16. Methods of Processing Grain

John Nolan

Learning objectives

On completion of this topic you should be able to:

• Discuss the various types of grain processing available.
• Explain how grain processing can impact on the digestion of grains.
• Discuss the impact of grain type on the selection of processing method.

Key terms and concepts

Options for grain processing; Processing and feeding management to manipulate site of digestion; Summary of objectives when processing grain.

Introduction to the topic

In this lecture we cover two major topics. Firstly there is a description of each type of grain processing. Secondly there is a discussion of the way grain processing can change site of digestion and thirdly, there is discussion of the objectives of grain processing.

16.1 Options for grain processing

Animal and microbial enzyme systems are most effective against hydrated starch, but processing grains to the point of hydrating all the starch is rare for animal feeding. However it occurs, to some extent, during steam–flaking, pelleting and exploding of grains. The minimum processing required to ensure efficient grain digestion by most animals is cracking the pericarp to expose the endosperm. The second level of processing involves the degree of grinding and rolling and the extent to which particle size is reduced. Particle size determines the surface area which is exposed to microbial and digestive enzymes and influences the number of starch granules freed from the protein and non–starch carbohydrate matrix of the endosperm. Even small particles can contain individual starch granules tightly bound within the endosperm matrix and protected from enzymic digestion. The third level of processing deals with the situation when starch granules are tightly held within the endosperm matrix it may be necessary to use high temperatures with or without water to disrupt the granules to expose the starch to enzyme digestion through hydration and/or gelatinisation.

Whole grains can be readily fed to sheep (which can efficiently chew grain) and in chickens (where grains are broken down by a combination of soaking and grinding in the crop and gizzard). The gizzard requires adaptation to allow full development and efficient breakdown of grains. The time taken for adaptation of the gizzard does not present a problem in layers but in broilers, feeding whole grains can reduce FCE because there is less time for the development of efficient crop and gizzard function. Cattle and pigs have only a limited ability to chew cereal grains, especially the smaller grains, and so it is essential to break the seed coat by either mechanical or chemical treatments before feeding. Oat grain represents an exception as it is efficiently used by cattle and horses, even when fed whole and without any processing. Table 16–1 summarises the major types of grain processing, the effects on the grain and consequences for animal digestion. Each of the processing techniques is described in more detail below.
Cracking, dry rolling and grinding

These methods, while not identical, are grouped together since the method of action is to break the seed coat, reduce particle size, and so increase the surface area for digestion. Rolling can be used to crack the seed coat in order to allow entry of bacteria and digestive enzymes while retaining a large particle size which will partially limit the rate and extent of digestion or fermentation. Grinding or milling, on the other hand, can produce extremely fine particles which can be rapidly fermented or digested. The hardness and vitreosity of the grain affect its response to physical processing. The harder the grain, the more the damage to the starch granules during processing. Harder grains are also more prone to shearing and shattering than are softer grains where the starch granules tend to remain intact.

The effect of particle size on the digestibility of starch in pigs (30 kg starting weight) fed sorghum grain is very clear from the work of Owsley et al. (1981) who found ileal digestibility increased from 72% for dry rolled sorghum (1.3 mm particle size) to 86% for hammer milled sorghum passed through a 3.2 mm screen (0.5 mm particle size). The effects of particle size on overall diet digestibility are not profound in older pigs although positive responses have been found for sorghum in weaner pigs and maize in finisher pigs. One limitation of reducing the particle size of grains for pigs is the associated increase in the incidence of stomach ulceration.

Table 16–1 Summary of the effect of various processing techniques on the grain and on digestive function. Source: Owsley et al. (1981).

<table>
<thead>
<tr>
<th>Treatment process</th>
<th>Digestion seed coat layer and/or covers endosperm</th>
<th>Reduces starch granules and/or digestive endosperm matrix</th>
<th>Strengthens starch granules and/or causes hydrolysis and gelatinisation</th>
<th>Processing increases to nitrogen fermentation, intestina</th>
<th>Intestinal digestion</th>
<th>Improves overall digestibility</th>
<th>Cattle</th>
<th>Pig</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry rolling</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td>++</td>
<td>+</td>
<td></td>
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<tr>
<td>Grinding/rolling</td>
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<td>+++</td>
<td>++</td>
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<tr>
<td>Steam flaking</td>
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<td></td>
<td>++</td>
<td>+</td>
<td></td>
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<tr>
<td>Extrusion</td>
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<td>++</td>
<td>++</td>
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<td>+++</td>
<td>++</td>
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<tr>
<td>Pelleting</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decortication/flaking</td>
<td>-</td>
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<td>++</td>
<td>++</td>
<td>+++</td>
<td>+</td>
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<td></td>
</tr>
<tr>
<td>Merizing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Decortication</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
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<td>+++</td>
<td>+</td>
<td></td>
<td></td>
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<tr>
<td>Steam flaking grain</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+++</td>
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</tbody>
</table>
| High moisture (reconstitution) treatment followed by rolling

This is a refinement on simple cracking or grinding with effects on the seed coat and surface area similar to, but less extreme than dry rolling (i.e. the individual grains typically remain intact). An additional effect is the activation of the endogenous enzymes of the grain, which may induce changes to the grain, making it more soluble and fermentable before feeding.

Pelleting

Pelleting is a common commercial process where small particles are combined into a larger particle by means of a mechanical process in combination with moisture, heat and pressure. Starch is partially gelatinised by the heat between the grain and steam used in the conditioning process (usually 10–15 seconds) as well as the heat of friction generated as the feed passes through the dye. A further feature of pelleting is that it allows flexibility with respect to particle size of the feed to be pelleted, and control over the density and the final pellet size. It therefore offers a mechanism for controlling rate and site of digestion.

Steam flaking

This treatment is performed whereby the whole grain is heated with steam for 10–40 minutes and subsequently rolled to varying degree. The process breaks the seed coat and endosperm, thus having a surface area effect although the whole grain does remain as one. In addition, the cooking gelatinises much of the starch making it more susceptible to amylase attack. The amount of cooking is very important in determining the extent of intestinal digestion.
Extrusion
Extrusion of grain involves moisture, high temperature and pressure. The feed being extruded is propelled through a barrel where it encounters resistance to flow, which generates frictional heat. The barrel may be steam jacketed or have steam injected into it. The temperatures of extrusion are high (125–170°C), however, there is a relatively short time (15–30 seconds) at these high temperatures. The principal aim of extrusion is to achieve a high level of starch gelatinisation. While the effect of extrusion cooking on digestibility of various cereals is well understood for human and monogastric nutrition, the interaction between degree of gelatinisation and the physical characteristics of the final feed is not well documented in terms of the combination of fermentation and digestive processes in ruminant animals.

Ensiling
Ensiling of grain allows partial conversion of the starch to organic acids, principally lactic acid, which in turn help preserve the grain. After ensiling, the starch granule is more readily attacked by microbial enzymes. The high moisture levels in silage allow endogenous enzyme activity until the pH drops as a result of fermentation. Provided anaerobic conditions are maintained, silage can be stored for long periods of time.

Micronisation
In this process, the grain is first soaked, then passed over high temperature infrared burners and finally rolled. The action is similar in principle to steam flaking, allowing the grain to remain partly intact but with a reduced density and increased susceptibility to amylolytic digestion.

Microwave treatment
Although well known as an energy efficient and rapid cooking technique in food preparation, it has not been widely evaluated as a means of treating grains for animal feeding. This has possibly been due to the restriction imposed by batch processing associated with traditional microwave technology, but may be useful now that continuous microwave processing is feasible.

Chemical treatment
Treatment of feeds with hydroxides reduces the resistance of the seed coat to digestion and the use of formaldehyde reduces microbial degradation of proteins. The use of formaldehyde to protect protein against microbial attack has been applied to a number of feed components. By coating starch, lipid or other ingredients with formaldehyde–treated protein, the whole complex can be protected against microbial attack. As various protein fractions are soluble in alcohol or alkali, it is possible that these chemicals could be used for pre– treatment of the endosperm, particularly in the case of sorghum grain.

16.2 Processing and feeding management to manipulate site of digestion
The site of digestion is important in terms of productivity and health in ruminants, horses, pigs and poultry. We will now consider improving intestinal digestion and minimising the risk of adverse effects of rapid fermentation of starch. While there is extensive information on the effect of processing on rumen and post– ruminal digestion, there is less information on the relative contributions of the small intestine and the large intestine to post–ruminal digestion and absorption of nutrients.

The relationship between the total intake of starch and the proportion that is fermented in the rumen is shown in Figure 16–1. With increasing level of intake, starch digestion in the rumen is decreased. This is most probably related to an increased rate of feed particle passage as intake increases, and reduced time for fermentation in the rumen. In horses the level of starch intake also has a major effect on pre–ileal digestion. It appears that with meal sizes greater than 1.8g/kg body weight, an increasing amount of starch passes undigested to the large intestine where it will be rapidly fermented.

Treatment of proteins with formaldehyde can greatly reduce their digestion by microbial enzymes in the rumen.
While the critical factors limiting intestinal starch digestion in the horse are not well understood, it is likely that digestive enzyme activity, methods of grain processing and rate of passage (digesta resident time) are all involved.

**Figure 16.1** Relationship between intake of starch and the percentage of dietary starch fermented in the rumen for a range of different grains and processing techniques.  
*Source: Huntington, (1997).*

**Effect of processing on rumen fermentation and post-ruminal digestion**

Steam flaking is a very effective form of grain processing since it acts to break the seed coat and endosperm and also to gelatinise the starch. Figure 16–2 summarises the effect of steam flaking on a range of different grains. It is clear that grains such as barley, wheat and oats, which have a naturally high fermentation and intestinal digestion when ground or dry-rolled, are not affected as much by steam flaking as are grains like sorghum and maize. The review by Owens et al. (1997) indicates there is a small but significant improvement in productivity associated with steam treatment of wheat, whereas consistent and significant benefits can be obtained for sorghum and maize by steam treatment and re-constitution procedures. Figure 16–2 also shows that the steam flaking process brings most of the grains to a similar level of digestibility and rumen fermentability. It illustrates the potential of both sorghum and maize for manipulation with respect to site of digestion, since both parameters are significantly increased by the physical and chemical transformation which takes place during steam pelleting. Sorghum and, to a lesser degree, maize, are far less extensively fermented in the rumen than barley or wheat and this characteristic provides the potential for feeding systems which deliver unfermented starch to the small intestine. The problem with both sorghum and maize is that starch escaping the rumen is only around 60–70% digested in the small and large intestines. The potential challenge is, therefore, to find processing treatments which are effective in improving post ruminal digestion without increasing the extent of rumen fermentation.

**Site of digestion in the horse**

The site of starch digestion in the horse is markedly affected by grain type and processing. Table 16–2 summarises the links between the pre–ileal starch digestion and the physical changes in starch granules determined by microscopic examination of the jejunal chyme. It highlights the importance of separation between starch granules as well as the process of digestion of individual granules. Kienzle et al. (1977) suggest that particle size may have more impact on microbial fermentation than the structure of the starch granule but that, for intestinal enzymic digestion, it is the structure of the granule, rather than the particle size, which is more important. The studies reported by Snow and O’Dea (1981) tend to support this suggestion in the case of barley but indicate significant effects of particle size on rate of enzymic digestion of starch in oat and wheat grains.
Figure 16–2 Effect of steam flaking on rumen fermentation and post–ruminal digestion of different grains. The “unflaked” grain was fed in a ground or dry–rolled form and measurements were made in cattle. Source: Huntington, (1997).

Table 16.2 Relationship between starch structure in jejunal chyme and pre–ileal starch digestion. Source: Kienzle et al. (1997).

<table>
<thead>
<tr>
<th>Grain</th>
<th>Processing</th>
<th>Pre-ileal digestibility</th>
<th>Loosening between</th>
<th>Evidence of granule digestion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>granules</td>
<td></td>
<td>Pin holes</td>
</tr>
<tr>
<td>Maize</td>
<td>Whole</td>
<td>29</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Ground</td>
<td>47</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Silage</td>
<td>80</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Barley</td>
<td>Ground</td>
<td>22</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Oats</td>
<td>Ground</td>
<td>80.85</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Potato</td>
<td></td>
<td>7</td>
<td>-</td>
<td>(+)</td>
</tr>
</tbody>
</table>

16.3 Summary of objectives when processing grain

Maximising ME and measuring it accurately
Cereal grains are principally fed to provide ME and, as a primary objective, processing techniques must be designed to maximise total digestibility of the diet. Being able to measure or predict the availability of ME is very important and this may not always be straightforward. With ruminants, the negative effect of rumen pH on fibre digestion may actually have the opposite effect on overall diet ME and feed intake to that predicted from measuring in vitro digestibility of the grain on its own. Similarly the contribution of high levels of grain to the availability of ME may be different to the overall effect when the grain fed is fed at low levels. It may therefore be necessary to develop a better measure of ME for ruminants animals fed high levels of processed grains where the negative effects of rapid fermentation and low pH may reduce the beneficial contribution of the grain to the nutritive value of the diet.
Maximising digestion of starch in the small intestine

There are three reasons for wanting to maximise intestinal digestion:

- starch digested and subsequently absorbed as glucose represents a more energetically efficient process than fermentation of starch and absorption of VFA;
- to provide specific nutrients such as glucose as opposed to VFA; and
- to reduce the risk of extensive and rapid fermentation in the hindgut increasing the risk of acidosis.

Black (1971) illustrated the relative efficiency of absorbing glucose, as opposed to allowing fermentation of the glucose to VFA, prior to absorption and utilisation by the animal. Fermentation of starch in the rumen is associated with loss of energy as heat and methane or hydrogen. The importance of small intestinal digestion of starch has recently been highlighted in heavy weight cattle fed for the Japanese beef market. Meat for this market requires a high level of intramuscular fat and recent work by Pethick et al. (1997) has identified the importance of glucose supply to increase fat deposition as intramuscular fat.

Reduce the rate and extent of starch fermentation in the rumen of sheep and cattle

The pH during fermentation in the rumen or the hind gut is determined largely by the rate of carbohydrate fermentation and, to a lesser extent, by the salivary and exogenous buffers and the rate of VFA absorption from the gut. Rapid fermentation leads to the accumulation of acid in the rumen: the low pH disrupts the microbial balance which results in fermentation characterised by lactic acid. Lactic acidosis has serious implications for production and health of the animal. The problems associated with acidosis are widely recognised and have a profound effect on the selection of grain, and the methods by which it is fed.

The objective of shifting the site of digestion from the rumen to the small intestine contrasts to some views expressed in the literature. Ørskov (1986) and Huntington (1997) suggested that for both dairy and beef cattle, ruminal starch digestion was overall more desirable than in the intestine. Their view was based on,

(i) an increased supply of microbial nitrogen as a result of starch fermentation in the rumen which will be important for dairy cattle and younger beef animals;
(ii) the negative relationship between extra glucose supply and milk fat, and perhaps most importantly
(iii) the apparent poor digestibility of starch in the small intestine of ruminants and the associated risk of acidosis in the large intestine.

If starch is incompletely digested in the small intestine the proximal part of the large intestine (caecum, proximal colon) can receive a significant and potentially harmful load of fermentable starch. Importantly, increased fermentation of this starch in the large intestine can have negative impacts on animal health. For example hindgut acidosis is the basis of laminitis in horses, and is associated with enteric disease in pigs and adverse behaviour in horses. Minimising the amount of undigested starch passing to the hind gut should therefore be considered as an important objective in grain selection and processing.
Readings

The following readings are available on CD:


Activities

Multi-Choice Questions Available on WebCT

Self Assessment Questions Submit answers via WebCT

1. Outline the ways in which steam flaking alters the structure of the grain and the effects of these changes on the site and extent of digestion of sorghum in the digestive tract of cattle.
2. Does steam flaking have as big an effect on extent and the site of digestion of wheat as it does on sorghum? What is the reason for the different responses?
3. Do you think that grain type is more important than the method of processing in determining the site of digestion of starch in horses?

Useful Web Links Available on WebCT

Assignment Questions Choose ONE question from ONE of the topics as your assignment. Short answer questions appear on WebCT. Submit your answer via WebCT

References


Pethick, D.W., McIntyre, M.L., Tudor, G. and Rowe, J.B. 1997. ‘The partitioning of fat in ruminants - can nutrition be used as a tool to regulate marbling’ in Recent Advances in Animal Nutrition in Australia, UNE, Armidale. pp151.158