Strategies, Benefits, and Challenges of Feeding Ethanol Byproducts to Dairy and Beef Cattle

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Introduction

Ethanol byproducts or coproducts (I may use the two terms interchangeably) result from the fermentation of grains, typically corn, to produce ethanol – either for fuel use or for human consumption - plus distillers grains and possibly other byproducts. Most of the ethanol produced in the U.S.A. today is via dry grinding, with dried distillers grains plus solubles (DDGS) as the main byproduct (Rausch and Belyea, 2006). Quantitatively, dry grind processing of 100 kg of corn produces approximately 40.2 L of ethanol, 32.3 kg of DDGS, and 32.3 kg of carbon dioxide. Wet milling is usually used for producing corn oil, corn sweeteners such as dextrose and high fructose corn syrup, but the starch can be fermented to produce ethanol. Byproducts of this process include corn gluten feed (CGF) and corn gluten meal (CGM). The CGF consists mainly of corn bran and steep liquor. Corn gluten meal is a high protein coproduct that also arises from wet milling while corn germ meal remains after extraction of oil from the corn germ. Quantitatively, one obtains approximately 67.2% corn starch (which can be fermented to ethanol), 19.6% CGF, 5.7% CGM, and 7.5% corn germ (50% oil) from the wet milling of corn (Long, 1985). Distillers grains and CGF can both be fed wet or dried with similar results.

This presentation will review research results from feeding ethanol byproducts to dairy and beef cattle. Emphasis will be on DDGS, especially for dairy cattle, and CGF. Other byproducts such as condensed corn distillers solubles (CCDS), corn germ, and some potentially new products available in the future will be mentioned. Byproducts available when fermenting other grains or feed sources will be mentioned, although research data is limited with those sources.

Nutrient Content of Ethanol Byproducts

Nutrient content of the major ethanol coproducts is outlined in Table 1 with values listed usually for products from corn fermentation. Specifics related to various products will be discussed later. These tabular values reflect primarily values reported in NRC (1996, 2001) as modified by more recently reported analytical information such as data from Spiehs et al. (2002) for “new generation” DGS and Birkelo et al. (2004) for

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the energy values of distillers grains. Such products tend to contain more protein, energy, and available phosphorus than distillers grains from older ethanol plants, which likely reflects increased fermentation efficiency in today's ethanol plants. Ethanol coproducts contain relatively high amounts of phosphorus, which can be a plus – if additional phosphorus is needed in diets – or a minus – if excess phosphorus in manure needs to be disposed.

Virtually all distillers grains is marketed as distillers grains plus solubles, although this may change in the future as some processors fractionate distillers products into various components, which will be discussed later. The composition of corn distillers grains is essentially the same with or without solubles added, except for a lower phosphorus content (~0.4%) without solubles because the solubles are quite high in phosphorus (~1.35%). Therefore, most of the animal performance data reported below use data for distillers grains with or without solubles interchangeably. The protein content of DDGS is often slightly higher and the fat content slightly lower without solubles. If a DGS product contains substantially more fat (e.g. >15%) and/or phosphorus (e.g. >1.0%) than the values listed in Table 1, it is very likely that more than normal amounts of distillers solubles were blended with the distillers grains, or that the processor had problems with separation of materials during the handling of solubles. Such variations also point out the importance of obtaining analytical data on the specific product being received from a supplier and the importance of suppliers providing uniform, standardized products. A complaint about some DDGS suppliers is an inconsistent, variable product, a situation which is stimulating some other suppliers to offer consistent, premium quality DDGS that are sometimes even branded. Both distillers grains and CGF can be fed wet or dried with similar nutrient contents, although slight differences will be commented on later in this presentation.

The distillers grains available in recent years contain more energy than older "book" values. Research by Birkelo et al. (2004) indicated that wet corn DGS contained approximately 2.25 Mcal/kg of NE_L, 10 to 15% more energy than published in older references and even more than in the recent dairy NRC (2001) for DDGS. This likely reflects a higher energy value for newer generation distillers grains and does not necessarily reflect higher energy in wet than in dried DGS; that is a separate comparison that has not been made.

Both distillers grains and CGF contain large amounts of NDF but low amounts of lignin. Thus, these are readily digestible fiber sources, which allows these products to serve as partial replacements for forages as well as for concentrates in diets of dairy and beef cattle. These nonforage fiber sources can supply energy needed for lactation or growth without the ruminal acid load caused by rapidly fermented starchy compounds (Ham et al., 1994). Such nonforage fiber sources of NDF can partially replace forages at times when forage supplies may be limited; however, because of the small particle size, DGS and wet CGF may lack sufficient "effective fiber" to prevent milk fat depression (Cyriac et al., 2005; Allan and Grant, 2000). Wet CGF was only 11 to 13% as effective as alfalfa hay in maintaining ruminal pH and rumination activity but 74% as effective as alfalfa silage in maintaining milk fat percentages (Allan and Grant, 2000).

There is less information available about the nutrient content of DDGS produced from the fermentation of other grains such as wheat, sorghum, or barley. However, data available indicate that the composition usually reflects the nutrient content of the grain, i.e. higher protein for wheat and barley DDGS than for corn DDGS and higher or lower protein for sorghum DDGS, depending on the source used.

Distillers Grains

Distillers grains, often referred to corn distillers grains, is a good source of ruminally undegradable protein (RUP). The reported value of 55% of CP as RUP is probably an appropriate figure to use in most cases, although some variation in reported values exists. Most reported values range from 47% to 69% RUP. Wet DGS usually has the lower RUP values, often 5 to 8% lower concentrations of RUP than does dried DGS. For instance, Firkins et al. (1984) reported 47% RUP for wet DGS and 54% RUP for the dried product, while Kleinschmit et al. (2007) reported a range of 59 to 72% of CP as RUP for five DDGS sources and slightly lower RUP (54%) for wet DGS. The highest quality DDGS products in that study contained less than 64% RUP. Most of the readily degradable proteins in corn have been degraded during the fermentation process, thus the protein remaining in the corn DDGS is going to be proportionately higher in RUP than in the original corn. However, if RUP values for DDGS are quite high (e.g. >80% of CP), it may be advisable to check for heat damaged, undigestible protein. While some may wish to think that a golden yellow color is a good indication of quality for DDGS, research data from Belyea et al. (2004) indicated that color is sometimes (e.g. Powers et al., 1995) but often not (Kleinschmit et al., 2006b) an accurate indicator of protein quality.

Response of Lactating Cows and Growing Cattle

Milk production and composition data summarized in Table 2 are from the more than two-dozen research trials with 98 treatment comparisons reported between 1982 and early 2005 in which corn distillers grains, either wet or dried, were fed to lactating cows. This table is an abbreviated summary of the meta analysis conducted by Kalscheur (2005) of this extensive survey of virtually all of the modern research data available about feeding DGS to lactating cows. Amounts of DGS fed ranged from 4.2% of total diet DM (Broderick et al., 1990) to 41.6% of DM (Van Horn et al., 1985).

Production was the same as or higher when fed DGS than when fed control diets in virtually all experiments except possibly when fed very large amounts (i.e. 30% or more of diet DM) as wet DGS, which will be discussed later. In experiments that compared DGS to soybean meal as the protein supplement, production was similar or higher than production achieved with soybean meal, even when DDGS and soybean-based diets were formulated to be equal in RUP (Pamp et al. 2006). Florida research (Powers et al., 1995) indicated higher production when fed DDGS from whiskey and from fuel ethanol plants than when fed soybean meal. However, when they fed a DDGS product that was darker and possibly heat damaged, milk production was lower than when fed lighter, golden colored DDGS but still similar to production when fed soybean meal. But be cautioned because research data by Belyea et al. (2004) indicated that color is often not an accurate indicator of protein quality. When Kleinschmit et al. (2006b) used a standard, good quality DDGS to evaluate the response to two specially processed DDGS products intended to have even better quality, milk production was higher for all three DDGS products evaluated than for the soybean meal-based control diet, with only small differences in response due to the improved DDGS quality.

We are completing the second year of a trial in which cows were fed 15% of diet DM as wet DGS for the entire lactation, during the dry period, and into the second lactation. After the first year, there were no differences in production (31.7 and 33.6 kg/d for control and wet DGS), while fat percent (3.75 and 4.07), protein percent (3.29 and 3.41), and feed efficiency (1.30 and 1.57 kg FCM/kg DMI) were greater for cows fed wet DGS (Mpapho et al., 2006). Reproductive efficiency and cow health were similar for both dietary groups.

The quality of protein in corn DDGS is fairly good. As with most corn products, lysine is the first limiting amino acid in corn DGS for lactating cows, but corn DGS is a very good source of methionine. Therefore, sometimes (Nichols et al., 1998) but not always (Liu et al., 2000) milk production increased when fed supplemental ruminally protected lysine and methionine with DDGS, or when the DDGS was blended with other protein supplements that contained more lysine. Kleinschmit et al. (2006b) showed that, while there may be differences in protein quality of various sources of DDGS present today (Kleinschmit et al., 2007), differences in yields of milk and milk protein might be slight, unless a product is greatly heat-damaged. Recent research (Kleinschmit et al. 2006a) indicates slightly greater production when 15% DDGS was fed with high alfalfa versus high corn silage diets, likely reflecting an improved amino acid status with the "blend" of alfalfa-DDGS proteins versus a diet containing predominantly corn-based proteins.

Wet versus Dried DGS. So far this presentation has contained information almost interchangeably about both wet and dried distillers grains, because the nutrient content of the dry matter is essentially the same for both wet and dried DGS, except for possibly slightly lower RUP values with wet than with dried DGS. Very few trials compared wet versus dried DGS; most trials simply compared DGS to a control diet. When Al-Suwaiegh et al. (2002) directly compared wet versus dried corn or sorghum DGS for lactating cows, they observed similar production for both wet and dried DGS but about 6% more milk ($P < 0.13$) with corn versus sorghum DGS. Research by Anderson et al. (2006) observed greater production when fed either wet or dried DGS than when fed the control diet, a tendency ($P = 0.13$) for greater production when fed wet DGS instead of dried DGS, and a tendency ($P = 0.12$) for greater production when fed 20% of the ration DM as DGS versus 10%, either wet or dried. Data comparing wet versus dried DGS with growing and finishing beef cattle (Ham et al., 1994) indicated similar animal performance when fed wet or dried products.

The main considerations regarding the use of wet versus dried DGS are handling and costs. Dried products can be stored for extended periods of time, can be shipped greater distances more economically and conveniently than wet DGS, and can be easily blended with other dietary ingredients. Some have reported problems with DDGS setting up when shipped extended distances in rail cars, but that seems to be a problem related to moisture and temperature that some ethanol plants are starting to address. Feeding wet DGS avoids the costs of drying the product, but there are other factors to consider when feeding wet DGS that are not concerns when feeding dried DGS. Wet DGS will not remain fresh and palatable for extended periods of time; 5 to 7 days is the norm. This storage time span will vary somewhat with environmental temperature as products will spoil and become unpalatable more rapidly in hot weather, but may be kept in an acceptable form as long as three weeks under cool conditions. Surface molds occasionally occur, thus there is usually some feed lost; a problem that wouldn't be a consideration with DDGS. The addition of preservatives such as propionic acid or other organic acids may extend the shelf life of wet DGS (Spangler et al., 2005) but refereed journal publications that document such results are limited. We at SDSU (Kalscheur et al., 2002; 2003; 2004a,b) successfully stored wet DGS for more than six months in silo bags. The wet DGS was stored alone or blended with soyhulls (Kalscheur et al., 2002), with corn silage (Kalscheur et al., 2003), and with beet pulp (Kalscheur et al., 2004). Some field reports indicate successful preservation of wet DGS for more than a year in silo bags.

Milk composition. The composition of milk is usually not affected by feeding DDGS unless routinely recommended ration formulation guidelines, such as feeding sufficient amounts of forage fiber, are not followed. Some field reports indicated milk fat depression when diets contained more than 10% of ration DM as wet DGS (Hutjens, 2004); however, those observations are not supported by research results. The meta analysis conducted by Kalscheur (2005) showed that there were no decreases in milk fat content when diets contained wet or dried DGS at any level, even as high as 40% of DM intake (see Table 2). In fact, the milk fat content was usually numerically highest for diets containing DGS. Incidentally, most of these studies were conducted during early to mid lactation, thus the data in Table 2 are typical for cows during these stages of lactation.

The only time when milk fat content may have been lower with DGS was when diets contained less than 50% forage (Kalscheur, 2005). That result hints at why field observations of milk fat depression may have occurred. Because DGS contains an abundance of NDF, one is often tempted to decrease the amounts of forage fed when formulations indicate more than sufficient amounts of NDF. However, the small particle size of DGS means that its "effective fiber" is not as great as that of the forage fiber it replaced. A recent study at SDSU support the observations from the meta analysis. Cyriac et al. (2005) observed a linear decrease in milk fat concentration while milk production remained unchanged and milk protein content increased when cows were fed 0, 7, 14, and 21% of DM as DDGS in place of corn silage even though dietary NDF content remained unchanged. The control diet contained 40% corn silage, 15% alfalfa hay, and 45% concentrate mix. Thus, the key to maintaining milk fat tests is to feed sufficient amounts of forage fiber.

The fatty acid content of milk fat when cows are fed DGS is not expected to be affected greatly but has been evaluated in a few studies. Because the fat in DGS, especially corn DGS, is quite unsaturated with typically more than 60% linoleic acid, it is logical to expect a modest increase in the concentration of unsaturated fatty acids in the milk produced as observed by Schingoethe et al. (1999). Leonardi et al. (2005) and Anderson et al. (2006) also reported modest increases in the healthful fatty acid *cis-9,trans-11* conjugated linoleic acid (CLA) and its precursor vaccenic acid (*trans-11 C18:1*).

Milk protein content is seldom affected by feeding DGS unless protein is limiting in the diet. Then the lysine limitation in DGS may cause a slight decrease in milk protein content (Kleinschmit et al., 2006b). This effect may be more noticeable in diets that contain more than 30% DGS (Kalscheur, 2005). Milk protein content is typically decreased about 0.1% when fed added fat from any source, so that can be a minor consideration when feeding DGS; however, most studies with DGS showed no effect on milk protein content.

<u>How much CDG can be fed?</u> We at SDSU and other researchers have demonstrated in a number of experiments that dairy producers easily feed up to 20% of ration DM as distillers grains. With typical feed intakes of lactating cows, this would be approximately 4.5 to 5.5 kg of dried DGS or 15 to 17 kg of wet DGS per cow daily. There are usually no palatability problems and one can usually formulate nutritionally balanced diets with up to that level of distillers grains in the diet using most combinations of forages and concentrates. For instance, with diets containing 25% of the dry matter as corn silage, 25% as alfalfa hay, and 50% concentrate mix, the DGS can replace most – if not all – of the protein supplement such as soybean meal and a significant amount of the corn that would normally be in the grain mix. The experiment by Anderson et al. (2006) illustrates this as feeding 20% of the diet DM as wet or dried DGS replaced 25% of the corn and 87% of the soybean meal fed in the control diet. With diets that contain higher proportions of corn silage, even greater amounts of DDGS may be useable; however, the need for some other protein supplement, protein quality (e.g. lysine limitation), and phosphorus concentration may become factors to consider. With diets containing higher proportions of alfalfa, less DGS may be needed to supply the protein required in the diet, and in fact the diet may not be able to utilize as much 20% DGS without feeding excess protein. When feeding more than 20% distillers grains, one is likely to feed excess protein, unless forages are all or mostly corn silage and/or grass hay.

Grings et al. (1992) observed similar DM intake and milk production when cows were fed as much as 31.6% of ration DM as DDGS. Schingoethe et al. (1999) fed slightly more than 30% of the ration DM as wet DGS with decreased DM intake but no decrease in milk production, likely reflecting the higher NE_L content of the wet DGS diet. However, research by our group (Hippen et al., 2003; 2004) in which as much as 40%

of ration DM was fed as DGS indicated possible problems when corn DGS provided more than 20 to 25% of the ration DM. Dry matter intake decreased with a corresponding decrease in milk production when wet DGS supplied more than 20% of the diet DM (Hippen et al., 2003). Gut fill may have limited DM intake of these wet diets (40 to 46% DM) because total DM intake often decreases when the diet is less than 50% DM, especially when fermented feeds are fed (NRC, 2001). However, when dried DGS was fed (Hippen et al., 2004), DM intake and milk production still decreased when diets contained 27 to 40% DDGS. An interesting observation is that, in the meta analysis of 24 experiments (Kalscheur, 2005), the highest DM intakes and milk production occurred when diets contained 20 to 30% DGS although, as expected, DM intakes and production decreased with 30 to 40% wet DGS.

Distillers grains for beef cattle. Beef cattle have been successfully fed as much as 40% of ration DM as wet or dried DGS (Al-Suwaiegh et al., 2002; Ham et al., 1994; Larson et al., 1993). A Minnesota study (Roeber et al., 2005) fed up to 50% of DM as wet or dried DGS with no effect on beef tenderness or palatability. Such diets cited above were fed primarily as energy sources but, admittedly, contained more protein and phosphorus than finishing cattle needed. These experiments suggested that wet DGS contained 29 to 40% more NE_{gain} than dry-rolled corn, but dried DGS contained only 21% more NE_{gain} than dry-rolled corn (Ham et al., 1994). Increased feed efficiency when fed distillers grains products or wet CGF (Krehbiel et al., 1995) in place of corn may in part be due to fewer off-feed problems and reduced subacute acidosis (Ham et al., 1994; Larson et al., 1993). That is because, even though the DGS contains similar amounts or more energy than corn, the energy in DGS is primarily in the form of digestible fiber and fat while in corn most of the energy in the form of starch. Ruminal starch fermentation is more likely to result in acidosis, laminitis, and fatty liver. Lodge et al. (1997) determined that corn wet DGS was more digestible than was sorghum wet DGS, and wet DGS products were more digestible than dried DGS.

Distillers Grains Blended with Other Feeds. Distillers grains have also been successfully fed blended with other feeds for both beef and dairy cattle. Lodge et al. (1997) reported that a composite of wet CGF, condensed distillers solubles, corn gluten meal, and tallow, formulated to be similar in nutrient content to wet DGS improved the feed efficiency of finishing steers compared to wet CGF or corn.

Several experiments have been conducted at SDSU in which wet DGS was blended with other high fiber feeds. Such approaches may be helpful in times when forage supplies are limited or expensive. For instance, a 70:30 (DM basis) blend of wet DGS and soyhulls reduced the dustiness of soyhulls, reduced the seepage that is common with wet DGS, provided more desirable protein (21% CP) and P (0.6%) contents, and yet provided a high energy, high fiber feed (Kalscheur et al., 2002). Growth rates of heifers fed the blend were similar (1.22 and 1.27 kg/d) to gains when fed conventional diets (Kalscheur et al., 2004). When heifers were fed a blend of wet DGS (69% of DM) and corn stalks (31%), weight gains were less (1.04 kg/d) than when fed conventional diets (1.27 kg/d). Ensiling wet DGS alone or in combination with corn silage indicated that preservation of each could be enhanced by combining the feedstuffs with a 50:50 blend likely optimal (Kalscheur et al., 2003).

Corn Distillers Solubles

Distillers solubles are usually blended with the distillers grains before drying to produce DGS, but the solubles may be fed separately. DaCruz et al.(2005) fed 28% DM condensed corn distillers solubles (CCDS) at 0, 5, and 10% of total ration DM to lactating cows. Milk production (34.1, 35.5 and 35.8 kg/d for 0, 5, and 10% CCDS diets) increased when fed the CCDS, although milk fat content (3.54, 3.33, and 3.43%) was slightly lower and milk protein content (2.93, 2.97, 2.95%) was unaffected by diets. In a recently completed experiment, Sasikala-Appukuttan et al. (2006) fed as much as 20% of the total ration DM as CCDS (4% fat from the CCDS) with no apparent adverse affects on DM intake or milk composition. Milk yield tended to be higher for cows fed 10 and 20% CCDS than for cows fed the control diet. Thus, CCDS by itself can be a good feed for dairy cattle. However, we would not recommend feeding as much as 20% CCDS because diets including that much CCDS contained more than 0.5% phosphorus.

Pingal and Trenkle (2005) fed 12% of DM as CCDS to finishing steers with good animal performance results. Condensed and thin distillers solubles have also been successfully used as protein and energy sources in beef cattle diets (see Ham et al., 1994).

Other Distillers Products

One will likely see a growing list of distillers products available as feeds for livestock in the future as processors continue to improve the efficiency of ethanol production and look for ways to fractionate byproducts resulting from the process. For instance, distillers bran is a new byproduct feed produced as primarily corn bran plus distillers solubles (53% DM) containing 14.9% CP. When fed to finishing steers, animal performance was similar to DDGS at the same inclusion level (Bremer et al., 2005).

Abdelqader et al. (2006) recently completed an experiment feeding the germ that was removed from the corn grain prior to ethanol production. The germ (~21% fat) was fed to lactating cows at 0, 7, 14, and 21% of ration DM. Inclusion at 7 and 14% of DM increased milk and fat yields, however, feeding 21% corn germ decreased the concentration and yield of milk fat. Corn germ from wet milling operations may contain 45% or more fat, but feeding trials with that product are limited.

Corn Gluten Feed

Corn gluten feed, often fed as wet CGF, is a relatively high fiber, medium-energy, medium-crude protein product that can be fed to dairy and beef cattle. The energy value of wet CGF is 92 to 100% of the energy value of shelled corn (Firkins et al., 1985; Ham et al., 1995); values were slightly lower for dry CGF. Schrage et al. (1991)

determined the $NE_{maint.}$ and NE_{gain} of wet CGF to be 1.60 and 1.32 Mcal/kg of DM, respectively.

Lactating cows can consume quite large amounts of CGF with acceptable performance, but the response was more variable in earlier studies (see Van Baale et al., 2001). Staples et al. (1984) reported linear declines in DM intake and milk yield as amounts of wet CGF increased from at 0 to 40% of DM in 50% corn silage diets. Dry matter content of the total diet may have been part of the problem as mentioned earlier regarding the feeding of wet DGS. However, Armentano and Dentine (1988) observed no reductions in DM intake and milk yield when diets contained as much as 7.9 kg/d (~36% of ration DM) as wet CGF. Wet CGF replaced only concentrates in most of the above studies. When wet CGF replaced up to 35% of ration DM as a mix of alfalfa hay, corn silage, and corn grain, milk production was greater than when fed the control diet (Van Baale et al., 2001). In experiments that included as much as 45% of ration DM as wet CGF, Schroeder (2003) concluded that 18.6% of dietary DM as wet CGF in place of portions of both forage and concentrate would maximize milk yield without negatively affecting milk composition or feed efficiency.

Cattle can be fed very large amounts of wet CGF with very acceptable animal performance. Sindt et al. (2003) obtained the highest weight gains and feed efficiencies when diets fed to finishing steers contained 30% wet CGF rather than 0 or 60% wet CGF. This amount (30% of DM) was similar to the 27% of DM as wet CGF that Bernard et al. (1991) indicated could be fed to lactating cows without altering milk yields. A summary of beef feedlot research (Stock et al., 1999) indicated that the efficiency of gain was improved by 5% when diets containing 25 to 50% wet CGF were compared to dry-rolled corn.

Data from Boddugari et al. (2001) indicated that a new wet corn milling product (CMP) can effectively replace all of the concentrate and up to 45% of the forage in the diet of lactating cows. The CMP, which is similar to wet CGF, was composed of corn bran, fermented corn extractives, corn germ meal, and additional sources of ruminally undegradable protein to increase the metabolizable protein content of the product. This wet CMP contained (DM basis): 23.1% CP, 9.9% RUP, 40.3% NDF,13.7% ADF, and 2.6% ether extract. A modified corn fiber (MCF) produced by a secondary bacterial and yeast-driven fermentation of the corn bran may enable corn processors to more fully recover ethanol from corn (Peter et al., 2000). However, feeding MCF (23.9% CP, 49.4% NDF, 45.4% ADF) resulted in poorer performance of heifers, suggesting a limited feeding value because of the high acid detergent insoluble nitrogen content and slow protein digestion.

Corn Gluten Meal

Corn gluten meal (CGM) is a high protein (65% CP) high RUP (75% of CP) feed that is a very good protein supplement. However, it is best to blend CGM with other protein supplements for optimal animal performance. Because of its high RUP level and lysine limitation, feeding CGM as the only protein supplement did not support the same amount of milk production as soybean meal-containing diets in a series of multi-university studies, even when the CGM diets were supplemented with ruminally protected lysine and methionine (Polan et al., 1991). A blend of several high quality proteins (blood meal, CGM, canola meal, and fish meal) supported milk production similar to production supported by soybean meal-containing diets (Piepenbrink et al., 1998).

The Future?

One doesn't know what corn coproducts will be available to the feed industry in the future. However, if one can speculate, improved products and new products are likely to become available. For instance, improvements in fermentation technology already provide DDGS today that contains more protein and energy than DGS of previous years contained. It is also becoming feasible to "fractionate" in some manner DGS into products that are higher in protein, other products that are higher in fat or in fiber, and products that are higher or lower in phosphorus (Rausch and Belyea, 2006). And some products from ethanol production may find their way into human food uses and non-food uses such as building products. Also, some ethanol producers are currently evaluating the use of much of the fat in DGS as biodiesel. This fat may be extracted from the germ prior to ethanol fermentation or from the distillers solubles. These comments are based on prior research experience with feeding whey, the coproduct from cheese manufacturing. At one time there was a choice between "whole whey" or "whole whey", either liquid or dried. Today, a large number of whey products varying from protein concentrates to lactose are available to the human food and animal feed industries. A similar situation could also occur with ethanol coproducts.

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Table 1. Nutrient content of ethanol byproducts.[1]

Item	Product			
	DDGS[2]	Distillers solubles	CGF[3]	CGM[4]
	(% of DM)			
Crude protein	30.1	18.5	23.8	65.0
RUP[5]% of CP	55.0	30.0	30.0	75.0
$NE_{maintenance}$, Mcal/kg	2.07	2.19	1.87	2.54
NE_{gain}, Mcal/kg	1.41	1.51	1.24	1.79
$NE_{Lactation}$, Mcal/kg	2.26	2.03	1.73	2.38
Neutral detergent fiber (NDF)	41.5	20.0	35.5	11.1
Acid detergent fiber (ADF)	16.1	5.0	12.1	8.2
Ether extract	10.7	21.5	3.5	2.5
Ash	5.2	12.5	6.8	3.3
Calcium	0.22	0.30	0.07	0.06
Phosphorus	0.83	1.35	1.00	0.60
Magnesium	0.33	0.60	0.42	0.14
Potassium	1.10	1.70	1.46	0.46
Sodium	0.30	0.23	0.13	0.05
Sulfur	0.44	0.37	0.44	0.86

[1]Most data are from NRC (1996, 2001), Spiehs et al. (2002), and Birkelo et al. (2004)
[2]DDGS = corn distillers grains
[3]CGF = corn gluten feed
[4]CGM = corn gluten feed
[5]RUP = ruminally undegradable protein

Table 2. Dry matter intake (DMI), milk yield, milk fat, and protein content when fed diets containing wet or dried corn DGS.[1]

Inclusion level	DMI	Milk	Fat	Protein
(% of DM)	(kg/d)		(%)	
0	22.1[b]	33.0[ab]	3.39	2.95[a]
4 – 10	23.7[a]	33.4[a]	3.43	2.96[a]
10 – 20	23.4[ab]	33.2[ab]	3.41	2.94[a]
20 – 30	22.8[ab]	33.5[a]	3.33	2.97[a]
> 30	0.9[c]	32.2[b]	3.47	2.82[b]
SEM	0.8	1.4	0.08	0.06

[a,b,c]Values within a column followed by a different superscript differ ($P < 0.05$).
[1]Adapted from Kalscheur (2005).