Take Home Message

- Processing allows grain to be mixed with supplements, increases digestibility, and affects palatability, digestion and passage rates.

- Dry rolling is the recommended processing method of grain for cattle. Supplements can be pelleted to prevent separation and sorting.

- All kernels in dry-rolled barley grain should be broken and fines (particles less than 1 mm in diameter) should be less than 3%. The digestibility of whole barley will be 10-25% less than that of rolled barley.

- Corn does not need to be processed although improvements in feed efficiency of up to 10% may be associated with steam-processing.

- Oat grain does not need to be processed for calves but should be dry-rolled for older cattle.

- The feeding value of unprocessed wheat will be reduced by 20-25%.

Does Grain Need to be Processed?

Although it is possible to feed whole grain to cattle, it is normally processed for a variety of reasons.

Reduced separation and sorting of feed

It is impossible to mix protein, mineral, or vitamin supplements and feed additives with whole grain and have the material stay well mixed from the mixer to the animals mouth. If whole grain is fed, mix the grain and supplement together with silage to help keep it together or use a pelleted supplement to prevent separation.

Processing for improved digestibility

The main reason why grain is processed is to increase digestibility. The hull is a barrier which is relatively impermeable to rumen microorganisms and digestive enzymes and must be broken by either processing or chewing, otherwise much of the useful nutrients in the grain will pass...
Figure 1. Effect of quartering on grain digestion in the rumen.

out in the manure. Data in Figure 1 demonstrates the percentage of wheat, barley and corn dry matter remaining undigested after various times of exposure to microbial digestion in the rumen. The grain was incubated in the rumen as whole kernels or after it had been cut into quarters.

Animals vary with respect to their ability to break open the grain by chewing. Sheep, for example, chew more rapidly and have a smaller mouth than cattle, so whole grain can be used in their diet. Similarly grain processing is less important for calves than for older cattle, particularly when these have bad teeth. The structure of the grain kernel also influences the need for grain processing. Small, hard kernels require processing whereas there is some question whether it is economical to process the larger oat kernel for calves or corn grain for older cattle.

Other benefits

There are other somewhat intangible benefits from grain processing. Processing can have either a positive or negative effect on the palatability of grains. There is evidence that cattle fed whole grain are more susceptible to bloat and digestive upsets than those fed rolled grain (17, 34) and that individual animal performance is much more variable when whole grain is fed.

The rate of passage of grain though the digestive tract and hence the proportion of digestion which occurs in the rumen and intestines can be influenced by grain processing methods. Processing can also change the rate of digestion of the grain in the rumen. Steam-rolled grain disappears more slowly from bags suspended in the rumen than dry-rolled grain (6, 5). Treatment of grain with chemicals such as formaldehyde (7, 20) or ammonia (30) decreases the rate of starch and protein degradation in the rumen. At this time there is insufficient information to draw firm conclusions concerning the ideal ruminal degradation rate thus grain should be processed to optimize digestibility as discussed below.
Rolling

The recommended grain processing method for cattle is rolling it by passing between two large steel rollers since this is the least expensive and the amount of fine particles in feeds can be kept to a minimum. Fines are undesirable since they reduce palatability, increase sorting and feed refusals, increase the incidence of acidosis, and may contribute to respiratory diseases.

Grain can be rolled without the addition of moisture (dry-rolling), after addition of water (see tempering), or after the addition of steam (steam-rolling). Steam may be applied under pressure for a short duration or at atmospheric pressure for a longer interval. Several large feedlots in Alberta now temper grain prior to rolling to reduce fines. Tempering also facilitates processing of grain containing different sizes of kernels; reduce loss of grain as dust during processing; reduce dustiness and improve handling characteristics; and increase the moisture content of the diet. Since the moisture content of tempered or steam rolled grain is normally increased by 4 to 8%, storage times must be less than 1 to 2 days to minimize heating and spoilage problems. With the exception of corn and sorghum, the nutritive value of grain with water or steam added is normally less for feedlot cattle than that of dry-rolled grain on an equal weight basis because of the diluting effect of the additional moisture on grain nutrients.

Grinding

Barley can be ground through a hammer mill which consists of rotating hammers which strike the grain repeatedly until the particles are small enough in size to pass through a screen. A screen size with openings of 3/8 inch (9.5 mm) is the minimum which should be used for cattle. A more uniform grind is obtained when the hammer speed is reduced. Burr mills, in which grain is passed between a stationary and a rotating plate, can also be used to grind grain for cattle. Grinding is not as desirable for cattle as rolling because processing costs are higher and more fines are produced.

Pelleting

The total concentrate mixture, grain portion of the diet, or supplements and feed additives can be pelleted together or separately by forcing the material through small openings in a die under pressure. Pelleted supplements are very useful since pelleting prevents particle segregation during handling and
feeding. It is too expensive to process grain by this method for cattle. Moreover, fine particle sizes in pelleted grain have resulted in increased rumen wall damage and reduced performance in the feedlot when all-concentrate diets have been fed (13). Fine particle sizes in pelleted grain are not as detrimental with diets containing adequate amounts of forage.

High moisture grain

Grain is physiologically mature when kernel moisture falls below 35%. Grain yields are slightly higher when grains are harvested at 30% moisture because of reduced losses from shattering and retention of more small kernels in the harvesting process (see High Moisture Grain Production). High moisture grain must, however, be stored under anaerobic conditions in a silo or silo bag to prevent spoilage. Research has demonstrated that rates and efficiency of gain do not differ when dry barley and high moisture barley are compared in the feedlot (15).

Other methods

Grain can be micronized with infrared treatment, popped, boiled, etc. Generally, these processing methods are not recommended since they do not result in sufficient increases in rate or efficiency of gain to justify the expense. McAllister et al. (22), however, reported that micronization of wheat which increased kernel temperature to 90 to 100 °C for 1 minute, slowed the rate of degradation of the wheat in the rumen, and improved daily gain and feed efficiency.

Processing Barley Grain

Barley grain should be processed for all classes of cattle since whole grains are not chewed enough to reach maximum digestibility.

Tempering

See Tempered vs. Dry Barley for Feedlot Cattle.

Dry vs. steam rolling

Steam treatment of barley grain for a short period of time has not resulted in improved cattle performance in Arizona and Saskatchewan studies (10 as cited in 11, 27) even though Christensen (4) measured an increase in dry matter digestibilities from 77 to 79% when barley was steamed for 70 seconds. Similarly, digestibilities may be slightly improved by steaming barley for 20 to 25 minutes before rolling or flaking, and the product has a better appearance than dry-rolled grain,
generally there has been little response in either cattle liveweight gain or efficiency of gain to this processing method (Table 1, below). However, steam rolling may be beneficial with very dry grain or when steam processing allows grain with varying kernel sizes to be processed more uniformly by reducing the amount of shattering thereby reducing the amount of fines produced.

Degree of processing

The degree to which barley is processed has a large influence on digestibility as well as rate and efficiency of gain. Excessive amounts of fine particles in processed barley can reduce palatability, cause a greater degree of digestive upsets and abscessed livers (3, 12), cause rumenitis and abnormal papillae within the rumen (13), reduce ruminal pH and microbial growth (26), and result in reduced rates and efficiencies of gain (13). The degree to which fine particles in feed can reduce feedlot performance is a little unclear at this time, although there is evidence that rate of gain will be reduced more than feed efficiency by over-processing. Mathison (16) reported that steers fed ground barley (1/4 inch or 6.4 mm screen) grew 6% more slowly, had a 0.9% poorer feed efficiency, and had less carcass fat than those fed rolled barley.

Excessive (>3%) fines (particles passing through a screen with 0.8-1.0 mm openings) therefore must be avoided. If fines are a problem the grain should be tempered or steamed before rolling. If this is not feasible, add 2-3% molasses to keep the fines from separating from the larger particles. Excessive fines cause less problems when grain is fed in a total mixed diet containing silage.

<table>
<thead>
<tr>
<th>Type of cattle</th>
<th>% Barley</th>
<th>Daily gain (kg)</th>
<th>Dry matter/gain</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% increase with steam rolling</td>
<td>% decrease with steam rolling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry rolled</td>
<td></td>
<td>Dry rolled</td>
</tr>
<tr>
<td>Steers 62-75</td>
<td>62-75</td>
<td>1.31</td>
<td>7.6</td>
<td>6.35</td>
</tr>
<tr>
<td>231 kg steers</td>
<td>85</td>
<td>1.67</td>
<td>1.2</td>
<td>5.41</td>
</tr>
<tr>
<td>395 kg steers</td>
<td>89</td>
<td>1.64</td>
<td>1.2</td>
<td>5.98</td>
</tr>
<tr>
<td>340 kg steers</td>
<td>81</td>
<td>1.56</td>
<td>-1.9</td>
<td>6.16</td>
</tr>
<tr>
<td>260 kg steers</td>
<td>74</td>
<td>1.31</td>
<td>-2.2</td>
<td>5.77</td>
</tr>
<tr>
<td>Mean</td>
<td>74</td>
<td>1.50</td>
<td>1.18</td>
<td>5.93</td>
</tr>
</tbody>
</table>

1Barley was steamed for 20 min. with the exception of the trial of Hale et al. (10) in which it was steamed for 25 min.

2Result with thin flakes; with coarse flakes there was a -1.5% improvement in gain and a +2.4% improvement in feed efficiency.
Because of the problems of excessive fines in some dry-rolled grain, nutritionists have previously been careful to recommend barley should only be processed enough so that majority of the kernels are cracked. The appearance of some whole kernels was considered to be unavoidable and a less serious problem than the presence of fines. With new information and the routine use of silage in feedlot diets it is now clear that the proper degree of processing is when essentially all of the barley particles are broken. Research from Alberta and California supporting this concept is shown in Figure 2.

Experimental results demonstrate that the effect of processing on barley digestibility is not markedly influenced by the proportion of grain in the diet.

A description of the expected effect of processing on the feeding value of barley grain for feedlot cattle is given in Table 2. Improper processing will have a greater effect on older cattle. Specific recommendations are that less than 3% of the weight of a sample of processed barley should be small enough to pass through a 1 mm screen. In an Alberta survey, 75% of samples collected in commercial feedlots met this criteria. It is also recommended that the number of whole kernels in the sample be less than 3% of the sample weight when whole kernels are defined as those which cannot be easily broken with the fingers. More than 60% of samples collected at commercial feedlots met this criteria in the Alberta

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**Table 2. Description of rolled barley for cattle.**

<table>
<thead>
<tr>
<th>Processing degree</th>
<th>Fines (^1) (%)</th>
<th>Whole kernels (^2) (%)</th>
<th>Loss in feed value (^3) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole grain</td>
<td>&lt;1</td>
<td>100</td>
<td>16</td>
</tr>
<tr>
<td>Many whole kernels</td>
<td>&lt;1</td>
<td>70</td>
<td>40</td>
</tr>
<tr>
<td>Most kernels cracked</td>
<td>&lt;2</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>Kernels in 2-4 pieces</td>
<td>&lt;3</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Excessive fines</td>
<td>&gt;6</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

\(^1\)Fines are those particles which pass through a 1 mm screen.

\(^2\)Expressed as a percentage of total sample weight.

\(^3\)Approximate loss in digestibility. Losses in feed efficiency will be similar for high grain diets but higher when rates of gain are low. If excessive fines are present intakes and rates of gain will be reduced but reductions in feed efficiency will be less than reductions in rate of gain.
survey. Because of the importance of degree of processing on efficiency of grain utilization, and the difficulty in describing the degree of process precisely by just looking at a sample, it is recommended that cattle feeders have a sieve with a 1 mm screen for determination of fine material in processed feeds and another with a 2 mm screen for quick separation of whole kernels from the rest of the grain sample. A simple scale is also required.

**Barley Processing Index**

The barley processing index (L. Rode and K. Beauchemin) is a simple measure of bushel weight (weight per unit volume) after processing as a percentage of bushel weight before processing to obtain the Processing Index (PI). Commercial feedlots typically have a PI of 80%. It is suggested that maximum feed efficiency and average daily gain is obtained when the PI is between 80 to 85%. It is unlikely there is an optimum PI for all cattle types, diets and management but rather a range. PI is an easy procedure to apply at the feedlot since most grain processing facilities have equipment for measuring the weight of a known volume of grain.

The limitations to PI is that weight per unit volume data is only significantly related to kernel widths and that it is influenced by the moisture content at which the grain is rolled. Since fat kernels tend to have higher moisture content than thin kernels, there is a risk of processed barley still having significant whole grain present and yet still have a PI within the suggested 80 to 85% range. For example, in one trial (19) temper rolled barley had a lower weight per unit volume as a percentage of the original weight than dry rolled barley even though there were more whole undamaged kernels in the tempered barley samples. Moreover, although the correlations were obtained across moisture levels, concentrates which contained slightly rolled and medium rolled tempered grain had similar volume weights even though 71% and 38% whole undamaged kernels by weight, respectively in these samples. This suggests that procedures using PI (weight per unit volume) have limited application in precisely describing degree of processing of barley grain. Where PI can be most useful is in the repeatability of quality control on the farm. Increased quality control of barley rolling can be achieved by the feed mill operator taking repetitive PI samples and relating back to that particular grain.
Processing Corn Grain

Arizona data summarized by Hale (11) indicates that processing corn grain has very little effect on rate of liveweight gain and that dry-rolling has no effect on feed efficiency of cattle fed corn-based diets. Although steam-rolling and flaking improved feed efficiency in these and other studies, it has generally been concluded (26, 29, 2) that processing of corn grain is not economically justified.

Processing Oat Grain

There is little data concerning the effect of processing oat grain on the digestibility and performance of feedlot cattle. However, my assessment is that rolling will not improve the digestibility of oats by more than 5% for calves and 10% for cattle up to 2 to three years of age. Therefore rolling of oats cannot be economically justified in terms of increasing digestibility for calves less than 6 months of age. For older cattle, oats should be rolled in most cases. There is no information concerning the effect of steam-rolling on the feeding value of oat grain but the extra expense of this processing method would not appear to be justified.

Processing Wheat Grain

Starch degradability of unprocessed wheat averaged 56% and ranged from 14 to 83% in studies of Tolland (32), Tolland (33), Orskov et al. (28), and Fulkerson and Michell (8). There is therefore little doubt that it will pay to process wheat for cattle since rolling costs will be less than the 20-25% loss in energy content of the diet if it is not rolled.

<table>
<thead>
<tr>
<th>Type of animal</th>
<th>% Oats in diet</th>
<th>Diet digestibility&lt;sup&gt;1&lt;/sup&gt;</th>
<th>% decrease for whole</th>
<th>Ref&lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Rolled (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 years</td>
<td>67</td>
<td>81.0</td>
<td>5.6</td>
<td>2</td>
</tr>
<tr>
<td>17 months</td>
<td>50</td>
<td>65.4</td>
<td>10.1</td>
<td>3</td>
</tr>
<tr>
<td>12-18 months</td>
<td>59-74</td>
<td>64</td>
<td>-2.8</td>
<td>4</td>
</tr>
<tr>
<td>12-18 months</td>
<td>33-51</td>
<td>64</td>
<td>1.6</td>
<td>5</td>
</tr>
<tr>
<td>Cows</td>
<td>50</td>
<td>62.6</td>
<td>1.9</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>67.4</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup>Losses in feed efficiency will be similar for high grain diets but higher when rates of gain are low.

<sup>2</sup> References 2, 3, 4, 5 and 6 are Tolland (32) (Values are only for the grain portion of the diet only), Morgan and Campling (25), McDonald and Hamilton (23), McDonald and Hamilton (23) and Moran (24), respectively.
It is unclear how different processing procedures for wheat compare. There will, however, be less fines in dry-rolled than in ground wheat. Although improvements in feed efficiency have been reported when wheat is steam-rolled instead of being dry-rolled (36), the reason for this difference is an improvement in intake and not an increase in the amount of useful energy from the wheat. It is therefore doubtful if a response to steam processing can be expected, particularly if wheat is included in a diet containing silage.

McAllister et al. (22) have demonstrated that micronization of wheat decreases the rate of its degradation in the rumen and has a positive effect on rate and efficiency of gain (Table 4). Therefore, if available, micronized wheat should be fed rather than rolled wheat when more than 50% wheat is included in the diet.

### Table 4. Micronized vs. steam-rolled wheat¹.

<table>
<thead>
<tr>
<th>Barley:wheat ratio and treatment</th>
<th>Daily gain (kg)</th>
<th>Dry matter intake (kg/day)</th>
<th>Dry matter intake/gain ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>58:42 Steam-rolled</td>
<td>1.52</td>
<td>8.92</td>
<td>6.38</td>
</tr>
<tr>
<td>Micronized</td>
<td>1.49</td>
<td>9.06</td>
<td>6.52</td>
</tr>
<tr>
<td>42:58 Steam-rolled</td>
<td>1.24</td>
<td>9.24</td>
<td>7.26</td>
</tr>
<tr>
<td>Micronized</td>
<td>1.68</td>
<td>9.83</td>
<td>5.99</td>
</tr>
<tr>
<td>0:100 Steam-rolled</td>
<td>1.29</td>
<td>10.11</td>
<td>8.17</td>
</tr>
<tr>
<td>Micronized</td>
<td>1.51</td>
<td>9.33</td>
<td>6.07</td>
</tr>
</tbody>
</table>

¹Data from McAllister et al. (22). Diets contained 80% grain on an as-fed basis.

Conclusions

Normally grain should be processed to maximize net returns in cattle feeding operations. The exceptions are that it may not be economical to process oats for calves or corn for various classes of cattle. In virtually all situations barley grain should be processed since the costs of processing will be less than the minimal 15% loss in feeding value of unprocessed barley.

The recommended method of processing grain for cattle is dry rolling in most instances.

The degree to which grain is processed can have an important influence on the efficiency of feed utilization in the cattle. For this reason it is recommended that cattle feeders routinely sieve samples of processed grain to ensure that they are achieving an ideal degree of processing.
References