Using Wheat Distillers in Dairy Rations

John McKinnon

Department of Animal & Poultry Science, Room 6D04, Agriculture Building, 51 Campus Drive University of Saskatchewan, Saskatoon, SK S7N 5A8
Email: john.mckinnon@usask.ca

■ Take Home Messages

- Cereal grain-based ethanol production will have dramatically increased in North America over the decade from 2000 to 2010; concurrently, the supply of ethanol byproducts for livestock feed will increase.
- Wet byproducts are only of practical use to producers in close proximity to the plant; Dried distiller's grains with solubles (DDGS) is the primary dried byproduct that dairy producers will encounter.
- Wheat-based DDGS contains 38 to 40% crude protein of which as much as 60% is rumen bypass protein. Based on limited research with growing cattle, the energy value of wheat-based DDGS appears to be at least equal to that of barley grain.
- Over feeding DDGS will result in over feeding protein, which will come at a metabolic cost to the animal as well as have environmental implications.
- Despite relatively high NDF content, the effective nature of DDGS fibre for stimulating chewing and rumination is open to question due to small particle size.
- DDGS, particularly corn-DDGS are a source of added fat and must be considered when looking at total dietary fat levels.
- Mineral levels of DDGS are concentrated 3-fold relative to the original cereal grain used in the fermentation process. Emphasis should be placed on implications for total dietary levels of specific minerals such as sulfur and phosphorus when DDGS is fed.
- When feeding wheat-based DDGS, producers are encouraged to consult a nutritionist to develop rations that meet requirements for cows in each stage of lactation and to develop manure management programs that consider the potential environmental impact from feeding this byproduct of the ethanol industry.

▪ Introduction

Dairy and beef producers are starting to hear a lot about the potential of distiller's grains and other byproducts of the bio-fuel industries as feed sources for their cattle. Since feed accounts for a significant proportion of operating costs, it is not surprising that many are starting to ask questions regarding cost, nutritional value and supply. Much of the interest in feeding distiller's grains stems from the rapid increase in ethanol production capacity across North America. For example, in the past five years the United States has increased ethanol production capacity from 1.5 to slightly greater than 6 billion gallons annually with a further 6 billion gallon of annual capacity currently under construction (Ethanol Producer, 2007). Similarly in Canada with plants in operation or under construction, we will have a capacity close to 1.5 billion litres in the next 6 to 12 months. With a national mandate for 5% inclusion of ethanol in unleaded gasoline in 2010, it is fair to say that we will see the continued growth of the ethanol industry in Canada.

With an increased ethanol industry, there is an increased supply of byproducts that can serve as excellent cattle feed. Consider the example of a 130 million litre or larger wheat-based ethanol plant. In the next year, 3 such plants will operate in western Canada, in addition to several corn-based plants of the same or larger size in eastern Canada. These plants will produce approximately 1000 tonnes of dried distiller's grains with solubles (DDGS) for each million litres of ethanol produced or 130,000 tonnes of DDGS per year for a 130 million litre plant. Thus, it is not hard to understand why dairy and beef producers are anxious to learn about the feed byproducts of these plants and how to use them in their feeding programs.

▪ Distiller's Grains – What are they and how do they fit?

In order to fully understand the answers to these questions, it is necessary to step back and examine how ethanol and its feed-related byproducts are produced. Most wheat- and corn-based ethanol plants built today incorporate dry milling into the ethanol production stream. Dry milling starts with putting the grain through a hammer-mill or in some cases a roller-mill to break up the whole grain. The processed grain then goes through a series of steps to prepare it for fermentation. First the complex starch in the grain must be broken down to simpler sugars. This is accomplished by a process known as liquefaction and cooking and is aided by the addition of enzymes (i.e. alpha amylase). During fermentation, the complex sugars are broken down to glucose, which are then converted to ethanol and carbon dioxide by the addition of further enzymes (i.e. gluco-amylase) and yeast. Following fermentation, "the beer" is transferred to a distillation column where the ethanol is removed. At this stage the remaining material is called whole stillage and consists of all the components of the original cereal grain (except the starch), spent yeast cells and added water. It is this whole stillage that forms the starting point for the feed related byproducts that result from an ethanol plant of which there are two general classes – wet and dry distiller's byproducts.

Wet Distiller's Byproducts:

Wet distiller's byproducts include wet distiller's grains and thin stillage, which are formed by simply pressing or centrifuging the whole stillage. Wet distiller's grains contain approximately 30 to 35% dry matter, while thin stillage is only 5 to 7% solids. The nutritional composition of wheat-based wet DDGS and thin stillage is presented in Table 1. Both of these products are high in protein and energy when considered on a dry matter basis and can be used as sources of these nutrients in dairy and beef rations (Iwanchysko et al. 1999; Fisher et al. 1999). Consider for example, Pound-Maker AgVentures Ltd., at Lanigan, Saskatchewan. This company has operated an integrated 12 million litre ethanol plant and 28,000 head beef feedlot for more than 15 years. Their feeding and management program is an excellent example of how wet byproducts can be used in growing and finishing rations. In their case the wet distiller's grain is added to the total mixed ration, while the thin stillage is fed to the cattle in water bowls. In cooperation with Pound-Maker AgVentures Ltd., the University of Saskatchewan has carried out extensive research documenting the feeding value of wheat-based wet distillers' grains and thin stillage to beef cattle (Mustafa et al. 2000; Fisher et al. 1999; Ojowi et al. 1997; Iwanchysko et al. 1999).

Table 1. Nutrient composition of wet distiller's grains and thin stillage from wheat-based ethanol production

Nutrient[1]	Thin Stillage[2]	Distiller's Grains[3]
Number	10	4
DM%	6.3 $\pm$ 1.0	30 – 35
CP%	46.6 $\pm$ 4.9	28.6 $\pm$ 1.6
SCP (%CP)	19.9 $\pm$ 2.1	13.4 $\pm$ 1.7
NDF%	38.4 $\pm$ 5.9	56.4 $\pm$ 2.4
ADF%	2.0 $\pm$ 0.2	20.5 $\pm$ 1.8
Ether extract %	6.9 $\pm$ 1.1	7.6 $\pm$ 0.25
Ash	9.4 $\pm$ 1.1	ND

[1]All values %DM unless indicated; [2]Adapted from Iwanchysko et al. 1999; [3]Adapted from Penner and Christensen (unpublished undergraduate thesis); ND = not determined.

Limited research has been carried out with wet byproducts from wheat-based ethanol production for dairy cattle. Unpublished work by Penner and Christensen at the University of Saskatchewan compared wet wheat-based distiller's grains as a replacement for forage in early lactation rations for Holstein cows producing 40 kg of milk per day. Wet distiller's grains were substituted for barley silage at 10% of diet dry matter. Their results indicated that feeding wet wheat-based distiller's grains increased milk yield by 7% and milk protein content by 9%. While fat milk yield was not affected, milk fat % was reduced (3.04 vs. 3.36%) for cows fed wet distiller's grains relative to the control cows. This reduction was attributed to less time spent ruminating and total chewing activity for cows fed the distiller's grains.

With respect to use of wet byproducts, dairy producers need to be aware that they must be relatively close to the ethanol plant to make these products work in their rations, as transportation costs can become prohibitive due to their high moisture content.

Dry Distiller's Byproducts:

There are 3 classes of dry byproducts that can arise from a cereal-based ethanol facility. These include dried distiller's grains (DDG), condensed distiller's solubles (CDS) and dried distiller's grains with solubles (DDGS). These products arise from differential drying of the whole stillage remaining after the ethanol has been distilled off. Condensed distiller's solubles (also called syrup) and DDG are produced when whole stillage is separated via centrifuging into a coarse fraction at 30 to 35% dry matter and a liquid fraction known as thin stillage at 6 to 8% dry matter. The coarse solids can be dried to 90% dry matter and sold as distillers dried grains. Since this product does not have the soluble material added back to it, it is lower in nutrient content and resembles the nutrient profile of wet distiller's grains outlined in Table 1. The thin stillage at 6 to 8% dry matter is put through an evaporator and dried to approximately 30% dry matter. At this point it can be marketed as condensed distiller's solubles. Condensed distiller's solubles typically is a more concentrated source of certain nutrients than other byproducts from ethanol production. For example CDS samples from wheat-based ethanol production in western Canada have analyzed from 42 to 53% CP; 1.4 to 1.5% P and 0.4 to 0.47% S. Other nutrients such as fibre (ADF and NDF) and fat may be similar or less than that in the coarse fraction. As with wet byproducts, it should be noted that unless one is close to an ethanol plant it is unlikely that one would consider CDS as a feed ingredient as this product is not readily available and is costly to transport.

Dried distiller's gains with solubles (DDGS) are the form of ethanol byproduct that most cattle producers in Canada will encounter. Dried distiller's grains with solubles results from the complete drying at the ethanol plant of the residual whole stillage. After the centrifuge and evaporator, the condensed distiller's syrup (at 30% dry matter) is added back to the coarse solids (at 30 to 35% dry matter) and the mixture is dried down to approximately 90% dry matter. As such this product can be transported great distances and stored without fear of spoilage.

Table 2 shows the nutrient content of wheat-based DDGS derived from 2 western Canadian ethanol plants which differ in drying technology. Within and between plant variation in nutrient profile of DDGS can be an issue. In particular, drying conditions can significantly influence protein quality and availability of the resulting product (Kleinschmit et al. 2007).

Table 2. Nutrient content[1] of wheat-based dried distiller's grains with solubles (DDGS) from 2 western Canadian ethanol plants (mean ± SD).

Nutrient	Plant 1	Plant 2
N	3	3
DM %	90.6 ± 2.7	88.1 ± 1.4
CP %	41.9 ± 2.4	41.0 ± 1.4
Soluble CP (%CP)	20.1 ± 4.1	26.2 ± 6.7
NDICP %	22.0 ± 4.7	19.0 ± 5.6
ADICP %	6.6 ± 1.6	4.4 ± 1.1
ADF %	14.9 ± 2.0	15.4 ± 3.2
NDF%	42.1 ± 0.8	38.6 ± 11
Ether Extract %	4.8 ± 1.2	5.3 ± 1.2

[1]All analysis from one commercial laboratory of samples collected by University of Saskatchewan.

From the table you can see that the nutritional benefits of DDGS arise from the nutrients that are left over after the fermentation process to produce ethanol. In particular nutrients such as fat, protein and fibre are concentrated. A rule of thumb is that nutrients in DDGS that are not metabolized during ethanol production are concentrated approximately 3 fold relative to the original cereal grain.

Table 3 shows the mineral content of wheat-based DDGS derived from 2 western Canadian ethanol plants. As with other nutrients, minerals such as phosphorus (P) and sulfur (S) are concentrated approximately 3-fold in dried distiller's grains with solubles.

Table 3. Mineral content[1] (mean ± SD) of dried distiller's grains with solubles (DDGS) from 2 western Canadian ethanol plants.

Nutrient	Plant 1	Plant 2
N	3	3
Ca %	0.13 ± 0.0	0.16 ± 0.05
P %	0.99 ± 0.17	0.99 ± 0.05
Mg %	0.42 ± 0.09	0.40 ± 0.03
K %	1.36 ± 0.32	1.15 ± 0.13
S %	0.48 ± 0.07	0.44 ± 0.05
Mn ppm	105 ± 7.0	112 ± 4.0
Zn ppm	91 ± 12.7	113 ± 26.0
Cu ppm	23 ± 12.0	9.0 ± 5.0

[1]All analysis from one commercial laboratory of samples collected by University of Saskatchewan.

When comparing DDGS samples from corn vs. wheat it is important to consider that differences in nutrient content between DDGS derived from different cereal grains are similar to differences between the original cereal grains. For example, wheat has higher protein (i.e. 15%) than corn (i.e. 9%). Similar differences are evident in the DDGS derived from each source (35 to 40% for wheat-based DDGS vs. 27 to 32% for corn-based DDGS). In contrast the fat content of corn-based DDGS is considerably higher than that of wheat (i.e. 6 vs. 11%). As ethanol plants often alter the types of grains they use for ethanol production, it is a good idea that the chemical composition of each lot of DDGS be determined.

▪ What Dairy Producers Need to Know About Feeding DDGS!

Rations for high producing, early lactation cows (i.e. 650 kg cows @ 40 kg milk per day @ 3.6 % milk fat) typically average 17.5 to 18.5% crude protein and are formulated to 33 to 35% rumen undegradable or bypass protein (NRC 2001). Traditionally DDGS have been fed as a source of both crude protein (Table 2) as well as rumen bypass protein. As indicated above, in terms of crude protein, wheat-based DDGS is superior to corn-based DDGS. Boila and Ingalis (1994) reported that the rumen bypass value of dried distillers grains from an older generation wheat-based ethanol plant averaged 63%. Similar values (i.e. 59.1 to 71.7 % rumen bypass protein) were reported for corn-based DDGS from new-generation plants (Kleinschmit et al. 2007). In contrast, Kononoff et al. (2007) reported that corn-based DDGS from Nebraska had a rumen bypass protein content of 43%. The within and between plant variability in rumen bypass protein is attributed to differences in the temperature and duration of drying that exists between plants. In contrast, rumen bypass protein content of wet distiller's grains is typically lower due to the absence of drying (Mustafa et al. 2000; Kleinschmit et al. 2007).

As the supply of DDGS increases and if competitively priced, producers will be tempted to maximize inclusion levels of this byproduct into their rations. Typical inclusion levels of corn-based DDGS aimed at meeting nutrient requirements for high producing dairy cows range from 15 to 20% (Kononoff and Erickson, 2006). Research has shown that higher levels can be fed, however, producers need to realize that they will be over feeding protein to their cows (Schingoethe, 2006). This protein must be metabolized to urea and excreted. This is not only a metabolic cost to the animal but can potentially lead to poor fertility if blood urea nitrogen levels are excessive (Butler, 1997). High dietary protein levels also pose a potential environmental concern, as the manure from these animals will be high in nitrogen and must be handled in a responsible manner.

Both corn and wheat-based DDGS are somewhat unique supplements for dairy and beef cows in that they are concentrated sources of energy and protein. With corn-based DDGS, work from the University of Nebraska indicates that the energy value of wet distiller's grain when fed to beef cattle at 40% of the diet dry matter is approximately 1.4 times that of corn while when fed dry as DDGS, it had a value approximately 1.2 times that of corn grain (Hamm et al. 1994). The high energy value of corn-based DDGS when fed either wet or dry is primarily due to its high fat content. Unpublished work from both the University of Saskatchewan (McKinnon and Beliveau) and Agriculture Canada at Lethbridge (McAllister, Gibb and Hao) indicates that wheat-based DDGS has an energy value equal to that of barley when fed at levels up to 40% of the ration dry matter (i.e. NE_m = 2.00 and NE_g = 1.34 mcal / kg DM) in growing rations. This would equate to a NE_l value for wheat-based DDGS of 2.0 Mcal / kg of DM.

As indicated in Table 2, wheat-based DDGS has a high fibre content, particularly that of neutral detergent fibre (NDF). As dietary inclusion levels of this byproduct increase, diet NDF levels also increase. Recommended NDF levels depend on forage to concentrate ratios as well as on the effectiveness of the forage for stimulating chewing activity (NRC 2001). It is tempting for producers too rely on DDGS as a source of dietary NDF. However, producers need to be aware that due to small particle size the effective fibre present in wheat- and corn-based DDGS is minimal (Kononoff and Christensen 2007). Diets lacking in coarse fibre can lead to reduced chewing activity and rumen pH and as a result milk fat depression (Beauchemin, 1996; Eastridge, 2005). The lack of effective fibre in DDGS likely explains the depression in chewing activity and reduced milk fat content observed by Penner and Christensen (unpublished data). The take home message here is do not rely on the high neutral detergent fibre content of distiller's grains to provide effective fibre to the rumen.

Producers should also be aware that as the dietary inclusion level of DDGS increases, dietary fat content increases. Wheat-based DDGS typically contains 5 to 6% fat while corn-based DDGS contains 9 to 11% fat. The unsaturated nature of fat in corn-based DDGS is potentially a concern for milk fat depression if fed at too high an inclusion level (Kononoff and Christensen, 2007). This problem however, is only likely to be encountered at high DDGS inclusion levels and can be avoided by proper ration formulation.

Concentration of minerals in DDGS can also be an issue for both beef and dairy producers. The phosphorus requirement of dairy cows is met at levels of 0.37 to 0.42% of diet dry matter (Eastridge, 2005; VandeHaar and St-Pierre, 2006). In DDGS, phosphorus levels are approximately 1.0% (or more) of dry matter. If we over feed DDGS in significant amounts, the result can be high levels of phosphorus excreted in the manure. This would require a sound environmental farm plan in order to make efficient use of these nutrients as fertilizer. Similarly high sulfur levels in DDGS contribute to overall sulfur levels in the diet. If diet sulfur levels start to exceed 0.45 to 0.50% on a DM basis, there is potential for "polio" to develop in cattle. Thus it is a good idea to consult a nutritionist before feeding these byproducts to any great extent.

▪ Conclusions

Wheat-based DDGS is an excellent source of energy and protein for both high producing dairy cows and growing and finishing beef cattle. Wet distiller’s byproducts are typically only available to producers in close proximity to the ethanol plant. Wheat-based DDGS contains 38 to 42% CP of which greater than 50% has been shown to bypass the rumen. Fat levels of wheat-based DDGS are 5 to 6% while that of corn-based DDGS can average 10% or more. The neutral detergent fibre level of DDGS is relatively high, however, the effectiveness of this fibre is open to question due to the small particle size of this byproduct feed. Dietary mineral levels, particularly that of phosphorus and sulfur, should be monitored when feeding DDGS supplemented rations. Producers are encouraged to consult a nutritionist for assistance when feeding DDGS-based diets and to develop sound manure management programs.

▪ Acknowledgements

Wheat-based research at the University of Saskatchewan has been supported by the Saskatchewan Agriculture and Food, Advancing Canadian Agriculture and Agri-Food Saskatchewan, Husky Energy and Pound-maker

AgVentures of Lanigan, Sk.

References

Beauchemin, K. 1996. Using ADF and NDF in Dairy Cattle Diet Formulation – a Western Canadian Perspective. Anim. Feed Sci. & Techn. 58:101-111.

Boila, R.J. and J.R. Ingalls, 1994. The Ruminal Degradability of Dry Matter, Nitrogen and Amino Acids in Wheat-Based Distillers' Grains in sacco. Anim. Feed Sci. Techn. (48):57-72.

Butler, W.R. Review: 1998. Effect of Protein Nutrition on Ovarian and Uterine Physiology in Dairy Cattle. J. Dairy Sci. 81:2533-2539.

Eastridge, M.L. 2006. Major Advances in Applied Dairy Cattle Nutrition. J. Dairy Sci. 89:1311-1323.

Fisher, D.J., J.J. McKinnon, A.F. Mustafa, D.A. Christensen, D. McCartney. 1999. Evaluation of Wheat-based Thin Stillage as a Water Source for Growing and Finishing Cattle. J. Anim. Sci. (77):2810-2816.

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. 1994 72: 3246-3257.

Iwanchysko, P., J.J. McKinnon, A.F. Mustafa, D.A. Christensen, D. McCartney. 1999. Feeding Value of Wheat-based Thin Stillage: In Vitro Protein Degradability and Effects on Rumen Fermentation. J. Anim. Sci. (77):2817-2823.

Kleinschmit, D.H., J.L. Anderson, D.J. Schingoethe, K.F. Kalscheur,
And A.R. Hippen. 2007. Ruminal and Intestinal Degradability of Distillers' Grains Plus Solubles Varies by Source. J. Dairy Sci. (90):2909-2918.

Kononoff, P.J., and Erickson, G.E. 2006. Feeding Corn Milling co-Products to Dairy and Beef Cattle. Proceedings of the Southwest Nutrition and Management Conference, Tempe, Az. Pp 155 – 163.

Kononoff, P.J., and Christensen, D.A. 2007. Feeding Dried Distiller's Grains to Dairy Cattle. Proceedings of the 2007 Western Nutrition Conference. Saskatoon, Sk. pp 197-205.

Mustafa, A.F., J.J. McKinnon, and D.A. Christensen. 2000. The Nutritive Value for Ruminants of Thin Stillage and Wet Distillers' Grains for Ruminants – A Review. Asian-Aus. J. Anim. Sci. (13) 1609-1618.

National Research Council Nutrient Requirements of Dairy Cattle. 2001. National Academy Press, Washington, D.C. 7th revised edition.

Ojowi, M., J.J. McKinnon, A. Mustafa, D.A. Christensen. 1997. Evaluation of Wheat-based Wet Distiller's Grains for Feedlot Cattle. Can. J. Anim. Sci. (77) 447-454.

Penner, G.B. and Christensen, D.A. 2004. An Investigation into the Nutritive Properties of Distiller's Grain for High Yielding Holstein Cows. University of Saskatchewan Undergraduate Thesis.
Schingoethe, D.J. 2006. Utilization of DDS by Cattle. Proceedings of the 2006 Western Nutrition Conference. Winnipeg, Mb. 13 pp.
Vandehaar, M.J. and St-Pierre, N. 2006. Major advances in dairy nutrition: Relevance to the Sustainability of the dairy industry. J. Dairy Sci. 89:1280-1291.