CEREAL GRAINS AND BYPRODUCTS: WHAT'S IN THEM AND HOW ARE THEY PROCESSED ?

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When you go into a feed store and purchase a bag of feed, the label gives you certain information. Law requires that labels include net weight, product name, guaranteed analysis, ingredient listing, and manufacturer's name. Medicated feed must also list the active ingredient along with any precautionary statements and adequate directions for use. For formula feeds, guarantees must be listed for minimum crude protein, minimum crude fat, maximum crude fiber, minimum and maximum calcium, minimum phosphorus, minimum and maximum salt. There should be a list of ingredients used to make the feed; however, today many of the ingredients are listed as "collective terms" (groupings of feed ingredients) rather than individual ingredients. This allows the manufacturer to substitute ingredients, within a defined group such as grain by-products, without having to change labels every time there is a reformulation. These changes are most often due to changes in supply or costs.

Although the guarantees and other information provided on a label aid us in comparing products and making purchasing decisions, these guarantees tell us nothing about the quality of the feed.

Grains such as oats, corn, and barley and grain byproducts such as wheat bran, wheat middlings, and wheat mill run are used primarily as energy sources in horse feeds. Soybean meal is the primary source of protein used in North America. Nearly all cereal grains and any number of byproducts from the food and feed industry can be, and are fed to horses to supply digestible energy (DE). Several other protein sources are also available when formulating diets. This paper will discuss the nutrient composition of these ingredients and how processing affects their quality. I will also briefly describe some of the processing techniques used in manufacturing horse feeds, again focusing on areas where feed quality may be affected.

Grain is marketed by grade according to certain quality characteristics. Some of the criteria used to determine the grade are bushel test weight, foreign material, damaged kernels, and moisture. As test weight decreases and the other factors increase, the grade goes down and the price usually decreases accordingly. Generally, as bushel test weight goes down, the protein content increases and starch content decreases. Although the protein content increases, protein quality generally decreases. The berries are often more shriveled and seed coats are harder. Often times the grain can still be used, but the nutritional profile has changed and must be accounted for. If molds or mycotoxins are detected, however, the grain should not be used in horse feeds.

Soybean meal

Soybean meal was once merely the by-product of the soybean oil processing industry. Today it is a major protein source in livestock feeding. There are two main types of meal produced in the US, 44% protein solvent extracted and 48% protein dehulled solvent extracted meal. The difference in protein content is because hulls are added back to the extracted meal of the solvent extracted type. The dehulled, solvent extracted meal can be fed to all classes of livestock and poultry. The solvent extracted meal can also be fed to all types of livestock; however, it is better utilized by animals, such as mature ruminants, having the ability to digest higher concentrations of fiber.

The process of extracting oil from beans, thus producing soybean meal is as follows:

1. Raw beans are cleaned and then dried, hulls are separated.
2. Beans are passed through cracking rolls and then heated to 165°F to 175°F for 10 minutes.
3. Beans are then flaked and passed through the extraction tower. Solvents such as hexane or other hydrocarbons are used to extract the oil from the flakes. The oil level is reduced to less than 1%. Temperature is 113°F.
4. The extracted flakes are dried at 208°F for 10 minutes, toasted at 220°F for 90 minutes and ground into meal. This meal is generally 48% to 50% protein. Hulls are then added back to produce the 44% protein meal.

Good quality soybean meal (defined by AFIA, 1992) should have the following physical characteristics:

Color: light tan to light brown.
Odor: fresh, typical of the product, not sour, musty, or burned.
Taste: Bland and free of any “bean” or burned taste.
Texture:homogeneous, free flowing, without coarse particles or excessive fines.
Bulk density: 36 - 40 lbs per cubic foot.
Screen analysis: 95 - 100% through US Standard Sieve No. 10, 40 -60% through US Standard Sieve No. 20, and a maximum 6% through US Standard Sieve No. 80.
Moisture:12% or less improves flowability and reduces incidence of mycotic growth.

The final product must not contain more than 3.5% crude fiber. It may contain an inert nontoxic conditioning agent, either nutritive or non-nutritive, to reduce caking and improve flowability. The conditioning agent may not exceed 0.5% and the name must be shown on the label as an added ingredient. Frequently calcium carbonate is used as the conditioning agent.

Soybean meal must be properly cooked during processing to provide optimum protein nutrition for animals. These antinutritional factors are primarily digestive enzyme (protease) inhibitors. Soy hemagglutinin and trypsin inhibitor are the greatest concern to producers.

The aim of heat processing is to reduce the inhibitors to acceptable levels, not to totally destroy them. Underheating soybean meal fails to reduce the effects of growth inhibitors, resulting in low protein efficiency, reduced growth and feed efficiency in monogastric and young ruminant animals. It has been shown in turkey poults that underheated soybean meal greatly increases the need for vitamin D to prevent rickets.

Overheating soybean meal tends to inactivate or destroy essential amino acids such as lysine, cystine, methionine, and possibly others. Overprocessed soybean meal is seldom a problem with commercial vendors because of the energy required to process soybean meal. However, soybeans processed on the farm or at smaller crushing plants are likely to be over or underprocessed if the operator does not carefully monitor the temperature.

The two main assays for determining soybean meal quality are urease activity and protein solubility. Feed manufacturers tend to prefer the urease method because it is easy, quick and relatively inexpensive. It indirectly determines the amount of inactivation of trypsin inhibitor by measuring urease activity, an enzyme present in soybeans similarly destroyed by heating. A major limitation of the urease assay is it cannot measure overheated soybean meal. Protein solubility can measure both over and under processed meal, but the assay is more complex and requires an analytical laboratory. Numerous studies have shown decreases in weight gain and feed efficiency when bean meal has been overprocessed.

We normally think of soybean meal strictly as a protein source; however, there is a significant amount of carbohydrate in soybeans (Table 1.). After the oil is removed, the remaining constituents are predominantly protein, ash, and carbohydrate. The carbohydrate fraction is approximately 42%. Since hulls are removed during processing and, by definition, dehulled meal can have a maximum of 3.5% fiber, that leaves 38% - 40% available carbohydrates. These are primarily oligosaccharides or complex sugars, raffinose, and stachyose.

Table 1. CHEMICAL COMPOSITION OF SOYBEAN PRODUCTS

Product	*Protein %*	*Fat %*	*Ash %*	*Crude Fiber %*	*Cell Wall (NDF%)*	*Carbohydrate %*
Whole beans	40	21	4.9	5.3	–	34
Flakes/Meal	47.5-49	1	6	3.5	12	40
Hulls	8	1	4.0	36	65	4.3

Corn

Corn is the leading crop in America in terms of volume and value. It is a major cereal grain used in horse feeds. Chemical composition is shown in Table 2. As in most cereal grains, corn is used primarily for its energy, thus its carbohydrate components are usually considered to be most important. The starch, found mainly in the endosperm, comprises 70-72% of the corn kernel. The type of starch may be horny or floury, depending on variety. The starch in dent corn, the type normally used for feed, is approximately 74% amylopectin or branched glucose and 26% amylose, or long chain glucose. These starch granules are readily available to enzymatic digestion by amylases and amyloglucosidases.

Table 2. CHEMICAL COMPOSITION OF CORN AND CORN PRODUCTS

Product	*Protein %*	*Fat %*	*Ash %*	*Crude Fiber %*	*Cell Wall (NDF%)*	*Carbohydrate %*
Grain	10.0	4.3	1.5	2.9	9	71.7
Hominy feed	11.5	7.7	3.1	6.7	55	78.2
Gluten meal	47	2.4	3.4	4.8	14	19.5
Gluten feed	25.6	2.4	7.2	9.7	41	48.7
Germ meal	22.3	4.1	4.2	13.1	–	49.6

Corn is considered to be low in protein, generally averaging 8% - 10%. Because of the high incorporation rate in feeds, however, substantial amounts of protein are supplied by corn. Corn protein is especially deficient in lysine, 0.25% as opposed to 0.40% for oats and barley, 0.6% for wheat mill run, and 3.1% for soybean meal.

Most of the corn used in the feed industry is No. 2, sometimes No. 3, with the following general specifications for grinding and use in feed:

Test weight: 50 lbs/bu. (No. 1 corn is 56 lbs/bu)
Maximum foreign material: 4%
Maximum damaged kernels: 10%
Maximum moisture: 15.5%
Color: bright to golden yellow
Odor: no moldy, sour, or musty smell should exist.

Grains are routinely stored for long periods of time, thus the quality factors often revolve around proper storage conditions and the adverse effects resulting from improper storage. In general, particular attention must be paid to moisture and temperature. Microbe growth is minimized when grains are stored at less than 13% moisture. Corn is normally harvested at 22-28% moisture to maximize efficiency of harvesting and reduce the amount of broken kernels. The corn must be dried for proper storage. Corn dried at temperatures greater than 140°F often becomes cracked or damaged, making it more susceptible to insect or microbial damage. Studies have shown that corn stored at 14.5% moisture at 55°F retained condition for 1.5 years. The same corn stored at 68°F changed only slightly after 1.5 years. At 15.2% moisture, corn stored at 77°F deteriorated rapidly. Corn that is stored too wet may begin to mold, and in some extreme instances may heat up enough to cause severe damage to the kernels.

Moldy or musty smelling corn should not be used in horse feed. If a moldy or musty odor can be detected, the corn has been severely damaged, since changes take place long before the odor is detectable. Certainly the possibility exists that toxins have been produced by the infestation. These toxins are, for the most part, very heat stable and even if the feed is pelleted or extruded, the toxins will not be destroyed.

Oats

Because the average oat grain is about 30% hull (fiber), and oats contain sufficient protein, calcium and phosphorus to meet the requirements of mature horses, oats have traditionally been the predominant grain used by horsemen. Oats once made up nearly 31% of all equine feed consumed. Horses digest oats easily in comparison with heavier whole grains like wheat and corn (Coffman, 1961).

During the mid 1950's, over 40 million acres of oats were harvested in the US, but more recently production has dropped below 10 million acres. The decline has been mainly due to poor yields. Genetic gains have been only 9-14% compared to 35-100% increases in other crops.

In spite of the poor yields, the quality of the oat groat cannot be denied. Oats are the most balanced cereal grain, from an amino acid standpoint. Generally, as the protein quantity in cereal grains increases, the quality decreases. This does not occur in oats. A ranking of protein quality among cereal grains lists oats first followed by barley, corn, and wheat.

Nutrient composition of oats and oat products appears in Table 3. As mentioned earlier, approximately 30% of the whole oat is hull. Oat hulls are relatively low in energy and nutritive value. The majority of the protein is found in the groat. Protein content averages 12% but ranges from 11.5% - 24%. Lysine in the same test cultivars ranged from 3.2% - 5.2%. This points out one of the precautions that must be taken when formulating a ration with oats, as nutrient composition varies greatly between cultivars and is very susceptible to environmental factors.

Table 3. CHEMICAL COMPOSITION OF OATS

Product	*Test Wt. lb/bu.*	*Protein %*	*Fat %*	*Crude Fiber %*	*Cell Wall (% NDF)*	*Ash %*	*NFE %*
Whole Oats	38.5	12.1	5.1	12.1	32	3.4	61.4
Groats	52.0	15.8	7.2	2.8	7.0	1.9	66.6

Starch is the major carbohydrate in oats, averaging 52.8% and ranging from 43.7% to 61%. The carbohydrate fraction is low in free sugars, amylose content is 19% - 28%. Starch level varies inversely with protein content. Carbohydrate, reported as NFE in the proximate analysis scheme, is 71.8% in rolled oats, 72.1% in oat groats and 64.2% in whole oats.

Fiber content is as follows:

Oat fraction	*Crude Fiber %*	*Cell Wall (NDF%)*	*Hemicellulose %*	*Cellulose %*	*Lignin %*
Whole oat	10.7	24.4	10.4	11	3
Rolled oat	1.7	–	–	–	–
Hull	33.2	78	28.8	39.2	10.0

General specifications of oats for grinding and use in feed are:

Test weight: 27 lbs/bu. (No. 1 32 lbs/bu.)
Maximum foreign material: 5%
Maximum heat damaged kernels: 3%
Color: soft yellow or buff, may vary from almost white to dark yellow or gray.
Odor: no moldy, sour, or musty smell should exist.

Quality of oats usually relates to the deterioration or oxidation of the lipid. Lipid content is low in hulls, higher in groats and varies widely with cultivars. Average content ranges between 5% - 9%. Approximately 95% of the fatty acids are palmitic (C16:0), oleic (C18:1) and linoleic (C18:2). Whole oats and intact groats can be stored successfully at 10% moisture and normal temperatures; however, free fatty acids increase rapidly in ground oats at normal temperatures and the deterioration rate increases rapidly at storage temperatures of 85°F. Quality is determined by measuring the free fatty acid levels.

Barley

Barley is used as a feed grain, for malting and brewing of beer and for distillation of liquors. In the US, barley ranks only behind corn and sorghum in terms of feed grain production, and constitutes 4% of the total grain used in livestock feed (Feed Management, 1985). Barley must be differentiated in terms of the desired end use; cultivars are developed for specific purposes. Malting and feed barley are distinctly different; high protein content is desirable in feed grain but not for malting. In general, barley has a feeding value of 95% that of corn.

Table 4 lists the nutritive profile of barley. Barley is generally categorized as Pacific coast and non-Pacific coast, with the Pacific coast being lower in protein. Barley is relatively high in crude protein for a feed grain, ranging from 8% to 13%, but is relatively low in lysine and methionine. Because most feed barley contains the hull, fiber content is relatively high, 5% - 7%. Starch makes up nearly 65% of the kernel. Additionally, the kernel has approximately 1% simple sugars and 2% sucrose.

Table 4. CHEMICAL COMPOSITION OF BARLEY

Product	*Sugars %*	*Protein %*	*Fat %*	*Crude fiber %*	*Cell wall (%NDF)*	*Ash %*	*Others %*
Grain	2-3	8-13	2-3	5.6	28	2-2.5	5-6

General specifications of barley for grinding and use in feed are:

Test weight: 40 lbs/bu. (No.1 @ 48 lbs/bu.)
Maximum foreign material: 6%
Maximum heat damaged kernels: 3%
Color: yellow to golden yellow, should be free of excessive dustiness with no evidence of seed treatment.
Odor: no moldy or musty smell should exist.

The grain tends to be hard and requires some type of processing to make the nutrients more available to the animal. The most common types of processing include rolling and steam flaking. Concerns for barley quality, again, surround storage issues. Improper storage will allow fungus, molds and insects to enter the grain and alter the nutrient profile.

Wheat byproducts

Wheat byproducts were part of the beginning of the feed industry. Many of the earliest feed companies were flour milling companies looking for an outlet for their byproducts. Since wheat byproducts are so important to the feed industry, it is essential that proper terminology be used to differentiate between the fractions, particularly between wheat bran, wheat middlings and wheat mill run. AAFCO (Association of American Feed Control Officials) official definitions for these products are:

Wheat bran - the coarse outer covering of the wheat kernel as separated from cleaned and scoured in the usual process of commercial milling.

Wheat middlings - fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and some of the offal from the "tail of the mill." This product must be obtained in the usual process of commercial milling and must contain not more than 9.5% crude fiber.

Wheat mill run - coarse wheat bran, fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and offal from the "tail of the mill." This product must be obtained in the usual process of commercial milling and must contain not more than 9.5% crude fiber.

All too often these terms are used interchangeably and, as the above definitions indicate, they are not the same. When flour is milled from wheat, the amount of the outer layers of the kernel that are removed are determined by the quality of the flour desired. As flour purity goes up, yield goes down. The amount of milling that occurs is dictated by the marketplace, both the price of grades of flour and the price of byproducts. For example, if the market price for bran is high and the demand for midds is low or the price is low, the milling process will be adjusted such that more of the starchy endosperm will be diverted into the bran fraction.

The nutrient composition of wheat and wheat byproducts appear in Table 5. Wheat is generally classified by agronomic and utilization criteria. Hard wheats are generally grown in medium temperate zones, low rainfall, small hard berries, and moderately strong gluten (wheat protein). Soft wheats are found in milder climates, more rainfall, larger kernels. Hard wheats are generally higher in protein. Winter wheats are planted in the fall, spring wheats are planted in the spring. The resulting varieties, then, are numerous, i.e. hard red spring, hard red winter, soft white spring, etc.

The nutrient composition of wheat grain, because of varietal differences, tends to be more variable than any other grain, especially with respect to protein content. Protein content of hard red winter wheat ranges from 13% to 15%, soft white winter from 10% to 12%. The endosperm makes up almost 83% of the kernel and contains

73% of the total protein. Bran is about 14% of the kernel and contains 19% of the total protein. The germ makes up the remaining 3% of the kernel and contains 8 % of the total protein. The majority of the vitamins are in the bran. Perhaps the most attractive aspect of wheat byproducts as a feedstuff is the relatively high protein content, 17.5% in bran, 18.5% in midds and 17.3% in mill run.

Table 5. CHEMICAL COMPOSITION OF WHEAT AND MILLED WHEAT PRODUCTS

Product	*Wheat %*	*Protein %*	*Fat %*	*Crude Fiber %*	*Cell Wall (%NDF)*	*Ash %*	*Starch %*	*Total Sugars %*
Wheat	100.0	15.3	1.9	2.9	14	1.8	53.0	2.6
Bran	16.4	16.7	4.6	11.3	51	6.5	11.7	5.5
Midds	8.4	18.5	5.2	8.2	37	5.0	19.3	6.7
Mill run	–	15.6	4.1	9.1	–	5.1	16.9	5.9

Moisture is one of the major considerations in maintaining the quality of wheat byproducts. Wheat is tempered to between 17% and 19% moisture prior to milling to improve the efficiency of the milling process. Byproducts are often stored at this higher moisture content and if not properly managed, will heat up and begin to sour and mold rather quickly. Some flour mills are pelleting their midds and mill run to help stabilize the byproduct and to improve storage, shipping, and handling characteristics.

From a practical standpoint, is there really anything we, the feed customer just stopping in at the local feed store to buy our week's supply of horse feed, can do to check or evaluate the quality of the feed? Certainly most of us have neither the expertise or wherewithal to go back into the mill and "check" the quality of the soybean meal or grain being used in our feed. We certainly should use our sense of smell and sight to detect musty or moldy odors or changes in colors that may indicate overprocessing. We might be able to detect burned soybean meal if we are feeding a mash. There are a few things we should be aware of that may help in making purchasing decisions. Most major feed manufacturers have Quality Control (QC) programs that include establishing ingredient specifications with vendors along with checks of incoming ingredients. If a supplier has a load of "off spec" meal, he knows he cannot sell it to a mill that has a good QC program. Likewise, vendors also know who does not check, and thus where that particular load can be sold. One cannot assume that buying from one of the large feed manufacturers assures that only good quality ingredients are used. Although the size of the mill does not necessarily correlate with a good QC program, it is often the small, local mills where no one checks ingredients that receive poor quality ingredients. We, as consumers, must decide if the place we buy feed is reputable, if they appear knowledgeable, and if they seem to be conscientious about their work. If you are buying from a local manufacturer, ask where they purchase ingredients and if the quality of the soybean meal and other ingredients is ever checked; this will at least let them know you are aware and care about the quality of the horse feed you are buying.

Feed processing

Most of today's feeds are processed in some manner before being fed. Although some grains *can* be fed whole, processing, even if it is only grinding, usually makes the nutrients more available to the animal, thus improving digestibility and feed efficiency.

GRINDING

Grinding is done using either a hammermill or roller mill. Hammermills are the most abundant type in the feed industry, although roller mills have been gaining in popularity in recent years. Hammermills grind primarily by the impact of free swinging hammers on the grain as it falls through the grinding chamber. Screens with specific size holes surround the grinding chamber and, as the grain particles become small enough, they pass out through the holes. Roller mills have pairs of rolls, often two or three pairs per mill, that essentially crush the grain as it passes between the rolls. The space between rolls can be adjusted to give various particle sizes.

Dry heat processing

MICRONIZING

Micronizing is the heating of grain with infrared heaters. The grain is heated to approximately 300°F for 25 to 50 seconds causing kernel swelling and cell rupturing. The grain is slightly expanded and the moisture content is reduced to about 7% . This product can be stored in conventional units without spoiling. Micronized corn generally has a bulk density of 25 lb/cu. ft. compared to the normal 45 lb/cu. ft. Micronizing improves both rate of gain and feed efficiency in ruminant animals.

POPPING

Popping is achieved by rapid, intense heating of grain. Rapid heating with 700 to 800°F hot air makes the water expand all at once, thereby expanding the grain. Most feed grain does not pop like popcorn, but grain does expand and starch is gelatinized, resulting in the grain being much more available to digestive enzymes or organisms.

Bulk densities, in pounds per cubic foot, are: oats 22, barley 19, wheat 34, and corn 32. (Normal bulk densities are: oats 25-35, barley 38-43, wheat 45-52, corn 45). The low bulk density causes two problems: (1) feed is often blown from feeders causing waste, (2) the animal cannot consume sufficient feed resulting in reduced gains. Many users of popped grain roll the popped grain to increase the bulk density and to help flatten the grain for easier handling.

ROASTING

Roasted grain is similar to popped grain except the grain is heated at a much slower rate. Grain is passed through a rotating drum which lifts the grain through a flame. Grain temperatures reach 260 to 300°F. Water is lost without the expansion. Depending on the rate of heating, the starch may be gelatinized and some puffing may occur. This leads to improved rate of gain, 6% - 14% and improved feed efficiencies 10% - 14% in feedlot cattle.

In dry heat processing, because of the dry heat sources and the limited amount of water available within the grain, there is very little nutritional damage that occurs during normal processing. Obviously, if the grain is overprocessed (overheated) during any of these processes, damage will occur. This is normally not a problem as each process requires a large amount of energy; thus expense limits overprocessing. The more frequent problem is underprocessing, again due to energy costs. Although this does not harm the grain, it is wasteful because there are no added benefits if it not done correctly.

Wet processing

STEAM FLAKING

Steam flaking has become a very well defined process. It is the most popular method of processing feedlot grains. Steam flaking differs from steam rolling in the amount of time used to steam the grain. Flaking calls for longer conditioning times, sufficient to gelatinize some of the starch. Grain is conditioned at atmospheric pressure for 15 to 30 minutes. Grain temperatures should reach 200 to 210°F with moisture around 17 - 18%. The amount of starch gelatinization depends on heat, moisture and roll pressure. Studies conducted on steamed grain before and after rolling show most of the changes in starch occurred after the rolls. Properly flaked grain results in improved feed efficiency and rate of gain.

If the grain is not properly flaked, starch will not be gelatinized and there will be no benefits that could not have been achieved by dry rolling. Steam flaked grain must be fed relatively soon after flaking or it must be dried. In most operations, the added expense of drying the flakes makes it impractical. Steam flaked grains are often used in textured horse feeds and it is critical that the grain be properly dried or it will begin to mold almost immediately. Frequently when corn is flaked, the germ is dislodged from the remainder of the kernel. Often, if dryers are not properly adjusted, this material goes out with the air being passed through the drier and is lost. If this happens, the energy content of the flaked grain drops somewhat due to the loss of oil and protein.

PELLETING

Pelleting is the most common form of thermal processing used in feed manufacturing. Feed is heated by steam in a conditioning chamber, raising the temperature and moisture content. The temperature and moisture reached depend on the length of time spent in the conditioner. Temperature may range from slightly above ambient, if little steam is added, to nearly 200°F. Moisture may also range from that normally present in the grain to approximately 17%. Once the moisture gets above 17%, rolls begin to slip and the pellet mill plugs.

There are too many variables of the pelleting process to discuss the effects of all of them here. There are, however, some basic aspects that affect the quality of the feed. Pellets are hot when they leave the pellet die, the heat coming from the steam conditioning and/or the friction of being extruded through the die. Pellets should be properly cooled. As they are cooled, moisture content is also reduced. Pellets should not be stored until sufficient moisture has been removed or they will mold.

There are five general categories of feeds that require different conditioning for optimum production and pellet quality. They include high grain, heat sensitive, high natural protein, high urea-molasses, and complete dairy. High grain, for example, should be pelleted at high heat/high moisture to achieve maximum benefits. Heat sensitive feeds generally contain 5 to 25% sugars. These ingredients will caramelize at approximately 140°F, a temperature easily obtained in a thick die without any steam. When this caramelization occurs, lysine will be bound and become unavailable. This is especially a problem when pelleting diets for young animals, diets such as creep feeds.

Pellets can be burned and it is very evident. The pellets often have a very dark color and an unmistakable burnt odor. This can occur when the entire feed is pelleted, but is more often seen in compounded or textured feed. When pelleted alfalfa is used it is sometimes overheated during drying or pelleting. Often times the protein source, vitamins, minerals and other low level inclusion ingredients are pelleted and these pellets are then mixed with cracked or rolled grain. Because of the low grain level and the high temperatures needed to pellet protein feeds, pellets can be burned.

Pelleting has been shown to improve nutrient digestibility, feed efficiency and improved intake in several species. Some of the non-nutritive benefits of pelleting are: less dust, ease of handling and storage, elimination of sorting of ingredients and particles by the animal, reduced segregation during handling, reduced feed wastage, and in some cases improve palatability.

Although there are several advantages to pelleted feed, there are also some cautions that must be taken when considering pelleted feed for horses. Pelleted feeds may be consumed very rapidly and, if the grain used in the pellets has been finely ground and is particularly fermentable, this may lead to situations of colic. I feel that this is more of a management concern and can be controlled or avoided with proper formulation and pellet characteristics.

EXTRUSION

Extrusion cooking has become an important part of the feed industry. Basic to extrusion cooking of cereals is starch gelatinization. Gelatinization in feed is brought about by a combination of moisture, heat, mechanical energy, and pressure differential. Gelatinization enhances the ability of starch to absorb large amounts of water leading to improved digestibility in most cases and improved feed efficiency in some. Gelatinization also increases the speed at which enzymes can break down the starch into simpler, more soluble carbohydrates.

There are basically three types of extruders in use today: short time, high temperature (ST/HT) cookers, pressure cooking extruders and dry extrusion cookers. The most common are the ST/HT extruders. The process involves the following steps:

1. Steam preconditioning at atmospheric pressure at 150°F to 210°F .
2. A method of uniform moisture application.
3. The first portion of the extruder assembly works the moistened cereal or cereal mixture into a doughy consistency at temperatures of 180°F to 210°F .
4. The next section of the extruder raises the temperature of the dough to 230°F to 400°F during a very short time, 10 to 20 seconds. This is done both with the addition of heat to the extruder barrel and friction created by the screw configuration inside the barrel.
5. The last section of the extruder serves to form the gelatinized dough into the final shape by forcing the dough through specially designed dies.
6. A cutter slices the extruded material into the desired size material.
7. The extruded product must then be dried and cooled.

This ST/HT treatment minimizes the loss of available nutrients. Vitamins, in particular, were found to be most affected by this treatment. The increased popularity of this processing method has resulted in the development of many more stable vitamins and other additives.

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