Corn-Ethanol: One Process but Many Products...Do Cows Care?

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Abstract

Corn grain is a common ingredient in dairy diets; however, the utilization of corn for production of ethanol has impacted the dairy industry in such a way that corn grain is being partially replaced by corn milling byproducts in dairy diets. Corn milling byproducts are typically priced below the price of corn and their nutritional profile makes them suitable as animal feedstuffs, as they are good sources of energy and protein for ruminants. Dry-grinding of corn for ethanol produces distillers grains with solubles **(DDGS)**, either wet or dry, and unique industrial processes may also produce a high protein byproduct. Current trends in the production of livestock feed from ethanol production are focusing on removing fat from the byproducts stream. These processes produce a product referred to as reduced-fat DDGS. Research to date has demonstrated that byproducts may be strategically included into dairy rations by substituting out more expensive ingredients, such as corn or soybean meal, while maintaining milk production and composition. To be successful in using byproducts, it is important to balance rations that contain adequate effective fiber and metabolizable protein, and to avoid milk fat depression not contain excessive amounts of fermentable carbohydrates or polyunsaturated fatty acids.

Introduction

In 2013, the United States produced almost 14 billion bushels of corn with approximately 35% of which was used for ethanol production (RFA, 2014a). This production will result in 42 million tons of byproducts, and approximately 25% of this will be fed to dairy cows. With byproducts of the corn-ethanol industry being a major source of feed for the dairy industry, nutritionists are frequently faced with the decisions of how to formulate diets containing the feed, and more importantly, to be effective in doing so, they must be able to anticipate the response of the animal when the feed is used. To complicate this, the corn ethanol industry produces a number of different byproducts, which vary in chemical composition and nutritional value to the lactating dairy cow. The objective of this presentation is to outline the different byproducts that are produced by the corn-ethanol industry in the Midwestern United States and that are available to the dairy industry. Focus will be given to the effects on milk yield and composition.

Overview of Corn Ethanol Production and Resulting Products

Production process

Ohio, Michigan, and Indiana are home to 6, 5, and 12 bio-refineries, and these are capable

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of producing 528, 268, and 948 million gallons of ethanol per year respectively (RFA, 2014b). The bulk of this production is corn-ethanol. It is important to note that approximately two thirds of the corn kernel is composed of starch and subject to fermentation by yeast for the production of ethanol; therefore, the rest of the kernel flows into the stream of byproducts, which include a liquid fraction called distillers solubles and a solid fraction called distillers grains. These two are commonly blended into a single byproduct generically referred to as distillers grains with solubles **(DGS)**, and upon further processing, they can be dehydrated to obtain an approximate 90% DM, resulting in dried distillers grains with solubles **(DDGS)**. Production of DDGS represents 59% of the total DGS produced by the corn-ethanol industry (RFA, 2013a). This byproduct is characterized by its high content of protein and energy, which make it suitable for feeding to dairy cattle.

Dry milling for ethanol production (Figure 1) starts with reception of corn at the ethanol plant which tests a sample of grains for chemical composition typically using near-infrared spectroscopy analysis. Once the grain is tested and approved, it is unloaded and pooled in grain storage structures. The following step involves cleaning of the grain to remove foreign material; this cleaning process is commonly done using screens, aspiration, fans, and other milling techniques. Once the grain is clean, it is subjected to a grinding process in a hammer mill to obtain a meal with powder-like consistency, which will become the feedstock for the fermentation process.

The ground corn is added to large fermentation vats where water, enzymes, and yeast are blended and form a mash from which yeast will produce alcohol by fermenting the starch. The fermented mash is referred to as beer; the resulting beer is then distilled to obtain the alcohol. The remaining material is called whole stillage, which is centrifuged resulting in 2 fractions. The liquid fraction contains most of the water, fine particles, and yeast cells; this fraction is called thin stillage. The solid fraction contains primarily bran and germ fragments and is called distillers grains. Further processing via evaporation condenses the thin stillage into a syrup called condensed distillers solubles which may be marketed as livestock feed or blended with the distillers grains to produce DGS. This feed byproduct may be marketed to feed livestock in a wet or dry form of DDGS with solubles.

Dried distillers grains with solubles

The productive response when cows consume DDGS is a function of what ingredients are removed from the diet to allow inclusion of DDGS. Common ingredients replaced with DDGS include forages (Kelzer et al., 2009), protein sources (Paz et al., 2013), and starch sources (Ranathunga et al., 2010). There are many reports in the scientific literature that have evaluated the response of feeding ethanol byproducts to dairy cows, and typically, the results show comparable performance to the control treatment. In some cases, there are improvements in milk yield, depending on the level of inclusion (Anderson et al., 2006; Kleinschmit et al., 2007; Ramirez-Ramirez et al., 2011).

It is important to note that only a few experiments have fed DDGS at levels $\geq$ 30%, and most experiments limit the inclusion level up to 20% of the dietary DM. Janicek et al. (2008) reported a linear increase in DMI and milk yield when cows where fed 0, 10, 20, and 30% DDGS with no significant effects on milk composition. Similarly, Benchaar et al. (2013) reported up to 8 lb/day greater milk yield with increasing levels of DDGS from 10, 20, or 30%, as well as greater DMI. Interestingly, Hollmann et al. (2011a) conducted a meta-analysis and reported a quadratic response in milk yield when feeding distillers grains which peaked at 21% inclusion and resulted in a 2.7 lb/day increase in milk yield. Therefore, the observation of Hollmann et al., (2011a) supports the general notion that DDGS may be included at a maximal rate of approximately 20% of dietary DM to sustain production. In another meta-analysis, Paz et al. (2013) reported that an increase in the inclusion of corn DGS in dairy diets tended to increase milk yield.

Research suggests that DDGS may be safely included in dairy diets without negative effects on milk composition, as long as appropriate dietary considerations are taken into account, such as sufficient amount of effective fiber (Schingoethe et al., 2009). Janicek et al. (2008) reported no changes in concentration and yields of milk fat and protein with increasing levels of DDGS in dairy diets; on average, cows produced milk with 3.65% fat and 3.17% protein. In a similar study, Benchaar et al. (2013) reported linear decreases in milk fat and protein concentrations. These effects are the result of a linear increase in milk yield, but actual yields of fat and protein were similar across dietary treatments averaging 2.9 lb and 2.6 lb, respectively. Similar diluting effects have been reported by others; Leonardi et al. (2005) reported that cows consuming 15% DDGS produced milk with lower fat concentrations compared with cows receiving the control treatment (3.24 and 3.38% milk fat for DDGS and control treatment, respectively, corresponding with increased milk production and ultimately similar milk fat yield for both treatments). Field observations have reported cases of milk fat depression **(MFD)** when feeding DDGS, and the inclusion level is often kept below < 20% in commercial dairy diets (Janicek et al., 2008; Schingoethe et al., 2009; Hollmann et al., 2011a). The field reports of MFD when feeding DDGS may be the result of additional factors other than simply adding DDGS to the diet. For example, Hollmann et al. (2011a) reported that lactation response to DDGS is dependent on diet fermentability. Diet fermentability plays a major role on the outcome of a successful feeding program, including DDGS, and when this factor surpasses adequate levels, it is possible to encounter issues, such as MFD. For instance, Owens et al. (2009) reported milk fat depression when feeding DDGS in combination with high-moisture corn but not with dry ground corn, which suggests an effect of diet fermentability leading to MFD. Similarly, Ramirez Ramirez et al. (2012) reported MFD when feeding DDGS in a dairy diet with high inclusion of corn silage and high fermentability evidenced by lower ruminal pH and marked changes in microbial community structure. Another factor that influences the response on milk fat is the profile and availability of the lipids present in the feed. Abdelqader et al. (2009) reported that diets with 6% ether extract containing DDGS or corn oil as sources of fat resulted in a slight decrease in milk fat concentration and yield compared to a diet containing corn germ, suggesting that fat in DDGS and corn oil is more readily available in the rumen and likely alter biohydrogenation pathways.

Effects on milk protein

Schingoethe et al. (2009) indicated that feeding DDGS will seldom affect milk protein content unless protein is limiting in the diet. Similarly, the meta-analysis conducted by Paz et al. (2013) reported that the inclusion of DGS was not associated with milk protein concentration unless the supply of metabolizable protein **(MP)** and Lys are limiting or close to limiting. Feeding corn milling byproducts may increase the protein content of the diet and improve the supply of MP because of increased microbial crude protein (MCP) synthesis (Gehman and Kononoff, 2010) and increased supply of RUP (Janicek et al., 2008). Hollmann et al. (2011b) described that protein quality and origin (corn-protein and non-corn protein) are important factors to consider when including distillers grains in dairy diets because of the reduced supply of lysine in corn derived products.

In spite of decreased protein percentage as DDGS were included in diets at increasing levels from 0 to 30%, some researchers have reported increased protein yield due to an increase in milk production. Janicek et al. (2008) reported that cows produced increasing amounts of milk protein when fed 0, 10, 20, and 30% of the dietary DM as DDGS, and Benchaar et al. (2013) reported increasing amounts for a similar arrangement of treatments. Conversely, Kleinschmit et al. (2007) fed dairy cows 15% DDGS with alfalfa or corn silage as the source of forage and observed no changes in protein concentration (3.3 ± 0.05%) but reported that inclusion of alfalfa hay tended to increase the yield of protein, which underscores the importance of considering different sources of protein and their solubility, rumen degradability, and amino acid profile. Overall feeding DDGS to dairy cows has no detrimental effect on milk protein production as long as diets are formulated to meet the MP requirements of the cow.

Wet distillers grains with solubles (WDGS)

To date, very little research has been conducted on dairy cattle consuming wet distillers grains and solubles **(WDGS)**. One reason for this is that it may be difficult to store so that spoilage is avoided, and most university research facilities are small. As a consequence, most research facilities are unable to utilize loads at amounts necessary to maintain the frequency of delivery needed to keep WDGS fresh. In one study designed to evaluate the level and form of DGS, diets were formulated to contain either 10 or 20% of DGS in either wet or dry form (Anderson et al., 2006). In that study, cows consuming WDGS produced similar amounts of milk, but this milk contained a higher concentration of fat and protein than from cows consuming DDGS. Interestingly, a higher feeding value of WDGS over DDGS also has been documented in the performance of feedlot cattle consuming a high grain finishing ration (Nuttelman et al., 2013). Although less research has been conducted in growing cattle fed high forage diets, recent research at the University of Nebraska-Lincoln suggests that the difference in feeding value is less (Ahern et al., 2011). Further research in lactating dairy cattle is needed to determine the impact on milk production when feeding either WDGS or DDGS.

High protein dried distillers grains (HPDDG)

High-protein distillers dried grains **(HPDDG)** may be produced from the dry milling industry when the germ and bran are removed and fermentation occurs with nutrients supplied by the remaining gluten and endosperm (Kelzer et al., 2009). Using HPDDG which contained 46% CP to replace soybean meal and a bypass soy product, Hubbard et al. (2009) observed an increase in 3.5% FCM and yield of both fat and protein. Kelzer et al. (2009) fed diets that contained either conventional DDGS or HPDDG and compared production to animals consuming a control. In this study, milk production and composition were unaffected. In a study conducted at South Dakota State University, Christen et al. (2010) reported that the inclusion of HPDDG in replacement soybean meal resulted in similar production. Interestingly, despite the fact that lysine became first limiting when cows consumed HPDDG, this did not affect milk protein yield and also resulted in a higher concentration of casein in the milk protein, suggesting that the amino acid profile delivered to the animal was most desirable.

Reduced fat distillers grains with solubles (RFDDGS)

Current efforts in the dry milling technology may partially remove fat during the manufacturing process and market it as feedstock for the biodiesel industry (Majoni et al., 2011). This may be done in one of two ways. The first method occurs at the front-end of dry milling processes and involves removing the germ from the kernel before the fermentation process (Atkinson et al., 2012). The second method involves the removal of fat after the fermentation process using chemical and physical extraction processes, including pH treatment, solvent extraction, or centrifugation of the condensed solubles fraction. The final fat content of DDGS varies depending on the method used to recover the fat (Majoni et al., 2011), and the resulting product is commonly referred to as reduced fat dried distillers grains **(RFDDGS)**. Generally speaking, solvent extraction has been noted to remove more fat than centrifugation; for instance, Mjoun et al. (2010) reported 3.5% ether extract in RFDDGS obtained by a solvent extraction method, while Jolly et al. (2013) reported 9% ether extract in de-oiled modified DDGS obtained by centrifugation of the condensed solubles that were added to the final product. Obviously, the extent to which fat is removed varies across plants, and this underlines the importance of accurate estimates of feed characterization when balancing rations.

At the present time, there is limited information on feeding RFDDGS to ruminants, but a concern is that the removal of the fat also reduces the amount of energy available to the animal. Surprisingly, this has not been observed in dairy cows (Mjoun et al., 2010) and feedlot steers (Atkinson et al., 2012; Jolly et al., 2013). Mjoun et al. (2010) conducted an experiment testing 0, 10, 20, and 30% solvent extracted RFDDGS in dairy diets and reported no significant effects on DMI (51 lb/day) and milk yield (78 lb/day), which were similar to the control diet containing soybean products as sources of protein. Similarly, Castillo-Lopez et al. (2014) formulated diets containing 0 to 30% of the diet DM as RFDDGS, from which fat was extracted by centrifugation technology. In this study, both milk yield and milk composition was unchanged. Overall, this information supports the use of RFDDGS in dairy diets without compromising milk production.

Conclusions

The expansion of the corn-ethanol industry has lead to an increase in the availability of feed byproducts which are highly suitable for dairy cows. The most common of these feedstuffs is DDGS. This byproduct is an excellent source of protein, especially rumen undegradable protein and energy and can be used in replacement for more expensive energy and protein sources, such as corn and soybean products. Trends in the corn-ethanol industry are geared towards producing more value-added products from the corn kernel; hence, the current implementation of technology to extract residual fat from the byproducts stream to use it as feedstock for the biodiesel industry is occurring; this technology produces RFDDGS. Research has shown that byproducts can be safely included in diets for dairy cows at levels as high as 30% of the dietary DM while maintaining milking performance. Practically speaking, feeding rates are usually much lower, but the use of byproducts in dairy rations is recommended because they can be safely used to replace many more expensive high energy or protein ingredients.

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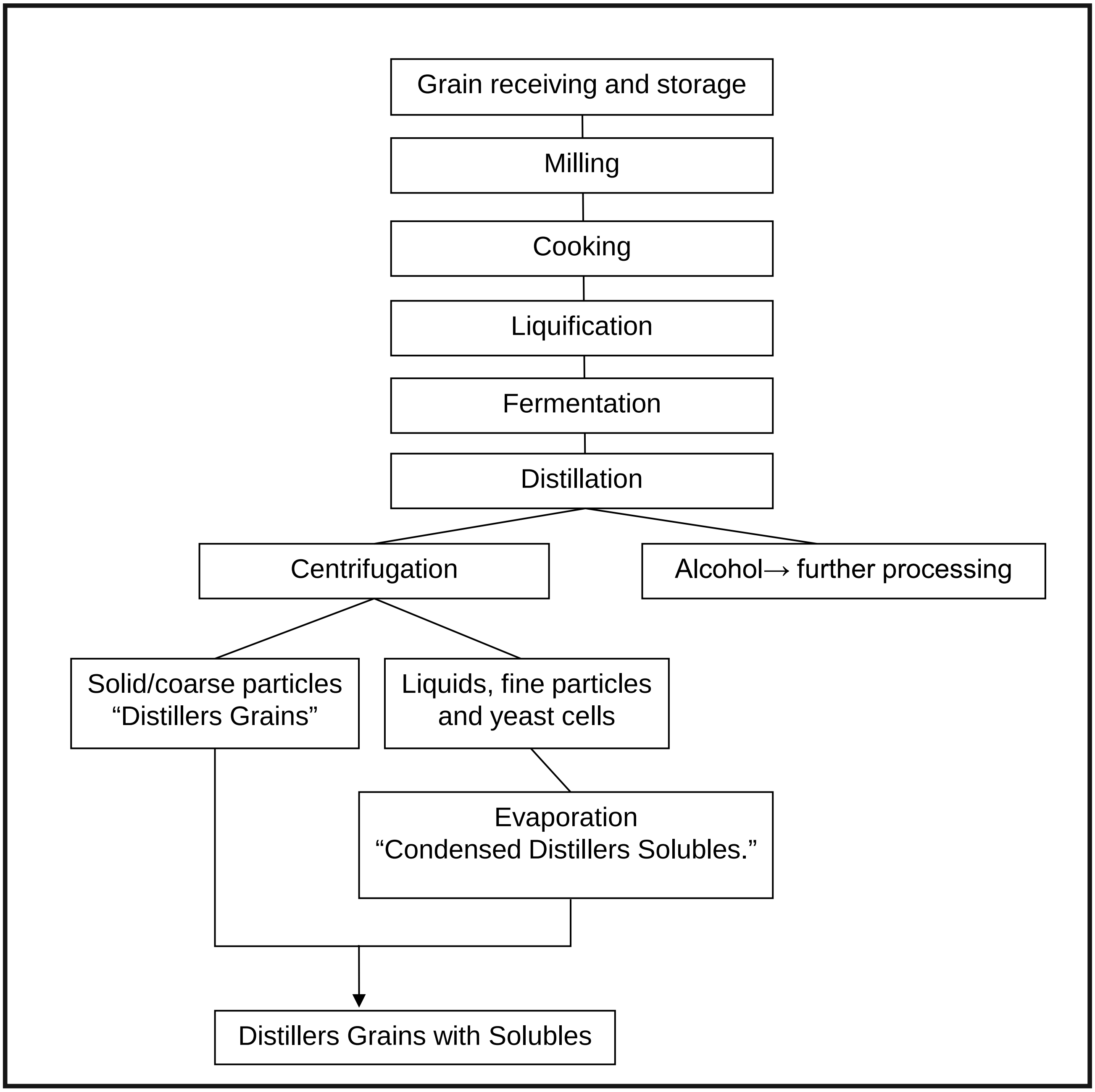

Figure 1. Corn dry milling process for ethanol production (Adapted from Renewable Fuel Association, 2013b).