# Chapter 3

# Use of Distillers Co-products in Diets Fed to Dairy Cattle

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This chapter reviews research results from feeding ethanol by-products (co-products) to dairy cattle. While the main emphasis is on feeding the milking herd, the use of ethanol co-products in diets of calves, growing heifers, and dry cows is also discussed. The emphasis here is on distillers grains with solubles (DGS), both wet and dried, but other by-products such as condensed corn distillers solubles, corn germ, and some potential new products for which data are available are mentioned. Co-products that result when fermenting other grains or feed sources are mentioned, although research data are limited for many of those sources.

There is a tremendous amount of DGS and other distillers co-products available at competitive prices for feeding to livestock. Most of this is currently available as DGS, but in the future we will see a completely new list of distillers co-products from which to choose. Some of these products for which animal performance data are available are mentioned later in the chapter.

## Nutrient Content of Ethanol By-products

Other chapters in this book give details of the nutrient composition of DGS; however, some items of special concern to those formulating diets for dairy cattle are also mentioned in this chapter. Distillers grains have been fed for more than 100 years, but it is only recently that large quantities are becoming available and at competitive prices. In addition, the products available today usually contain more protein and energy (Birkelo, Brouk and Schingoethe, 2004) than older "book values," even more than listed in the recent dairy nutrient requirements report of the National Research Council (NRC, 2001), and can be of uniformly good

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quality. This reflects the improved fermentation efficiency of the new-generation ethanol plants (Spiehs, Whitney, and Shurson, 2002). See the University of Minnesota (2008) distillers grains Web site (www.ddgs.umn.edu), which includes current updates on compositional analyses of distillers dried grains with solubles (DDGS) from a large number of ethanol plants in the U.S. Midwest.

Nutrient content of DGS and distillers solubles are presented in Table 1. These tabular values reflect primarily values reported in the dairy NRC report (NRC, 2001) as modified by more recently reported analytical information such as data from Spiehs, Whitney, and Shurson (2002) for new-generation DGS and Birkelo, Brouk, and Schingoethe (2004) for 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

**Table 3.1. Nutrient content of corn distillers dried grains with solubles (DDGS) and distillers solubles**

| | Product | |
|---|---|---|
| **Item** | **DDGS** | **Distillers Solubles** |
| | (% of Dry Matter) | |
| Crude protein | 30.1 | 18.5 |
| RUP[a] % of crude protein | 55.0 | 30.0 |
| $NE_{maintenance}$, Mcal/kg | 2.07 | 2.19 |
| $NE_{gain}$, Mcal/kg | 1.41 | 1.51 |
| $NE_{Lactation}$, Mcal/kg | 2.26 | 2.03 |
| Neutral detergent fiber (NDF) | 39.0 | 20.0 |
| Acid detergent fiber (ADF) | 16.1 | 5.0 |
| Ether extract | 10.7 | 21.5 |
| Ash | 5.2 | 12.5 |
| Calcium | 0.22 | 0.30 |
| Phosphorus | 0.83 | 1.35 |
| Magnesium | 0.33 | 0.60 |
| Potassium | 1.10 | 1.70 |
| Sodium | 0.30 | 0.23 |
| Sulfur | 0.44 | 0.37 |

*Source*: Most data are from NRC, 2001; Spiehs, Whitney, and Shurson, 2002; and Birkelo, Brouk, and Schingoethe, 2004.

[a]RUP is ruminally undegradable protein.

today's ethanol plants. Distillers grains from new-generation plants contain very little starch versus as much as 5% to 10% starch in DGS from older, less-efficient ethanol plants. Corn DGS contains relatively high amounts of a quite digestible phosphorus (Mjoun et al., 2007), which can be a plus—if additional phosphorus is needed in diets—or a minus—if excess phosphorus in manure needs to be disposed at times when additional phosphorus is not needed for soil fertility. Sulfur content is usually not a concern; however, there have been reports of high levels of sulfur (as much as 1%) in DGS from some plants. Recent surveys (Schingoethe et al., 2008) indicate that an average of 0.5% to 0.6% sulfur in DGS may be more the norm than the NRC report value of 0.44% listed in Table 1. Higher sulfur may be related to amounts of acid used in pH control and cleaning operations that get added to the DGS. In some cases, high sulfur content of the water used may also be a contributor.

Virtually all of the distillers grains available today are in the form of DGS but this may change in the future as processors do more fractionating of the DGS. 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 (~1.3% to 1.5%). Therefore, most animal performance studies use data for distillers grains with or without solubles interchangeably. 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 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. When Noll, Brannon, and Parsons (2007) added incremental amounts from 0% to 100% of the solubles generated from a batch of distillers grains back into the distillers grains, this increased the fat content from 8.9% to 11.7% of dry matter in the dried grains. Phosphorus and sulfur contents likewise increased while protein changed very little. Such variations point to the importance of obtaining analytical data on the specific product being received from a supplier and the importance of suppliers providing uniform, standardized products.

Ruminally undegradable protein (RUP) and ruminally degradable protein (RDP) fractions of the diet are important considerations in formulating diets for dairy cattle, especially for high-producing dairy cows. Corn

DGS is a good source of RUP, usually ranging between 47% and 64% of the crude protein as RUP for higher-quality DGS, with wet DGS usually 5% to 8% lower in RUP than dried DGS (Firkins et al., 1984; Kleinschmit et al., 2007a). However, if RUP values for DGS are quite high (e.g., >80% of crude protein), it may be advisable to check for heat-damaged, undigestible protein. As in other corn products, lysine is the first limiting amino acid in corn DGS, although DGS is a good source of methionine. Limited data (Kleinschmit et al. 2006; 2007a,b) indicate that higher-quality DGS products may contain more available lysine than do lower-quality products. In fact, a recent survey of dried DGS available from a large number of ethanol plants in the Midwest (University of Minnesota, 2008) indicated higher concentrations of lysine (3.05% of crude protein) versus 2.24% of crude protein listed in the latest NRC dairy report (2001). While some may wish to think that a golden yellow color is a good indication of quality for DGS, research data from Belyea, Rausch, and Tumbleson (2004) indicated that color is sometimes (e.g., Powers et al., 1995) but often not (Kleinschmit et al., 2007a) an accurate indicator of protein quality.

New-generation DGS contain more energy than older "book" values. Research by Birkelo, Brouk, and Schingoethe (2004) indicated that wet corn DGS contained approximately 2.25 Mcal/kg of NEL, 10% to 15% more energy than published in even the recent NRC report (2001) for dried DGS. 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. At least a part of this high energy content in DGS is due to the fat, while some is also attributed to the highly digestible fiber in DGS.

Distillers grains contain large amounts of neutral detergent fiber (NDF) but low amounts of lignin. While most DGS contain 38% to 40% NDF, it is not unusual for some sources of DGS to contain less than that. Such readily digestible fiber sources can partially replace forages as well as concentrates in diets of dairy cattle; however, for lactating cows, it is recommended that DGS replace concentrate ingredients in the diet and not forage ingredients. Because of the small particle size, DGS contain little effective fiber, only 3.4% to 19.8% physically effective NDF (Kleinschmit et al., 2007a) which is not sufficient to prevent milk fat depression (Cyriac et al., 2005). Nonforage fiber sources such as DGS can supply energy needed for lactation or growth without the ruminal acid load caused by rapidly fermented starchy compounds (Ham et al., 1994).

There is less information available about the nutrient content of DGS produced from other crops such as wheat, barley, triticale, or sorghum. However, data available indicate that the composition usually reflects the nutrient content of the grain after removal of starch via fermentation to ethanol. Thus, the concentrations of protein, fat, fiber, and other nutrients in the DGS from various grain sources usually reflect proportionate increased concentrations of those components relative to the starting grain after removal of the starch (Lodge et al., 1997; Mustafa, McKinnon, and Christensen, 2000). For instance, wheat and barley DGS are usually higher in protein but lower in fat and energy than corn DGS, while sorghum DGS are higher or lower in protein than corn DGS, depending on the source used.

## Response of Lactating Cows to Distillers Grains

More than two dozen research trials with more than 100 treatment comparisons have been conducted since 1982 in which corn distillers grains, either wet or dried, were fed to lactating cows. Table 2 is an abbreviated summary of the meta-analysis conducted by Kalscheur (2005) with most of these data and is similar to the recent results of Hollmann, Beede, and Allen (2007) that summarized much of the same data. Other studies conducted since the summary by Kalscheur (2005) are also discussed, especially if results differ from the previous summary. Amounts of DGS fed

**Table 3.2. Dry matter intake (DMI), milk yield, milk fat, and protein content when fed diets containing wet or dried corn DGS**

| Inclusion level | DMI | Milk | Fat | Protein |
|---|---|---|---|---|
| (% of dry matter) | (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 | 20.9[c] | 32.2[b] | 3.47 | 2.82[b] |
| SEM | 0.8 | 1.4 | 0.08 | 0.06 |

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

ranged from 4.2% of total diet dry matter (Broderick, Ricker, and Driver, 1990) to 41.6% of dry matter (Van Horn et al., 1985). The lactational response to feeding various amounts of DGS, as well as the response to wet versus dried DGS, is covered later in this chapter.

Production was the same or higher when fed DGS as when fed control diets in virtually all experiments except possibly when fed very large amounts (i.e., 30% or more of diet dry matter) as wet DGS (Kalscheur, 2005). Part of the additional production due to DGS may have been attributable to a slightly higher fat content in DGS diets because fat content of diets was not always balanced across diets in all experiments. However, in experiments such as by Pamp et al. (2006) that compared DGS to soybean protein as the protein supplement, production was similar or higher, even when DGS and soybean-based diets were formulated to be equal in RUP and fat. Production was similar when fed whiskey DGS or fuel ethanol DGS (Powers et al., 1995). In both cases, production was higher than when fed the soybean meal control diet. However, when cows were fed a DGS product that was darker and possibly heat damaged, milk production was lower than when fed lighter, golden-colored DGS but was still similar to production when fed soybean meal. When Kleinschmit et al. (2006) used a standard, good-quality DGS to evaluate the response to two specially processed DGS products intended to have even better quality, milk production was higher for all three DGS products than for the soybean-meal-based control diet, with only small differences in response due to the improved DGS quality.

Many research trials are of relatively short duration, such as four- or five-week periods in Latin-square-style experiments. Dairy producers are likely to be more concerned about long-term responses and whether the shorter-term research experiments accurately reflect the response expected when feeding DGS continuously for long periods of time. Therefore, an experiment was conducted in which cows were fed wet DGS as 15% of diet dry matter 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 percentage fat (3.75% and 4.07%), percentage protein (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; however, the response in feed intake and milk production tended to be more consistent when fed DGS, possibly reflecting fewer digestive problems. Response during the dry period and first 70 days of the next lactation was similar for control and wet DGS fed cows (Mpapho et al., 2007).

Production responses to DGS are usually similar with all forages (Kalscheur, 2005), although Kleinschmit et al. (2007b) observed slightly greater production when 15% DDGS was fed in high alfalfa versus high corn silage diets, likely reflecting an improved amino acid status with the "blend" of alfalfa-DGS proteins versus a diet containing predominantly corn-based proteins. The summary by Hollmann, Beede, and Allen (2007) likewise showed a greater response to DGS with alfalfa-based than with corn-silage-based diets. While there may be differences in protein quality of various sources of present-day DGS (Kleinschmit et al., 2007a), differences in yields of milk and milk protein might be slight, unless a product is greatly heat-damaged.

Production is usually similar or higher when DGS replace some of the starch in diets of dairy cattle. The starch content of diets is decreased from the typical 23% to 26% starch to less than 20% starch when fed DGS. Ranathunga et al. (2008) demonstrated that replacing incremental amounts of starch in diets from 28% starch in a diet that did not contain DGS to only 17.5% starch in a diet containing 21% DGS had no effect on milk production or composition but tended to improve feed efficiency. All diets contained 49% forage and were balanced for fat content (4.7% of dry matter) in that study such that the response measured was a response to DGS fiber versus corn starch.

Fewer data are available regarding the production response to DGS obtained from other grains. Research (Beliveau, McKinnon, and Racz, 2007) indicated that the energy value of wheat-based DGS was at least equal to that of barley grain for feedlot cattle, and triticale DGS supported similar milk production to that of corn DGS (Greter et al., 2007). Diets containing barley DGS supported similar milk production to that of soybean-meal-based diets (Weiss et al., 1989). When fed sorghum DGS, production (31.9 kg/d) was slightly less ($P < 0.13$) than when fed corn DGS (33.2 kg/d) (Al-Suwaiegh et al., 2002). This result agreed with data that indicates that sorghum DGS are slightly less digestible than corn DGS (Al-Suwaiegh et al., 2002).

## Milk Composition When Fed Distillers Grains with Solubles

The composition of milk is usually not affected by feeding DGS unless routinely recommended ration formulation guidelines, such as feeding sufficient amounts of forage fiber, are not followed. Field reports of milk fat depression when diets contained more than 10% of ration dry matter as wet DGS are not supported by research results. Research showed no decreases in milk fat content when diets contained wet or dried DGS at any level, even as high as 40% of dry matter intake (see Table 2). In fact, the milk fat content was usually numerically highest for diets containing DGS. Incidentally, most of those studies were conducted during early to mid lactation; thus, the data in Table 2 are typical for cows during these stages of lactation. In studies that included cows fed DGS during the entire lactation (Mpapho et al., 2006), milk fat tests averaged 4.07% for Holsteins and Brown Swiss, while Kleinschmit et al. (2006) and Pamp et al. (2006) observed fat tests of 3.54% to 3.60% for mid-lactation Holsteins and Kleinschmit et al. (2007b) observed an average of 3.72% fat for late-lactation Holsteins.

Milk fat content was lower with DGS only when diets contained less than 50% forage (Kalscheur, 2005), which provided 22% forage NDF. That result hints at why field observations of milk fat depression may have occurred. Because DGS contain an abundance of NDF, one may be 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. Research at Wisconsin (Leonardi, Bertics, and Armentano, 2005) and at South Dakota State University (Cyriac et al., 2005; Hippen et al., 2007) support observations from the meta-analysis. Cyriac et al. observed a linear decrease in milk fat concentration while milk production remained unchanged when cows were fed 0%, 7%, 14%, and 21% of dry matter as dried DGS in place of corn silage, even though dietary NDF content remained unchanged at 32% of dry matter. The control diet contained 40% corn silage, 15% alfalfa hay, and 45% concentrate mix. Thus, the key to maintaining milk fat is to feed sufficient amounts of effective forage fiber.

The fatty acid content of milk fat when cows are fed DGS is not expected to be affected greatly, but this 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 concentrations of unsaturated fatty acids in the milk produced, as observed by Schingoethe, Brouk, and Birkelo (1999). Leonardi, Bertics, and Armentano (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). But they observed little change in fatty acids such as *trans-10, cis-12* CLA that are often associated with milk fat depression (Baumgard et al., 2002).

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 (Nichols et al., 1998; Kleinschmit et al., 2007b). This effect may be more noticeable in diets that contain more than 30% DGS (Kalscheur, 2005), reflecting the high RUP and lysine limitation in DGS. The meta-analysis (Kalscheur, 2005) indicated slightly higher milk protein percentages when fed blends of alfalfa and corn silage with DGS than with either forage alone, but milk protein yields were the same for all forage combinations. Kleinschmit et al. (2007b) observed no differences in milk protein content or yield when feeding 15% dried DGS in diets in which the forage varied from all alfalfa to all corn silage. However, amino acid balance was improved with the alfalfa diet, indicating a more desirable blend of amino acids in the diet versus a high corn-based-product diet with corn silage, DGS, and corn, which was limiting in lysine.

Feeding distillers products likely does not affect milk flavor or processing of the various products produced from the milk. The author is not aware of any research evaluating the effects of feeding DGS on milk quality; however, there is no reason to expect problems.

## Wet versus Dried Distillers Grains with Solubles

The response to wet or dried DGS is usually considered to be equal. However, very few trials actually compared wet versus dried DGS; most trials simply compared DGS to a control diet. When Al-Suwaiegh et al. (2002) compared wet versus dried corn or sorghum DGS for lactating cows, they observed similar production for both wet and dried DGS but 6% more milk ($P < 0.13$) with corn versus sorghum DGS. Anderson et al. (2006) observed greater production ($P < 0.02$) when fed either wet or dried DGS (42.5 kg/d) than when fed the control (corn-soybean meal) diet (39.8 kg/d), a tendency ($P = 0.13$) for greater production when fed wet DGS (43.0 kg/d) instead of dried DGS (41.7 kg/d), and a tendency ($P = 0.12$) for greater production when fed 20% of the ration dry matter as DGS (43.0 kg/d) versus 10% (41.7 kg/d), either wet or dried. Fat content of the control diet (2.3% of dry matter) was slightly lower than the 3.2% and 3.8% fat for the 10% and 20% DGS diets, respectively, but would have accounted for minimal proportions of the differences in production responses.

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 and can be shipped greater distances more economically and conveniently than wet DGS. Feeding wet DGS avoids the costs of drying the product, but wet DGS will not remain fresh and palatable for extended periods of time; five to seven days is the norm. Some silage additives can extend the storage time of wet DGS by a few days (Spangler et al., 2005). Researchers at South Dakota State University have successfully stored wet DGS for more than six months in silo bags when the wet DGS were 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.

## How Much Distillers Grains with Solubles Can Be Fed?

The review by Kalscheur (2005) (see Table 2 for a summary) indicated that milk production was maintained with increasing amounts of DGS in the diet and actually numerically the highest when fed as much as 30% of diet dry matter as dried DGS. For wet DGS, the highest production was at 20% of diet dry matter. It was only when feeding about 40% DGS, wet or dried, that production declined. This is further illustrated by the recent study of Janicek et al. (2008), which reported a linear increase in milk production when going from 0% to 30% dried DGS in diets. Thus, one can easily feed more than the 5% to 10% DGS that is often fed by many dairy producers.

A practical and appropriate nutrient management approach is to feed 20% of the diet dry matter as wet or dried DGS. Researchers at South Dakota State University (e.g., Nichols et al., 1998; Anderson et al., 2006) and elsewhere have demonstrated in several experiments that dairy cows can easily consume up to 20% of the ration dry matter as distillers grains. With typical feed intakes of lactating cows, this is approximately 4.5 to 5.5 kg of dried DGS or 15 to 17 kg of wet DGS per cow daily. There are 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% as 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. This was illustrated in the experiment by Anderson et al. (2006) in which feeding 20% of the diet dry matter as wet or dried DGS replaced 25% of the corn and 87% of the soybean meal that was fed in the control diet. With diets that contain higher proportions of corn silage, even greater amounts of dried DGS may be feasible; however, the need for some other protein supplement, the protein quality (e.g., lysine limitation), and the phosphorus concentration may become factors to consider. With diets containing higher proportions of alfalfa, less than 20% DGS may be needed to supply the protein required in the diet. Thus, there are no strong advantages to feeding more than 20% distillers grains, but the possibility of feeding excess protein and/or phosphorus may occur. This can be a concern in areas in which nutrient management dictates that minimal amounts of nutrients such as nitrogen and phosphorus be returned to the soil as manure or commercial fertilizers. If feeding more than 20% to 25% of dry matter as wet DGS with other moist feeds such as corn silage also in the diet, gut fill may limit dry matter intake and milk production (Hippen et al., 2003; Kalscheur, 2005). Such diets often contain less than 50% dry matter, conditions which may limit dry matter intake (NRC, 2001).

The economics of ration formulation often indicates that it is most profitable to feed as much DGS as possible. Even with the current high feed prices, formulating diets that contain, for example, 15% DGS in place of ingredients such as soybean meal, corn, cottonseed, and tallow can decrease daily feed costs by $0.90 per cow; feeding 30% DGS daily would save another $0.14 per day. Admittedly, feeding very large amounts of

DGS may mean excessive amounts of nitrogen and phosphorus to dispose of in manure; however, this manure may be a cheaper source of these soil fertility nutrients than commercial sources of fertilizer.

## Distillers Grains for Dairy Calves, Heifers, and Dry Cows

Most of the studies of DGS use for growing cattle are with beef cattle; however, DGS can likewise be appropriately used in diets for dairy calves, heifers, and dry cows. Weight gains were similar for calves fed calf starter containing 0%, 28%, and 56% of the dry matter as dried DGS (Thomas et al., 2006a). Rumen papillae development seemed to be optimal with the 28% DGS diet (Thomas et al., 2006b). Distillers grains have also been successfully fed to growing dairy heifers, including blending with other feeds (Kalscheur et al., 2002, 2003). Growth rates are very good when diets are nutritionally balanced, containing appropriate amounts of DGS and other feeds for the age group of animals being considered.

For dry cows, DGS can be fed in appropriate amounts but likely at about 10% of diet dry matter. However, Mpapho et al. (2007) successfully fed 15% of the dry matter as wet DGS throughout the dry period in their long-term feeding experiment.

## Distillers Grains for Grazing Cattle

There is virtually no information in the scientific literature about feeding DGS with grazing systems; however, it is safe to assume that it can be done. Research is currently in progress (A.R. Hippen, 2008, unpublished results) in which cows grazing pasture are also fed one of three supplemental total mixed rations—with protein from soybean meal, fish meal, or wet DGS—estimated to supply 50% of the cow's daily dry matter intake.

In general, when formulating diets to supplement pasture, one would formulate the same as under other dietary conditions. Admittedly, one does not always know accurately the amount and composition of the forages consumed, and nutrient content will vary with maturity stage. Thus, some estimates have to be made in that regard. For instance, DGS can likely be included at up to 20% of the total diet dry matter if the forages are low in protein. In many cases, the forages will likely be quite high in protein such that around 15% DGS may satisfy protein needs of the cow. Because fresh forages are quite wet, typically around 20% dry matter, feeding dried DGS rather than wet DGS may be preferred to avoid gut fill limiting total dry matter intake.

## Other Distillers Products

Several distillers products in addition to DGS are already available as livestock feeds, and more will be available in the future. For instance, distillers solubles, modified distillers grains, corn bran, corn germ, high-protein distillers grains, and other products may be higher or lower in fiber and phosphorus than are some current products. Some of these products, for which data are available, are discussed next.

Distillers solubles (~20% protein, 20% fat, and 1.4% phosphorus on a dry matter basis) are usually blended with the distillers grains before drying to produce DGS, but the solubles may be fed separately. The solubles, which are also referred to as syrup, are usually condensed to 25% to 30% dry matter before blending with distillers grains or fed as condensed corn distillers solubles (CCDS). Some dairies and feedlots include a small amount of CCDS in diets to decrease dustiness and minimize ingredient separation. When DaCruz, Brouk, and Schingoethe (2005) fed 28% dry matter CCDS at 0%, 5%, and 10% of total ration dry matter to lactating cows, milk production increased 4% with CCDS, although milk fat content was slightly lower while milk protein was unaffected. Sasikala-Appukuttan et al. (2008) fed as much as 20% of the total ration dry matter as CCDS (4% fat from the CCDS) with no apparent adverse affects on dry matter intake or milk composition. Milk yield tended to be higher for cows fed 10% and 20% CCDS than for cows fed the control (corn-soybean meal-based) diet. However, it is not recommended that producers feed as much as 20% CCDS when nutrient management is a concern because diets including that much CCDS contained more than 0.5% phosphorus. When Bharathan et al. (2008) fed 10% of dry matter as CCDS with a small amount of fish oil (0.5% of diet dry matter), concentrations of *cis-9, trans-11* CLA in the milk fat increased. Whitlock et al. (2002) reported that when cows were fed a small amount of fish oil in combination with a source of linoleic acid (extruded soybeans in that experiment), the CLA content of milk fat increased more than when either fish oil or a high linoleic acid fat source were fed separately. In this experiment (Bharathan et al., 2008) with CCDS as the source of linoleic acid and then with fish oil added, *cis-9, trans-11* CLA increased 0.59 g/100g of fatty acids when fed CCDS alone but increased a similar amount (0.62 g/100g of fatty acids) when fed CCDS plus fish oil.

Some ethanol plants offer products termed “modified distillers grains”; however, there are currently no industry guidelines as to what “modified” means. In some cases the distillers grains are partially dried to, for example, 50% dry matter. Sometimes greater or lesser amounts of solubles are added to the distillers grains, or there may be other modifications. These can be very good products to incorporate into dairy cattle diets. However, it is important that the supplier provide accurate composition analysis data, and that the product be consistent from batch to batch.

New distillers products that result from “fractionation” of distillers grains are becoming available. Traditional corn-ethanol production uses a system in which the whole corn kernel is ground, cooked, and fermented. An alternative method separates the kernel into its three major components, namely, bran, germ, and endosperm, prior to fermentation. Some of these products are becoming more available as feeds for livestock.

The bran contains similar amounts of NDF (30%), fat (10%), and phosphorus (0.7%) but less protein (13%) and more nonfiber carbohydrate (45%) than DGS (Janicek et al., 2007). When bran was fed to lactating cows at 10%, 17.5%, and 25% of dry matter in place of portions of corn silage and alfalfa in diets that were already low in forage (40% of dry matter as forage in the 10% bran diet), milk yield tended to increase ($P < 0.07$) with increasing amounts of bran in the diet, and feed efficiency (milk/dry matter intake) increased. However, milk fat content tended to decrease ($P < 0.06$), likely because the diets contained only 15.8% to 9.9% forage NDF even though total NDF in the diets was 31% to 33%.

Corn germ can provide an alternative fat source for dairy cattle diets. The germ from dry grinding of corn contains approximately 20% fat while corn germ obtained from wet milling contains 45% or more fat. The fat in the corn germ from wet milling is typically extracted for use as food-grade corn oil and thus seldom finds use in livestock feeds. Most of the research in this area concerns feeding corn germ from dry grinding.

When Abdelqader et al. (2006) fed the germ from dry grinding at 0%, 7%, 14%, and 21% of ration dry matter, inclusion at 7% and 14% increased milk and fat yields; however, feeding 21% corn germ decreased the concentration and yield of milk fat and tended to decrease dry matter intake. Thus, one can safely feed at least 14% corn germ to lactating cows, but higher amounts may be questionable. However, in their experiment, the problem with feeding as much as 21% corn germ may not have been a problem with the corn germ so much as a problem with total amount of fat in the diet. All diets in that experiment contained 1% additional fat from another source, which caused the 21% corn germ diet to contain more than 8% fat, a situation long known to cause problems with ruminal fat digestion and feed intake (NRC, 2001). When Abdelqader et al. (2008) fed cows diets that were isolipidic at 6% ether extract, 2.5% supplemental lipid as ruminally inert fat (control), 14% corn germ, 30% dried DGS, or 2.5% corn oil, dry matter intake was higher with corn germ (27.2 kg/d) than with the control diet (24.8 kg/d) but similar (26.2 kg/d) for all of the corn fat diets (i.e., corn germ, DGS, and corn oil). Milk production was similar (34.7 kg/d) for all diets. Milk fat content did not decrease with corn germ but did decrease with corn oil and tended to decrease with DGS. Feeding oils such as corn oil often decreases milk fat content whereas feeding the fat as oilseeds or other forms usually does not cause problems (NRC, 2001). Concentrations of *cis-9, trans-11* CLA modestly increased when feeding corn germ and significantly increased when feeding DGS or corn oil. Kelzer et al. (2008) found no differences in total tract digestibility when corn germ or other corn milling products were fed, although ruminal acetate concentrations decreased.

Higher-protein distillers grains can be produced by removing corn germ, by not adding solubles to distillers grains, or by extracting fat. Two products are currently being evaluated and will soon be marketed: high protein distillers grains (HP-DG) from the corn endosperm, which is around 45% crude protein (Hubbard et al., 2008; Kelzer et al., 2008); and de-oiled (low-fat) DGS (dDGS), created after fat is extracted for use in biodiesel, which is around 35% crude protein (Mjoun et al., 2008). One advantage of HP-DG is that it contains similar concentrations of protein as present in many other common protein supplements such as soybean meal. However, the high RUP value and low lysine content of HP-DG may be considerations in some ration situations. Both of these higher-protein DG products have the advantage of containing more protein than traditional DGS but may be lower in energy content because they contain less fat.

In milk production evaluations, two recent Nebraska studies illustrated that HP-DG constitute a good protein feed to include in diets of lactating cows. Hubbard et al. (2008) observed increased milk production when feeding a diet containing 20% HP-DG in place of soy-based protein; milk fat and protein concentrations were not affected by feeding HP-DG. Kelzer et al. (2008) observed similar dry matter intake and milk production when cows were fed isonitrogenous diets containing HP-DG or regular dried DGS as the protein supplement.

Evaluations at South Dakota State University indicated that dDGS also provide a good feed protein for lactating cows. Mjoun et al. (2008) fed 0%, 10%, 20%, and 30% of diet dry matter as dDGS in place of soy-based products. Milk production (34.9 kg/d) was similar for all diets. Likewise, milk composition was not adversely affected by the diets, and milk fat content actually tended ($p < 0.09$) to increase with increasing amounts of dDGS in the diet.

Some higher-fiber distillers products are currently being evaluated in beef cattle studies. While such products may find use in diets for growing heifers and dry cows, they are less likely to be used in diets of lactating cows. This is because dairy producers are usually seeking higher-energy feeds to include in lactation diets, although when forage sources are in short supply or expensive, such higher-fiber distillers products may be considered as alternative ration ingredients for lactating cows.

## Concerns and Potential Problems with Distillers Grains in Dairy Production

There are several items often cited by dairy producers and nutrition consultants that should be mentioned here (see chapter 10 for greater detail on these issues).

Inconsistency (variability) of product within plants and between plants is frequently mentioned. This often occurs with new ethanol plants, a situation that can be solved by correcting and standardizing processing procedures. Variation in concentrations of fat, protein, and phosphorus makes it difficult to formulate diets accurately, which can be costly to the dairy producer. For instance, if a producer formulates a diet assuming that the DGS contain 29% protein but then discovers that the DGS actually contain 32% protein, the excess protein fed would be an expensive waste. On the other extreme, if the DGS were assumed to contain, for example, 32% protein but actually contained only 29% protein, milk production might be limited. Variation in fat and/or phosphorus content of DGS often means that variable amounts of solubles were blended with the distiller grains or there was separation in the solubles tank, which may have resulted in more or less of the fat being taken up. These are plant management situations that should be controllable.

High phosphorus or sulfur content in the DGS usually comes through the solubles. A high phosphorus concentration in DGS usually indicates that more-than-normal amounts of solubles were blended with the distillers grains. Sulfur-containing compounds are often used for controlling pH and cleaning equipment during various stages in the ethanol plant operation, and these compounds often end up in the solubles. While high amounts of sulfur in DGS are not usually a problem, if one is feeding more than 30% DGS that may contain higher-than-normal amounts of sulfur, and this is coupled with high sulfur water or other feeds that are also high in sulfur, the diets may approach the recommended dietary maximum of 0.4% sulfur in total ration dry matter (NRC, 2001).

Difficulty with flowability of dried DGS causing bridging in trucks or rail cars has also been a concern voiced by some. Apparently, ethanol processors are making a greater effort to minimize such problems by better controlling the drying and temperature of the DGS.

Because dairy cows are producing a consumable product every day, it is important that the cows not be fed anything that may ultimately contaminate the milk. Mycotoxins, molds, and other potential contaminants are sometimes a problem. Ethanol plants routinely sample and test all loads of grain coming into the plants and reject contaminated loads. This is important because mycotoxins are not destroyed during the ethanol fermentation process or during the production of distillers grains. Thus, contaminated DGS could pose a risk to human health because a metabolite of mycotoxins can transfer to milk (Garcia et al., 2008). Any antibiotics used in ethanol plants are approved products and are ultimately destroyed or inactivated during the processing.

## Summary

The major by-product (co-product) of ethanol production, usually made from corn, is distillers grains with solubles (DGS), which can be fed to dairy cattle and other livestock as part of the ration. Distillers grains are a very good protein source, high in ruminally undegradable protein, and are a very good energy source to include in dairy rations. The modest fat concentration and readily digestible fiber contribute to the high energy in DGS.

Research results on animal performance using DGS were usually similar when fed wet or dried products, although some results tended to favor the wet products. Diets fed to dairy cattle can contain DGS as replacements for portions of both concentrates and forages, but they usually replace concentrates. Distillers solubles are often blended with distillers grains to provide DGS, but the solubles can also be fed separately as "thin stillage" or as "condensed corn distillers solubles." Nutritionally balanced diets can be formulated that contain 20% or more of the diet dry matter as DGS. There is usually no nutritional advantage of feeding more than 20% DGS because such diets may contain excess protein and phosphorus, although production performance was very high even with more than 30% dried DGS in the diet, and the economics often indicates advantages of feeding higher amounts of DGS. Milk composition is unchanged at all levels of DGS feeding, but fat content can decrease if inadequate amounts of forage fiber are fed. The fiber in DGS, which often replaces high starch feeds, does not eliminate acidosis but minimizes its problems.

The availability and use of other co-products from DGS processing, such as condensed corn distillers solubles, corn germ, corn bran, and high-protein distillers grains, will increase in the future. Innovations in processing technology will likely result in additional distillers co-products from which to choose for use as livestock feeds.

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