The Ethanol Industry and Its Co-Products for Swine and Poultry Feeding: A Primer on an Emergent Industry

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Introduction

At the elevator, in the feedlot and the layer barn, in fast food cereals, and in sweeteners for pop: everyone has taken note of the ethanol industry, the newly come player to our world of cereal grains for (mostly) food. The North American thirst for energy has driven a massive increase in the grain to fuel business[1]. This paper will examine some of the recent and continuing changes in ethanol production; briefly discuss ethanol production processes and will address the feeding value of co-products for poultry and swine from the fastest growing segment of that industry – dry grind ethanol production.

Ethanol industry and co-product overview

All industrial ethanol production in the U.S. has the same basic underlying principal: using yeast to convert sugars to ethanol. Ethanol production had its roots as the potable distilling industry. The new corn to fuel ethanol business is focused on producing ethanol efficiently in large quantities. Each potable distillers plant is producing it's own unique product. Potable brewers achieve product differentiation, in part, by altering the "mash bill" prior to fermentation. These and changes in fermentation technology yield a co-product that may be widely variant in color and composition. This is easily understood given the goal of the potable industry distiller. It should be pointed out that the potable spirits industry remains a sizable industry. However, the co-product generation of the potable industry is becoming increasingly insignificant in view of the growth of the industrial ethanol industry and further discussion will focus on production from the ethanol for fuel industry.

Ethanol for fuel, as an industry, is not a new one. Ethanol fueled some of the earliest produced automobiles and helped meet the demand for fuel during the world wars. Co-products from older plants is most aptly characterized as widely variable and often dark and poorly suited as a non-ruminant feedstuffs. This has been elegantly demonstrated by several, in particular Cromwell et al.[2] and Fastinger and Mahan[3]. It should also be noted that until the information about "new generation" distiller's co-products from Dr. Jerry Shurson's laboratory at the University of Minnesota broke upon the industry the reputation of the "old" ethanol industry and its co-products[4] stood as an effective barrier to entry of ethanol co-products into the non-ruminant feed ingredient market.

Fuel ethanol processes

Discussion at this point will turn to a description of the corn for energy process. Ethanol plants can be widely grouped into two processes: wet milling and dry grind. Wet milling plants in the U.S.A. are almost exclusively millers of corn. Their products are varied including, among others, corn starch, high fructose corn syrup, dextrose, glucose, and of course – ethanol. In this process, corn is first steeped in dilute sulfurous acid. The resultant steep liquor is separated from the grain and is an available co-product. The steeped corn is milled and separated into starch, germ, gluten and bran. The starch is then cooked (to gelatinize), is converted into sugars by enzymes, and converted into ethanol by yeast during fermentation. The germ may be dehydrated and sold as a co-product. It is often de-oiled to produce corn oil with the resultant co-product being germ meal. The proteins and other material from the endosperm are marketed as gluten meal. Most commonly the bran, germ meal and steep liquor are combined and sold wet or dehydrated as gluten feed. The wet milling process has seen little growth - the last commissioning of a new plant occurred in 1995. However, feeding of wet milling plant co-products has been stimulated by the massive increase in the dry grind plants and their resultant co-products.

Unlike the wet milling process, in the dry-grind ethanol process the entire cereal kernel is milled and fermented. Also dissimilar to wet milling, the dry grind process is not exclusive to corn but is readily and commonly adapted to cereal grains other than corn. To begin the process, grain is ground and then mixed with water and cooked to gelatinize the starch. The starch is then converted to glucose by enzymes and then into ethanol by yeast. After distillation, the distiller's grains are separated by centrifuge and may be sold wet or dry. The resultant thin stillage (after centrifugation) is condensed by evaporation to produce condensed distiller's solubles, commonly know as syrup. In corn form this product is properly termed Corn Condensed Distillers Solubles or CCDS. This syrup is combined with distiller's grains to produce distiller's grains with solubles. This may be sold wet or dry or in various combinations of grains and syrup of varying moisture commonly known as modified distiller's grains. The AAFCO definition for distiller's grains requires that the grain of majority inclusion be listed as the source[5]. Thus corn distiller's grains could be from as much as 49% of from some other grain, such as sorghum or wheat.

Dry grind growth

Almost all of the recent growth in the ethanol industry has come in dry grind plants. In 1996 the ethanol industry produced about one million tons of dried distiller's grains. In 2006 the industry produced well over 10 million tons. That figure is expected to double again within the next 8 to 10 years. The reasons for this growth are readily apparent in the media and have been summarized elsewhere[6]. To further emphasize the growth of the industry, ethanol is expected to consume over 15% of the 2006 U.S. corn crop. As of the writing of this report over 100 ethanol plants are in production (the number changes weekly) and almost half that many are under construction. The USDA has projected that more than 12 billion bushels will be needed from the 2007 corn crop to meet the resultant demand. All these factors emphasize this fact: ethanol feed co-products will find their way into animal feeds as never before - at unprecedented levels of consumption. A corollary to this is that the informed user of distiller's products has a tremendous opportunity for profitability from judicious use, particularly over the next few years.

Accounting for variability

Despite awareness (and progress) of the emerging industry in quality control substantial variation in color and composition of DDG/S yet remains. Contributing factors are many including: process differences between systems, plant-to-plant variation and annual and regional variations in grains. In our industry we are accustomed to products that are physically and/or chemically processed in a continuous flow system such as ground corn or soybean meal. These processes can produce very uniform product. Fermentation is neither continuous nor physical/chemical; it is a batch system that depends upon a live entity (yeast). Therefore fermentation and the resultant co-products, despite diligent QA/QC, are inherently prone to variability. Spiehs, et al.[7] and Robinson[8] have demonstrated some of these differences. For proper formulation it is important for a nutritionist to know not only mean nutrient values but also variation about that mean, if possible. Reduction of that variation by careful selection of vendors is strongly encouraged.

It is easy to blame the "old industry" for dark distiller's grains. The truth is that even today's new generation plants can produce dark DDG/S. What makes DDG/S dark and why is it important? The darkening (or caramelization) of DDG/S is due to formation of Maillard reaction components. This occurs when sugars and carbohydrates react with proteins (primarily lysine). This process is accelerated by heat. This reaction, which darkens DDG/S, is also the same type of reaction that results in nicely browned bread, a wonderful brown caramel, and even for the intense caramelization that takes place under the right conditions for hay that is put up too wet. Unfortunately, this process reduces the digestibility of lysine – a critical nutrient in cereal-based non-ruminant diets. Batal and Dale[9] and Stein et al.[10] have demonstrated that color is highly correlated with lysine digestibility for broilers and growing pigs. Extreme browning of DDG/S can reduce energy digestibility as well as amino acid digestibility. This may be one reason why the existing NRC values for metabolizable energy for swine are so low in comparison to recent evaluations. Contrary to energy and lysine, P digestibility may be increased by heating[11,12].

How do we best characterize variable product? As has been discussed earlier color "lightness" as measured on the Hunter L scale is well correlated with amino acid digestibility. It should be pointed out that use of this measure across plants, especially those that differ in process, introduces substantial variation and is not recommended. As of this date prediction equations for lysine digestibility are not existent. Other methods to predict nutrient availability are under investigation. The IDEA assay by Novus shows promise in this regard, especially in poultry[13]. Other methods are also under investigation.

Co-product composition

Fermentation of corn results in an approximate yield of one third mass in ethanol, DDG/S and CO_2. Therefore an approximate tripling of nutrient value of corn is achieved. DDG/S composition from a single DDG/S marketer is given in Table 1. Mycotoxins present in the corn are not destroyed by fermentation. Therefore, monitoring of mycotoxins in DDG/S has merit. Whereas knowledge of amino acid level and availability are becoming more commonplace, few are aware that DDG/S is high in choline and also low in pH. Nutrient availabilities for poultry are given in Table 2. Whereas poultry NRC[14] values for energy are roughly equivalent to new dry-grind plant DDG/S, lysine availability can be substantially higher than that listed in NRC[9,15].

Feeding DDGS to poultry

The evidence continues to mount that DDG/S can be incorporated into poultry feeding programs without deleterious effects, particularly at modest inclusion rates. In actuality, thanks to the supports of the Distillers Grains Council, the feeding of DDG/S to poultry has a more positive history than that of swine. Sally Noll presented an excellent review of past data at this meeting in 2004. More recent data summarizing performance of growing birds fed varying levels of DDG/S are summarized in Figures 1 and 2. It is evident that DDG/S has only modest effects on poultry performance and that ADG and feed conversion are largely unaffected by inclusion rates up to 15% of the complete diet. Data for broilers also indicate inclusion rates higher than 15% of the complete diet may reduce the rate and efficiency of weight gain but performance is largely unaffected prior to that level1[17,18,19,20]. In contrast to swine, there is very little evidence of negative effects on feed intake in poultry.

Roberson et al.[21] and Lumpkins et al.[22] have suggested that DDG/S inclusions of up to 15% will result in similar layer performance. This is especially the case if dietary energy is increased. Roberson et al.[21] also demonstrated that yolk color could be improved in as little as 4 weeks by feeding 10% DDG/S. It is a commonly shared anecdote in all classes of swine that introduction of high levels of DDG/S (10% or more) may result in transient decreases in feed intake.. Such a response has also been suggested by Roberson et al.[21] for laying hens. A rule of thumb may be that inclusions should not change beyond 7.5% of the diet within a two week period. Additional work in this area is warranted. Last year a research report published by researchers at Iowa State University[23] suggested that the inclusion of DDG/S in layer diets may reduce the emissions of ammonia from layer manure. Currently additional studies are underway to further investigate this response.

Formulation fundamentals

Proper formulation constraints when utilizing DDG/S contribute to improved profitability. Factors which are commonly of value are amino acids, fat (or ME) and P. Likewise as discussed earlier choline can contribute value in swine and poultry diets and indeed some nutritionists may consider NDF as an economically beneficial characteristic. However, if DDG/S is to contribute to the profitability of the diet the preexisting sources of these nutrients must be allowed to decrease or at least change in comparison to diets without DDG/S. Specifically, available P sources, including phytase, must be allowed to change in diets to fully capitalize on value. Likewise a full understanding of digestible amino acid ratios and lack of constraint on inclusion of crystalline amino acids is also essential. In other words, a conservative rigid upper constraint on crystalline amino acids is likely to result in a loss of potential profitability.

New Processes

The ethanol industry continues to evolve. As of the writing of this article, three dry grind plants that fractionate corn prior to fermentation, similarly to wet milling plants, are in large scale production. These bio-refining plants, operated by the Broin group, produce corn germ, a bran mix which combines bran and the syrup, and a high protein DDG (this is not a DDG/S because the solubles are not combined with the distillers grains). The germ and high protein DDG have been shown to have excellent energy digestibility in poultry[15]. To date, the effect of these products on swine performance is undefined. Similar to the processes for the Broin group, the Renessen process will begin production soon in pilot plant form. Furthermore several plants are being modified to remove corn oil at some point during the process. These processes will undoubtedly change the feeding values of the resultant co-products. Thus, the need remains for purchasers to be ever diligent in terms of characterization of distillers co-products.

Summary

In summary, the rapid growth of dry grind ethanol plants makes a massive amount of product available to the market. Although the “new” methods of producing DDG/S result in generally superior in nutrition to the old, a large amount of variation in product still exists. Knowledge of your supplier and variability within their system is warranted. Color is a convenient, fast, economical method of characterizing DDG/S quality, lighter being better. Other methods are under investigation. DDG/S can easily be incorporated into swine grow-finish and broiler diets with little impact on performance at inclusion rates of 15% or lower. Utilizing all positive characteristics of DDG/S is important to maximizing profitability. The ethanol industry continues to evolve and associated co-products will evolve as well.

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Table 1. Nutrient Composition of DDG/S[a]	
Nutrient	% of DM[b]
Proximate Analysis	
Dry matter	90.7
Crude Protein	29.3
Crude Fat	10.7
Crude Fiber	6.7
Ash	4.6
Amino Acids	
Alanine	2.59
Arginine	1.42
Aspartic Acid	1.94
Cystine	0.81
Glutamic Acid	4.87
Glycine	1.17
Histidine	0.84
Isoleucine	1.00
Leucine	3.22
Lysine	0.98
Methionine	0.58
Phenylalanine	1.44
Proline	2.38
Serine	1.41
Threonine	1.12
Tryptophan	0.31
Tyrosine	1.21
Valine	1.42
Minerals	
Calcium	0.04
Phosphorus	0.87
Sodim	0.21
Pottasium	1.08
Magnesium	0.36
Sulfur	0.95
Copper	7 ppm
Iron	87 ppm
Manganese	19 ppm
Zinc	98 ppm
Miscellaneous	
ADF	9.3
NDF	26.0
Choline	2,637 ppm
pH	~ 4 – 4.5
Xanthophyll	~ 20-40 ppm

[a] Provided by Dakota Gold Research Association, Sioux Falls, SD
[b] All values expressed as a percentage of dry matter unless otherwise noted.

Table 2. Nutrient Availability of Dakota Gold BPX™ DDG/S for Poultry	
Nutrient	Availability
Amino Acids[a]	
Aspartic Acid	79 %
Threonine	76 %
Serine	83 %
Glutamic Acid	88 %
Proline	88 %
Alanine	89 %
Cystine	81 %
Valine	83 %
Methionine	80 %
Isoleucine	83 %
Leucine	91 %
Tyrosine	87 %
Phenylalanine	84 %
Histidine	84 %
Lysine	76 %
Arginine	92 %
Tryptophan	83 %
Energy[b]	
True Metabolizable $Energy_n$	3108 kcal/kg
Phosphorus[c]	
Phosphorus	85%

[a] Amino acid digestibility for cecectomized cockerels compiled from references 9, 13, and internal data.
[b] Metabolizable energy for cecectomized cockerels based on reference 9 and internal data.
[c] Phosphorus availability in comparison to calcium phosphate compiled from references 11 and 12.

Figure 1. Effect on Inclusion Rate of DDG/S on Gain of Broilers and Turkeys

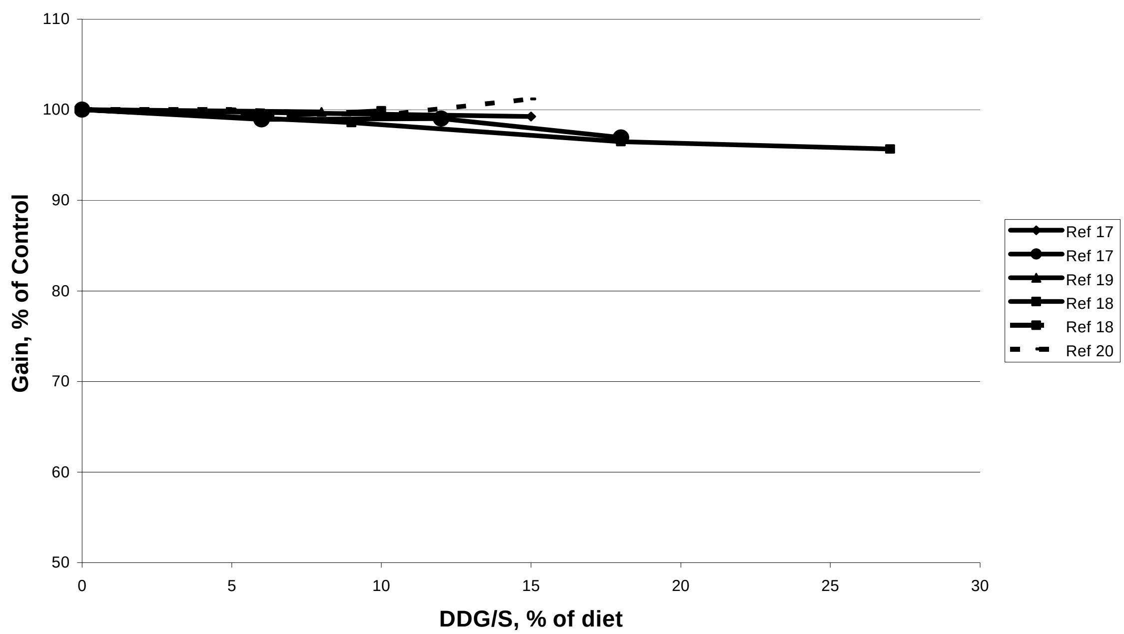

Figure 2. Effect of Inclusion Rate of DDG/S on Gain:Feed of Broilers and Turkeys