Using Distillers Grains in Dairy Cattle Diets

Kenneth F. Kalscheur

Associate Professor of Dairy Cattle Nutrition
Dairy Science Department, South Dakota State University
Email: kenneth.kalscheur@sdstate.edu Phone: (605) 688-5482

Distillers grains with solubles (DG) is a unique feedstuff providing protein, fat, highly digestible fiber, and minerals, all of which can be utilized in dairy rations. Distillers grains with solubles are coproducts from the manufacture of ethanol. Although other cereal grains, such as sorghum, wheat, or barley, can be used to produce ethanol, the predominant cereal grain used in the United States to produce ethanol is corn (*Zea mays*). During the dry milling process used for ethanol production, the entire corn kernel is used in the fermentation process (Bothast and Schlicher, 2005). The corn is cleaned and then hammer milled to a medium-coarse to fine grind meal. The resulting flour is combined with water to form a slurry, and enzymes are added to convert the starch in the kernel to sugar. The resulting mash is then cooked and sterilized to kill unwanted bacteria. Once the mash is cooled, yeasts are added to the mash and the sugar is converted to ethanol and carbon dioxide. The ethanol is then extracted in the distillation process, and the remaining water and solids are collected and referred to as whole stillage. Whole stillage can be pressed, but more commonly it is centrifuged to separate the coarse solids from the liquid. The liquid is referred to as distillers solubles, also known as thin stillage. The thin stillage can be concentrated in an evaporator to become condensed distillers solubles (CDS), also referred to as syrup. The coarse solids collected from the centrifuge are known as wet distillers grains. Wet distillers grains and CDS are combined and dried to form dried DG.

Nutrient Composition of DG

Knowing accurate nutrient composition of DG is critical when formulating diets for livestock. Laboratory testing of purchased DG is highly recommended, although not always practical for every shipment. This information may also be provided by the ethanol plant. Table 1 shows nutrient composition of DG tested from various ethanol plants located mostly in the upper Midwest. The NRC values are book values published in the Nutrient Requirements of Dairy Cattle (1989, 2001). In addition, researchers at the South Dakota State University (Holt and Pritchard, 2004), University of Minnesota (Harty et al., 1998; Spiehs et al., 2002), and University of Wisconsin (Kaiser, 2005) have analyzed DG samples from numerous ethanol plants in Minnesota, Nebraska, South Dakota, and Wisconsin. Nutrient content of DG is influenced by factors such as the type of grain, grain quality, milling process, fermentation process, drying temperature, and the amount of solubles blended back into the wet DG at the time of drying.

Distillers grains being fed in dairy cow diets today contain more protein and energy than older book values (NRC 1989). The newest dairy NRC (2001) lists crude protein (CP) at 29.7% for DG with solubles, a number that is close to reality. Average CP for DG is around 30%, but these studies illustrate that CP ranging from 27 to 35% is not unusual.

Of particular interest to dairy nutritionists is that DG is a good source of rumen undegraded protein (RUP). Most reported values range from 47% to 57% RUP, however, more recent research suggests the RUP may be higher. Research conducted at South Dakota State University (Kleinschmit et al., 2005) determined the RUP of five different sources of dried DG and found that RUP varied from 63.5 to 78.0%. Some of the readily degradable proteins in corn are degraded in the fermentation process, so the protein remaining in DG will be higher in RUP than in the original corn. This study also evaluated one wet DG sample and found that wet DG had a lower RUP value (54.7%) compared to the dried DG samples. The lower RUP value attributed for the wet DG was likely due to the fact that drying was not required.

Rumen-undegraded protein values for DG that are very high (e.g. > 80% of CP), are usually a result of heat-damaged, indigestible protein. Heat-damaged protein would be indicative of a high ADICP, although there is not a clear relationship between ADICP and protein digestibility in DG as there is in other types of feeds. The quality of protein in DG can be good, although as with most corn products, lysine is the first limiting amino acid. Since lysine is very sensitive to heat, it is believed that extensive heating, or darker distillers grains, will have reduced concentrations of digestible lysine.

Some researchers speculate that the DG available today may contain more energy than indicated by the NRC book values. Although no work has been published using dried DG, Birkelo et al. (2004) determined the energy value of wet DG for lactating cows. In this study, digestible energy (DE), metabolizable energy (ME), and NE_L of wet DG were 4.09, 3.36, and 2.27 Mcal/kg of DM, respectively. These energy values are 7 to 11% and 10 to 15% higher than previously published values reported in the 1989 and 2001 NRC (Table 1).

Neutral detergent fiber (NDF) (~ 39%) and acid detergent fiber (ADF) (~ 19%) can vary significantly. Some newer DG has been reported to have concentrations of NDF and ADF considerably lower than NRC values, 27.1 and 14.4 %, respectively (Robinson, 2004).

One concern for nutritionists is that the level of fat in DG can vary greatly, and can be higher than 12%, much higher than values reported in the NRC (2001). Distillers grains contain high levels of unsaturated oil, predominantly linoleic acid (C18:2), reflecting the composition of corn oil (Elliot et al., 1993). Research at South Dakota State University showed that fat concentration was 13.1 and 12.1% for dried and wet DG respectively. It should be noted that the method of fat analysis can significantly affect this value. The study from Wisconsin measured fat at two labs and found two significantly different results (10.5 vs. 16.4% fat). These differences were attributed to different ether extract assays used in each lab. High levels of unsaturated fatty acids are a concern when balancing diets for lactating dairy cows because they can cause increase incomplete biohydrogenation in the rumen, potentially resulting in milk fat depression.

Although complete fermentation of starch is desirable to increase ethanol production, there is usually some starch remaining in DG. During the 1980s and ‘90s, starch in dried DG was measured to be 10 to 15% (Belyea et al., 1989; Batajoo and Shaver, 1998). Recently analyzed samples of DG resulted in 5% starch. Improved efficiency in fermenting more of the starch that was in the corn to ethanol is most likely the reason for these changes in the composition of DG.

Environmental concerns regarding excessive phosphorus have increased the awareness of phosphorus concentrations in DG. Most DG contain between 0.65 and 0.95% phosphorus. High producing dairy cows often need some supplemental phosphorus, therefore lower inclusion levels of DG usually replace inorganic sources. The greatest concern of using DG will be in regions of the U.S. where soils are already high in phosphorus. The other mineral that can be highly variable is sulfur. High sulfur levels in feed and water can result in central nervous system disorders which can lead to poor performance or death. This is rarely reported in dairy cattle, but has been reported in beef cattle.

Production Response of Cows Fed DG

Twenty seven studies evaluating the addition of DG to dairy cow diets have been reported in the U.S. since 1982. Of these studies, 19 evaluated the inclusion of dried DG in dairy cow diets. The remaining studies evaluated the inclusion of wet DG to dairy cow diets. Prior to the late 1990s, many of the experiments evaluating DG used DG originating from production of drinking alcohol. Since that time, all DG evaluated in dairy cow studies have used DG originating from modern fuel-ethanol plants.

Since DG was first recognized as a good source of protein, most research was developed to test DG as an alternative source of CP and RUP for dairy cow diets. More recently, research is focusing on DG as a source of energy from the fat and highly digestible fiber found in DG.

Distillers grains as a protein source

Most previous studies replaced soybean meal or a combination of soybean meal and corn when including DG into dairy cow diets. Feeding isonitrogenous diets, Palmquist and Conrad (1982) found different milk production responses in Holstein versus Jersey cows. Jersey cows responded positively to the addition of 24% dried DG; however, Holstein cows were unaffected. Van Horn et al. (1985) reported a reduction in milk yield and milk protein percentage when feeding 22.5 and 41.6% of the diet DM as dried DG in diets formulated to provide 14 and 18% CP. The dried DG in this experiment contained high levels of acid detergent insoluble nitrogen (ADIN), and these authors attributed the loss of production as a result of high ADIN content. Weiss et al. (1989) fed a dried DG produced from a blend of 65% barley and 35% corn. In this experiment, dried DG was fed up to 12.9% of the diet DM and did not affect intake, milk production, or milk composition.

Owen and Larson (1991) reported the results of a study comparing dried DG and soybean meal in diets for early lactation cows. Cows increased in milk production when dried DG was fed at 18.8% of the diet DM, most likely due to increased dietary RUP, but milk production decreased when dried DG was included at 35.8% of the diet DM. The authors concluded that lower protein digestibility and lysine levels contributed to the decreased performance of cows fed the 35.8% DG diet. The decrease in milk protein percentage on the dried DG diets in this study indicated that available lysine may have been deficient in these corn silage-based diets.

Powers et al. (1995) compared three different sources of dried DG with soybean meal at two dietary crude protein concentrations (14 and 18%). Designated by source, DDGS1 and DDGS2 were light in color and were lower in ADIN, whereas DDGS3 was dark in color with a higher ADIN. Dry matter intake was not affected by source of dried DG or by the CP level. Cows fed DDGS1 and DDGS2 produced more milk than cows fed 0% DG (soybean meal diet) and the DDGS3 diet. In addition, cows fed dried DG incorporated into the diet at 26% of the diet DM produced more milk than cows fed 13%.

More recently, Kleinschmit et al. (2006) compared three different sources of dried DG from modern fuel-ethanol plants. The three DG sources were processed differently with the intent to reduce protein damage, thereby improving the protein quality of the DG feedstuff. Dry matter intake did not change, but cows fed diets containing DG (at 20% of the diet) produced more milk than cows fed the control diet containing no DG. Milk fat percentage was not changed, but milk protein percentage declined from 3.28 to 3.16 with the addition of DG. The source of DG had very little impact on overall lactation performance.

Since DG is often used as a source of RUP in dairy cow diets, Pamp et al. (2006) investigated the effect of source and level of RUP in lactating diets by comparing dried DG to soybean protein. Soybean protein included a combination of SBM 44%, extruded soybeans, soyhulls, and expeller soybean meal. These feeds were combined together to create a blend similar in nutrient content to DG. Diets were formulated to contain 5.3, 6.8, and 8.3% RUP (DM basis) and included 0, 11, or 22% dried DG as the source of the RUP. Milk production increased with the addition of RUP and was greater for cows fed diets containing DG versus soybean protein. Milk fat percentage was not affected by addition of RUP or by source of RUP, but milk protein percentage was greater for cows fed DG compared to cows fed soybean protein (2.85 vs. 2.80%). This research supports the conclusion that DG can replace soybean protein as a source of RUP without reducing milk production and milk protein percentage if diets are formulated properly.

Distillers grains with solubles are a good source of methionine, but are low in lysine, therefore supplementation of rumen-protected lysine would theoretically allow one to maximize the use of DG in dairy cow diets. Nichols et al. (1998) reported an increase in milk production when cows were fed a ruminally protected lysine and methionine product in diets where dried DG was included at 20.25% of the diet DM. However in a following experiment, Liu et al. (2000) did not observe increased milk production when ruminally protected lysine and methionine were fed to cows with 18.85% dried DG included in the diet. Results of experiments with added amino acids by ruminally protected amino acids or by feedstuffs such as blood meal have been variable. In general, dried DG is a good quality protein source that can often be used as the only source of supplemental protein in properly formulated diets.

Distillers grains as a fiber source

Research has also been conducted to evaluate the ability of DG to replace a portion of the forages found in dairy cow diets. Since DG is high in NDF, it is tempting to replace some of the NDF provided from forages with the NDF from DG. Clark and Armentano (1993) tested the effect of replacing alfalfa NDF with NDF from dried DG on milk production and composition. Replacing 12.7% of the alfalfa DM with dried DG resulted in both milk production and milk protein percentage increases. Although the proportion of alfalfa in the diet dropped from 44% to 31% of the diet DM when dried DG was added, milk fat production was not altered.

One concern about replacing forage NDF in dairy diets is that the removal of physically effective fiber may alter normal rumen function causing milk fat depression. In a recent study, Cyriac et al. (2005) evaluated the replacement of forage fiber from corn silage with non-forage fiber from dried DG in dairy cow diets. Diets were formulated to include 0, 7, 14, and 21% dried DG replacing an equal portion of corn silage. The basal diet included 40% corn silage, 15% alfalfa hay, and 45% concentrate. Diets contained 15% alfalfa hay across all four diets. Dry matter intake increased as DG increased in the diets, but milk production remained the same. Milk fat percentage, however, decreased (3.34, 3.25, 3.04, and 2.85%) and milk true protein increased (2.82, 2.90, 2.93, and 3.04%) as the percentage of DG increased in the diet. To prevent changes in milk fat composition, sufficient physically effective fiber from forage must be included when formulating diets with DG.

Wet versus dried DG

Only two direct comparisons of wet DG versus dried DG have been conducted. Al-Suwaiegh et al. (2002) fed lactating dairy cows wet and dried DG at 15% of the diet DM. No differences in dry matter intake, milk production, and milk composition between wet and dried DG were found, indicating no advantage of one form over the other. More recently, Anderson et al. (2006) fed iso-nitrogenous diets formulated to include wet or dried DG at 0, 10, and 20% of the diet (DM basis). Milk production increased with the addition of DG in either form (wet or dried) compared to the control diet containing 0% DG. Both milk fat and milk protein percentage were similar for cows fed the control compared to DG; however, cows fed the wet DG diets resulted in greater milk fat and milk protein percentages than cows fed dried DG. Both of these studies demonstrate that wet DG can be successfully formulated in dairy cow diet without decreasing milk production and milk fat percentage.

High inclusion rates of DG

In practical application, it is generally accepted that DG can be included in dairy cow diets at 10% of the diet DM without negatively affecting milk production and composition. But the overall question remains: How much distillers grains can be included into dairy cow diets, and what effect does it have on milk fat and protein composition, and overall milk production?

Several studies have been conducted evaluating the level of inclusion of DG in dairy cow diets. Hippen et al. (2004) conducted a study which included dried DG up to 40% of the diet DM. Diets were formulated to include dried DG at 0, 13, 27, and 40% of the diet replacing other concentrate feeds. These diets were not iso-nitrogenous, and CP% increased from 16.5 to 18.9%. Intake increased with the addition of DG at 13%, but declined as DG was further included in the diets. Milk production mirrored these results and was highest when DG was included at 13% of the diet, but declined as DG was further added to the diet (40.7, 41.7, 39.1, 36.3 kg/d). Milk fat percentage was lower for cows fed DG in the diets compared to cows fed control diet (3.16 versus 3.40%), but did not differ across inclusion level. Milk protein percentage was not affected by inclusion of DG.

A similar experiment evaluated the effect of including wet DG in dairy cow diets (Hippen et al., 2003). This study included wet DG at 10, 20, 30, or 40% in iso-nitrogenous diets (18% CP) replacing other concentrate feeds. When wet DG was included at a level greater than 20% of the diet, DMI and milk production declined. At the high inclusion levels (30 and 40% DG), DM concentration of the total diet was only 40 to 46%. The authors concluded that gut fill of cows fed the high wet DG diets may have limited intake and consequently milk production. Milk fat and protein were not affected by inclusion rate.

Because alfalfa is a good source of lysine, it was thought that alfalfa-based diets may be a better forage base to which to add DG. Grings et al. (1993) added dried DG to alfalfa-based diets at 0, 10.1, 20.8, and 31.6 % of the diet DM. These diets were formulated to provide 13.9, 16.0, 18.1, and 20.0% CP. Although DMI did not vary across diets, milk yield and milk protein percentage increased linearly with increasing levels of DG. It should be noted that dietary CP% of these diets was not kept constant, therefore as DG increased in the diet, so did CP%. Cows fed the 31.6% DG diet produced the same amount of milk as those fed the 20.8% DG diet. Cows fed the 31.6% DG diet were fed in excess of their protein requirement; therefore no additional production response resulted at this level of DG inclusion.

Meta-analysis of DG studies

In order to assess the impact of inclusion of DG on lactation performance, a meta-analysis of previous feeding studies was conducted. Twenty-three studies investigating the inclusion of DG in dairy cow diets were compiled into a database with 96 treatment comparisons. An abbreviated summary of this extensive survey is listed in Table 2. Overall, DMI increased when DG was included up to 20% of the dry matter in dairy cow diets. However, DMI was also affected by form of the DG. Whereas intake of cows fed wet DG was highest at lower inclusion levels (< 20% of the DM), cows fed dried DG increased DMI up to the 30% inclusion. Decreases in intake at higher inclusion levels may be caused by higher dietary fat concentrations, or in the case of wet DG, high dietary moisture concentrations.

Milk production was not affected by form, but there was a curvilinear response of increasing DG in dairy cow diets. Cows that were fed diets containing 4 to 30% DG produced the same amount of milk, approximately 0.4 kg per day greater than cows fed diets containing no DG. When cows were fed the highest inclusion rate (> 30%), milk yield decreased. Cows fed wet DG decreased in milk production when included in the diet greater than 20%. This was most likely related to decreased DMI.

Milk fat percentage varied among inclusion levels and was not significantly affected by inclusion level or form. The current dataset does not support the theory that feeding DG results in milk fat depression. Many factors play an important role in causing milk fat depression. When formulating diets it is important to include sufficient fiber from forages in order to maintain rumen function. Distillers grains provide 28 to 44% neutral detergent fiber, but this fiber is finely processed and rapidly digested in the rumen. As such, fiber from DG is not considered ruminally effective fiber and should not be considered equal to forage fiber. High levels of fat provided from DG may also impact rumen function leading to milk fat depression, but it is often a combination of dietary factors which lead to significant reduction in milk fat percentage.

Milk protein percentage was not different for cows fed diets with 0 to 30% DG inclusion and the form of the DG did not alter composition. However, milk protein percentage decreased 0.13 percentage units when DG was included at concentrations greater than 30% of the diet compared to cows fed control diets. At the higher inclusion levels, DG most likely replaced all other sources of protein supplementation. At these high levels of inclusion, lower intestinal protein digestibility, lower lysine concentrations, and an unbalanced amino acid profile may all contribute to lower milk protein percentage. It should be noted that the lower milk protein percentages were most evident in studies conducted in the 1980s and 1990s. Newer studies are not as consistent in showing this effect. Lysine is very heat sensitive, and can be negatively affected by processing and drying. Improved processing and drying procedures in the newer fuel-ethanol plants may have improved amino acid quality of the product.

Summary

Distillers grains with solubles is an excellent source of protein and energy for lactating dairy cows. Research suggests that DG can replace more expensive sources of protein, energy, and minerals in dairy cow diets. Because DG can be highly variable, it is recommended that it be tested to determine exact nutrient composition in order to properly formulate diets. When balancing diets with DG, care must be taken to provide sufficient physically effective fiber to maintain normal rumen function and prevent milk fat depression. Nitrogen and phosphorus concentrations in DG-based diets also need to be monitored to prevent excessive losses to the environment. As technology improves, new ethanol coproducts will be developed and become available to livestock producers. Current recommendations for feeding DG to dairy cows would be to include DG up to 20% of the diet DM.

References

Anderson, J. M., 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.

Batojoo, K. K. and R. D. Shaver. 1998. In situ dry matter, crude protein, and starch degradabilities of selected grains and by-product feeds. Anim. Feed Sci. Technol. 71:165-176.

Belyea, R. L., B. J. Steevens, R. J. Restrepo, and A.P. Clubb. 1989. Variation in composition of by-product feeds. J. Dairy Sci. 72:2339-2345.

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

Bothast, R. J. and M. A. Schlicher. 2005. Biotechnological processes for conversion of corn into ethanol. Appl. Microbiol. Biotechnol. 67:19-25.

Clark, P. W. and L. E. Armentano. 1993. Effectiveness of neutral detergent fiber in whole cottonseed and dried distillers grains compared to alfalfa haylage. J. Dairy Sci. 76:2644-2650.

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).

Elliot, J. P., J. K. Drackley, D. J. Schauff, and E. H. Jaster. 1993. Diets containing high oil corn and tallow for dairy cows during early lactation. J. Dairy Sci. 76:775-789.

Harty, S. R., J-M. Akayezu, J. G. Linn, and J. M. Cassady. 1998. Nutrient composition of distillers grains with added solubles. J. Dairy Sci. 81:1201 (abstr).

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. 87:1965 (abstr).

Holt, S. M. and R. H. Pritchard. 2004. Composition and nutritive value of corn co-products from dry milling ethanol plants. South Dakota Beef Report, BEEF 2004-01, pp. 1-7. http://ars.sdstate.edu/extbeef/2004/BEEF_2004-01_Pritchard.pdf.

Grings, E. E., R. E. Roffler, and D. P. Deitelhoff. 1992. Responses of diary cows to additions of distillers dried grains with solubles in alfalfa-based diets. J. Dairy Sci. 75:1946-1952.

Kaiser, R. M. 2005. Variation in composition of distillers wet grains with solubles. Proceedings of the 4-State Dairy Nutrition & Management Conference, Dubuque, IA, June 15-16.

Kalscheur, K. F. 2005. Impact of feeding distillers grains on milk fat, protein, and yield. Distillers Grains Technology Council. 9th Annual Symposium. Louisville, KY. May 18-19.

Kleinschmit, D. H., J. M. Ladd, D. J. Schingoethe, K. F. Kalscheur, and A. R. Hippen. 2005. Ruminal and intestinal digestibility of distillers grains with solubles varies by source. J. Dairy Sci. 88(Suppl. 1):186 (abstr).

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

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.

National Research Council (NRC). 1989. Nutrient Requirements of Dairy cattle. 6th rev. ed. Natl. Acad. Sci., Washington, DC.

National Research Council (NRC). 2001. Nutrient Requirements of 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.

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

Palmquist, D. L. and H. R. Conrad. 1982. Utilization of distillers dried grains plus solubles by dairy cows in early lactation. J. Dairy Sci. 65:1729-1741.

Pamp, B. P., 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).

Powers, W. J., H. H. VanHorn, 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.

Robinson, P. H. 2004. Nutritive value of distillers grains: Conventional vs. Dakota Gold™. University of California, Cooperative Extension.

Spiehs, M. J., M. H. Whitney, and G. C. Shurson. 2002. Nutrient database for distillers dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota. J. Anim. Sci. 10:2639-2645.

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.

Weiss, W. P., D. O. Erickson, G. M. Erickson, and G. R. Fisher. 1989. Barley distillers grains as a protein supplement for dairy cows. J. Dairy Sci. 72:980-987.

Table 1. Nutrient composition of distillers grains (DG) with solubles (on a 100% DM basis) from various references.

Item,[1] %	NRC (1989)[2]	NRC (2001)[3]	Harty et al. (1998)[4]	Spiehs et al. (2002)[5]	Holt et al. (2004)[6]	Holt et al. (2004)[7]	Kaiser (2005)[8]	Common ranges[9]
Type of DG	dried	dried	dried	dried	dried	wet	wet	
DM	92	90.2	92.7	88.9	90.0	31.4	35.6	88-92
CP	25	29.7	30.1	30.2	33.3	35.5	26.7	27-35
RDP, %CP	53	. . .	46.6	. . .	. . .	. . .	. . .	. . .
RUP, %CP	47	. . .	53.4	. . .	. . .	. . .	. . .	. . .
NDICP	. . .	8.6	. . .	. . .	. . .	. . .	8.9	. . .
ADICP	. . .	5.0	8.0	. . .	3.2	3.5	. . .	. . .
NDF	44	38.8	48.8	42.1	42.7	42.3	30.2	28-44
ADF	18	19.7	15.5	16.2	13.2	12.1	. . .	14-24
Fat	10.3	10.0	10.5	10.9	13.1	12.1	10.5, 16.4	8-15
Ash	4.8	5.2	4.3	5.8	4.1	3.8	5.6	. . .
Ca	0.15	0.22	. . .	0.06	. . .	. . .	0.1	0.03-0.15
P	0.71	0.83	. . .	0.89	0.74	0.59	0.9	0.60-0.95
K	0.44	1.10	. . .	0.94	0.91	0.63	1.2	0.70-1.20
Mg	0.18	0.33	. . .	0.33	0.31	0.24	0.3	0.30-0.40
S	0.33	0.44	. . .	0.47	0.48	0.38	. . .	0.30-0.80
NE_L, Mcal/kg	2.04	1.97	. . .	. . .	. . .	. . .	. . .	. . .

[1]Nutrients: DM = dry matter, CP = crude protein, RDP = rumen-degraded protein expressed as a percentage of CP, RUP = rumen-undegraded protein expressed as a percentage of CP, NDICP = neutral detergent insoluble nitrogen expressed as CP, ADICP = acid detergent insoluble nitrogen expressed as CP, NDF = neutral detergent fiber, ADF = acid detergent fiber, and NE_L = net energy for lactation.
[2]NRC Nutrient Requirements of Dairy Cattle, 6th Rev. Ed. (1989).
[3]NRC Nutrient Requirements of Dairy Cattle, 7th Rev. Ed. (2001).
[4]Sampled from 8 ethanol plants in Minnesota, South Dakota, and Nebraska.
[5]Sampled from 10 ethanol plants in Minnesota and South Dakota every 2 months for 3 years.
[6]Sampled from 4 ethanol plants in South Dakota and Minnesota for 3 consecutive months.
[7]Sampled from 3 ethanol plants in South Dakota and Minnesota for 3 consecutive months.
[8]Sampled from 3 ethanol plants in Wisconsin over a period of 9 months.
[9]Commonly observed nutrient composition ranges for DG in the field.

Table 2. Lactation performance of dairy cows fed increasing levels of DG[1].

Inclusion level (DM basis)	DMI, kg/d	Milk, kg/d	Fat, %	Protein, %
0%	22.2[b]	33.0	3.39	2.95[a]
0 – 10%	23.7[a]	33.4	3.43	2.96[a]
10 – 20%	23.4[ab]	33.2	3.41	2.94[a]
20 – 30%	22.8[ab]	33.5	3.33	2.97[a]
> 30%	20.9[c]	32.2	3.47	2.82[b]
SEM	0.76	1.4	0.08	0.06

[a,b,c] Values within column followed by a different superscript letter differ ($P < 0.05$). No superscript would indicate no significant difference between treatments.
[1]Adapted from Kalscheur (2005).