

FEEDING BARLEY TO CATTLE

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Abstract

Barley is a cereal grain that has demonstrated world-wide importance. Although generally considered an energy source, barley has more protein than other cereals commonly used in ruminant diets. Nutritional composition of barley can be affected by geographic location and climatic conditions. Varietal differences account for some of the differences observed in nutrient composition. However, it is thought that test weight has a more significant effect upon nutrient composition. Barley needs to be processed to be used effectively in cattle diets but the procedure need not be elaborate. Steam treatment of barley has a less pronounced effect than is observed with either corn or grain sorghum. Promising results have been obtained through chemical processing of whole barley, but such procedures are still in the experimental stage. Because barley has a relatively rapid fermentation rate it should be gradually introduced into cattle diets.

Introduction

Archeological evidence has shown that barley was one of the earliest cultivated cereal grains. Directions on how to successfully grow barley have been found inscribed on clay tablets dating from 1700 B.C. (42). Today barley is ranked third among feed grains cultivated in the U.S. (70). In Europe barley is the most widely cultivated cereal grain used in animal feed (117). Barley is a cool season plant and has been adapted throughout temperate growing regions by development of specific cultivars that matched local growing conditions. Extremes in climatic conditions have been observed to alter the nutritional composition of barley, but with careful management all barley can be used as livestock feed (54). Feed use of barley may account for 50 percent or more of total consumption. Exports are variable and usually less than domestic use. In the U.S. barley is used as the major cereal component in beef and dairy diets throughout much of the Great Lakes region, the northern plains and mountain states, the northwest coast and Alaska.

Because barley contains a large proportion of starch it is used primarily as an energy source (82). Compared to most other grains barley has more protein and important vitamins and minerals. By-products generated during the brewing and distilling processes offer high quality and are widely used as feed ingredients. The barley plant can be made into whole-plant or head-chop ensilage. The straw and chaff left after grain harvesting can be used as roughage (fiber) sources for ruminants.

Nutritional Value of Barley

Starch is the major constituent of the barley kernel and its percentage is inversely related to protein content. Expressed on a dry matter basis barley has 7.5-18% protein and a total digestible nutrient (TDN) value of 80-84%. Varietal differences, soil fertility and climatic conditions have

all been found to influence the protein content. High levels of soil nitrogen provide for increased protein content. Low to moderate protein content is preferred by malsters. Barley with an unacceptably high protein content for malting can still be used by livestock feed manufacturers. When balancing diets for ruminants the nutritional composition of all feedstuffs used should be carefully considered. A cost advantage may be provided when barley is included as an ingredient.

Energy

Suleiman and Mathison (110) evaluated the net energy gain (NEg) values of barley diets fed to cattle. In summer feeding trials the average NEg content of barley was found to be 1.39 Mcal/kg of dry matter. NRC (85) NEg values for barley grain and Pacific Coast barley grain are 1.40 and 1.45 Mcal/kg of dry matter, respectively. All feeds have lower NEg values in winter weather, and barley is no exception. Suleiman and Mathison (110) obtained a mean NEg value of 1.03 Mcal/kg of dry matter for barley. NRC (84) estimates the net energy lactation (NEL) values for barley are 1.94 and 1.99 Mcal/kg of dry matter for barley and Pacific coast barley grain, respectively.

Seasonal variation has no major effect on the net energy maintenance (NEm) content of barley (110). They estimated the NEm content of barley to be 1.82 or 1.91 Mcal/kg of dry matter depending upon the analytical method used. These values were similar to those reported by NRC (85) for barley grain and Pacific Coast barley grain, which were 2.06 and 2.12 Mcal/kg of dry matter, respectively.

The majority of energy in cattle finishing diets is supplied by starch. It is therefore important to identify the site where starch is digested and to quantify the extent to which it is utilized. Diets prepared using grain sorghum had total tract digestion values which were lower than those obtained when corn, barley or wheat were used. The values were 72%, 83%, 84% and 88% respectively (86). Results from steer feeding trials showed that total tract digestibility of dry processed barley or corn was greater than dry processed grain sorghum; 79% and 81% vs. 76% (105). Total tract starch digestion was observed to be greater for steers fed barley or corn when compared to those fed grain sorghum; 99.2% and 99.1% vs. 97.2%. Maximum total tract digestion of starch and other organic matter is related to the rumen degradability of those components (106).

Although digestion of starch in the small intestine is more efficient than digestion in the rumen, the capacity of the small intestine is limited. Grain sorghum can be expected to have a greater amount of starch entering the small intestine. The percent post-ruminal starch digestion for grain sorghum is lower than for barley and corn, but total grams digested post-ruminally per day is greater (105).

Investigations have been done on slowing the digestion rate of barley by treating it with formaldehyde (76). Such treatments may reduce some of the bloat-acidosis problems sometimes associated with feeding high levels of barley.

Steam processing may alter the site of digestion for grain sorghum and corn but does not appear to significantly affect the site of barley digestion. Rumen organic matter digestibility is greater for dry rolled or steam flaked barley versus dry rolled corn and grain sorghum; 61.7% vs. 48.5 and 42.6% (104). However, total tract organic matter digestibilities were not different; 78.8%, 83.8% and 80.7%, respectively.

Protein

Compared to corn, barley has more protein and fiber with slightly less metabolizable energy and total digestible nutrients. Generally, increased protein and fiber contents result in decreased energy content. Protein content of most barley grain ranges from 7.5 to 17% on a dry matter basis with 75% of that protein being digestible. However, protein levels in excess of approximately 13.6% dry matter may not substantially increase the value of barley to livestock feeders (67) if other feed ingredient costs are held constant.

The major feed ingredients included in cattle finishing diets are also the primary sources of dietary crude protein. Spicer et al. (107) observed that total tract digestion of crude protein was less for grain sorghum based diets than for either corn or barley diets; 62.4% vs. 66.6 and 68.4%, respectively.

Fiber

The NRC (84) lists crude fiber values of 5.7 to 7.1% for barley. Fiber levels in barley are normally greater than those of grain sorghum or corn. Some authors have indicated that this extra fiber may be of benefit in feeding lower amounts of roughage. However, the faster fermentation rate of barley may somewhat reduce its use as an effective fiber source. Weiss (122) observed that dairy cows fed a grain based concentrate mix of corn or barley had similar dry matter intakes, milk production and fat-corrected milk (FCM). Both diets were similar in neutral detergent fiber (NDF), but the barley diets tended to depress milk fat production. Thomas et al. (112) also observed a reduction in digestibility of ADF when barley was fed with silage. One may be able to reduce milk-fat depression by adding feeds such as alfalfa pellets, beet pulp or oat hulls (6). Nutritionists should utilize barley's beneficial aspects as a high energy source and relatively high protein grain but not depend on it as a totally effective fiber source.

Vitamins

Barley, like corn, lacks sufficient carotene. One can meet the requirements by feeding supplemental vitamin A or injecting it. The vitamins which should be considered in cattle production are vitamin A, perhaps vitamin D in confinement situations with no sunlight, vitamin E, thiamine, and niacin.

Minerals

Barley, corn and grain sorghum are low in calcium content. However, barley contains more phosphorus than corn or milo (85). The primary need for supplemental macrominerals will be calcium. Potassium levels should also be evaluated. Barley is low in several trace minerals, but

requirements can usually be met by providing trace mineral salt. Trace mineral deficiency is principally a geographical problem and consultation with soils experts and nutritionists in specific areas is necessary to determine if supplementation is necessary and what type of supplementation is needed. Fortifying diets with vitamin E, choline, zinc and sulfur did not improve the performance of cattle finished on high-energy rations based on dry rolled barley and a standard supplement (22). However, cattle requirements for these nutrients have changed since this study was done due to livestock genetic selection for growth.

Test Weight and Effect on Quality

The nutrient composition of barley is variable. This variation may be caused by geographic location, year of production and variety (cultivar). Thin kernels may result from unfavorable environmental conditions or plant diseases. Extremely hot weather during maturation results in premature ripening and prevents normal filling of the kernels. Lack of available soil moisture may limit the nutrient supply and cause shrunken kernels. Wet springs can delay planting, which results in light test weights. Kernel weight, hectoliter weight or bushel weight, percent plumpness and the presence or absence of hulls are all related to nutritional quality.

The price of feed barley has traditionally been based on test weight. As test weight decreases fiber content increases and the energy decreases. Thomas et al. (113; 115) reported reduced animal performance in animals fed barley that had a test weight of 60.1 kg/hl compared to barley with a test weight of 66.8 kg/hl. Hinman (46; 49; 50) used barley with test weights that ranged from 56 to 68 kg/hl and observed reduced gains for feedlot steers fed the lower test weight barley. Mathison and Milligan (73) observed similar gains for steers fed barley with test weights that ranged from 46.1 to 68.2 kg/hl. However, feed efficiency favored the heavier test weight barley. Steers fed the light test weight barley required 4% more feed per unit gain than those fed medium or heavy barleys, but the difference was not significant. Hanke and Jordan (40) reported that heavy test weight barley produced faster and more efficient gains in young lambs than light test weight barley.

Variety Effects

Plumper barley is generally higher in starch and lower in fiber and two-row varieties usually produce larger kernels than six-row types. Other than plumpness, there are no major differences in physical or chemical properties between two-row and six-row barleys (9). Hinman (47) and Hinman (48) used Klage, a two-row malting barley, and Steptoe, a six-row feed barley, to compare malting versus feed barley varieties on beef cattle performance. The Steptoe had a test weight of 630 g/L as compared to the 700 g/L for Klage. Barley with a higher test weight should have a greater percentage of starch or energy in the kernel. The barley was steam rolled and fed as 81% of the diet. Both diets produced similar average daily gains. Although not significant, the Klage fed steers tended to eat less but were more efficient. The differences in efficiency were contributed to the difference in test weight as much as to differences in variety.

Preston and Herlugson (96) fed two cultivars (Steptoe and Boyer) to yearling steers. Test weights of the Steptoe and Boyer barleys were similar. Statistical analysis of interaction between the physical form of the barley and roughage level indicated improved rate of gain when steam

rolled barley was compared to whole barley when 5 or 15% roughage was included. However, there was no improvement observed when 25% roughage was included. The two varieties provided similar results when steam rolled. Boyer had a 10 to 12% advantage over Steptoe with regard to rate of gain and feed efficiency when both were fed as whole grains. When whole grain Boyer barley was fed in conjunction with 25% roughage it produced a slightly greater average daily gain than did steam rolled Boyer barley fed at the same roughage level.

Based on the preceding information, there appears to be some varietal difference. However, differences in performance may also be due to test weight variation. Therefore, test weight should always be considered when purchasing barley from various sources. Information supplied from one area to another may not be applicable because geographic variation is more pronounced in barley than in corn (25). Most of the barley produced in North Dakota is six-row and is used for malting or feeding. In Montana and Washington barley production is predominately two-row feed varieties. In the southwest and in California six-row is preferred. The designation "feed barley" does not always identify a particular variety. The term "feed barley" may only mean barley that is not suitable for malting, regardless of variety.

Determining Quality and Value of Barley

The market price of a grain commodity is an excellent indicator of value for the farmer, but it is only the initial reference for cattle producers. Cattle ingest barley and other grains, but they gain weight or produce milk based on the amount of protein and energy contained in the grain. Therefore, animal feeds should be valued according to their dollar value and their nutritional value.

Three pieces of information are needed to determine the value of barley. First, the prices of the various grains must be collected. Second, estimates of the nutritional value of the grains must be assigned. Third, prices and nutrient contents of the other feedstuffs used in the diet need to be known. A computer program that has a least-cost ration balancing function is the best way to utilize all this information. Such computer programs can be used to determine the least expensive diet that fulfills the nutritional requirements of cattle. Most existing computer programs do not account for the negative associative effects that grains and roughages have when fed together. These can become important when deciding whether to supplement a roughage based diet with grain or a protein supplement.

Processing Barley

Grain processing has become synonymous with modern cattle feeding operations. Feed can be the single most costly item in cattle production, representing 70 to 80% of the total cost of gain. Most processing methods have been developed to improve starch and protein availability.

Feeding Barley Whole

Consumption by cattle of feed containing whole barley grain will be greater than consumption of feed containing ground or rolled barley, but gain will be at a slower rate and thus less efficient (2; 95). It appears unlikely that the proportion of forage in the diet would influence the relative

efficiency of utilization of whole or rolled barley. Broadbent (12) used diets which had 37% roughage and observed greater gains in cattle fed rolled barley when compared to whole barley. Ahmed et al. (1) observed similar results using a diet which contained 54 to 64% forage.

Variation in performance of cattle fed whole barley is primarily due to differences among animals as regards their ability to masticate and digest whole grain. Morgan and Campling (78) suggested that whole grain oats were better utilized because more whole oats than whole barley could be transported to the mouth during regurgitation due to the lower specific gravity of oats and thus their positioning within the rumen. Nicholson et al. (83) suggested that small ruminants had a smaller reticulo-omasal orifice which restricted the flow of whole grain. Larger ruminants do not appear to have this problem.

More needs to be done with feeding whole barley to veal calves. Latrille et al. (68) observed veal calves fed a milk replacer combined with either whole corn or whole barley concentrates had similar performance.

Grinding and Rolling

Grinding and rolling are processes used to reduce the size of whole grains. The physical forces employed include: impact to create fractures; abrasion/attrition to scrape off material; shear to slice apart; and pressure to crush (deform) structure. Particle size reduction is important to the feed industry for the following reasons. First, particle size reduction increases surface area, which leads to improved utilization of grains through increased exposure of endosperm material to digestive enzymes. It is estimated that only about 60% of the starch in whole (unprocessed) grains is digested. Second, particle size reduction provides improved mixing characteristics of dissimilar feed ingredients. Third, particle size reduction of ingredients prior to pelleting produces improved pelleting efficiency through increased pellet durability and reduced energy consumption. Fourth, particle size reduction provides improved acceptability and handling of fibrous feedstuffs.

In the livestock feed industry the most common type of equipment used to reduce the particle size of grains is the hammermill. Size reduction is accomplished by using gravity or mechanical flow to position grain kernels within the primary contact zone of spinning hammers. The hammers are attached to a rotor which spins within a screen. The physical forces of impact, shear and abrasion are used. Hammermills operate at relatively high speeds. Hammer tip speed is governed by the speed of the rotor and the diameter from hammer tip to hammer tip across the rotor. Rotor speeds of 1,800 to 3,600 rpm are common, with diameters of 61 to 122 cm. Thus, hammer tip velocities range between 3,450 to 13,800 m/min. Hammermills are better suited to fine grinding.

Roller mills rely on the forces of pressure (crushing) and abrasion to reduce particle size. They do not have any effect on fibrous material. Gravity flow is used to pass grain kernels between rotating rolls. The degree of size reduction depends on several factors. First is the relation of kernel size (diameter) and the distance between the rolls (nip). Kernel diameter must be slightly greater than nip distance, so uniformity of the kernels is important. Second, the rolls may turn at different speeds (differential). This in conjunction with various types of surfacing cuts

(corrugation) helps pull kernels into the nip. The corrugations for coarse rolling are three to six grooves per inch. Third, pairs of rolls may be placed on top of one another, so that as pieces exit the nip of the first set of rolls they fall into a narrower nip of the set below. This practice allows for greater control over the degree of size reduction and provides greater flexibility to the system. Two and three high roll stands are common in the feed industry.

Each device has advantages and disadvantages. Roller mills provide a more uniform distribution of size and produce fewer fine particles, but they do not work on fibrous material. Hammermills offer the greatest control over degree of size reduction because screens having different sized openings can be used. Roller mills are less costly to purchase, operate and maintain. Foreign material (ferrous metal and stones) will cause damage to both. The danger of fire or explosion is perhaps greater for the hammermill because it generates more dust and fine material.

Increased surface area is the final result, and the cost of attaining that increase is the ruler by which success is judged. Digestibility of all constituents except cellulose was found to be increased by rolling (79). Dry rolling is faster and requires less energy than grinding. May and Barker (75) found that it was profitable to mill barley when the unit value of the feed exceeded by 2.16 times the unit cost of milling. Kreft and Boyles (65) observed that whole barley was not competitive with ground barley until the cost of processing increased to \$37 per ton. Currently the cost of rolling or grinding barley is between \$2 and \$5 per ton.

A conscientious manager will obtain the same results from either ground or rolled barley (126). The production of fines is less likely with rolled barley than ground. A more uniform particle size is obtained from rolled barley. Breaking the kernel into two to three grits is acceptable. May and Barker (75) ground barley through a 9-mm screen, which produced grains that were cracked and kept production of fines to a minimum. Hawthorne and Fromm (43) used a hammermill with a 9.5 mm screen. Bettenay (8) produced ground barley with two to three pieces. Putnam and Davis (98) found that when particle size of hay was .38 cm gains were best when rolled barley was fed. However, when the particle size of the hay was 3.8 cm gains were best using ground barley.

More fines than normal can be generated when barley of relatively low moisture content is ground through the size of screen commonly used in the feed industry. This can be avoided by operating grinders at a slower than normal speed, which prevents the kernels from shattering into fine particles. Barley that contains more than 25% fine particles may cause digestive disturbances. Adding higher moisture feeds such as silage, molasses (5%) or fat (3%) to the rations will help hold the fines in suspension. Adding approximately 8 percent water prior to feeding may reduce the problem with fines if high moisture feeds are not available.

The temperature of the grain is increased by 1 to 6° F during grinding or rolling. The greatest temperature increase is observed in the grinding process, which can cause shrink (loss of weight by driving off moisture). The amount of shrink can be controlled through proper system design. Loss of more than .5% would be considered unacceptable in most feed manufacturing operations.

Pelleting

Pelleted barley diets have not demonstrated improved performance in ruminants (13; 24; 30; 31; 40; 121). Feeder lambs produced gain in less time and were more efficient when fed whole barley rather than rolled or pelleted barley (30; 40). The destruction of the barley hull during pelleting may coincide with increased acidosis and bloat problems. Whole barley can be pelleted when a die aperture of approximately 1 cm is used (123).

Moist Processing of Barley

Potential advantages may be offered when moisture is added to or retained by barley. There would be less destruction of the hull and reduced likelihood of acidosis/bloat. This may explain why pelleting barley for cattle is discouraged. Barley should normally be rolled at about 16% moisture (97). However, barley should be reduced to a moisture content of 12 to 14% for storage. Moisture can be added back to barley by injecting water immediately before rolling or allowing the barley to soak for 24 hours prior to rolling. It has not been established that adding moisture back to dry barley will improve nutritive value (14). For rolling it is probably best to store high moisture barley under anaerobic conditions, thereby minimizing damage to the hull (97). However, such a practice would preclude the sale of the grain as a dry commodity.

High Moisture Barley

High moisture barley is more readily accepted by beef cattle than dry barley (94). High moisture barley should improve the feed efficiency of cattle compared to feeding dry barley (64). The main reason may be that cattle go on feed faster and have fewer digestive upsets (23; 124). Perry (94) quoted a Minnesota report in which cattle fed high moisture barley gained 8.6% faster and required 9.3% less feed per unit of gain than cattle fed dry rolled barley. Windels et al. (124) and Krall (63) reported improved gains and feed efficiency for steers fed high moisture barley instead of dry ground barley. Kovic'ko et al. (62) observed a 4.6% improvement in gain of beef bulls fed high moisture barley compared to dry rolled barley. However, Ingalls et al. (57) observed slightly lower milk production in dairy cows with high moisture barley compared to dry barley.

Ensiling high moisture barley is not a common practice (23). High moisture barley cannot be stored in bins and the producer becomes committed to feeding the barley. However, there may be advantages if barley is harvested when the kernel moisture exceeds 20%. Under such practices: harvest season would be extended; hail risk would be reduced; the swathing operation could be eliminated; assistance in weed control would be offered; shattering losses would be reduced; reduced production of dust; early tillage might be possible and yields might be increased.

It is generally recommended to process the grain prior to storage except in oxygen limiting silos. In general, to reduce spoilage upon exposure to air, moisture levels should be higher than 25%. Krall and Thomas (64) observed that crushing the kernel prior to ensiling enhanced the process. Research has been conducted with plastic-lined grain storage bins. However, some difficulties have been encountered when removing the stored barley from such bins without disturbing the seal (23).

To roll high moisture barley, some adjustment of the rollers is needed and the use of scrapers on the rollers is recommended. The roller tension requirements are generally less than with dry

grain. Problems can be reduced if tension against the rollers is loosened to a point where the barley is nearly whole, then tightened until a level of flaking occurs. Smooth rollers offer improved performance.

Hammermills and burr mills can be used to process high moisture grain, but dough may collect on the screens after prolonged use. If a pneumatic system is used to move the processed grain larger than normal fans may be needed, but a dust collector is not required (63).

Stability of aerobically stored high moisture barley is relatively brief (58). High moisture grain will spoil in about three days, so it does not lend itself to self-feeding. When stored as whole grain, processing on a daily basis is recommended.

Grain preservatives have been investigated as an alternative to ensiling or drying high-moisture grain (34). Propionic acid treatment did not provide improved feed value or increased storage life to ensiled barley (62). However, Flipot and Pelletier (29) suggested that storing high moisture barley with a preservative could extend the harvesting period. Mathison et al. (71) observed that barley treated with anhydrous ammonia (1%) enhanced performance of feedlot cattle. It is thought that ammonia slows the rate of fermentation (100). Sulfur dioxide proved satisfactory in inhibiting mold, yeast and aerobic bacteria in high moisture barley but had no impact on animal performance (71). However, Mathison et al. (72) could not recommend sulfur dioxide as a preservative for high-moisture grain since it did not preserve grain in all instances and can have a detrimental effect on the performance of cattle. Rode et al. (100) concluded that ammonia and to a lesser extent urea could be used to increase the digestibility of whole high-moisture barley. Neither ammonia or urea alter the digestibility of rolled high moisture barley. Therefore, various additives may reduce spoilage but physical processing is needed to maximize digestibility.

Tempering

Soaking for 24 hours prior to rolling increased the feed value of barley (52). Tempering was accomplished by adding water at 10% of barley weight, mixing in a horizontal mixer, and storing in a bin for 24 hours prior to rolling. An 8% increased rate of gain that was accompanied by a 5% increase in feed intake were observed for tempered barley. Feed efficiency favored wet rolled barley over dry rolled barley by nearly 2.5%. Hinman and Combs (51) reported that during the grower phase cattle fed tempered rolled barley gained faster than those fed dry rolled barley, while those fed steam rolled barley were intermediate in performance. Differences during the finishing phase were less pronounced, although steers fed tempered or steam rolled barley appeared to have improved performance.

Steam Rolling

Steam applied to barley before rolling has shown improved but not necessarily consistent effects on cattle performance. Steam rolled barley is produced by exposing barley to steam for three to five minutes and then rolling it. This process produces fewer fines than dry rolling or grinding. Parrott et al. (92) observed an interaction between processing and barley source when studying the digestibility of barley nutrients by cattle. Subjecting barley to low-pressure, high moisture steam for several minutes prior to rolling produced a superior feed for finishing cattle. Steam

rolled barley brought about increased feed consumption and gain, although feed efficiency may not change (36). Staley (109) indicated that steam rolled barley produced superior performance to ground barley in finishing cattle diets. However, Hoffman et al. (53) showed that ground barley was equal in feed value to steam rolled barley for feedlot cattle. Thomas and Meyers (114) reported that steam rolled barley produced slightly faster gains than dry rolled barley in one out of three trials. Similar results were found by Hayer et al. (44), who observed that steam preparation had no effect on the digestibility of protein or starch and that a higher level of volatile fatty acids occurred in rumen fluid of cattle fed dry rolled barley than cattle fed steam rolled barley. Garrett (32) confirmed the lack of effect by steam rolling on available energy of barley. Steam rolled barley contained 1.36 Mcal/kg of net energy for production compared to 1.38 Mcal/kg for ground barley. Steam rolled barley was not superior to dry rolled barley for dairy calves (102). Ralston et al. (99) found no significant differences between steam rolling and grinding.

Steam Flaking

Osman et al. (91) observed increased enzymatic starch digestion when barley was flaked using pressures of 1.4-5.6 kg/cm². Steam flaking caused disorganization of the starch granules and disruption of the protein matrices (27). Hale et al. (36) reported that steers fed steam flaked barley had higher rates of gain and improved feed intake when compared to those fed dry rolled barley. Waldern and Fisher (120) and Lima et al. (69) observed conflicting results for steam flaked barley compared to steam rolled barley with young dairy calves.

The two methods of steaming grains can be termed high pressure and low pressure. The low pressure method is accomplished by exposing the grain to low pressure, high moisture steam for 20-30 minutes and attaining temperatures of 95-99 C. The grain should then have about 15-20% moisture and is then rolled flat. The high pressure method involves the use of a pressure cooker in which the grain is subjected to moist steam at a pressure of about 3.5 kg/cm² for approximately three minutes. The heated grain is then flaked, or allowed to cool to 95-99 C and then flaked. Frederick et al. (28) suggested that optimum cooking pressure for grain sorghum and barley was 4.2 kg/cm². Approximately three minutes were required to reach the desired gauge pressure after which the grain is cooked for one to five minutes. Maximum digestibility of the flaked barley was reached at 22-24% moisture. More research is needed to determine the optimum time and temperature for barley. The authors of this paper were unable to find any data on the use of grain conditioners with barley.

The thinner the flake the better it will be utilized. However, when operated in a manner to produce optimum flake thinness the throughput (tons/hr) is reduced (127). As throughput is retarded retention time in the steam chest is increased. It is not known if longer steaming affects feed quality. Thinner flakes are also susceptible to shattering and thus may become smaller than desirable at the feed bunk. It is not known what the ideal flake thickness should be for barley.

Steam flakers can reduce or eliminate shrinkage. There is a 1 or 2% loss in weight when grains are ground or rolled, but steam flaking increases the weight of the grain by approximately 2%. Steam processing and flaking grains renders the starch fraction more available to rumen microorganisms and enzyme attack. Steam processing may not proportionally improve barley as

much as it does grain sorghum since barley has most of its starch digested in the rumen even without steam processing. However, many feedlot operators feel that steam flaking barley reduces management problems such as fines, improves palatability, and helps maintain cattle on feed. Steam flaking or extensive processing of barley will improve intake and gain but not necessarily feed efficiency (35; 92). The cost of steam flaking has come under scrutiny because of the propane or natural gas needed to fire the boilers. Steam flaking is approximately 2-3 times more expensive than dry rolling (51).

Chemical Treatment of Whole Barley

Chemical treatment of barley may be the future method of processing if energy costs continue to add to the cost of drying and mechanical processing (116). The reduction in intake of roughage can be alleviated to an extent by feeding whole cereals since the more stable rumen pH conditions allow survival of cellulolytic bacteria. While whole unprocessed grains are effectively digested by sheep, many whole grains pass intact through the bovine digestive tract.

Orskov et al. (88) observed that sodium hydroxide (NaOH) treatment reduced the rate of digestion and resulted in less interference with cellulolytic activity. NaOH application rate was 15, 25, 35 or 45 g/kg applied in a 32% solution and added in a feed mixer. The feed was mixed with NaOH for 30 minutes and left for seven days. The barley was then fed whole. Digestibility of dry matter and organic matter increased with increasing application rates of NaOH but responses were small at the highest levels used. Berger et al. (7) observed the digestibility of NaOH, treated whole barley *in situ* was increased compared to that of untreated ground barley. Thomas and Arnzen (116) observed that 3.5% NaOH treated whole barley had 28% higher dry matter digestibility than untreated whole barley. NaOH apparently ruptures the seed coat. The concentration 3.0-3.5% (25-35 g/kg) NaOH was found to be sufficient when cereals form the entire diet. It is quite likely that the concentration of NaOH required when roughages are fed may have to be increased.

Orskov and Greenhalgh (90) found that spraying whole barley with a solution of water and NaOH at a rate of 10-60 g NaOH per kilogram of barley was an acceptable process when feeding barley in conjunction with roughages. Orskov et al. (89) observed calves receiving alkali treated whole grain (35 g NaOH/kg) ate more hay than those receiving torried grain or grain subjected to crimping, rolling or pelleting. Calves on pelleted grain ate less than those getting rolled, crimped or torried grain. There was more acetic acid produced in the rumen with NaOH treated barley.

Sriskaularajah et al. (108) fed 30 g NaOH/kg of whole barley to grazing lactating cows. A 25% NaOH:75% H₂O solution did not cause reduced palatability and inflammation of the mouth compared to a 50% NaOH:50% H₂O solution. The experimenters observed that the grain became hard after spraying unless it was turned twice during the first 24 hours after spraying. There was a smaller effect on rumen pH with NaOH treated barley, therefore maintaining cellulose digestion. Incremental response to rolled and NaOH treated barley were 0.38 and 0.54 kg milk/kg of grain. Milk production response to NaOH was greatest during early lactation. Kung et al. (66) observed milk persistencies tended to be greater for cows fed high moisture rolled barley and least for NaOH treated barley.

Moran (77) reported a variable response of whole barley to alkali treatment with NaOH. Despite the benefit of NaOH treatment of cereal grains in terms of improved milk production, such procedures involve handling large quantities of corrosive NaOH. One must also cope with solidification of grain and internal heating of grain stores. But of greater long term significance is the higher incidence of kidney lesions (nephritis) in dairy cows on NaOH treated grains. Ammonium hydroxide may be a better alternative for dairy cattle.

The Effect of Barley on Forage Digestion

Grain supplementation will be most appropriate when protein content of the forage is already high or when protein supplements alone will not raise the energy content of the total diet to the necessary level (60). Bohman et al. (10) observed that a protein-phosphorus supplement was more effective than barley for calves on semi-desert range. Orskov (87) indicated 20 to 30% added grain normally causes little or no depression in intake and digestibility of roughage, but a higher proportion can depress intake to such an extent that it is no longer a supplementation but rather a substitution.

Both corn and barley have negative effects on digestibility of fiber contained in forages. Brake et al. (11) fed dairy steers receiving either orchardgrass or bermudagrass hay, barley (1.07% of body weight) or corn (1.00% of body weight). Total dry matter intake was higher with grain supplementation than without. However, hay dry matter intake was depressed by grain supplementation. Total organic matter digestion was greater for supplemented diets, but total neutral detergent fiber (NDF) digestion was greater without grain supplementation. Corn depressed NDF digestion more than barley. Dry matter intake was increased more by barley than by corn, probably because barley improved the nitrogen or protein status of the animal to a greater extent.

When cows were given a 70% hammermilled barley diet (DM basis), rumen pH declined to a minimum value of 5.4 by six hours after feeding (119). Rumen ammonia-nitrogen concentrations were also lower for the barley diet compared to lupin, pea and faba beans. Both these factors contribute to depression in fiber digestion for barley diets.

Barley did not depress hay digestibility when it was given with hay diets containing bicarbonate (66% NaHCO₃: 24% KHCO₃) as 3.5% of barley dry matter (81). Negative associative effects could be avoided if rumen pH is maintained above the level inhibitory to cellulolysis. It was suggested that this could partially be achieved by offering roughage in long form (increased saliva:increased buffering) to maintain a rumen pH of 6.7.

Supplementing beef cows grazing winter range is a costly procedure. Reducing these costs requires supplemental practices that meet nutritional requirements while maintaining forage utilization. Supplements of alfalfa cubes, 30% cottonseed meal, or 50% barley cake can be fed to meet half of the crude protein requirement (20) Both improve performance compared to no supplement. Similarly, Harris et al. (41) improved the performance of ewes on winter range and did not reduce forage dry matter intake with a soybean meal-barley pellet compared to no supplement. A supplement of peanut meal had no advantage over barley when an ample supply of herbage of high crude protein was available (17). In general, it appears protein

supplementation of forage diets low in crude protein (< 6%) usually increases intake (18). Effects of protein supplementation on diets containing 6 to 8% crude protein are variable. Incorporating a protein supplement with barley may assist with maintaining the digestibility of forage-based diets.

Barley and Silage

Aston and Tayler (4) observed barley increased gains, intake and dry matter digestibility of corn and grass silage. Barley is an excellent supplement to clover silage for lactating dairy cows (16). Grass silage supplemented with barley reduced the amount of ruminal ammonia but increased the amount of bacterial protein (19). Pectchez and Broadbent (93) observed steers fed a total mixed ration of barley and silage had 8.9% greater intake than steers fed barley and grass silage separately.

Barley and Alfalfa

Cattle tend to bloat more on barley-based feedlot diets compared to other cereal grains, especially when barley is fed with alfalfa hay. It is preferable to feed a 70:30 or 30:70 mix of barley and alfalfa than a 50:50 mix. However, Embry et al. (26) reported bloat problems with only 15% alfalfa compared to using prairie or bromegrass hay. These problems can be reduced by blending barley with other grains such as oats, corn or grain sorghum. Feeding an alfalfa-grass hay mixture instead of pure alfalfa hay should further reduce problems of bloat. Probably the best method of reducing bloat problems on a barley-alfalfa hay diet is to include an ionophore.

Windels et al. (125) observed no particular problems of feeding barley with alfalfa haylage. However, Windels et al. (124) observed bloat to be a serious problem on dry-ground barley diets and alfalfa haylage but of minor importance in cattle fed high moisture barley and alfalfa haylage.

Barley versus Grain Sorghum

Barley is often competitively priced with grain sorghum for producers in the western U.S. and Mexico. Hale et al. (39) reported a series of trials in which barley resulted in a 5% increase in daily gain and a 9% improvement in feed efficiency compared to grain sorghum. These data were confirmed by further studies reported by Saba et al. (101); Keating et al. (59); Kercher and Bishop (61). However, Garrett et al. (33) observed similar performance for feedlot steers fed a 70% concentrate diet of barley or sorghum. Hale et al. (38) concluded that steam rolled barley was superior to steam rolled grain sorghum. Steam flaking grain sorghum will greatly improve feedlot performance.

Barley and Grain Sorghum

Hale et al. (37; 38) observed improved gain and feed efficiency in feedlot steers fed a combination of 25% barley and 75% grain sorghum compared to 100% grain sorghum as the only source of grain. Garrett et al. (33) found no advantage in animal performance when feeding

a 50:50 mix of barley and sorghum compared to all barley or milo as the concentrate portion of the diet. A portion of the complementary effect of certain grain mixtures may be due to an improvement in starch utilization.

Barley versus Corn

There is no question that corn is an excellent feed grain. However, barley is frequently competitively priced. Barley is often given a feed value of 90% that of corn. If corn is assigned a net energy value of 100, the net energy value of barley is 90.3. This is based on its energy content and does not take into account the additional amino acids (45). Protein can be very expensive to supplement. Barley is higher in phosphorus than corn. In addition, the phosphorus in barley is more biologically available than phosphorus in corn.

Corn is higher in net energy than barley (85). However, there are cases in the literature where barley is of equal feed value to corn (25; 74). Barley can be equal to corn when it is included as between 40 and 60% of the concentrate mixture for dairy cows. Feeding corn or barley to dairy cows did not affect milk composition (21). Apparent digestibility of dry matter and energy was not different but fiber digestibility was significantly lower in the barley diet; milk production was not affected.

Tyrell and Moe (118) evaluated the net energy value of corn and barley in lactation rations. The results of their study demonstrated the net energy for lactation was higher for corn but that the net energy value of both barley and corn decreased as intake increased. They concluded that the efficiency of use of digestible energy for milk production was not affected by energy sources.

Barley and Corn

Moss (80) observed no differences between barley, corn and 50:50 mixes for milk and butterfat production. The barley diets also required less protein supplementation. Daily gains and feed efficiencies of whole corn and rolled barley may not significantly differ. Anderson and Boyles (3) determined that price of grains and supplements is more important in choosing various blends of corn and barley than feedlot steer performance. Corn-barley mixes provided greatest return and minimized feed cost although similar in performance (15). Hill and Utley (45) compared corn fed alone to a corn-Kline barley mix diet for heifers. Average daily gain was similar (1.28 kg/hd/d) but feed to gain appeared to favor the barley-corn diet (6.7 vs 7.2).

Barley and Molasses

The addition of 5% molasses to a barley based diet may assist with starting cattle on feed but does not significantly improve performance if left in the diet for the entire feeding period (26). Therefore, other than for the apparent advantage of getting cattle to a full feed, molasses at 5% of the ration would not appear to be an economical addition to rolled barley unless molasses costs no more per pound than barley.

Frost Damaged or Sprouted Barley

An early frost and moderate rainfall during harvest can lead to a damaged barley crop. Frost and sprouting produces changes in the composition of barley. In general, the proportion of crude fiber, ash and crude protein in the grain increases and the proportion of carbohydrates decreases. Neither frosting nor sprouting should significantly affect average daily gain or feed efficiency. If the sprouts have grown to the point where they are knocked off during harvest, then energy is lost from the grain and would reduce feed value of the grain. The primary effect of sprouting or low test weight grain will be an increase in feed consumed per unit of gain.

Barley and Additives

Horton and Nicholson (56) observed that monensin improved feed efficiency and average daily gain of feedlot steers fed a 60% rolled barley diet and 36% dehydrated alfalfa diet. Horton et al. (55) concluded monensin beneficial for lambs and steers.

Sharma et al. (103) found 0, 5, 10, 15% protected tallow could replace some of the barley to maintain high milk production. One should monitor milk production and milk fat and one may observe a slight reduction in milk protein.

Bass et al. (5) studied the effect of limestone supplementation on the performance of cattle given barley-based diets. Ten grams of limestone per kg of diet was provided. This level of limestone increased intake and average daily gain (1.22 vs 0.92 kg). Limestone inclusion did not appear to influence the low concentration of starch present in the feces but there was a significant difference in fecal pH. Concentrate diets normally require calcium supplementation.

Conclusions

Cattle should be introduced to barley over a two- to three-week period. Molasses may be added to starting diets to encourage cattle to consume more feed. Others have found that young calves accept barley diets more readily if the starting diet contains a blend of feed grains (111). Buffers can also be used when starting cattle on feed.

Barley can comprise 40-50% of the beef cattle diets until novice producers obtain sufficient experience to advance to higher levels. Higher levels of barley can range from 1.0% to 1.7 percent of body weight on a dry matter basis. Some experienced feeders are able to only use 10% hay in a barley based diet. All rolled barley diets have been fed but superior bunk management is required.

Dairy cattle are fed differently than beef cattle; therefore, the amount of barley fed to lactating dairy cows also differs from beef cattle. Forage comprises a much larger percentage of the diet for dairy animals than for feedlot animals. Higher forage diets tend to result in a more adequately buffered rumen so larger amounts of barley can be fed. For average producing cows (19 kg) barley can make up the entire grain portion of the diet. Lead feeding during the last two weeks of gestation should be practiced if large amounts of barley are to be fed. This lead feeding may need to be 30-45 days for first calf heifers.

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