	Final Wt.	Steer No.	Initial Wt.	Final Wintering	Final Wt.
	lb	lb	lb		lb	lb	lb
	Outside				Inside		
			Whole Barley				
759	651	732	1274	731	643	768	1181
762	596	710	1193	758	573	672	1093
771	676	744	1195	784	563	693	1066
837	642	757	1180	847	590	712	1043
863	571	655	1069	902	502	616	1001
922	548	624	1032	937	510	648	1040
			Steam-rolled Barley				
740	621	710	1269	729	571	730	1125
741	746	893	1365	750	582	667	1070
776	565	672	1178	767	513	643	1017
825	668	776	1224	805	516	755	1228
888	581	730	1284	820	670	911	1346
892	535	677	1165	909	535	617	1041
			Complete Ration				
739	567	705	1220	753	615	728	1117
770	628	762	1158	754	575	740	1126
778	546	683	1212	783	515	628	1035
799	587	732	1215	790	647	777	1147
803	589	722	1223	808	498	638	1066
904	545	675	1208	910	553	688	1068

LITERATURE CITED

Allison, A. D. 1917. Preparation of corn for fattening two-year-old steers. Missouri Agr. Expt. Sta. Bull. 149:1.

Anonymous. 1961. Rolled vs. pelleted barley. Oregon's Agr. Prog. Rpt. Vol. 8: No. 1.

Atkison, F. W. and G. H. Beck. 1942. The advantage of grinding Atlas sorghum grain for dairy cattle. J. Dairy Sci. 25:211.

Buchanan-Smith, 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. Anim. Sci. 27:525.

Burkhardt, J. D., L. B. Embry, C. J. Lewis and R. M. Luther. 1969. Processing methods for dry and reconstituted high-moisture corn for finishing beef cattle. South Dakota Beef Cattle Field Day Rpt. A. S. Series 69-4.

Calovos, N. F. and H. A. Keener. 1954. Coarse grain or fine? Guernsey Breeders J. 90:728.

Clanton, Donald C. 1961. Comparison of 7- and 10-day collection periods in digestion and metabolism trials with beef heifers. J. Anim. Sci. 20:640.

Clanton, Donald C. and Walter Woods. 1966. Performance of steers and rumen fermentation as influenced by physical form of ingredients and alfalfa:corn ratio. J. Anim. Sci. 25:102.

Cullison, A. E. 1961. Effect of physical form of the ration on steer performance and certain rumen phenomena. J. Anim. Sci. 20:478.

Darnell, A. L. and O. C. Copeland. 1936. Ground versus unground grain for lactating dairy cows. Texas Agr. Expt. Sta. Bull. No. 530.

Dinusson, W. E., D. W. Bohn, D. O. Erickson and M. L. Buchanan. 1960. Fattening beef cattle on barley- barley meal- barley pellets- rolled barley are compared with corn. North Dakota Farm Research Bimonthly Bull. 21:7:4.

Dinusson, W. E., C. N. Haugse, D. O. Erickson and M. L. Buchanan. 1962a. Barley for fattening beef cattle - A comparison of: - Supplements level of supplemental protein. North Dakota Farm Research Bimonthly Bull. 22:6.

Dinusson, W. E., D. O. Erickson, C. N. Haugse and M. L. Buchanan. 1962b. Barley for fattening beef cattle- Steam versus dry-rolled. North Dakota Farm Research Bimonthly Bull. 22:6.

Dinusson, W. E., D. O. Erickson, C. N. Haugse and M. L. Buchanan. 1964. Barley for beef- with beet pulp, -with malt sprouts, -with alfalfa. North Dakota Farm Research Bimonthly Bull. 23:5.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1.

Embry, L. B., A. E. Dittman, F. W. Whetzal, R. D. Goodrich and G. F. Gastler. 1967. Barley rations for finishing beef cattle. South Dakota Agr. Expt. Sta. Bull. 539.

Evans, J. L., and M. W. Colburn. 1967. Disappearance in the rumen of grain dry matter with different physical forms. J. Dairy Sci. 50:394.

Garrett, W. N., G. P. Lofgreen and J. L. Hull. 1971. Influence of processing methods on energy utilization of feed grain. Hilgardio. 41:6.

Geurin, H. B., J. L. Williamson, J. C. Thompson, H. L. Wilcke and R. M. Bethke. 1959. Rolled common barley serves as both grain and roughage for fattening steers. J. Anim. Sci. 18:1489.

Givens, R. L., S. R. Morrison, W. N. Garrett and W. B. Hight. 1967. Influence of pen design and winter shelter on beef performance. California Feeders Day Rpt. 7th Annual. P. 64.

Goodrich, R. D., F. W. Whetzal and L. B. Embry. 1962. Effects of grinding and rolling on the feeding value of shelled corn for cattle. South Dakota Beef Cattle Field Day, 6th Annual, A.H. Mimeo series 63.

Hale, W. H. and C. Brent Theurer. 1972. Feed preparation and processing. In. Digestive Physiology and Nutrition of Ruminants. D. C. Church (Ed.) Covallis, Oregon, Vol. 3.

Harper, O. F., L. S. Pope, D. F. Stephens and G. R. Waller. 1962. Supplements to all-barley rations for fattening steers. J. Anim. Sci. 21:999 (Abstr.).

Harris, Lorin E. 1970. Nutrition Research Techniques for Domestic and Wild Animals. Pub. Lorin E. Harris, Logan, Utah, Vol. 1.

Henderson, Hugh E., H. W. Newland and Merle L. Esmay. 1965. Series I. Square footage requirements, controlled atmosphere and slotted floors for feedlot cattle. Michigan Beef Cattle Day Rpt. AH-BC-643: p 29.

Henderson, High E., and H. W. Newland. 1966. Effect of animal density on feedlot performance. Michigan Beef Cattle Day Rpt. AH-BC-656: p 57.

Henderson, Hugh E., Mitchell Geasler and David Hawkins. 1967. Effect of animal density on feedlot performance. Michigan Beef Cattle Day Rpt. AH-BC-667: p 59.

Hilton, J. H., J. W. Wilber and T. E. Hienton. 1933. The value of grinding grains for young dairy calves. Indiana Agr. Expt. Sta. Bull. 373:1.

Hironaka, R., and C. B. Bailey. 1968. Performance of steers receiving equal amounts of digestible energy from rations differing in proportion of hay and barley. Canadian J. Anim. Sci. 48:131.

Hoffman, M. P. and H. L. Self. 1970. Shelter and feedlot surface effects on performance of yearling steers. J. Anim. Sci. 31:967.

Ingalls, J. R. and M. E. Seale. 1967. Dairy bulls and steers in open vs heated housing. J. Anim. Sci. 26:1467.

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

Kick, C. H., Paul Gerlaugh, A. F. Schalk and E. A. Silver. 1937. The effect of mechanical processing of feeds on the mastication and rumination of steers. J. Agr. Res. 55:587.

McCandlish, Andrew C. 1923. Studies in the growth and nutrition of dairy calves. VIII. The use of the self feeder with young dairy calves. J. Dairy Sci. 6:500.

McCarrick and M. J. Drennan. 1972. Effect of winter environment on growth of young beef cattle. Anim. Prod. 14:107.

Meiske, J. C. and R. D. Goodrich. 1970. How can we meet roughage needs of finishing cattle? Hay? Plastic? Whole corn? Proceedings of Thirty-first Minnesota Nutrition Conference.

Meiske, J. C., R. D. Goodrich, R. L. Larson, J. A. Moore and E. Allred. 1970. Finishing yearlings in insulated housing equipped with an oxidation ditch waste disposal system. Minnesota Feeders Day Bull. B-137:29.

Meiske, J. C., R. D. Goodrich, R. L. Larson, J. A. Moore and R. A. Hegg. 1971. Finishing yearling in insulated housing equipped with an oxidation ditch waste disposal system: Summary of four trials. Minnesota Feeders Day Bull. B-154:56.

Meiske, J. C., R. L. Larson, J. A. Moore, R. O. Hegg and R. D. Goodrich. 1972. Finishing yearlings in insulated housing equipped with an oxidation ditch waste disposal system: Summary of ten trials. Minnesota Feeders Day Bull. B-171:23.

Morrison, Frank B. 1956. Feeds and Feeding. The Morrison Publishing Co., Ithaca, N.Y.

Myers, Lyle L. 1962. Effect of barley preparation and roughage level upon the performance of fattening steers. Master's Thesis. Montana State University, Bozeman, Montana.

Otis, D. H. 1904. Experiments with hand-fed calves. Kansas Agr. Expt. Sta. Bull. 126:163.

Parrot, C., Herold Loughead, W. H. Hale and Brent Theurer. 1968. Effect of concentrate level on digestible energy intake with steers. J. Anim. Sci. 27:1173 (Abstr.).

Peters, W. H. 1931a. Ground barley, whole barley or shelled corn for fattening cattle. Minnesota Agr. Expt. Sta. Bull. 274:8.

Peters, W. H. 1931b. Grinding shelled corn, barley and alfalfa hay. Minnesota Agr. Expt. Sta. Bull. 274:18.

Ray, Maurice L. and Calvin L. Drake. 1949. Effects of grain preparation on preferences shown by beef cattle. J. Anim. Sci. 18:1333.

Richardson, D., E. F. Smith, F. H. Baker and R. F. Cox. 1961. Effects of roughage concentrate ratio in cattle fattening rations on gains, feed efficiency, digestion and carcass. J. Anim. Sci. 20:316.

Shaw, R. S. and H. W. Norton, Jr. 1906. Feeding whole grain. Michigan Agr. Expt Sta. Bull. 242.

Smith, R. E., H. E. Hanke, L. K. Lindor, R. D. Goodrich, J. C. Meiske and D. W. Bates. 1970. A comparison of five housing systems for feedlot cattle. Minnesota Feeders Day Bull. B-136:11.

Smith, R. E., H. E. Hanke, L. K. Lindor, R. D. Goodrich, J. C. Meiske, P. R. Hasbargen, D. W. Bates and D. M. Ryan. 1971. A comparison of five housing systems for feedlot cattle. Minneosta Feeders Day Bull. B-152:26.

Smith, R. E., H. E. Hanke, L. K. Lindor, R. D. Goodrich, J. C. Meiske, M. Thonney, D. Crawford, P. R. Hasbargen, D. W. Bates and D. M. Ryan. 1972. A comparison of five housing systems for feedlot cattle. Minneosta Feeders Day Bull. B-170:3.

Steel, Robert G. D. and James H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill. N. Y.

Street, Joseph C., John E. Butcher and Lorin Harris. 1964. Estimating urine energy from urine nitrogen. J. Anim. Sci. 23:1039.

Thomas, O. O., Gary Wilcock, Gary Cowman and L. G. Young. 1961. Fattening cattle on high concentrate rations. J. Anim. Sci. 20:666.(Abstr.).

Vance, R. D., R. R. Johnson, E. W. Klosterman, B. A. Dehority and R. L. Preston. 1970. All-concentrate rations for growing-finishing cattle. Ohio Agr. Res. Beef Cattle Res. Summary 43: p 49.

Vetter, R. L., Earl Mobley and Nelson Gay. 1970. Confinement feeding of feedlot cattle: Progress Report. Results of Cattle Feeding Experiments. Iowa State Univ. A.S. Leaflet R 144 (AS-352).

Wiktorsson, H. 1971. Digestibility experiments with dairy cows consuming different quantities of concentrates. J. Dairy Sci. 54:374.

Windels, H. F., R. D. Goodrich and J. C. Meiske. 1971. Comparison of housing systems and building designs for feedlot cattle in northern climates. Minnesota Feeders Day Bull. B-153:48.

Windels, H. F., R. D. Goodrich and J. C. Meiske. 1972. Comparison of housing systems for feedlot cattle in northern climates. Minnesota Feeders Day Bull. B-172:30.

Wise, M. B., T. N. Blumer, E. R. Barrick and G. Matrone. 1961. Investigations on the feeding of all concentrate rations to beef cattle. J. Anim. Sci. 20:957 (Abstr.).

Wise, Milton B., T. N. Blumer, G. Matrone and E. R. Barrick. 1961 Investigations on the feeding of all concentrate rations to beef cattle. J. Anim. Sci. 20:561.

Wise, M. B., R. W. Harvey, B. R. Haskins and E. R. Barrick. 1968. Finishing beef cattle on all-concentrate rations. J. Anim. Sci. 27:1449.