Utilization of DDGS by Cattle[1]

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▪ Take Home Message

Distillers grains with solubles (DDGS), the major byproduct of ethanol production, is a good protein and energy feed for cattle. The DDGS can be fed wet or dried with animal performance usually similar when fed as wet or dried products; however, some research results favored the wet products. Cattle diets can contain DDGS as replacements for portions of both concentrates and forages, although DDGS usually replaces concentrate ingredients. Most DDGS is from corn although wheat, barley, sorghum and other grains can be used for ethanol and DDGS production. The composition of DDGS from other grains often reflects the composition of that grain minus its starch that was fermented to ethanol. Distillers grains from corn is usually >30% CP, is high in ruminally undegradable protein, and is very good energy source (NE_L ~2.25 Mcal/kg of DM) for lactating cows, growing, and finishing cattle. The modest fat concentration (10% of DM) and the readily digestible fiber (39% NDF) contribute to the high energy in DDGS. Distillers solubles are often blended with distillers grains to provide DDGS, but the solubles can also be fed separately as "thin stillage" or as "condensed distillers solubles". Protein and energy values are similar for distillers grains with or without solubles but the phosphorus content is elevated when solubles are included. The recommended amount of DDGS for feeding lactating dairy cows is up to 20% of total ration dry matter; higher amounts - as much as 40 to 50% of ration dry matter - can be successfully fed as an energy source to finishing cattle. The fiber in DDGS, which often replaces high starch feeds, does not eliminate acidosis but minimizes its problems. Innovations in processing technology and fractionation of the distillers products will likely result in additional products for future use as livestock feeds.

▪ Introduction

Ethanol byproducts or coproducts (I may use the two terms interchangeably) result from the fermentation of grains, typically corn, but other grains such as barley, wheat, and sorghum can also be used 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 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 and corn gluten meal, and will not be discussed extensively in this presentation.

This presentation will review research results from feeding ethanol byproducts to dairy and beef cattle. Emphasis will be on DDGS, especially for dairy cattle. Byproducts available when fermenting other grains such as wheat and barley will be mentioned, although research data is limited with those sources.

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▪ Nutrient Content of Ethanol Byproducts

Nutrient content of DDGS from corn as well as from wheat, barley, and sorghum is outlined in Table 1. Corn DDGS is the major DDGS available in most areas but DDGS from wheat, barley are available in some areas of Canada and Europe while DDGS from sorghum is available in the southwestern United States. 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" DDGS and Birkelo et al. (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 today's ethanol plants. Ethanol coproducts contain relatively

Table 1. Nutrient content of distillers grains with solubles from various grains.[1]

Item	Grain source			
	Corn	Wheat[2]	Barley[3]	Sorghum
	(% of DM)			
Crude protein	30.1	36.2	15.4	32.0
RUP[4]% of CP	55.0	37.2[3]	49.0	55.0
$NE_{maintenance}$, Mcal/kg	2.07	2.18	1.87	2.11
NE_{gain}, Mcal/kg	1.41	1.50	1.24	1.39
$NE_{Lactation}$, Mcal/kg	2.26	2.02	1.73	1.91
Neutral detergent fiber (NDF)	41.5	41.4	74.3	46.0
Acid detergent fiber (ADF)	16.1	17.3	31.1	28.4
Ether extract	10.7	6.7	6.0	11.5
Ash	5.2	5.4	4.2	3.6
Calcium	0.22	0.30	---	0.10
Phosphorus	0.83	1.05	---	0.84
Magnesium	0.33	0.60	---	---
Potassium	1.10	1.70	---	---
Sodium	0.30	0.23	---	---
Sulfur	0.44	0.57	---	---

[1] Most data are from NRC (1996, 2001), Spiehs et al. (2002), and Birkelo et al. (2004)
[2] Source: Information is a composite from several sources.
[3] Mustafa et al. (2000) from a mix of 70% barley, 20% wheat, and 10% rye/triticale
[4] RUP = ruminally undegradable protein

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.

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 (~1.35%) in phosphorus. 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 DDGS 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.

The distillers grains available in recent years contain more energy than older "book" values. Recent research (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.

Distillers grains 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 may lack sufficient “effective fiber” to prevent milk fat depression (Cyriac et al., 2005).

There is less information available about the nutrient content of DDGS produced from the fermentation of other crops such as wheat, barley, 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. The starch content in corn is greater than in sorghum, which is greater than in wheat, which is greater than in barley. Thus, the concentrations of protein, fat, fiber, and other nutrients in the DDGS from various grain sources usually reflect proportionate increased concentrations of those components relative to the starting grain after removal of the starch. For instance, wheat DDGS is usually higher in protein but lower in fat and energy than corn DDGS. The data listed in Table 1 for wheat DDGS is an average of some highly variable reports. For instance, protein content of wheat DDGS varied from 30.5 to 44.7%, fat from 3.1 to 9.9%, NDF from 33.4 to 57.0%, and ADF from 11.1 to 24.3%. Thus, it would be important to have accurate analysis on a product that one is intending to feed.

Corn DDGS, 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 exits. Most reported values range from 47% to 69% RUP. One often assumes that wet DGS has lower concentrations of RUP than does dried DGS, but the differences are slight, at least for corn DGS. Firkins et al. (1984) reported 47% RUP for wet corn DGS and 54% RUP for the dried product, which probably represents a realistic difference in RUP for the wet versus the dried products. Kleinschmit et al., 2006a) reported a range of 62 to 76% of CP as RUP of five DDGS sources and slightly lower RUP (55%) for wet DGS. The highest quality DDGS products in that study contained less than 65% RUP. Most of the readily degradable proteins in corn - and it is assumed in other grains as well - have been degraded during the fermentation process, thus the protein remaining in the DDGS is going to be proportionately higher in RUP than in the original grain. However, if RUP values for corn DDGS are quite high (e.g. > 80% of CP), it may be advisable to check for heat damaged, undigestible protein. Pamp et al.(2006) recently reported that increasing dietary RUP in the form of DDGS increased milk yields and milk component yields to a greater extent than RUP supplied by soybean protein. The RUP values for wheat and barley are likely lower than for corn, reflecting the lower RUP in the starting grain.

▪ Production response by lactating cows to DDGS

Milk production and composition summarized in Table 2 is from the more than two-dozen research trials with 98 treatment comparisons conducted since 1982 in which corn distillers grains, either wet or dried, were fed to lactating cows is. 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).

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	20.9[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).

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% 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. 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 that 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 soybean meal-based control diet, with only small differences in response due to the improved DDGS quality.

We are in 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 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.

Less data are available regarding the production response to DDGS produced from other grains. Recent Canadian research (Penner et al., 2007) with feeding wet or dried wheat DGS demonstrated similar production for cows fed a barley-based control diet or diets containing 10% wet wheat DGS, dried wheat DGS, or dried corn DGS (39.2, 41.7, 38.7, and 38.2 kg/d, respectively). 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)..

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., 2006a), differences in yields of milk and milk protein might be slight, unless a product is greatly heat-damaged. The lysine content of wet corn DGS was slightly greater than in several dried corn DGS products evaluated, indicating that - even with the best of drying conditions - some heat damage may occur with DDGS (Kleinschmit et al., 2006a). With other grains such as wheat, the DDGS may have a more balanced amino acid composition. For instance, the lysine content of wheat DDGS is higher than in corn DDGS and is even higher in a barley-based DDGS (Mustafa et al., 2000).

▪ Wet versus dried DGS

So far this presentation has contained information almost interchangeably about both wet and dried distillers grains. That is 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 for wet than for 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. Research by Anderson et al. (2006) observed greater production when fed either wet or dried corn 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. Penner (2007) observed similar production for wet or dried wheat DGS. 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. 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., 2004b). 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 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. 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.

▪ How much distillers grains can be fed?

We at SDSU and other researchers have demonstrated in a number of experiments that dairy producers can 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 concentrate mix. In 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. In 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 (Birkelo et al., 2004). 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 may decrease 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 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, growing calves and heifers

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, provided 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, while dried DGS contained only 21% more NE_{gain} than dry-rolled corn (Ham et al., 1994). Increased feed efficiency when fed distillers grains products 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). Similar results were observed when feeding wet corn gluten feed (Krehbiel et al., 1995). 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; in corn most of the energy is as 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. Wet wheat DGS was similar in digestibility to barley silage digestibility (Penner et al., 2007).

Weight gains were similar for calves fed calf starter containing 0, 28, and 56% of the DM as DDGS (Thomas et al, 2006a). Rumen papillae development seemed to be optimal with the 28% DDGS diet (Thomas et al., 2006b). Distillers grains have also been successfully fed to growing dairy heifers as discussed in the next section about feeding DGS blended with other feeds. Growth rates are very good with when diets are nutritionally balanced.

▪ Distillers Grains Blended with Other Feeds

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., 2004a). 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).

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 corn gluten feed, 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 corn gluten feed or corn.

▪ 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% added 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.

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). Cattle with access to thin stillage from wheat-based ethanol products had greater weight gains than cattle without the thin stillage (Ojowi et al., 1996).

▪ 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). Higher protein lower fat distillers products may soon be marketed in some areas.

Abdelqader et al. (2006) recently completed an experiment feeding the germ that was removed from the corn grain prior to ethanol production. The germ, which contained 20% 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 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 (J. E. Shirley, Kansas State University, unpublished data).

▪ The Future?

One doesn't know what ethanol coproducts will be available to the feed industry in the future. However, if one can speculate, one should not be surprised to see improved products and new products available. For instance, improvements in fermentation technology already provide DDGS today that contains more protein and energy than DDGS 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 non-food uses such as building products. I base these comments on prior research experience with feeding whey, the coproduct from cheese manufacturing. At one time there was a choice between "liquid whole whey" or "dried whole whey". Today, a large number of whey products from protein concentrates to lactose are available to the human food and animal feed industries. A similar situation could also occur with ethanol coproducts.

▪ References

Abdelqader, M. M., A. R. Hippen, D. J. Schingoethe, K. F. Kalscheur, K. Karges, and M. L. Gibson. 2006. Corn germ from ethanol production as an energy supplement for lactating dairy cows. J. Dairy Sci. 89(Suppl. 1):156 (Abstr.)

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105-1111.

Anderson, J. L., D.J. Schingoethe, K.F. Kalscheur, and A.R. Hippen. 2006. Evaluation of dried and wet distillers grains included at two concentrations in the diets of lactating dairy cows. J. Dairy Sci. 89: 3133-3142.

Belyea, R. L., K. D. Rausch, and M. E. Tumbleson. 2004. Composition of corn and distillers dried grains with solubles from dry grind ethanol processing. Biores. Technol. 94:293-298.

Birkelo, C. P., M. J. Brouk, and D. J. Schingoethe. 2004. The energy content of wet corn distillers grains for lactating dairy cows. J. Dairy Sci. 87:1815-1819.

Bremer, V., G. Erickson, T. Klopfenstein, M. Gibson, K. Vander Pol, and M. Greenquist. 2005.Feedlot performance of a new distillers byproducy (Dakota bran) for finishing cattle. J. Anim. Sci. 83(Suppl. 1):125 (Abstr.)

Broderick, G. A., D. B. Ricker, and L. s. driver. 1990. Expeller soybean meal and corn byproducts versus solvent soybean meal for lactating dairy cows fed alfalfa silage as the sole silage. J. Dairy Sci. 73:453-462.

Cyriac, J., M. M. Abdelqader, K. F. Kalscheur, A. R. Hippen, and D. J. Schingoethe. 2005. Effect of replacing forage fiber with non-forage fiber in lactating dairy cow diets. J. Dairy Sci. 88(Suppl. 1):252 (Abstr)

DaCruz, C. R., M. J. Brouk, and D. J. Schingoethe. 2005. Utilization of condensed corn distillers solubles in lactating dairy cow diets. J. Dairy Sci. 88:4000-4006.

Firkins, J. L., L. L. Berger, G. C. Fahey, Jr., and N. R. Merchen. 1984. Ruminal nitrogen degradability and escape of wet and dry distillers grains and wet and dry corn gluten feed. J. Dairy Sci. 67:1936-1944.

Grings, E. E., R. E. Roffler, and D. P. Deitelhoff. 1992. Response of dairy cows to additions of distillers dried grains with solubles in alfalfa-based diets. J. Dairy Sci. 75:1946-1953.

Ham, G. A., R. A. Stock, T. .J. Klopfenstein, E. M .Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.

Hippen, A. R., K. F. Kalscheur, D. J. Schingoethe, and A. D. Garcia. 2004. Increasing inclusion of dried corn distillers grains in dairy cow diets. J. Dairy Sci. 87: (Abstr.)

Hippen, A. R., K. N. Linke, K. F. Kalscheur, D. J. Schingoethe, and A. D. Garcia. 2003. Increased concentration of wet corn distillers grains in dairy cow diets. J. Dairy Sci. 86(Suppl. 1):340 (Abstr.)

Hutjens, M. F. 2004. Questions about wet distillers'. Hoard's Dairyman 149:261.

Kalscheur, K. F. 2005. Impact of feeding distillers grains on milk fat, protein, and yield. Proc. Distillers Grains Technology Council, 10th Annual Symposium, Louisville, KY.

Kalscheur, K. F., A. D. Garcia, A. R. Hippen, and D. J. Schingoethe. 2002. Ensiling wet corn distillers grains alone or in combination with soyhulls. J. Dairy Sci. 85(Suppl. 1):234 (Abstr.)

Kalscheur, K. F., A. D. Garcia, A. R. Hippen, and D. J. Schingoethe. 2003. Fermentation characteristics of ensiling wet corn distillers grains in combination with corn silage. J. Dairy Sci. 86(Suppl. 1):211 (Abstr.)

Kalscheur, K. F., A. D. Garcia, A. R. Hippen, and D. J. Schingoethe. 2004a. Growth of dairy heifers fed wet corn distillers grains ensiled with other feeds. J. Dairy Sci. 87:1964 (Abstr.)

Kalscheur, K. F., A. D. Garcia, A. R. Hippen, and D. J. Schingoethe. 2004b. Fermentation characteristics of ensiled wet corn distillers grains in combination with wet beet pulp. J. Dairy Sci. 87(Suppl. 1):53 (Abstr.)

Kleinschmit, D. H., J. L. Anderson, D. J. Schingoethe, K. F. Kalscheur, and A. R. Hippen. 2006a. Ruminal and intestinal digestibility of distillers grains plus solubles varies by source. J. Dairy Sci. 89: (submitted).

Kleinschmit, D. H., D. J. Schingoethe, K. F. Kalscheur, and A. R. Hippen 2006b. Evaluation of various sources of corn distillers dried grains plus solubles for lactating dairy cattle. J. Dairy Sci. 89: (in press).

Krehbiel, C. R., R. A. Stock, D. W. Herold, D. H . Shain, G. A. Ham, and J. E. Carulla. 1995. Feeding wet corn gluten feed to reduce subacute acidosis in cattle. J. Anim. Sci. 73:2931-2939.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim. Sci. 71:2228-2236.

Leonardi, C., S. Bertics, and L. E. Armentano. 2005. Effect of increasing oil from distillers grains or corn oil on lactation performance. J. Dairy Sci. 88:2820-2827.

Liu, C., D. J. Schingoethe, and G. A. Stegeman. 2000. Corn distillers grains versus a blend of protein supplements with or without ruminally protected amino acids for lactating cows. J. Dairy Sci. 83:2075-2084.

Lodge, S. L., R. A. Stock, T. J. Klopfeinstein, D. H. Shain, and D. W. Herold. 1997. Evaluation of corn and sorghum distillers byproducts. J. Anim. Sci. 75:37-43.

Montgomeery, S. P., J. S. Drouillard, E. C. Titgemeyer, J. J. Sindt, T. R. B. Farran, J. N. Pike, C. M. Coetzer, A. M. Trater, and J. J. Higgins. 2004. Effect of wet corn gluten feed and intake level on diet digestibility and ruminal passage rate in steers. J. Anim. Sci. 82:3526-3536.

Mpapho, G. S., A. R. Hippen, K. F. Kalscheur and D. J. Schingoethe. 2006. Lactational performance of dairy cows fed wet corn distillers grains for the entire lactation. J. Dairy Sci. 89:1811 (abstr.).

Mustafa, A. F., J. J. McKinnon, and D. A. Christensen. 2000. Chemical characterization and in situ nutrient degradability of wet distillers' grains derived from barley-based ethanol production. Anim. Feed Sci. Technol. 83:301-311.

National Research Council. 1996. Nutrient Requirements for Beef Cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

National Research Council. 2001. Nutrient Requirements for Dairy Cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Nichols, J. R., D. J. Schingoethe, H. A. Maiga, M. J. Brouk, and M. S. Piepenbrink. 1998. Evaluation of corn distillers grains and ruminally protected lysine and methionine for lactating dairy cows. J. Dairy Sci. 81:482-491.

Ojowi, M. O., D. A. Christensen, J. J. McKinnon, and A. F. Mustafa. 1996. Thin stillage from wheat-based ethanol products as a nutrient supplement for cattle grazing crested wheatgrass pastures. Can. J. Anim. Sci. 76:547-554.

Owen, F. G., and L. L. Larson. 1991. Corn distillers dried grains versus soybean meal in lactation diets. J. Dairy Sci. 74:972-979.

Pamp, B. W., K. F. Kalscheur, A. R. Hippen, and D. J. Schingoethe. 2006. Evaluation of dried distillers grains versus soybean protein as a source of rumen-undegraded protein for lactating dairy cows. J. Dairy Sci. 89(Suppl. 1):403 (Abstr.)

Penner, G. B., D. A. Christensen, and P.Yu. 2007. The effect of replacing forage or concentrate with wet or dry distillers' grains on milk production and composition and chewing activity in dairy cattle. J. Dairy Sci. 90: (submitted)

Pingel, D., and A. Trenkle. 2005. Effects of replacing corn grain and urea with condensed corn distillers solubles in diets of finishing steers. J. Anim. Sci. 83(Suppl. 1):47 (Abstr.)

Powers, W. J., H. H. Van Horn, B. Harris, Jr., and C. J Wilcox. 1995. Effects of variable sources of distillers dried grains plus solubles or milk yield and composition. J. Dairy Sci. 78:388-396.

Rausch, K. D., and R. L. Belyea. 2006. The future of coproducts from corn processing. Applied Biochem. and Biotechnol. 128:47-85.

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Impact of feeding distillers grains on beef tenderness and sensory traits. J. Anim. Sci. 83 (Suppl 2):53 (Abstr.)

Sasikala-Appukuttan, A. K., D. J. Schingoethe, A. R. Hippen, K. F. Kalscheur, K. Karges, and M. L. Gibson. 2006. The feeding value of corn distillers solubles for lactating dairy cows. J. Dairy Sci. 89(Suppl. 1):82 (Abstr.)

Schingoethe. D. J., M. J. Brouk, and C. P. Birkelo. 1999. Milk production and composition from cows fed wet corn distillers grains. J. Dairy Sci. 82:574-580.

Schrage, M. P., H. D. Woody, and A. W. Young. 1991. Net energy of ensiled wet corn gluten feed in corn silage diets for finishing steers. J. Anim. Sci. 69:2204-2210.

Spangler, D., S. Gravert, G. Ayangbile, and D. Casper. 2005. Silo-King enhances the storage life and digestibility of wet distillers grains. J. Dairy Sci. 88:1922 (Abstr.).

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient data base for distillers dried grains with solubles produced from new generation ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 80:2639-2645.

Thomas, M., A.R. Hippen, K.F. Kalscheur, D.J. Schingoethe. 2006. Growth and performance of Holstein dairy calves fed distillers grains. J. Dairy Sci. 89:1864 (Abstr.)

Thomas, M., A. R Hippen, K. F Kalscheur, D. J. Schingoethe. 2006. Ruminal development in Holstein dairy calves fed distillers grains. J. Dairy Sci. 89(Suppl. 1):437 (Abstr.)

Van Horn, H. H., O. Blanco, B. Harris, Jr., and D. K. Beede. 1985. Interaction of protein percent with caloric density and protein source for lactating cows. J. Dairy Sci. 68:1682-1695.