Manufacturing and Feeding Corn Milling Feed Ingredients

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Sweet Bran

The corn plant efficiently converts light energy to energy sources that can be digested by humans and animals. Corn grain, corn silage, and feed ingredients resulting from the milling of corn grain, are the most widely fed ingredients in livestock diets. Corn grain has been grown and improved for many years. Corn milling also has a long history and has continuously evolved to create more products and feed ingredients.

An early example of corn milling is the fermentation of corn mash into alcohol for human consumption. Today, a kernel of corn may be ground and fermented into alcohol for fuel or human consumption, or the kernel may be separated into its components (starch, oil, fiber, and protein). Individual components may be purified and used as-is or they may be further refined to a number of products (ethanol, plastic, sweeteners, etc.). No matter which milling process is used, or which products are manufactured, there are residual portions of the kernel that can be utilized, to various degrees, by ruminant and non-ruminant livestock. Since most of the residual feed ingredients have significant digestible fiber content, the ruminant is well suited to utilize them.

To understand corn milling and feed ingredients from corn milling, it is necessary to understand components of the corn kernel. Corn milling facilities harvest various components of the corn kernel depending on their physical design and the product they intend to produce. Thus various corn milling feed ingredients are made up of different portions of the corn kernel. Although corn kernels have a similar makeup of components, the ratio of components varies between varieties and from year-to-year due to growing conditions. This variation can influence the nutrient content of corn milling feed ingredients, and to some extent, the amount of a corn milling feed ingredient that is produced. For example, if the starch content of corn is less than in normal years, more corn will be needed to produce a given amount of corn sweetener or ethanol.

Corn milling processes, and the resulting feed ingredients, are often misunderstood. Due to these misunderstandings, assumptions are made that may be inaccurate. Incorrect assumptions regarding nutrient content may lead to feed ingredient purchases and formulation decisions that have unexpected, or less than optimum, economic ramifications. Inaccurate assumptions are typically a result of lack of information, or the application of traditional concepts to a feed ingredient for which it does not apply.

Traditional concepts may have worked for ingredients produced in the past, or that are produced today in certain corn milling facilities, but may not work for another corn milling ingredient that *appears* to be the same ingredient. To add to the confusion, 2 manufacturing facilities that produce a feed ingredient with an identical name, such as corn gluten feed (**CGF**), may be producing feed ingredients with differing nutrient specifications and different fractions of the corn kernel. Furthermore, both of the ingredients likely meet the definition of CGF. There is nothing illegal or immoral about this variation, because it is simply the feed ingredient the facility is designed to produce. The responsibility lies on the consultant to know the nutrient content and quality of the feed ingredient being fed.

The intent of this document is to focus on the primary feed ingredients from the wet corn milling (CGF) and dry corn milling distillers grain (**DG**) processes, and to communicate information in an attempt to clarify some of the misunderstanding. This document is not intended to imply that one ingredient is superior to another. Each ingredient has its place, and value, in the livestock feeding industry. We, as a livestock industry, must learn to properly feed these ingredients.

Just as ingredients differ (CGF vs DG), manufacturing facilities differ (quality control, primary ingredients produced, grain quality, etc.). Distillers grain and CGF are well suited for feeding the ruminant. We must take off our blinders, challenge traditional thinking, and value each ingredient for its true nutrient content. Then, we must find the best application for each ingredient. We will accomplish this through industry research, university research, on farm work by nutrition consultants, and through trial and error. Together we must learn how to effectively use these ingredients.

When a new ingredient is introduced into the livestock feeding market, or a new concept of feeding an existing ingredient emerges, we tend to expect our current mathematical models to accurately predict performance. Often this is too great an expectation because the ingredient or feeding regime was not part of the data set that created the model. At times, existing models predict a new ingredient flawlessly, and at other times cattle respond very differently than the existing model predicts. In this case, we must determine the expected outcome so that a model can be modified to accurately predict performance.

To understand the feed ingredients produced by the corn milling industry, one must have a general understanding of the milling processes. There are 2 primary processes: wet milling and dry milling. *Wet* and *dry* refer to the initial step in the milling process. The dry milling process begins with grinding of dry corn; whereas, the initial step in the wet milling process is screening out broken kernels and soaking (steeping) whole kernels. Both wet and dry milling processes use traditional field corn.

It should be noted that wet and dry milling terminology is in no way an indication of whether feed ingredients produced in the facility will be wet or dry. Although drying DG or CGF has the advantage of increasing shelf life, increasing ease of handling, and reducing freight expense, excessive heat during drying may reduce digestibility of nutrients and may decrease palatability if it has a burnt aroma. It is important to remember that color may not be an accurate indicator of burnt CGF. A burnt aroma should be the test. Color changes vary with changes in steep liquor color from light tan to very dark brown.

Every 56 lb bushel of corn grain, processed by the traditional dry milling process to produce fuel ethanol, results in 18 lb of DG, 2.7 gal of ethanol, and 18 lb of carbon dioxide. In comparison, every 56 lb bushel of corn grain, processed by the traditional wet milling process results in 12.5 lb of CGF, 2.5 lb of corn gluten meal, 31.5 lb of corn starch, and 1.6 lb of corn oil. Distillers grains production has steadily increased in past years and it is projected to continue the increase in 2010 due to demand for fuel ethanol.

Corn gluten feed production will likely be relatively similar to recent years, since the demand for sweeteners is not projected to increase significantly. If production of CGF remains at a similar rate as currently, the amount of CGF available to feed to US cattle may increase somewhat due to decreased exports. The decreased export market has been a trend for more than 12 yr. Although there has been some growth in wet milling due to expansion of existing mills, the recent, rapid, growth in corn milling has primarily been growth in dry milling facilities for fuel ethanol production.

DRY CORN MILLING

Dry milling is the process of grinding corn grain, hydrating the ground corn, enzymatic conversion of starch to dextrose (alpha amylase and glucoamylase), yeast fermentation of dextrose to ethanol, and the distillation of ethanol (Figure 1). Residue from fermentation and distillation (whole stillage) is subjected to centrifugation. Centrifugation separates grains (30 % DM; wet cake) from thin stillage (12 % DM). Moisture is evaporated from thin stillage to produce thick stillage (syrup; 35-40 % DM). Thick stillage and grains (wet cake) are combined in different ratios to produce wet DG with solubles of differing dry matter, protein, and fat content. As the concentration of thick stillage increases, fat content increases and protein content decreases.

The most common forms of DG are wet DG (**WDG**; 30 - 35 % DM), dried distillers grains (**DDG**; approximately 90 % DM), DDG with soluble (**DDGS**; 90 % DM), and modified WDG (**MWDG**; 45 - 55 % DM). If dry milling facilities install drying equipment, they can vary the ratio of dry and wet DG. The ratio of wet feed ingredients to dry feed ingredients may be determined by the local market for wet versus a more distant market for dry, and the cost of drying. Due to the variation in types of DG, simply assuming DG to be corn grain minus its starch content may be an inaccurate assumption. Most dry milling operations produce ethanol to be blended with gasoline as fuel for automobiles and DG to be fed to ruminants. Syrup (thick stillage) may be sold directly into the livestock feeding industry or mixed at various rates with wet cake (grains) to make DGS.

If a dry milling facility produces DDG or DDGS, they will likely have a ring drier (flash drier) or rotary dryer. Rotary driers have the potential of over-heating feed ingredients. Rotary driers may have a higher temperature and longer retention time compared to ring driers. That said, it is not a guarantee that rotary dried product will be over-heated, there simply is a greater likelihood of over-heating. Over-heating may be detected by the burnt smell.

The conversion of dextrose to ethanol by yeast fermentation is approximately 52 % efficient.

1 Dextrose ➧ 2 Ethanol + 2 Carbon Dioxide

To help preserve the efficiency of this process, antibiotics are used to remove undesirable microbial organisms.

Conversion of glucose to acetic acid is an example of an undesirable fermentation that reduces efficiency of converting dextrose to ethanol. There are yeasts that more efficiently convert dextrose to ethanol; however, they are not commercially available at this time.

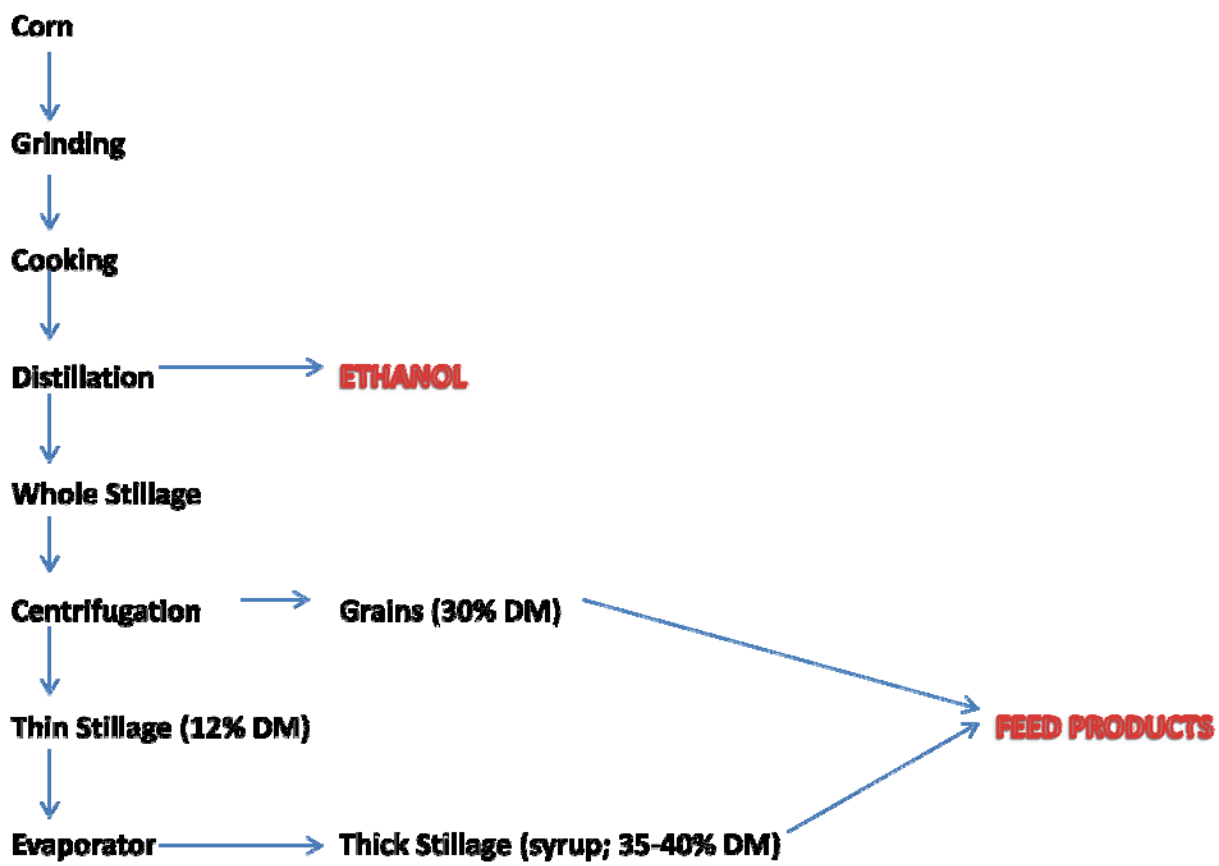

Figure 1: Dry Corn Milling Process

Although this manuscript is devoted to corn milling, it must be noted that DG are labeled according to the predominant grain in the mash from which ethanol was distilled. That is, if ethanol is being produced from a mixture of 55 % corn and 45 % milo, or if the mash is 100 % corn, the resulting DG will be labeled as corn DG.

Newer dry milling facilities tend to be built to produce 100,000,000 gal of ethanol/yr. They mill approximately 100,000 bu of corn/d.

WET CORN MILLING

Wet milling facilities are very large operations and may use as much at 500,000 bu of corn/d. Wet milling begins by removing broken kernels and soaking whole kernels 30 - 40 hr in a solution that loosens kernel components such that they can be mechanically separated. Through soaking, mechanical separation, centrifugation, floatation, and filtration; the kernel is separated into bran (fiber), corn gluten meal (protein), starch, and germ (Figure 2).

Through solvent extraction, corn oil is extracted from the germ; leaving solvent extracted germ meal (**SEM**). Solvent extracted germ meal may be mixed into CGF or sold as a protein and energy source into the livestock industry. Steep liquor is a combination of water (added into the system) that soaked the corn in the initial steeping process, and water that is used to wash starch to a purified form. In the starch washing process, sugars and proteins are removed and become part of the steep liquor. Steep liquor may be mixed with corn bran to make CGF or may be sold into the livestock feed market. Starch harvested in the wet milling process can be purified and sold as corn starch, or it may be further refined to ethanol, sweeteners, plastic, etc. Corn gluten feed pellets (CGF; 90 % DM) and wet CGF (WCGF; 35 - 45 % DM) are primary feed ingredients produced at wet milling facilities.

Just as dry mills can vary the ingredient/nutrient composition of DG, wet mills can also vary the ingredient/nutrient content of CGF by varying the fractions and/or the amount of each fraction that is mixed into CGF. For example, the amount of steep liquor has a significant effect on the protein content of CGF. Steep liquor can be sold as an ingredient into the livestock feed industry or can be included at a greater level in CGF. Corn germ may be sold into the livestock feed industry as an individual ingredient or as a component of CGF. If SEM is included in CGF, the CGF will be of greater protein quality. Germ meal has a more-concentrated lysine content.

Corn Gluten Feed

Corn gluten feed is the primary feed ingredient produced by wet milling facilities. Corn gluten feed is the part of commercial shelled corn that remains after the extraction of the larger portion of the starch, gluten, and germ by the processes employed in the wet milling manufacture of corn starch or syrup. It may or may not contain one or more of the following: fermented corn extractives, corn germ meal.

Fermented corn extractives refer to corn steep liquor. This fraction contains sugars and highly degradable protein, and can be extremely palatable to feedlot and dairy cattle.

Corn gluten meal is the dried residue from corn after the removal of the larger part of the starch and germ, and the separation of the bran by the process employed in the wet milling manufacture of corn starch or syrup, or by enzymatic treatment of the endosperm. It may contain fermented corn extractives and/or corn germ meal.

Solvent extracted germ meal is the feed ingredient remaining after solvent extraction of corn germ. It may be sold in livestock feeding industry as an individual ingredient or as a portion of CGF.

Distiller Grains

Distillers grains is a term used for a variety of feed ingredients that are a result of ethanol production. They vary in dry matter, protein, fat, fiber, and energy content. Definitions for specific feed ingredients are:

1) Distillers dried grains (**DDG**): Feed ingredient obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by separating the resultant coarse grain fraction of the whole stillage and drying it (AAFCO, 2004).
2) Corn distillers dried grains with solubles (**DDGS**) is the product obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of a grain or grains

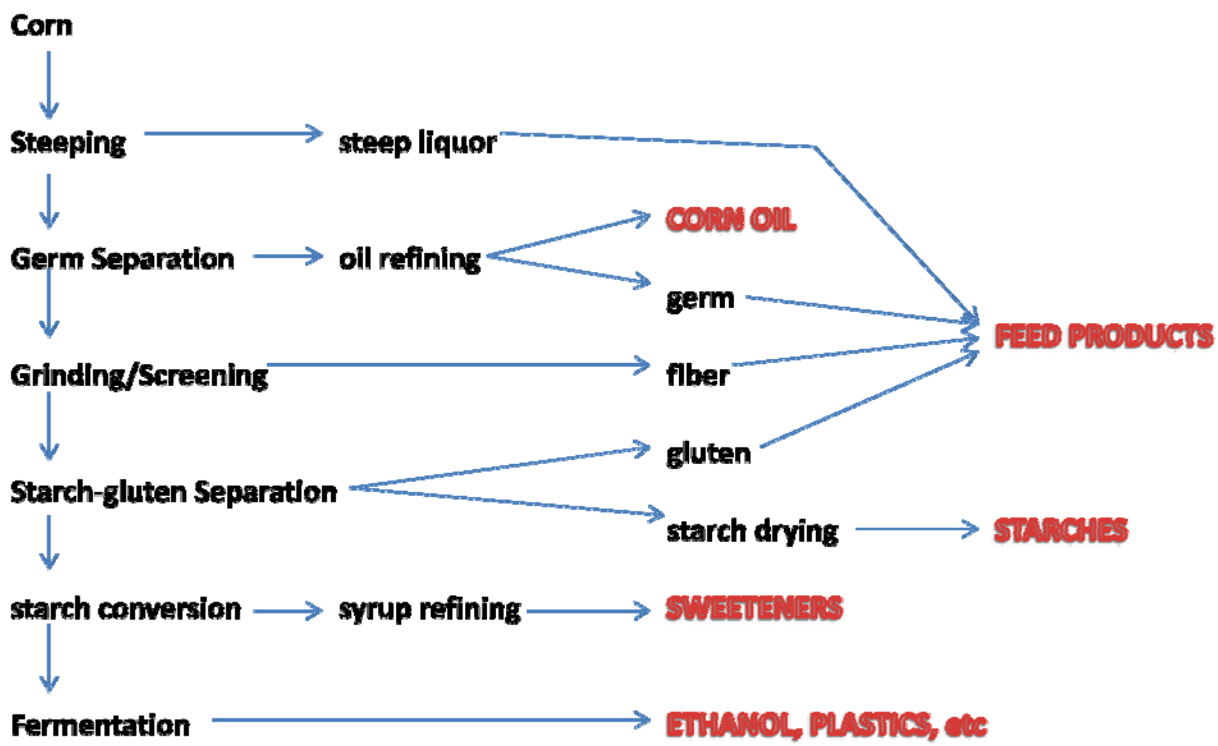

Figure 2: Wet Corn Milling Process

Distillers Grains

mixture by condensing and drying at least ¾ of the solids of the resultant whole stillage by methods employed in the grain distilling industry (AAFCO, 2004).

1) Condensed distillers solubles (**CDS**) is feed ingredient obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by condensing the thin stillage fraction to a semi-solid (AAFCO, 2004).
2) Distillers dried solubles (**DDS**) is feed ingredient obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by condensing the thin stillage fraction and drying it (AAFCO, 2004).

In addition to these ingredients, relatively new technology allows dry milling facilities to extract oil and produce bio-diesel. It is yet to be seen how the resulting, higher protein feed ingredient fits into the livestock feeding industry.

FEEDING DISTILLER GRAINS AND CORN GLUTEN FEEDS

The nutrition consultant's goal should be to obtain the optimal level of production for a dairy producer's feed dollar. To extract the best performance from corn milling ingredients, or any ingredient, one must know and understand their nutrient/feeding value. Feed ingredients that result from corn milling vary greatly in form of energy (fiber, fat), protein quality, dry matter, and nutrient consistency, etc; but are often lumped into one category, corn milling byproducts. I prefer to discuss these ingredients collectively, as corn milling *feed ingredients* rather than corn milling *byproducts*. The reason is that there are corn milling feed ingredients that are properly classified as *byproducts* and others that are properly classified as *products*. The difference between a *product* and *byproduct* is the intent of the manufacturer. If a manufacturer extends the effort (quality control, service, etc.) to produce a consistent feed ingredient that has a distinct purpose, it is a product. If the intent of the feed ingredient is to be just like the others, with little consistency and quality control, it is better classified as a byproduct. The key here is that a nutritionist typically controls variability within ingredients by feeding a limited amount of each ingredient (maximum of 10 % of dry matter intake) if variability is expected. If the nutrient content is known and variation is not expected, a nutritionist can easily formulate greater inclusion rates without fear of reduced performance due to nutrient variability.

Whether a wet or dry milling facility, feed ingredients may be fed in wet or dry forms. Drying provides handling, transportation, and shelf life advantages for CGF and DG; but has the potential of decreasing energy value and palatability. Palatability is vital. Energy and protein value is of no consequence if cattle will not consume the ingredient. The drying process has been estimated to reduce energy value by approximately 15-20 %, compared to the same ingredient that was never dried. Wet ingredients tend to assist in holding total mixed rations together, and increase dry matter intake.

Mycotoxins associated with corn milling feed ingredients are often a topic of discussion. Wet and dry milling facilities utilize traditional field corn from the same pool, so the mycotoxin issue varies from year to year. Mycotoxins are not destroyed in the wet or dry milling process and are concentrated approximately 3 fold in CGF and DG, compared to the corn grain that was milled. Mycotoxin concentration is due to the fact that mycotoxins are not associated with the starch or oil fractions of the kernel. Although mycotoxins are undesirable for wet and dry milling facilities, wet milling facilities must have a heightened awareness of mycotoxins since wet mills produce food for human consumption (corn sweeteners) and companion animal consumption (corn gluten meal).

Sulfur content of DG and CGF is an issue given considerable attention due to excess sulfur having a negative effect on cattle performance. Primary concern is polio encephalomalacia. The sulfur content of DG and CGF vary from facility to facility. DG can easily range from 0.4 to 1.2 % of dry matter. It is extremely important that the sulfur content of all suspect ingredients is known so that proper formulation may occur. Don't forget about sulfur content of water when/if issues occur. Sulfur is not simply concentrated in corn milling feed ingredients, it may be introduced into the milling process in the form of various chemicals, and for cleaning purposes. Keep in mind that it is not important that "no high sulfur ingredients" are fed, it is important that the ration remains below a toxic level of sulfur. It appears the toxic level of sulfur varies with type of ration being fed. Most cases of polio encephalomalacia tend to be associated with high grain rations fed to feedlot cattle.

Phosphorus content of CGF and DG is often a concern. Depending on inclusion rate in the ration, both usually supply adequate phosphorus to meet nutritional needs. Depending on inclusion rate, phosphorus concentration may be in excess of requirements. Producers must be environmentally conscious, but also need to consider the cost of hauling manure further from the dairy as an alternative to limiting use of a profitable ingredient. As commercial fertilizer has increased in cost, manure has become more valuable to farmers as a complete fertilizer.

The residual ingredients of wet and dry milling are well suited for feeding the ruminant. The milling process (wet or dry milling), along with products produced in the facility, determine which residual ingredients are available and, to some degree, the digestibility of them. When formulated and fed properly in cattle rations, performance by cattle fed feed ingredients from the corn milling industry, in replacement of a portion of their traditional corn intake, is often greater than cattle fed corn as the only concentrate source. For feedlot cattle, this is likely due to acidosis control, since the ration contains less starch. However, in the lactating dairy cow, there are likely positive associative effects on rumen fermentation and increased dry matter intake that elicit milk and component production responses that have been documented.

Some of the initial dairy nutrition research with CGF and DG was not favorable at high inclusion rates. More recently, researchers and nutritionists have learned that the protein quality was limiting performance, not the energy fraction(s). Now that we are more informed regarding protein quality of corn milling feed ingredients (the need for more metabolizable protein), researchers have successfully fed much greater levels in lactating dairy rations. That is, some research has shown very favorable results at levels as much at 35-40 % of dry matter intake to high producing dairy cattle. Compared to a traditional diet, milk and component production was improved. Positive results have been seen with DG, however, the oil content effect on butterfat can be a limiting factor. A key to increasing the inclusion of DG in lactating cow rations is to control fat level, such that it is consistent from load-to-load.

The traditional assumption is that corn grain has greater energy content than CGF. However, the energy value of any ingredient is determined by the ration in which it is fed. For example, CGF can be at least equal to corn as an energy supplement in forage-based developing heifer diets. Corn grain can depress forage (fiber) digestibility; whereas, CGF does not appear to depress fiber digestibility. In fact, there is evidence that fiber digestion may be increased when digestible fiber is included in the diet. The true energy value to the cow is the sum of all effects it has on energy liberation from the ration. If nutritionists are asked to compare the energy value of CGF to corn grain, answers will range from 75 % of corn grain to nearly equal to corn grain. In reality, both may be correct based on ration fed and source of CGF. It is generally accepted that DDGS and WDGS have greater energy value than corn grain, but it must be remembered that the energy increase over corn grain is due to fat concentration.

A key element in this discussion is to recognize that starch can be removed from corn grain and the resulting ingredients have the potential to have a greater energy value than corn. Why? Because, in the case of DG, starch is fermented into ethanol; but fat (corn oil) content is concentrated approximately 3 fold. Since fat has a greater energy content than starch, gross energy of the resulting ingredient may be greater than corn. Due to the greater fat content of DG, nutritionists much be aware of the corn oil content of rations containing DG to prevent butterfat depression.

Regarding protein quality, the primary difference between CGF and DG is that corn gluten meal is removed in the wet milling process. Hence, CGF has a lesser bypass protein content than DG. On the other hand, DG typically has greater protein content and greater indigestible (fiber bound) protein content. The soluble protein content of CGF is greater than DG because the primary protein source for CGF is steep liquor. If SEM is added into CGF, the protein quality is greatly improved. Corn germ meal is very high in lysine. That is, a CGF that contains a significant amount of SEM has greater value as a protein source for the high producing dairy cow than CGF depending on steep liquor as its only protein source. Addition of SEM to CGF allows less bypass lysine sources (bypass soybean meal, blood meal, etc.) to be fed in high producing cow diets.

Formulation philosophies differ from nutritionist to nutritionist. Some continue to take the approach that a corn milling feed ingredient may comprise a maximum of 10 % of the total ration, while others search for optimum use of all ingredients based on their nutrient values. The more conservative philosophy likely is proper if nutrient content is variable and/or unknown. However, if nutrient content is consistent from load-to-load, greater inclusion rates can be explored and evaluated on a cost/return basis.

A consistent, palatable, source of DG and WDG can be fed to a level that fat content is optimized based on ration cost and milk component production. A consistent source of WCGF may be fed at levels greater than 30 % of dry matter intake. At levels exceeding 25 % of dry matter intake, a portion of concentrates and a portion of forages are replaced with WCGF. It is very important to monitor total starch inclusion and typically reduce it compared to starch levels fed with traditional forage inclusion rates. This is not intended to imply that WCGF is a forage replacement, it is intended to imply that reducing starch content and increasing the digestible fiber content of the ration with WCGF allows a reduction in forage inclusion. As inclusion rates of CGF and DG increase, one must ensure bypass amino acids are properly balanced, based on production level.

There are numerous reasons to explore greater inclusion rates of DG and CGF including:

1) poor forage quality,
2) limited forage supply,
3) potential for increased performance,
4) choice to procure less forages, and
5) added moisture to a TMR without adding water, etc.

For the foreseeable future, the supply of DG and CGF available to the livestock industry will increase with increased ethanol production. Most of the ingredient growth will likely be in DG from dry milling facilities.

The High Plains Dairy Conference does not support one product over another and any mention herein is meant as an example, not an endorsement.