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# Grain processing

Grinding, pressure and heat improve the digestibility of nutrients found within grain, enhancing feed efficiency. Grains are also processed for the purpose of improving palatability, to improve handling characteristics, to reduce the presence of toxic substances, and to preserve them better. Grinding, cracking, rolling, and crimping increase the amount of surface area available for the rumen microbes to attach. Mechanical processing increases starch digestibility in both the rumen and in the intestine. Gelatinization destroys the crystalline nature of a starch granule making the surface of the starch more available to digestive solvents and enzymes as well as to the rumen microbes. It speeds up and increases the overall digestive process to convert starch into energy and microbial protein. Sodium hydroxide, dry heat, pelleting, high moisture ensiling, steam-flaking, steam-rolling, and extrusion all gelatinize starch to various degrees. Plant proteins are heated at various temperatures, time intervals, and moisture levels to decrease the solubility of the protein (denaturation) and to block sites for enzymatic digestion by causing linkages to form between peptides and carbohydrates. Cereal grains and oilseeds are processed to produce a number of products for human consumption and industrial use. Original plant products and manufacturing processes vary. Routine nutrient analysis for all by-product feeds is recommended.

Much of the grain fed to dairy cows is processed in some way prior to feeding. It has been estimated that 25% of the grains fed to dairy cows are byproducts from the manufacturing of other plant products. Grinding, pressure and heat improve the digestibility of nutrients found within grain, enhancing feed efficiency. Grains are also processed for the purpose of improving palatability, to improve handling characteristics, to reduce the presence of toxic substances, and for preservation.

# Starch

Cereal grains, such as corn and barley, provide the greatest proportion of the starch in a cow's diet. tarch is made up of glucose sugar units that are bonded together. Starch digestibility, both in the rumen and intestine, has a crucial impact on milk production. Depending on the starch source and processing, the glucose units may be very tightly bonded and compacted together or they may be weakly linked together. For this reason, different starches may be either rapidly or slowly fermented in the rumen. The rates of starch digestion in the rumen vary from 6-60% per hour, depending on starch source and processing. The goal is to get maximum total tract digestibility and maximum microbial protein production from starches in the rumen. But, at the same time it is desirable toavoid adversely affecting rumen health by causing a build up of fermentation acids in the rumen.

***Starch Processing***

## 1. Mechanical Processing

Grinding, cracking, rolling, and crimping increase the amount of surface area available for the rumen microbes to attach. Of particular importance when mechanical processing is the breaking of the pericarp on the outside of the grain. This allows the endosperm on the inside of the grain to be more accessible. Mechanical processing increases starch digestibility in both the rumen and in the intestine.

Grains may either be coarsely or finely ground. Finely ground grain will be digested to a greater extent. However, grinding too fine may cause more acidosis. Researchers at Michigan State University increased milk production by 3 pounds/cow/day (1.4 kg/cow/day) when they fed ground corn rather than cracked, dry shelled corn. This was an increase from 76 pounds to 79 pounds/cow/day (34.5 to 35.9 kg/cow/day). Milk protein increased by 0.1 percentage unit (from 2.8% to 2.9%) and milk fat decreased by 0.2 percentage units (from 3.7% to 3.5%).

**Recommended Particle Size of Corn Products (Sniffen et al., 1996)**

| | % Retained on a 1/8" screen (0.32 cm) |
|---|---|
| Cornmeal | 25 |
| HMC, 21% Moisture | 30 |
| HMC, 25% Moisture | 40 |
| HMC, 30% Moisture | 50 |

According to Dr. Charlie Sniffen of Miner Institute, Chazy, NY, if the amount of cornmeal retained on the 1/8" (0.32 cm) screen is only 5-10%, NEl can be adjusted upward by 5%. But, watch out for acidosis with this corn! If 30-35% of the cornmeal is retained on the 1/8" (0.32 cm) screen, NEl can be discounted by 5 to 10%. Remember, however, that the amount of effective fiber in the ration can impact the amount of energy in the corn. Coarsely ground cornmeal will stay in the rumen longer and be more completely digested if there is a good fiber mat.

## 2. Gelatinization

Gelatinization destroys the crystalline nature of a starch granule making the surface of the starch more available to digestive solvents and enzymes as well as to the rumen microbes. It speeds up and increases the overall digestive process to convert starch into energy and microbial protein. Gelatinization typically results from a combination of moisture, heat, mechanical energy, and pressure. Gelatinization temperature varies with starch type. Amylose is a more crystalline type of starch that requires more heat for gelatinization than amylopectin, a more branched type of starch.

Heating starches can also reduce starch digestibility if not done properly. After heating, amylose can potentially recrystallize (retrograde) and become less digestible than it was before heating. Overheating starches can result in carmelization. This condensation of amino acids with sugars produces indigestible Maillard product.

The following starch gelatinization processes are listed in order of their typical extent. Sodium hydroxide processing has the least effect on starch digestibility and extrusion has the greatest effect. It must be recognized that feeds may be heated for multiple purposes, including not only starch gelatinization but also to improve palatability, texture, handling and digestibility of other nutrients.

**Sodium hydroxide** (NaOH), a caustic chemical, is being used by some farmers to disrupt the protein matrix of grain and to gelatinize starch. It is used on whole grains as an alternative to grinding. However, rumen digestibility of this grain is generally lower than that of ground grains and, as a result, microbial protein synthesis may be reduced.

**Dry Heat Processing** simply heats grains using dry air. Natural moisture from the grain helps to gelatinize the starch. Examples of dry heat processing include micronizing, popping, and roasting. Micronizing involves the use of microwaves from infrared burners. Popping uses rapid heat to explode the grain. The principle is the same as that for making popcorn. With roasting, grains are heated to about 300oF (149oC) in some type of oven for a period of time.

**Pelleting** forces grains through a die, pressing them into a pellet. Steam is added to increase feed temperature to 140-180oF (60-82oC) and increase moisture to 12-13%. As gelatinization improves due to inclusion of grains with lower gelatinization temperatures and use of good manufacturing techniques, better quality pellets and fewer fines are produced. Wheat midds and flour, for example, have low gelatinization temperatures and are known to improve pellet quality.

One of the main reasons for pelleting is to ease feed handling. Pellets generally flow better than meal feeds (or grist feeds) through bins and augers used on farms. Another typical reason for pelleting feeds is to improve palatability by reducing fines. This may be especially important when grains are not fed within a TMR. Pellets help to reduce ingredient separation in a complete feed. Pelleting also helps to increase feed density. This is helpful especially if fibrous byproducts such as wheat midds are included within a complete feed. The heat of pelleting also reduces the levels of toxins that may be present in the grain.

## High Moisture Ensiling

Ensiling high-moisture grains (28-32% moisture) increases starch digestion by breaking down the protein structure of the grain and disrupting the crystalline structure of the starch. This allows the rumen microbes to more easily burrow into and digest the starch.

Because of the non-crystalline nature of the starch in high-moisture corn (HMC), it is usually recommended that it be rolled rather than ground. Grinding would usually make HMC degrade too rapidly and cause acidosis. However, sometimes we must deal with HMC that isn't 28-32% moisture, it is drier. In that case, it must be ground finer. Miner Institute in Chazy, New York reported a milk production increase of 5 pounds/cow/day (2.3 kg/cow/day) when corn at 23% moisture was ground with a hammer mill through a 1/2" (1.27 cm) screen.

**Steam-flaking and steam-rolling** gelatinize starch by heat and steam application. However, the degree of "cook" is highly dependent on the amount of moisture, pressure, and heat actually obtained. Steam-rolled grain is usually steamed for 10-15 minutes to increase grain moisture to 12-14%. Then, it is rolled into a thick flake. Its density is about 38 pounds (17.3 kg) per bushel. Steam-flaked grain is steamed for 30-60 minutes in a vertical steam chamber to increase grain moisture to 18-20%. Then, it is flaked through rollers. Its density is about 24-30 pounds (11-14 kg) per bushel. Lower flake densities indicate more extensive processing and starch gelatinization. Caution should be used against over-processing. In some studies, feeding low density flaked grains has resulted in lower production because of problems with intake and acidosis.

Studies have been conducted comparing ground, steam-rolled and steam flaked grains. Arizona researchers got a 5-pound (2.2 kg) per day response in milk production when they fed steam-flaked corn rather than steam-rolled corn. In this same study, they also compared steam-flaked corn versus finely ground cornmeal. In one part of the study, cornmeal in the diet produced more milk than the diet with steam-flaked corn (90 vs. 88 pounds/day) (40.9 vs. 40 kg/day). In the other part of the study, the diet containing steam-flaked corn rather than cornmeal yielded more milk (82 vs. 78 pounds/day) (37.3 vs. 35.5 kg/day). Steam-flaking is typically more expensive than grinding corn.

**Extrusion** presses feed through a screw, generating large amounts of pressure. This pressure creates heat. Typically, extruders cook feeds at temperatures of 280-320oF (138-160oC) and 20-40 atmospheres of pressure for 30 seconds or less. When the feed is released and the pressure is suddenly decreased, the feed expands and dehydrates. This expansion gelatinizes starch.

The benefit versus cost of heat processing varies with starch source. Since sorghum is naturally digested at a slow rate, heat treatment is generally considered to be cost-effective. Barley and wheat are rapidly digested without heat treatment. Cooking barley and wheat may create more acidosis problems, than observed with other grains.

## Protein Processing

Plant proteins are heated at various temperatures, time intervals, and moisture levels to decrease the solubility of the protein (denaturation) and to block sites for enzymatic digestion by causing linkages to form between peptides and carbohydrates. This reduces the amount of soluble protein (SIP) and degradable protein (DIP) and increases the amount of undegradable protein (UIP). Studies have shown decreases in urinary nitrogen excretion and increases in dietary nitrogen usage in dairy cows fed heat-treated soybean meal rather than solvent extracted soybean meal. Chemicals have also been used to change the pH at which a protein will degrade. This inhibits ruminal degradation (pH 6.5) but still permits degradation of protein in the acidic abomasum. Agents such as sodium hydroxide, formic acid, and formaldehyde have been used. Over-processing plant proteins with heat and chemicals can make proteins indigestible. So, care must be taken to process proteins enough to make more rumen undegradable protein (UIP) but not so much that the protein passes right out with the manure.

Heat processed full-fat soybeans are a good source of undegradable protein (UIP) and fat. Their value to the cow depends on the temperature and length of time that they are heated. In the U.S., soybeans are typically heat-processed by roasting. Researchers at the U.S. Dairy Forage Research Center concluded that heating soybeans at 295oF (146oC) and steeping (or conditioning) them at 275-285oF (135-140oC) for 30 minutes is optimal. Underheating results in too little undegradable protein (UIP). Overheating results in too much indigestible protein. A reasonable goal is to have 45-55% of the crude protein in roasted soybeans as undegradable protein (UIP). Post-processing analysis for ADIN (indigestible protein or bound protein) and undegradable protein (bypass protein) is extremely important.

Raw (untreated) soybeans contain very little undegradable protein and are therefore much less valuable than roasted soybeans as a feed source. The heat treatment involved in roasting destroys the trypsin inhibitor present in soybeans. Trypsin inhibitor can reduce protein digestion in the small intestine. Trypsin inhibitor is not a problem in the rumen but becomes a problem at the intestine if high levels of raw soybeans are fed.

## Grain By-Products

Cereal grains and oilseeds are processed to produce a number of products for human consumption and industrial use. The byproducts of these processes are generally classified as particular feed products and average nutrient analyses for these feed products have been compiled by researchers and feed associations. Due to the manufacturing processes involved, both starch and protein fractions of the feed may undergo some of the changes discussed above.

Unfortunately, original plant products and manufacturing processes vary. For this reason, one cannot assume that nutrient analyses for particular feed products are the same from one manufacturing facility to another or even that one facility will always produce a byproduct with a consistent nutrient analysis. Routine nutrient analysis for all by-product feeds is recommended. In some cases, determination of UIP and/or starch digestibility may also be warranted.

## Corn

Starch is extracted from corn for food and industrial purposes. From wet milling corn, corn gluten feed, corn gluten meal, corn germ meal, and condensed fermented corn extractives are produced as feeds for dairy cows. First, the condensed fermented corn extractives (about 7% of the corn) are taken off with the steepwater. Then, germ is separated away from the corn. Germ is extracted into corn germ meal (about 4% of the corn) and corn oil (about 4% of the corn). Bran (about 12% of the corn) is processed into corn gluten feed. Finally, corn gluten meal (about 5% of the corn) is separated away. About 67% of the corn is left as starch and sweetener. Corn gluten meal is the most consistent by-product generated. It is about 60% crude protein. Corn gluten feed is not a consistent product because it may be contaminated with other products besides the bran. Sometimes the germ may be included with corn gluten feed. The extent to which corn oil is removed from corn germ meal may also vary. Dry milling produces corn hominy feed. Hominy feed contains the bran, germ, and some starch. It fat level will vary with processing. Hominy feed from yellow corn tends to be lower in fiber and higher in fat than that from white corn.

Corn is fermented to produce alcohol, leaving corn distillers grains as a byproduct. The amount of solubles in corn distillers grains varies and impacts nutrient analyses. More solubles generally improves nutrient value. Other grains such as rye and barley may also be included with the corn when making alcohol and the byproduct will still be called corn distillers grains. Depending on processing conditions more or less yeast cells and their metabolites may be included in corn distillers grains. Dark color of corn distillers grains may be associated with overheating and too much indigestible protein or it may indicate that more solubles have been added back.

## Barley

Breweries produce brewers grains from barley fermentation. Brewers grains can be either wet or dry. Corn and rice may be added to the barley mix resulting in the production of brewers grains of higher nutritional value. Breweries remove starch from the grains using water and enzymes so no yeast cells are included in brewers grains.

## Wheat

Wheat is processed into flour. About 72% of the original wheat grain is converted into flour and the rest is feed byproduct. Wheat bran may contain both coarse and fine bran. Wheat red dog is generally regarded as flour with a little added bran and germ. Wheat shorts contain fine bran, germ, and red dog. Wheat germ meal contains germ and possibly some fine bran. Wheat middlings contains fine bran, germ, red dog, and possibly some ground screenings. Wheat mill run contains coarse bran, fine bran, germ, red dog, and possibly some ground screenings. The actual analysis of any of these products varies with the quality of the original wheat grain, flour products produced, manufacturing conditions, and options for waste handling. Most of the byproduct from the wheat milling industry is marketed as wheat middlings or wheat mill run.

## Soybean

Soybean processors extract the oil and are left with soybean meal without hulls (48% CP) or with some hull (44% CP) used for animal feed. Heating temperature and heating length affect the amount of rumen undegradable protein and amount of indigestible protein in soybean meal.

Extruded soybeans are subjected to friction heat (270-300oF) (132-149oC) using a screw-auger. Much of the oil (fat) is removed. They are fed primarily for their bypass protein and fat, but the level of fat is usually lower than that found in heat-treated full-fat soybeans. Because of the cost of this process, it is not commonly used in the U.S.

Expeller-Processed Soybean Meal, such as Soy-PLUS®, Homer Meal®, and Morameal®, is made by heat-treating raw soybeans at 290oF (143oC) for about 20 minutes and then processing the beans through an expeller that takes out most of the fat and provides more heat.

Lignosulfonate-Treated Soybean Meal, such as Soy Pass®, is also fed primarily as a source of bypass protein. It is made from 48% soybean meal. Lignosulfonate comes from the spent sulfite liquor made from the sulfite digestion of wood in the wood pulping industry. It contains xylose, a highly reactive sugar. Lignosulfonates are heated with 48% soybean meal to 205oF (96oC) for about 40 minutes.

Soy Hulls remain after soybeans are processed for oil and for soybean meal. Soy hulls are primarily fed as a source of energy and fermentable fiber in dairy rations. Soy hulls are very palatable. Soy hulls contain some pectin, a very digestible fiber that labs usually include in the NFC fraction. The NDF in soy hulls is very digestible. Some estimates of soy hull NDF digestibility have been as high as 90% as compared to beet pulp at 69% and wheat middlings at 52%.

### Cotton

Cottonseeds are grown for their lint and byproducts of this industry used for feeds are whole fuzzy cottonseeds, cottonseed meal, and cottonseed hulls. Whole fuzzy cottonseeds have become a very popular feed, especially in TMR's. The seed coat helps to slow the release fo fat and protein in the rumen. The original cottonseed and processing conditions will affect the nutrient content of these products.

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