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EFFECT OF THREE METHODS OF PROCESSING BARLEY ON INTAKE AND PRODUCTION OF LACTATING COWS

by

Carlos García Jáuregui

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Animal and Dairy Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1982

DEDICATION

This thesis is dedicated in memory of my mother, Prudencia Jáuregui de García who died in Mexico while I was doing my graduate program at Utah State University. Her death was traumatic to me and my family.

She was the mother of eleven children and always an extraordinary, patient, peaceful, wise, encouraging and exemplary mother and wife. She was an inspiration to all people in her presence. Against unaccountable barriers, she, together with my father, Fidel García Jiménez, wisely knew how to build a strong solid family foundation to which I deeply admire, profoundly respect and am proud to have belonged to such a marvelous united family. I hope I can inspire my own family in their teachings.

Carlos García Jáuregui

DEDICACION

Esta tesis la dedico muy especialmente en memoria de mi querida madre Prudencia Jáuregui de García, quien murió en México cuando estuve haciendo mis estudios de postgrado, para obtener mi maestría en Utah State University en Estados Unidos. Su muerte fué dolorosa y su lugar ha sido insustituible para mí y mi familia.

Siendo madre de 11 hijos, siempre fué una mujer extraordinaria, fiel y paciente, llena de paz alegría y sabiduría. Fortaleciendo a quienes le rodeaban; ella fué una ejemplar madre y esposa. Ella fué inspiración para todos los que la rodearon.

Ella, junto con mi padre Fidel García Jiménez y contra un sinnúmero de obstáculos, supieron perceptivamente como fundar un fuerte y sólido cimiento familiar, lo cual profundamente admiro y respeto y me hace sentir orgulloso de pertenecer a ese admirable cimiento familiar. Esperando que mi padre y mi madre se hallan sentido satisfechos y realizados de su obra que Dios les asignó en este planeta y que sus enseñanzas perduren en mí, mis hermanos y hermanas para la inspiración de nuestros propios cimientos familiares.

Carlos García Jáuregui

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Carlos García Jáuregui

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ABSTRACT

Effect of Three Methods of Processing Barley
on Intake and Production of Lactating Cows

by

Carlos Garcia Jauregui, Master of Science
Utah State University, 1982

Major Professor: Dr. Melvin J. Anderson
Department: Animal, Dairy and Veterinary Science

Twenty-four lactating cows were randomly assigned to three treatments within eight each 3 x 3 latin squares with three periods of 21 days duration. Three processing treatments of barley were 1) steam-rolled, 2) ground (fine), and 3) soak-rolled (soaked in water for appr. 24 hours, rolled, and fed within 48 hours). All rations were fed ad libitum and were comprised of 24% alfalfa hay, 16% corn silage, 35.5% barley, 12% whole cottonseed, 12% wheat bran, 0.3% salt, and 0.3% dicalcium phosphate on a dry matter (DM) basis. Electronic doors were used to collect individual feed intake data. Rations and feces grab samples were collected and analyzed chemically. Dry matter digestibility (DMD) was determined by acid insoluble ash. Body weights (BW) were taken every two weeks. Milk production was recorded daily and composition of milk fat, protein, and solids-not-fat (SNF) was determined twice a month. Produc-

tion (kg/day) of milk, butterfat, protein, SNF; DM consumed (kg); percent DMD; efficiency 1 (kg) 4% fat corrected milk (FCM)/kg DM intake); and efficiency 2 (kg) 4% FCM/kg digestible dry matter (DDM) for rations 1, 2, and 3 were 24.2, 22.7, 21.8; 0.88, 0.80, 0.86; 0.83, 0.78, 0.74; 2.17, 2.04, 2.01; 19.8, 20.8, 18.7; 67.05, 71.05, 67.20; 1.16, 1.04, 1.18; 1.76, 1.46, and 1.83, respectively.

The method of processing barley caused significant differences ($P < .01$) in production of milk, percent fat, amount of protein, DDM, and efficiency 1 and 2. Likewise, it caused significant differences ($P < .05$) for 4% FCM, amount of fat, and SNF, and DM consumed, but there were no significant differences for SNF, protein and percent DMD, amount of feed consumed and refused, DM refused, and BW. Treatment by period interactions were significant ($P < .01$) for feed and DM consumed, feed efficiency 1 and 2, and DDM. Group by period interactions were highly significant ($P < .05$) for BW, ($P < .05$) for total milk production, and amount of protein. Correlations among all the variables were with those previously reported except for the correlations of percent SNF with total milk production, which was positive but non-significant ($P > .05$).

The cows fed ration 1 produced more total milk and protein than those on rations 2 and 3. There were no differences in feed consumed (or fed) among cows on the three rations. Cows on ration 2 consumed more DM than those on

ration 3, but cows on ration 1 did not differ in DM consumption from those on either of the other treatments. Cows on ration 3 had the highest fat test, but showed no differences in the amount of fat produced compared to the cows on rations 1 and 2.

Cows on ration 2 had the highest percent DMD and DDM and since these were not the highest in total milk production but were the highest in DM consumption, they were the least feed efficient. Additionally, since cows on ration 3 consumed less DM than those on ration 2, the former had high feed efficiency equal to cows on ration 1.

(69 pages)

INTRODUCTION

Throughout human history, animals have played a major role in providing food, fiber, hides, transportation, etc., for man. As time goes on, production of food may not parallel demographic growth (11) and as a result the food supply could become an acute problem. Even now, available resources should be used optimally.

Ruminant animals have digestive systems that can utilize feeds which are inedible for humans and they transform these feeds into palatable and nutritious products. Animal products are important sources of energy and other important nutrients and the major sources of protein for humans (9).

Animal products are preferred items in the diet of most humans because of taste and nutritional characteristics. Brown (6) indicates that income and consumption of animal proteins are positively correlated; the lower the income the less consumption of milk or meat by an individual and his family.

If we are to continue to have animal products available for nearly all classes of people, the efficiency of converting feeds to animal products must continue to increase. This requires an updated knowledge of the availability of feed sources, their nutritive content and value, the animal's requirements, feeding practices, animal disease control, breeding practices, genetic advancement, and feed efficiency.

Grains comprise a substantial part of the diet for many animals particularly in the USA and are used mainly as sources of energy (12) but also supply considerable proteins and other nutrients. In Utah, barley (Hordeum vulgare, L.) is the major grain used in feeding livestock. It is usually steam-rolled or ground before feeding.

The fact that steam-rolled barley is acceptable and relatively free of dust when properly processed makes it an excellent feed for dairy cattle. Steam-rolling has been a popular method of grain processing (in the USA) for dairy cattle feeding. However, the machinery for steam-rolling is expensive and not adaptable to most on-farm situations. Relatively high processing costs occur with traditional steam-rolling. The steam increases the moisture content and frequently the farmer pays for the extra added moisture (12). The question frequently arises whether it is more economical for the individual farmer to process his own grain or have this done by feed dealers.

If a dairyman could purchase his year's supply of grain at the time of harvest he would frequently buy at a much lower price and could be assured of more uniform quality.

Portable hammermills are available on the market and adaptable to on-farm situations. These can be used for grain processing. Grinding of grain results in a feed which is dusty. This causes it to be less palatable and results in

lower consumption (41). However, this problem might be eliminated if the grain was fed in a complete feed which contains feeds (e.g. silage) that help control the dust.

A controversy exists whether ground grain is equal in feeding value to steam-rolled grain for ruminants. Esophagogastric ulcers from ground grain feeding have been reported in swine (24) and some dairy farmers believe ground grain causes problems. Therefore, a need arises to determine if steam-rolled barley is superior in feeding value to ground grain and if the extra expense warrants its use.

An alternative method of grain processing has been used at the C and Y Dairy (J. R. Simplot Co.), Malta, Idaho. They soak barley with water for 24 hours, then roll before feeding. They have used this method for seven years to feed 18 tons of barley per day to 1,200 dairy cows (3). Few research studies were found on this method of processing grain. It should be determined whether soaked-rolled barley would be a viable alternative to the other two methods.

The objective of this research was to compare the feeding value of steam-rolled, ground, and soaked-rolled barley as a component of the diet for lactating dairy cows by measuring production responses, feed intake, and dry matter digestibility.

REVIEW OF LITERATURE

Grain and Grain Processing

According to Church and Pond (8), barley is widely grown in Europe and in the cooler climates of North America and Asia. Most barley is used for animal feeding, a substantial amount goes into the brewing industry, and a smaller portion goes for human food. They also state that barley is a palatable feed for ruminants, particularly when rolled, and seldom causes digestive problems when properly managed.

For nonruminant animals the current varieties of barley are relatively high in fiber content which lowers the digestible energy. However, barley does contain more total protein than corn with a higher level of lysine, tryptophan, methionine, and cysteine (0.6, 0.2, 0.2, and 0.2%; 0.18, 0.09, 0.00 and 0.09% respectively). Hulless varieties are currently in development which should increase the digestible energy content.

Processing of feeds can be done chemically and physically. Processing is practiced to obtain an optimal nutritional value of feedstuffs for animal feeding (12). Several authors (8, 12, 17) have listed a variety of purposes for processing feed. Hale (16) cited about 18 of the most important methods of processing grains. These are grouped into dry and wet methods. The benefits achieved by grain proces-

sing as reported in published research depend upon the method, animal species, age and physiological function of the animal considered. Furthermore, the physical form of feeds substantially influences the animal's health, dry matter consumption, digestible dry matter, production responses, and palatability.

In order to select the most feasible grain processing method for a given condition, it would be advisable to check a number of aspects that Ensminger and Olentine (12) summarized as follows.

Nutrition considerations: 1) type of grain; 2) uniformity and quality of finished product; 3) moisture content beform and after processing; 4) change in structure of the starch; 5) feed intake, rate of production, and feed efficiency; and 6) effect on the animal health.

Nonnutritional considerations: 1) time of grain purchase; 2) size of operation; 3) type of ration and kind of operation; 4) capacity of mill; 5) initial investment in equipment; 6) maintenance, repair, and operating costs; 7) labor requirements; and 8) energy requirements.

Williamson (57) discussed the advantages and disadvantages of grain processing for dairy cattle and other animals. He related it to storing and handling. Certain methods of processing could produce desirable results for one species or type of animal while producing undesirable results for other animals. Although there seemed to be many unanswered

questions on the type and extent of grain processing for dairy cattle, some practical methods of processing grain for dairy cows are in use.

Ground Grain

Grinding is defined by Harris and Crampton (17) as a reduction in particle size caused by impact shearing or attrition. Grinding is the most common, cheapest, and least complicated grain processing method (8, 12, 57) which usually is accomplished with a hammer mill (impact) that reduces the particle size until it passes through a specific size screen.

Scientists have shown a variety of results in research on grinding grain for feeding livestock, i.e., Colovis (cited by Williamson, 57) pointed out that feeding ground grain to dairy cows improved the digestibility coefficient compared to whole grain. Later Bush et al. (7) determined that cows fed finely ground grain produced more milk ($P<.05$) and gained more body weight than cows fed medium or coarse ground grain. This is in contrast to the report by Wilber (56) which stated that grinding permits a more uniform mixture of the rations for dairy cows, but if feed is ground too finely, milk production may decrease. Williamson (57) reported a decrease in butterfat level as particle size of grain decreases, particularly when feeding high grain rations with low levels of roughage. Moe et al. (27)

reported that feeding ground corn causes a decrease in butterfat and metabolizable energy efficiency for milk production. They suggested caution in using energy values for feedstuffs without regard to the physical form of the grain and the nature of the product formed.

Kertz et al. (21) compared pelleted (.4 cm diameter), coarse (premix pellet with cracked corn), crumbled pellets, or meal forms of grain rations on the basis of rate of consumption by lactating cows. They concluded that physical form of the grain ration influences ration intake when eating time was limited, but that with longer eating times subsequent intake may be attributed to physiological feedback that can be influenced by physical form of the feed.

Preston et al. (43) stated that one of the hazards of barley feeding in intensive beef production is bloat, which is accentuated if the barley hull is broken down too finely, as happens if the grain is finely ground.

In an in vitro study with sorghum grain, a correlation of .87 was found between DM disappearance and particle size. The smaller the particle the faster the disappearance (55). These findings agreed with the results of Wilson et al. (58) who used the nylon bag technique to study disappearance of corn grain in the rumen. In a similar study Galyean et al. (14) obtained similar results but included two grains (sorghum and corn) and measured starch disappearance.

Orskov et al. (35) fed weaned lambs ground, steam-

flaked, and cracked corn (80% corn diets) and showed that 12, 5, and 4% of the starch consumed escaped ruminal fermentation.

Orskov (34) studied the effect of processing of cereals on their digestion and utilization by sheep and cattle. He concluded that cereals should be processed to avoid unacceptable reduction in digestibility, but said that excessive processing generally caused rumenitis when grains were fed alone and depressed cellulose digestion when fed with roughages. For sheep, both problems could be avoided by feeding whole grains because sheep chew, and thus digest, cereals efficiently, which is not true of cattle.

Several researchers (24, 39, 40, 42, 44) have found that with swine, the rate of gain and esophagastric ulcers increase as fineness and gelatinization (grinding followed by heating with steam) of grain increases.

Hudson (cited by Ott, 37) reported that when feeding one-third oats to two-thirds ear corn to mature horses with adequate time to masticate the grain properly, there was little advantage in grinding the grain. However, young and working horses consistently appear to respond positively to grinding of grain, although it may reduce palatability.

Steam-rolled Grain

Steam-rolling is defined by Harris and Crampton (17) as preconditioning of the grain with steam under pressure for a short period and then compressing between rollers. Roll-

ing may entail tempering or conditioning (bringing to predetermined moisture and temperature) or both, or just rolling. Rolling can be dry or wet. Steaming entails treatment with steam as in steam cooking. Ensminger and Olentine (12) pointed out that steam-rolling offers little or no advantage in feed efficiency over grinding or dry-rolling, but that the particle size and physical form of steam-rolled grains may improve palatability and animal acceptance. Furthermore, they stated that moisture content of steam-rolled grain is increased during processing (around 6%). When the whole grain is exchanged for processed grain on an equal weight basis by the farmers with the feed dealer, there is a reduction in the amount of DM returned to the farmer which increases his feed price.

Church and Pond (8) point out that steam-rolled grains have been used for a long time, partially to kill weed seeds. They agree with Ensminger and Olentine (12) that there is little if any improvement in animal performance with steam-rolled compared to dry-rolled grains.

A method of grain processing similar to steam-rolling has shown improvement over regular steam-rolling. Steam-processed, flaked grain (especially barley, corn, or sorghum) are prepared in a similar manner to steam-rolled, except that the grain is subjected to steam for a longer time (usually at 93° C for 15-30 minutes). The moisture content will reach 18-20% before the grain is rolled. The rollers

are set at near zero tolerance, which produces a flat flake. More rupture and gelatinization of the starch granules occur allowing a higher rate of digestibility than for regular steam-rolled grain. Schuh et al. (45) conducted a study using steam-processed flakes vs. steam-rolled grains for dairy calves. Results showed that the former exhibited greater feed efficiency than the latter, although rate of gain was similar for both types of processing. Schuh et al. (46) determined that steam-processing and flaking sorghum were comparable to pressure cooking for calves in a second study. Morrill et al. (28) found that steam-rolling or heat processing of grains did not improve animal performance but increased blood glucose levels after expanded sorghum grains were fed to calves.

A lowered level of fat in milk was reported when cows were fed rations low in roughage containing flaked grains (4, 49).

Williamson (57) reported a study with steam-rolled and cracked corn to dairy cows. Results showed that the former produced more milk with lower butterfat test than the latter (20 and 19 kg of milk/cow/day and 3.27 and 3.45% butterfat. He also reported results of another experiment with dairy cows in which pelleted and steam-rolled rations produced comparable amounts of milk and butterfat, but cows fed cracked corn produced less milk with more butterfat (22.6, 22.3, and 21.6 k_g of milk/cow/day, respectively, and

3.20, 3.34, and 3.67% butterfat, respectively).

Orskov et al. (36) reported the results of a study with barley grain converted to various physical forms or treated with NaOH. The intake of rolled barley grain was slightly higher than ground (34.9 and 34.4 g/kg $W^{.75}$/day). It was concluded that the deleterious effect of a cereal-based supplement on rate of digestion of cellulose and consequently voluntary intake can be largely overcome by use of processing methods of grain which reduce the rate of release of starch and yet ensure a high rate of digestion.

Parrott et al. (38) conducted two separate digestion trials to compare dry-rolled, steam-rolled and flaked barley fed at 85% of the ration to fattening steers. Processing method did not significantly affect digestibility of the proximate fractions or total digestible nutrients (TDN) of the ration during the first trial. From the second trial, they determined that steam-processing and flaking improved the TDN compared to dry-rolled. Digestibility and TDN were significantly higher during the first than the second period of the second trial.

Orskov (33) reported that when pelleted feeds were made with whole barley instead of rolled, the severity of pathological changes in the rumen wall of sheep were reduced. With unprocessed whole barley, pH of the rumen fluid was higher, there were not pathological symptoms, and there was no reduction in apparent digestibility.

Hudson (19) fed working horses commercial rations with

whole and rolled grain (50% corn and 50% oats). Results showed that horses fed rolled grain put on more weight and showed better animal performance than if fed whole grain. Lane (23) also stated that hard grains such as barley, milo, wheat, and rice are likely to be improved by rolling. Milo should be steam-rolled for horse feeding.

Soak-rolled Grain

Little research on the effects of soaking grain on subsequent utilization has been found. Some authors have briefly discussed the soaking method(s) of processing grain. Morrison (29) wrote:

> Likewise there is no benefit from soaking or cooking ordinary feeds. In the case of a cow on official test, the concentrate mixture is sometimes moistened before feeding in order to induce her to eat a greater quantity than she may take otherwise. Also dried beet pulp is sometimes soaked and fed as a substitute for corn silage (p. 611-612).

He further wrote:

> Barley, wheat, rye, and grain sorghums should be ground or crushed for horses, because the kernels are so small that the grain is chewed less thoroughly than corn or oats. If these smaller grains cannot conveniently be ground or crushed, they should be soaked before feeding, to soften the kernels (p. 827).
>
> If shelled corn or ear corn becomes very hard and/or dry on storage, it may pay to soak it before feeding to swine, though the increase in value is not usually very marked. When whole barley or oats

> cannot conveniently be ground, it may be economical to soak the grain, though soaking is a rather poor substitute for ginding. It does not generally pay to soak ground grain or a mixture of concentrates for swine (p. 578).

He also discussed research from Washington and Oregon on poultry. It was stated that soaking or adding enzymes to certain cereals, such as barley, pearl barley, oats, and rye improves their feeding value.

Ensminger and Olentine (12) indicated advantages for soaking of hard grains wthat were not mechanically processed. These grains were soaked for 12-24 hours. The soaking softened and swelled the grains. Dried beet pulp and soybean flakes may also be soaked before feeding. They indicated that reconstituted grain resembled soaked grains with a high moisture grain appearance. Reconstituted grain is described as a mature air dry grain with water added to 25-30% moisture and then stored in an oxygen-free structure for at least 15-25 days. During this time, fermentation of the grains occurs. The grains are rolled or ground at the time of removal from storage prior to feeding.

Church and Pond (8) discussed soaking grain in a manner similar to the other authors, except they add, "It has long been used by livestock feeders and that space requirements, problems in handling, and a potential souring have discouraged large scale use."

Frederick et al. (13) conducted research with barley

and sorghum. They found that addition of water to the grain by soaking (covered with 36% water and stored in the refrigerator overnight to retard fermentation) or by steaming at atmospheric pressure did not improve enzymatic starch degradation of barley and sorghum grains. Pressure response was greater with moist than with dry grains. They concluded that enzymatic starch degradation was greatest for processing treatments involving moisture, heat, and pressure (with hydraulic press on roller mill). In addition, soaking of sorghum grain (without pressing) improved ($P < .01$) starch digestibility over dry or steamed but unpressed grains (17 vs. 11 and 8% of moisture).

Mazzotti di Celso (25) compared barley, oats, wheat, and rye fed to sheep. His reports show that feeding value on a DM basis per 100 kg body weight was 117 FU., 115 FU., and 119 FU. respectively for milled, crushed, and soaked (for 24 hours in water) barley. Feeding values and digestibilities were not significantly different between method of processing each grain, except for try in which the values for soaked grain were significantly lower. The possible laxative effects due to water treatment may have caused the decreased values.

The C and Y Dairy Farm (J. R. Simplot Co.) Malta, Idaho, has been successfully soaking barley with water for 24 hours then rolling before feeding since 1974. Currently, approximately 18 tons of barley are fed to about 1,200

dairy cows daily (3).

Digestibility Method Using
Insoluble Ash

Numerous indirect methods to determine digestibility of feed for animals have been tried during this century. Few have been successful. The common drawbacks have been the complexity, expense, impracticality, and inaccuracy of the methods. Extensive research has been conducted using artificial (external) markers in digestion trials with animals. The disadvantages previously described are typical of these methods. Researchers (5, 20, 22, 26, 31, 47, 49, 50, 51, 52, 53, 54) have been looking for natural substances in feeds that can be used as markers to calculate digestibility of feeds and rations for both ruminants and nonruminants.

In 1977, Van Keulen and Young (53) developed a method for predicting digestibility from acid-insoluble ash (AIA) which is based on siliceous materials. They compared the total collection digestibility method to the AIA method with sheep. They compared three laboratory analytical procedures of AIA determinations: 1) concentrated hydrochloric acid, 2) 4N HCl, and 3) 2N HCl. The DM digestibility (DMD) coefficients were not significantly different between the AIA method and the traditional total collection method. They concluded:

> The use of natural markers offers distinct advantages over the total fecal collection method for digestibility studies. In addition to minimal time

> and labor, quantitative measurements of feed intake and fecal output are not required. Measurements can be made on single feed and fecal samples. AIA, therefore, has potential use in digestibility studies and feed testing laboratories where other methods may not be applicable (p. 228).

They determined, that of the three analytical procedures, the 2N HCl was the simplest and most convenient.

> The 2N HCl procedure, unlike the former two AIA analytical procedures, involved an initial oven dry step which allowed determination of DM content of the actual analyzed sample. Furthermore, ashing the sample prior to acid treatment removed the organic matter, thus reducing the strength of acid required and largely avoided the problem of unpleasant odors which arise when feed or feces are digested with acids. In addition, the figures were statistically comparable (p. 284).

MATERIALS AND METHODS

Experimental Design

Twenty-four Holstein lactating cows were selected from the Utah State University Dairy herd and were as uniform as possible in days of lactation (about 70 days of lactation), level of milk production, number of lactations, and age. They were randomly assigned to treatments within eight latin squares with three treatments and three periods. The duration of each period was five weeks. The first two weeks were used for adaptation of the cows to the new diet and the results were not included in the statistical analysis. This left three weeks of data for the analysis period.

The production responses measured were: milk, 4% fat corrected milk (FCM), percent and amount of fat, solids-not-fat (SNF) and protein, and body weight (BW).

Consumption and chemical composition of feeds were measured by computing feed and DM fed, feed and DM refused, and feed and DM consumed. DM, crude protein (CP), and ash were determined according to AOAC (1) methods; acid detergent fiber (ADF) and acid detergent lignin (ADL) by the procedure of Goering and Van Soest (15); AIA and DM digestibility by the AIA digestibility method according to Van Keulen and Young (53). Two measures of feed utilization efficiency were used which were calculated as the ratio of 4% FCM to

1) the feed DM consumed and to 2) the amount of DM digested.

Feeds, Rations, Feeding, and Management of the Cows

The treatments were three different methods of processing barley: 1) steam-rolled, 2) ground, and 3) soak-rolled. Steam-rolled and ground barley were processed by a local commercial feed dealer. Soak-rolled was soaked at the farm by submerging in culinary water overnight (approximately 12 hours), draining off the water and allowing to stand 12 hours, and then rolling at the farm before feeding. The batch processed this way lasted about 2 days. Barley for all treatments was from the same source.

The rolling for soaked barley was not crushed to the desired degree due to machinery problems. However, based on visual observation most of the barley was physically changed (rolled or cracked). The water drained from the soaking was not chemically evaluated.

The concentrate contained 59% barley. The concentrate mixture is shown in Table 1. The total ration was 60% concentrate and 40% roughages (Table 2) on a dry matter basis. The total proportion of feeds in the whole rations is shown in Table 3. The dry matter allowances were equal regardless of the three types of grain processing used.

The feed was weighed, mixed, and dropped in front of the feeding manger as a complete feed using a Uebler (780 model) mixer every evening and fed ad libitum. The cows

Table 1. Feed proportions of the concentrate mixture (DM basis)[a].

Feed	Proportions
Barley	59
Whole cottonseed	20
Wheat bran	20
Salt	.5
Dicalcium phosphate	.5
Total	100.0

[a]DM=Dry matter.

Table 2. Proportions of concentrate, corn silage, and chopped alfalfa (DM basis)[a].

Item	Proportions
Concentrate	60
Alfalfa	24
Corn silage	16
Total	100

[a]DM=Dry matter.

were housed in a free stall corral and each cow wore a neck-strap with a transponder that activated her respective electronic door enabling collecting of individual cow feed data. Feed refusals were measured prior to each evening feeding (2, 10).

Samples of feed and feed refusals were taken weekly, and feces were collected by grab sample method for the AIA digestibility method at the end of each period. The samples

Table 3. Total proportion of feeds in the ration (DM basis)[a].

Item	Feed	
Concentrate	Barley	35.5
	Whole cottonseed	12.0
	Wheat bran	12.0
	Salt	.3
	Dicalcium phosphate	.3
Roughage	Alfalfa	24.0
	Corn silage	16.0
	Total	100.0

[a]DM=Dry matter.

were taken to a dryer room and then left until dry. They were allowed to equilibrate to air dry condition, ground, and chemically analyzed.

Milking was done mechanically at 12-hour intervals by the regular USU dairy farm milkers. The milk from individual cows was sampled twice monthly. The cows were weighed at the beginning of the study and on a weekly basis after the morning milking. Water was restricted prior to the weighing. The normal USU dairy reproductive and health programs were followed.

Determination of Dry Matter Digestibility

The digestibility method used was the AIA as described by Van Keulen and Young (53). This procedure used the fol-

lowing steps: 1) duplicate 5 g samples of feed and feces (air-dried and ground) were placed into 50 ml crucibles, dried for 2 hours in a forced air oven at 135° C, cooled in a dessicator at room temperature, reweighed (W_s) and then ashed overnight at 450° C; 2) the ash was transfered to a 600 ml Berzelius beaker and 100 ml of 2N HCl were added, boiled for 5 minutes on a crude fiber digestion apparatus; 3) the hydrolysate was filtered through a Whatman paper No. 41 and washed free of acid with hot distilled water at 85 to 100° C, transfered (ash and filter paper) back into the crucible and ashed at 450° C overnight; 4) crucible and residues were cooled in the dessicator, weighed including the ash (W_f) and the crucible re-weighed after emptying (We).

The equation used to calculate AIA percent of a sample was as follows:

$$\text{AIA } \% = \frac{W_f - We}{W_s} \times 100$$

The equation used to calculate the DMD percent of the rations was as follows:

$$\text{DMD } \% = 100 - \frac{\% \text{ AIA of ration}}{\% \text{ AIA of feces}} \times 100$$

Missing data occurred for five observations because of samples which were destroyed or because of extreme variation in results from these samples.

Statistical Procedure

Preliminary analysis of the data indicated that different statistical models were most appropriate for separate

sets of variables studied (18).

The following model was used for amount and percent of milk fat, percent milk protein, amount and percent SNF, feed refused (as sampled), DM refused, and DMD:

Model 1: $Y_{ijkl} = \mu + g_i = c{:}g_{ij} + t_k + p_l + e_{ijkl}$

where: Y_{ijkl} = an observation on the jth cow in the gth group (square) on the kth treatment in the lth period;

μ = population mean;

g_i = effect due to the ith group of cows;

$c{:}g_{ij}$ = effect of the jth cow in the lth group;

t_k = effect of the kth treatment;

p_l = effect of the lth period;

e_{ijkl} = random variation unique to an individual observation.

The alternate model used for feed and DM consumed, DDM and feed, efficiency 1 and efficiency 2 was as follows:

Model 2: $Y_{ijkl} = \mu + g_i + c{:}g_{ij} + t_k + p_l + (tp)_{kl} + e_{ijkl}$

where: $(tp)_{kl}$ = interaction between the kth treatment and the lth period.

The alternate model used for milk, milk protein, body weight and 4% FCM was as follows:

Model 3: $Y_{ijkl} = \mu + g_i + c{:}g_{ij} + t_k + p_l + (gp)_{il} + e_{ijkl}$

where: $(gp)_{il}$ = interaction between the ith group of cows and the lth period.

RESULTS AND DISCUSSION

Chemical Composition of Samples

The average chemical composition of individual feeds used in the three rations is presented in Table 4. As expected, the chemical composition of each processed form of barley was similar since all barley was from the same source. Feeds were sampled at the beginning and at the end of the experiment. Duplicate laboratory samples were taken from each individual sample and the results averaged because the composition of the beginning and ending samples were similar. Whole barley grain was included in the chemical determinations in order to have a point of reference for comparison with processed forms. The results of the chemical composition analyses were compared to NRC tables (32) and Atlas of Nutritional Data on USA and Canadian Feeds (30) and all corresponded closely to those shown in these publications. Samples were not analyzed for neutral detergent fiber because they would not filter through the crucibles.

The average chemical composition of the rations is shown in Table 5 and the refusals in Table 6. Composites of five weekly samples from each period were analyzed. Duplicate laboratory samples were used and their results averaged. The chemical composition values among treatments were all uniform except for the DM of the soaked barley treatment. Lower DM for this treatment was due to the prefeeding water

Table 4. Average chemical composition of individual feeds (dry matter basis).

Feed	DM[b]	CP[c]	ADF[d]	ADL[e]	Ash[f]	AIA[g]
	(%)					
Steam-rolled barley	88.0	12.1	9.13	.96	2.99	.784
Ground barley	89.9	13.0	8.41	1.22	2.90	.779
Soaked-rolled barley	63.7	13.0	9.01		2.82	.655
Whole barley[a]	90.1	12.4	11.37		3.43	.948
Cottonseed	93.0	22.4	31.90	9.90	4.45	.308
Wheat bran	89.2	14.4	12.7	3.41	5.17	.189
Corn silage	32.8	8.8	28.6	4.01	5.03	1.760
Alfalfa hay	91.6	16.0	40.1	8.51	9.20	.359

[a]Not processed or included in the rations.
[b]Dry matter.
[c]Crude protein.
[d]Acid detergent fiber.
[e]Acid detergent lignin.
[f]Minerals.
[g]Acid insoluble ash.

treatment of the barley. Most refusals of the soaked and steam-rolled treatments consisted of alfalfa stems and cobs. Most refusals of the ground barley treatments consisted of ground barley residues (fines) and cobs from the corn silage. The AIA values of the rations were used to calculate DM digestibility of the rations.

The average chemical composition of the feces is shown in Table 7. Grab samples were taken from each cow at the

Table 5. Average chemical composition of ration (dry matter basis).

Ration	DM[a]	CP[b]	ADF[c]	ADL[d]	Ash[e]	AIA[f]
	(%)					
Steam-rolled barley	68.9	14.3	24.4	4.77	5.61	.886
Ground barley	68.9	14.4	24.7	5.10	5.90	.810
Soaked-rolled barley	63.3	14.4	23.4	4.20	5.75	.905

[a]Dry matter.

[b]Crude protein.

[c]Acid detergent fiber.

[d]Acid detergent lignin.

[e]Minerals.

[f]Acid insoluble ash.

Table 6. Average chemical composition of refusals (dry matter basis).

Treatment	DM[a]	CP[b]	ADF[c]	ADL[d]	Ash[e]	AIA[f]
	(%)					
Steam-rolled barley refusal	67.9	13.2	24.2	4.83	5.41	.790
Ground barley refusal	68.9	13.7	20.7	4.67	5.46	.730
Soaked-rolled barley refusal	64.9	13.6	21.6	4.50	5.08	.773

[a]Dry matter.

[b]Crude protein.

[c]Acid detergent fiber.

[d]Acid detergent lignin.

[e]Minerals.

[f]Acid insoluble ash.

Table 7. Average chemical composition of the feces (dry matter basis).

Treatment	DM[a]	CP[b]	ADF[c]	ADL[d]	Ash[e]	AIA[f]
	(%)					
Steam-rolled barley	15.8	13.9	42.6	16.6	10.3	2.80
Ground barley	18.2	13.7	44.9	16.6	10.8	2.91
Soak-rolled barley	17.8	14.5	39.6	15.3	10.1	2.93

[a]Dry matter.
[b]Crude protein.
[c]Acid detergent fiber.
[d]Acid detergent lignin.
[e]Minerals.
[f]Acid insoluble ash.

end of each period. Duplicate samples were analyzed from each individual fecal sample. The chemical composition values were generally uniform, except for the AIA of the soak-rolled treatment. DM content of fresh feces is lower than that of the rations used while concentrations of ADF, ADL, and AIA are higher in the feces. The AIA was used to calculate DM digestibility of the rations.

Dry Matter Consumption and Refusals

Means and standard errors for feed consumed, DM consumed, feed refused, and DM refused are presented in Table 8. The analyses of variance are in Appendix Tables 17 and 18. Processing method caused significant ($P < .05$) differences in

Table 8. Least squares means (LSM)[a] and standard error (SE) of feed consumed, DM[b] consumed, feed refused, and DM refused (dry matter basis) per cow daily.

Item	Steam-rolled		Ground		Soak-rolled	
	LSM	SE	LSM	SE	LSM	SE
	kg					
Feed consumed	28.8	.7	30.2	.7	29.6	.7
DM consumed	19.8[a b]	.5	20.8[a]	.5	18.7[b]	.5
Feed refused	6.5	.4	5.9	.4	6.5	.4
DM refused	4.4	.3	4.0	.3	4.2	.3

[a]Means in the same line with no common superscript are different at $P < .05$.

[b]Dry matter.

the amount of DM consumed. Cows on the ground treatment consumed more DM than those on the soak-rolled treatment. Consumption of DM by cows on the steam-rolled treatment did not differ significantly from DM intake on either the ground or soak-rolled treatment. The other variables (feed intake and refusals) showed no significant differences among treatments. The differences in DM consumed may have been influenced in part by the physical form of the treatments on the rations as stated by Kertz et al. (21).

Dry Matter Digestibility

Means and standard errors for DMD%, daily DDM, efficiency 1 and efficiency 2 are presented in Table 9. The analyses of variance are in Appendix Tables 17, 19, and 20. There were treatment differences observed for all of the variables.

Table 9. Least square means (LSM)[a] and standard error (SE) of DMD%[b], DDM[c], efficiency 1[d], efficiency 2[e].

	Steam-rolled		Ground		Soak-rolled	
	LMS	SE	LMS	SE	LMS	SE
DMD%	67.05[a]	1.2	71.05[b]	1.3	67.20[a]	1.4
DDM kg/day	13.41[a]	.30	14.92[b]	.31	12.24[c]	.34
Efficiency 1	1.16[a]	.02	1.04[b]	.02	1.18[a]	.02
Efficiency 2	1.76[a]	.05	1.46[b]	.05	1.83[a]	.05

[a]Means in the same line with no common superscript are different at $P < .05$.

[b]Dry matter digestibility %.

[c]Digestible dry matter

[d]Kg 4% FCM/kg consumed DM/cow/day.

[e]Kg 4% FCM/kg digested DM/cow/day.

DMD% and daily intake of DDM were significantly higher ($P < .05$) for the ground barley treatment than for the steam-rolled and soaked treatments. The intake of DDM by cows fed soaked-rolled treatment was significantly less than steam-rolled, but differences for DMD% for steam-rolled and ground were not significant. The higher digestibility of the ground treatment is in agreement with the report of Colovis (cited by Williamson, 57).

The fact that cows on the ground treatment were the highest in DMD percent might be explained by the smaller grain particles which may have influenced the availability of the nutrients in some way that resulted in less nutrients available for milk production than for the other two treatments. Another explanation could be some feces samples

were collected from the droppings on the ground. Although care was taken to collect only feces, some samples may have been contaminated with sand which would increase the AIA (silica) content. Some dust in the building where the animals were kept during the fecal collection may also have contributed more silica to some samples than others. The higher the concentration of AIA in the feces the higher the DMD percent calculated which influence the DDM, and efficiences 1 and 2.

Efficiency 1 and efficiency 2 for soak-rolled and steam-rolled were not different, but for both treatments efficiences were significantly higher ($P < .05$) than those of the ground treatment. This shows that in spite of cows on soak-rolled treatment having the lowest milk production (Table 9), they converted their ration into milk on an energy basis as efficiently as steam-rolled. Because milk production on soak-rolled was significantly lower than on steam-rolled, this equal biological efficiency of production may not represent equal economic efficiency.

Production Responses

Means and standard errors for milk production, 4% FCM, percent fat, protein, and SNF, and yield of fat, protein, and SNF, and BW are presented in Table 10. The analyses of variance are in Appendix Tables 18 and 20.

Method of processing grain caused significant ($P < .05$)

Table 10. Least squares means (LSM)[a] and standard errors (SE) of milk production, and 4% FCM[b], fat, protein and SNF[c] percent and amount of fat, protein, SNF, and BW[d].

Item	Steam-rolled		Ground		Soak-rolled	
	LSM	SE	LSM	SE	LSM	SE
Milk (kg/day)	24.2[a]	.4	22.7[b]	.4	21.8[b]	.4
4% FCM (Kg/day)	23.0[a]	.4	21.2[b]	.4	21.7[b]	.4
Fat %	3.69[a]	.09	3.55[a]	.09	4.04[b]	.09
Protein %	3.48	.04	3.47	.04	3.42	.04
SNF %	9.02	.08	8.99	.08	9.20	.08
Fat (kg/day)	.88[a]	.02	.80[b]	.02	.86[ab]	.02
Protein (kg/day)	.83[a]	.02	.78[b]	.02	.74[b]	.02
SNF (kg/day)	2.17[a]	.05	2.04[ab]	.05	2.01[b]	.05
BW (kg/cow)	645.6	2.6	640.9	2.6	641.2	2.6

[a]Means in the same line with no common superscript are different at $P < .05$.

[b]Fat corrected milk.

[c]Solids-not-fat.

[d]Body weight.

differences in milk production, 4% FCM, percent fat, and amount of fat, protein and SNF. Cows on the steam-rolled treatment produced more milk, 4% FCM, and protein than those on ground or soak-rolled treatments. The lower milk production from the ground barley coincides with the results of Wilber (56) but partially disagrees with the results of other researchers (4, 49). The higher milk production of cows on steam-rolled grain is supported by the report of Williamson (57).

Percent fat was higher from cows on soak-rolled treatment than that of steam-rolled and ground. The lower fat percent on the ground and steam-rolled treatments agrees with Williamson (57) and partially (low roughage was used in the diet) agrees with the results of other researchers (4, 49) who used steam-rolled barley.

Amount of fat was higher from cows on steam-rolled than for cows on ground treatment, but there was no significant difference between soak-rolled and the other two treatments. Amount of SNF was higher from cows on steam-rolled than for cows on soak-rolled treatment, but there was no difference between ground versus the other two treatments. BW, percent of SNF and protein were not significantly different among treatments.

Although the steam-rolled barley treatment was lowest in percent fat and the ground and soak-rolled barley treatments were similar, the total amount of fat for steam-rolled was the highest because more milk was produced by the cows fed steam-rolled. The same was true for the amount of SNF and protein.

Interactions

LSM and SE for group by period interaction of BW, milk production, 4% FCM, amount of milk protein and DDM, efficiency 1 and 2 are shown in Tables 11 to 14. Their analyses of variance are in Appendix Tables 17, 19, and 20.

Table 11. Least squares means (LSM) and standard error (SE) for BW[a] for the different groups during the three periods.

Group	Period 1		Period 2		Period 3	
	LSM	SE	LSM	SE	LSM	SE
1	647.7	7.17	630.8	7.17	654.7	7.17
2	735.6	7.17	747.4	7.17	761.8	7.17
3	613.0	7.17	639.0	7.17	660.8	7.17
4	688.2	7.17	645.3	7.17	670.6	7.17
5	545.6	7.17	514.5	7.28	533.2	7.28
6	677.4	7.17	709.5	7.17	727.2	7.17
7	524.5	7.17	542.3	7.28	573.2	7.28
8	672.1	7.17	649.1	7.17	659.0	7.17
LSM	638.0	2.53	634.7	2.53	655.1	2.53

[a]Body weight in kg.

Table 12. Least squares means (LSM) and standard error (SE) for milk production for the different groups during the three periods.

Group	Period 1		Period 2		Period 3	
	LSM	SE	LSM	SE	LSM	SE
1	28.3	1.12	25.6	1.12	25.0	1.12
2	23.2	1.12	22.0	1.12	19.7	1.12
3	27.6	1.12	25.2	1.12	22.3	1.12
4	18.9	1.20	23.8	1.20	21.4	1.12
5	24.2	1.12	23.1	1.12	24.3	1.12
6	22.9	1.12	21.2	1.12	15.9	1.12
7	23.7	1.12	24.1	1.12	23.4	1.12
8	22.4	1.12	20.5	1.12	20.8	1.12
LSM	23.9	.40	23.2	.40	21.6	.40

Table 13. Least squares means (LSM) and standard error (SE) 4% FCM[a] for the different groups during the three periods.

Group	Period 1		Period 2		Period 3	
	LSM	SE	LSM	SE	LSM	SE
1	29.8	1.17	26.6	1.17	25.4	1.17
2	22.3	1.17	21.2	1.17	18.9	1.17
3	26.1	1.17	26.4	1.17	21.7	1.17
4	18.7	1.17	23.4	1.17	21.1	1.17
5	22.1	1.17	20.9	1.19	20.4	1.17
6	23.1	1.17	22.2	1.17	16.0	1.17
7	22.1	1.17	22.2	1.19	20.5	1.19
8	20.3	1.17	17.1	1.17	18.9	1.17
LSM	23.1	.41	22.5	.41	20.4	.41

[a]Fat corrected milk

The group by period interaction was significant for BW ($P < .01$). Generally two patterns for BW were observed. Four of the groups (groups 2, 3, 6, 7) showed continuous increase in weight from period 1 to 3. Groups 1, 4, 5, and 8 decreased in weight from the first to the second period, but increased in weight during period 3. Of these latter four groups only group 1 cows exceeded period 1 weights at the end of the trial.

As expected the groups that showed continuous increase in BW from period 1 to 3 coincided with the groups that showed low persistency, except for group 7 in which all

Table 14. Least squares means (LSM) and standard error (SE) for milk protein for the different groups during the three periods.

Group	Period 1		Period 2		Period 3	
	LSM	SE	LSM	SE	LSM	SE
1	1.00	.041	.93	.041	.91	.041
2	.85	.041	.76	.041	.69	.041
3	.91	.041	.85	.041	.77	.041
4	.64	.041	.84	.041	.75	.041
5	.75	.041	.74	.041	.77	.041
6	.80	.041	.75	.041	.59	.041
7	.81	.041	.76	.041	.78	.041
8	.71	.041	.67	.041	.74	.041
LSM	.82	.015	.79	.015	.75	.015

cows were first lactation heifers. The other groups (2, 3, 6) consisted of cows that were in their second, third, and fourth lactation.

The groups (1, 4, 5, 8) that showed continuous decrease in BW were the cows that were higher milk producers and more persistent producers. These cows were using all their nutrients for milk production rather than body weight gain during the first two trial periods.

The group by period interaction was significant ($P < .05$) for milk production, 4% FCM, and protein. The LSM of milk production of cows per period generally showed a tendency to decrease from period 1 to 3. Milk production decreased con-

tinuously from period 1 to 3 for four (1, 2, 3, 6), whereas the remaining four groups (4, 5, 7, 8) were more persistent in milk production. The 4% FCM and protein generally tended to decrease from period 1 to 3, except from cows in group 4 for 4% FCM and cows in groups 4, 5, and 8 for protein. These groups generally were those that were higher in milk production more persistent, and lower in BW in period 3 than in period 1.

LSM and SE for treatment by period interaction of feed consumed, DM consumed, DDM, efficiency 1 and 2 are presented in Table 15. The analyses of variance are in Appendix Table 17, 19. There were significant treatment by period interactions for all the above variables at $P < .01$.

Cows responded differently to treatments depending on which period they received each treatment. There was an overall (non-significant) tendency for feed and DM consumption to decrease from period 1 to 3, except for the steam-rolled treatment which increased as the experiment advanced. This overall tendency coincides with the milk production, 4% FCM, and milk protein.

Likewise, there was an overall tendency of DDM and efficiency 1 to decrease ($P < .01$), and efficiency 2 was non-significant from period 1 to 3. The DDM was highest in period 2. The efficiency 1 was higher for period 1 and 2 than for 3. The tendency for the DDM to decrease as the experiment continued followed the same pattern as DM consumption and DMD percent

Table 15. Least squares means (LSM) and standard error (SE) for feed consumed, DM[a] consumed, DDM[b], efficiency 1[c] and 2[d] for the following variables during the three periods.

Variable	Treatment	Period 1 LSM	Period 1 SE	Period 2 LSM	Period 2 SE	Period 3 LSM	Period 3 SE
Feed consumed	1[e]	29.9	1.90	31.7	1.90	24.8	1.90
	2[f]	36.4	1.90	24.3	1.90	29.9	1.90
	3[g]	24.6	1.90	31.3	1.90	32.8	1.90
	LSM	30.3	.69	29.1	.69	29.2	.69
DM consumed	1	20.8	1.30	21.8	1.30	16.9	1.30
	2	25.1	1.30	16.8	1.30	20.6	1.30
	3	15.2	1.30	20.1	1.30	20.8	1.30
	LSM	20.3	.46	19.6	.46	19.4	.46
DDM	1	14.8	.83	15.3	.83	10.1	.83
	2	17.8	.83	13.5	.85	13.4	.83
	3	9.2	.85	14.4	.85	13.1	.88
	LSM	14.0	.31	14.4	.32	12.2	.32
Efficiency 1	1	1.11	.069	.98	.069	1.40	.069
	2	.81	.069	1.50	.069	.82	.069
	3	1.59	.069	1.02	.069	.94	.069
	LSM	1.17	.024	1.17	.024	1.06	.024
Efficiency 2	1	1.58	.13	1.47	.13	2.24	.13
	2	1.10	.13	1.96	.13	1.31	.13
	3	2.52	.13	1.43	.13	1.54	.13
	LSM	1.73	.05	1.62	.05	1.69	.05

[a]Dry matter.

[b]Digested dry matter

[c]Kg 4% fat corrected milk/kg DM consumed/cow/day.

[d]KG 4% fat corrected milk/kg DDM/cow/day.

[e]Steam-rolled treatment.

[f]Ground treatment.

[g]Soak-rolled treatment.

(Table 8 and 9). The overall tendency of efficiency 1 and 2 to decrease as the experiment advanced followed about the same pattern as 4% FCM (see Table 11), DM consumed, and DDM. Since these variables are dependent upon each other, these tendencies would be expected to be similar.

Correlations

Correlation coefficients for all combinations of variables are presented in Table 16. Since milk production was highly correlated ($P < .01$) to 4% FCM and both have similar correlations with the remaining variables, relationships involving total milk production are equally valid for FCM in most cases.

There were positive ($P < .01$) correlations between total milk and kg of fat, protein and SNF and negative but non-significant correlations ($P > .05$) with percent fat and percent protein except that 4% FCM was positively correlated ($P < .01$) with percent fat. These indicated that the greater the amount of milk produced the greater the amount of fat, protein, and SNF produced, and that fat and protein decreased as milk production increased. Contrary to that which has been found by other researchers, as cows in this experiment produced more total milk, they slightly increased the content and amount of SNF (non-significant at $P > .05$).

There were positive ($P < .01$) correlations between total milk and kg of feed consumed, DM consumed, and DDM, except

Table 16. Correlation coefficients between the variables studied[a].

	4% FCM kg	Fat %	Fat kg	Protein %	Protein kg	SNF %	SNF kg	Feed consumed kg	Feed refused kg	DM consumed kg	DM refused kg	DMD %	DDM kg	Efficiency 1	Efficiency 2	BW kg[i]
Milk kg	.82	-.17	.61	-.15	.86	.02	.91	.47	-.11	.47	-.10	-.050	.37	.18	.22	-.21
4% FCM kg[b]		.37	.95	-.068	.75	.20	.82	.42	-.11	.41	-.10	-.089	.28	.38	.40	-.20
Fat %			.61	.10	-.10	.24	-.070	-.12	.0060	-.12	.0049	.097	-.076	.37	.25	-.0013
Fat kg				-.015	.58	.28	.66	.33	-.098	.33	-.092	-.087	.20	.43	.43	-.17
Protein %					.37	.23	-.039	.0055	.20	-.0022	.20	-.28	-.20	.0088	.15	-.15
Protein kg						.18	.85	.46	.0068	.46	.016	-.23	.25	.17	.30	-.29
SNF[c] %							.44	.24	-.15	.23	-.15	-.019	.19	.056	-.0030	.24
SNF kg								.51	-.15	.51	-.15	-.074	.41	.14	.21	-.11
Feed consumed kg									-.52	1.00	-.52	-.21	.76	-.60	-.42	-.022
Feed refused kg										-.53	1.00	-.12	-.50	.39	.41	-.53
DM[d] consumed kg											-.52	-.19	.77	-.61	-.44	-.020
DM refused kg												-.13	-.50	.40	.42	-.53
DMD[e] %													.46	-.022	-.51	.34
DMD[f] kg														-.54	-.72	.18
Efficiency 1[g]															.86	-.090
Efficiency 2[h]																-.25
BW																

[a]Any correlation coefficient /.232/ is significant at P .05.
Any correlation coefficient /.302/ is significant at P .01.

[b]Fat corrected milk.

[c]Solids-not-fat.

[d]Dry matter.

[e]Dry matter digestibility.

[f]Digestible dry matter.

[g]4% FCM/kg DM consumed/cow/day.

[h]4% FCM/kg DDM/cow/day.

[i]Body Weight.

for 4% FCM with DDM ($P<.05$). All these indicated that total milk production increases when more feed and thus DM or DDM is consumed. Likewise, there were non-significant negative correlations between total milk production and kg of feed refused and DM refused indicating that cows which produced less milk had adequate opportunity to consume feed.

There were significant ($P < .01$) positive correlations between 4% FCM and feed efficiency 1 and 2 although the correlations between efficiency and total milk production were not significant. The difference in significance between milk and 4% FCM reflects the influence of the adjustment for the fat energy content in the latter as it relates to efficiency 1 and 2. The significance of the two feed efficiencies indicate that as cows produce more 4% FCM the feed efficiency tends to increase.

The BW of the cows showed a non-significant negative correlation with total milk production, indicating that when cows produce more milk their BW normally decreased, or their weight gains were lower than for cows that produced less milk.

There was a high negative correlation ($P < .01$) between feed efficiency (1 and 2) and kg of feed and DM consumed and DDM. This was because a decreasing proportion of geed was converted to milk and thereby lowered the feed efficiencies.

Cows showed non-significant negative correlation between BW and feed consumed, DM consumed, DDM, and total

milk production. This and the fact that feed consumed, DM consumed and DDM showed positive correlations to total milk production, indicated that as cows increased DM consumption more of this was used for milk production than for BW.

Feed efficiency 1 had a non-significant ($P > .05$) negative correlation with BW. Feed efficiency 2 had a significant ($P < .05$) negative correlation with BW. These indicated that as cows gained more weight they tended to be less efficient in converting feed to milk.

The DMD percent was negatively correlated (not significant) to the amount of feed consumed and refused and DM consumed and refused, indicating that the digestibility of the rations decreased as cows increased consumption of DM.

SUMMARY AND CONCLUSIONS

Summary

In an experiment to determine the effects of methods of processing barley on intake, production, digestibility and feed efficiency, twenty-four lactating cows were randomly assigned to 3 treatments within 8 each 3 x 3 latin squares with 3 periods of 21 days duration. Three processing treatments of barley were 1) steam-rolled, 2) ground (fine), and 3) soaked (soaked in water for approximately 24 hours, rolled, and fed within 48 hours). All rations were fed ad libitum and were comprised of 24% alfalfa hay, 16% corn silage. 35.5% barley, 12% whole cottonseed, 12% wheat bran, 0.3% salt, and 0.3% dicalcium phosphate on a dry matter (DM) basis. Electronic doors were used to collect individual feed intake data. Rations and feces grab samples were collected and analyzed chemically. Dry matter digestibility (DDM) was determined by acid insoluble ash. Body weights were taken every 2 weeks. Milk production was recorded daily and composition of milk fat, protein, and solids-not-fat (SNF) was determined twice a month. Production (kg/day) of milk, butterfat, protein, SNF; DM consumed (kg); DMD (%); and efficiency 1 (4% fat corrected milk (FCM)/kg DM intake); and efficiency 2 (4%FCM/kg digestible DM for rations 1, 2, and 3 were 24.2, 22.7, 21.8; 0.88, 0.80, 0.86; 0.83, 0.78, 0.74; 2.17, 2.04, 2.01; 19.8,

20.8, 18.7; 67.05, 71.05, 67.20; 1.16, 1.04, 1.18; 1.76, 1.46, and 1.83, respectively.

Method of processing barley caused significant differences ($P < .01$) for production of milk, percent fat, amount of protein, DDM, and efficiency 1 and 2. Furthermore, the method of processing barley caused significant differences ($P < .05$) for 4% FCM, amount of fat, and SNF, and DM consumed, but there were no significant differences for percent of SNF, protein, and DMD, amount of feed consumed and refused, DM refused, and BW. Treatment by period interactions were significant ($P < .01$) for feed and DM consumed, feed efficiency (1 and 2), and DDM. Group by period interactions were highly significant ($P < .01$) for BW and significant ($P < .05$) for total milk production and amount of protein. Correlations among all the variables were in agreement with those previously reported, except for the correlation of percent SNF with total milk production, which was positive, but non-significant ($P > .05$).

The cows fed ration 1 produced more total milk and protein than those on rations 2 and 3. There were no differences in feed consumed (as fed) among cows on the three rations. Cows on ration 2 consumed more DM than those on ration 3, but cows on ration 1 did not differ in DM consumption from those on either of the other treatments. Cows on ration 3 had the highest fat test, but showed no differences in the amount of fat produced compared to the cows on rations 1 and 2.

Cows on ration 2 had the highest percent DMD and DDM. These cows were lower in total milk production than ration 1 cows and were the highest in DM consumption and the least feed efficient. Additionally, since cows on ration 3 consumed less DM than those on ration 2, the former had high feed efficiency equal to cows on ration 1. This equal biological efficiency of production may not represent equal economic efficiency, due to the lower total milk production of cows on ration 3.

Conclusions

1. Steam-rolled barley is still one of the best choices in grain feeding for dairy cattle according to results on total milk production, and feed efficiency, observed in this study.

2. Ground barley was the least efficient feed studied. It was not the highest in total milk production, but had the highest DM consumption and percent DMD. These results may have been related to the fineness of grinding of the barley used in this experiment. Cows might have performed better on more coarsely ground barley.

3. Since soak-rolled barley had the highest butterfat test, was comparable to steam-rolled barley in feed efficiency, and could be relatively easy to adapt to on-farm practices, it is concluded that it offers, to some extent, promise as a practical on-farm method of grain processing.

Further research is recommended to optimize its processing cost, soaking time, degrees of sourness, molding and rolling, evaluation of the drained water, some management aspects through the whole year, and to compare it with cracked grain, and some other promising methods of processing grain.

4. It is recommended that further research include the measurement of volitile fatty acids in the rumen.

5. The inclusion of the AIA method to predict digestibility is encouraged because it is easy, economical and rapid. Care is needed in this analysis because of the small proportion present in feeds and feces.

6. Since economic success for the dairyman in the dairy industry is built on efficiency, it is recommended that such research should be done on the basis of economic efficiency.

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APPENDICES

Table 17. Mean squares (MS) from the analysis of variance for feed consumed, DM[a] consumed, and efficiency 1[b].

Source of Variation	DF	MS Feed Consumed	MS DM Consumed	MS Efficiency 1
Group	7	94.64*	43.12	.192
Cow:group (Error a)	16	29.10**	12.49*	.082**
Treatment	2	11.76	25.64*	.135**
Period	2	10.89	5.80	.103**
Linear	1	14.74	10.07	.160**
Quadratic	1	7.03	1.54	.047
Treatment x period	4	44.98**	21.77**	.184**
Error b	40	11.33	5.12	.015

*P .05.

**P .01.

[a]Dry matter.

[b]4% fat corrected milk/kg of DM consumed/cow/day.

Table 18. Mean squares (MS) from the analysis of variance for percent fat, fat, percent protein, percent SNF[a], SNF, feed refused, and dry matter refused.

Source of Variation	DF	MS fat %	MS amount of fat	MS protein %	MS SNF %	MS amount of SNF	MS feed refused	MS DM refused
Group	7	1.41	.159*	.279**	.358	.439	2.77	1.30
Cow:group (Error a)	16	.756**	.044**	.068	.174	.360**	1.16	.626
Treatment	2	1.54**	.046*	.024	.323	.169*	2.98	.804
Period	2	.139	.098**	.077	.094	.193*	25.15**	14.92**
Linear	1	.159	.169**	.108	.132	.375	49.45**	28.38**
Quadratic	1	.129	.026	.045	.056	.012	.843	1.46
Error	44	.175	.014	.046	.172	.059	3.27	1.53

[a]Soild-not-fat.

*P .05.
**P .01.

Table 19. Mean squares (MS) from the analysis of variance for DDM[a] and efficiency 2[b].

Source of Variance	DF	MS DDM	MS Efficiency 2
Group	7	29.86*	.431
Cow:group (Error a)	16	8.60**	.230**
Treatment	2	36.50**	.843**
Period	2	28.63**	.069
Linear	1	32.45**	.018
Quadratic	1	24.81**	.121
Treatment x period	4	13.59**	.431**
Error b	35	2.10	.052

[a]Digestible dry matter.

[b]4% fat corrected milk/kg DMD/cow/day.

*P .05.

**P .01.

Table 20. Mean squares (MS) from the analysis of variance for percent DMD[a].

Source of Variation	DF	DMD %
Group	7	21.86
Cow:group (Error a)	16	60.14
Treatment	2	113.11†
Period	2	437.11**
Linear	1	350.80**
Quadratic	1	523.42**
Error b	39	35.98

†P> .10

[a]Dry matter digestibility.

*P .05.

**P .01.

Table 21. Mean squares (MS) from the analysis of variance for milk, amount of protein, BW[a], and 4% FCM[b].

Source of Variation	DF	MS Milk	MS Amount of protein	MS BW	MS 4% FCM
Group	7	42.10	.063	48385.28**	65.95
Cow:Group (Error a)	16	41.49**	.040**	5836.10**	28.38**
Treatment	2	30.87**	.044**	154.76	20.27*
Period	2	33.43**	.024*	2861.41**	48.87**
Linear	1	63.71**	.048**	3491.84**	88.02**
Quadratic	1	3.15	.00036	2230.99**	9.71
Group x Period	14	9.74*	.014*	868.04**	10.17*
Error b	30	3.79	.0051	154.04	4.13

[a]Body weight.

[b]4% fat corrected milk.

*P .05.

**P .01.

VITA

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