

**Title:** Critical review of literature on feeding bio-fuels co-products to pigs. – NPB #07-173

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## **Industry Summary:**

The digestibility of nutrients in distillers co-products vary among sources. The variability is of the same magnitude as for other co-products. Heat damage to lysine often occurs, which results in a greater variation in the concentration of total and digestible lysine than for all other nutrients. It is, therefore, important that the concentration of lysine be measured before distillers co-products are included in diets fed to pigs. For corn DDGS, the average concentration of total lysine is approximately 0.78% and sources of corn DDGS with lysine concentrations below average also have concentrations of digestible lysine that is below average. Such qualities of corn DDGS should not be used in diets fed to pigs without extra fortification with crystalline lysine.

The inclusion of inorganic sources of phosphorus can be reduced in diets containing DDGS because the digestibility of phosphorus is greater in all fermented distillers co-products than in corn, but this is not the case for unfermented co-products. The concentration of starch is low in all distillers co-products and the concentration of fiber is relatively high in most co-products. The concentration of energy in the products is less variable than the digestibility of nutrients, but there is variation among the different co-products according to the procedure used to produce them.

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Contributing organizations for 2007 include: Arizona Pork Council, DPI Global, Eli Lilly/Elanco, Iowa Corn Growers Association, Iowa Pork Producers Association, Illinois Corn Marketing Board, Illinois Pork Producers Association, Kansas Corn Commission, Kansas Pork Association, Lucta USA, Minnesota Pork Board, Missouri Pork Producers Association, Monsanto, Mississippi Pork Producers Association, Montana Pork Producers Council, National Corn Growers Association, North Carolina Pork Council, Inc., National Pork Board, Nebraska Pork Producers Association, Inc., Ohio Pork Producers Council, Pioneer Hi-Bred International, Inc., Utah Pork Producers Association and the Wisconsin Pork Association.

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If corn DDGS of average or above average quality is used, approximately 30% can be included in diets fed to lactating sows, weanling pigs, and growing-finishing pigs, whereas 50% can be included in diets fed to gestating sows. Inclusion of sorghum DDGS should be limited to 20% in weanling pig diets, but 30% may be included in diets fed to growing-finishing pigs. Corn HP DDG may be included in diets fed to growing-finishing pigs in quantities sufficient to substitute all soybean meal, but there are no data on the inclusion of corn HP DDG in diets fed to sows or weanling pigs. Corn germ can be included in diets fed to growing-finishing pigs in concentrations of at least 10%.

Carcass composition and palatability is not influenced by the inclusion of DDGS, HP DDG, or corn germ in diets fed to growing-finishing pigs. However, belly firmness is reduced and fat iodine values are increased by the inclusion of DDGS and HP DDG in these diets. It may therefore, be necessary to reduce the inclusion of these products in the diets fed during the final 3 to 4 weeks prior to slaughter.

There is some evidence that feeding DDGS diets may enhance gut health of growing pigs, but more research is needed to determine if this response is repeatable. Formulating DDGS-containing diets on a digestible P basis reduces manure P concentration, but due to lower DM digestibility, manure volume is increased in pigs fed diets containing DDGS. Adding DDGS to swine diets seems to have minimal, if any impact on gas and odor emissions from manure, and with the exception of the concentration of P, the chemical composition of manure is not changed if pigs are fed DDGS containing diets. Research is needed to determine practical ways to enhance DM and energy digestibility in DDGS because there is great potential for improving the feeding value of DDGS if DM digestibility can be improved. An improvement in the digestibility of the insoluble fiber fraction is, therefore, needed.

All diets containing distillers co-products should be formulated in such a way that the concentration of crude protein is not greater than in traditional corn soybean meal diets. This requires the use of crystalline sources of amino acids to balance the amino acid profile of the diets.

Glycerin, a co-product from the biodiesel industry, may be included in diets for weanling pigs by at least 6% and in diets for growing-finishing pigs by up to 15%. At these inclusion levels, no change in pig performance or carcass composition will be observed.

### **Scientific Abstract:**

Distillers dried grains with solubles (DDGS) and other co-products from the bio-fuels industry may be included in diets fed to pigs in all phases of production. The concentration of DE and ME in DDGS and in corn germ is similar to corn, but high protein distillers dried grains (HP-DDG) contains more energy than corn. In contrast, if the oil is removed from DDGS, the product will have a lower energy concentration than corn or conventional DDGS. Glycerin, a co-product from the biodiesel industry also contains more energy than corn. Phosphorus in DDGS and HP DDG is highly digestible to pigs and apparent total tract digestibility values of approximately 60% have been reported for these ingredients. In contrast the digestibility of phosphorus in corn germ is similar to corn. The concentration of starch in DDGS is low (i.e., between 3 and 11%), but the concentration of fat in DDGS is approximately 10% and the concentration of ADF, NDF, and total dietary fiber in DDGS is approximately 3 times greater than in corn (9.9, 25.3, and 42.1%, respectively). The apparent total tract digestibility of dietary fiber is less than 50%, which results in low digestibility values for DM and energy in DDGS. The concentration of most AA in DDGS is approximately 3 times greater than in corn, but the standardized ileal digestibility of most AA is approximately 10 percentage units less than in corn. The same is the case for corn germ and HP DDG. Nursery pigs from 2 to 3 wk post-weaning, and growing and finishing pigs may be fed diets containing up to 30% DDGS without any negative impact on pig growth performance. However, the carcass fat in pigs fed DDGS-containing diets has a higher iodine value than in pigs fed no DDGS. It may, therefore, be necessary to withdraw DDGS from the diet of finishing pigs during the final 3 to 4 wk prior to harvest to achieve desired pork fat quality. HP DDG may be used in diets fed to growing finishing pigs in quantities sufficient to replace all the soybean meal in these diets and at least 10% of corn germ may be included in these diets. Up to 30% de-oiled DDGS can be included in diets fed to weanling pigs, but only 10% should be used in diets fed to growing-finishing pigs. Glycerin can be included in diets fed to weanling and

growing-finishing pigs in quantities of up to 6 and 15%, respectively. Lactating sows can be fed diets containing up to 30% DDGS, and DDGS can replace all of the soybean meal in diets fed to gestating sows without negatively impacting sow or litter performance. Inclusion of DDGS in diets fed to pigs may improve intestinal health and the immune system activation, but more research is needed to elucidate the mechanism responsible for these effects. Manure volume will increase if DDGS is included in the diets because of the reduced digestibility of DM in DDGS. Nitrogen excretion may also increase, but this can be prevented by the use of crystalline AA in diets containing DDGS. In contrast, P excretion can be reduced in diets containing DDGS if the total dietary concentration of P is reduced to compensate for the greater digestibility of P in DDGS.

### **Introduction:**

Feeding of DDGS and other co-products from the bio-fuels industry is surrounded with controversy because there is relatively little information about feeding these co-products to swine and non-scientific perceptions, therefore, often prevail when conclusions about these products are made.

An extensive characterization of the chemical composition of DDGS was published several years ago (Spiehs et al., 2002). There are also publications on the digestibility of amino acids (Fastinger and Mahan, 2006; Stein et al., 2006; Pahm et al., 2008), and energy and phosphorus (Pedersen et al., 2007; Widyaratne and Zijlstra, 2007) in DDGS and in some of the co-products from fractionating corn prior to fermentation (Widmer et al., 2007a). Results from experiments in which DDGS was fed to nursery or growing finishing pigs have also been published (Whitney et al., 2004; 2006; Widmer et al., 2007b; Widyaratne and Zijlstra, 2007). Most of the research conducted so far has been conducted with corn used in fuel-ethanol production, but there are a few experiments in which wheat (Nyachoti et al., 2005; Widyaratne and Zijlstra, 2007), sorghum (Urriola et al., 2007) or barley was used (Nasi, 1985). In most experiments, DDGS was fed to weanling or growing finishing pigs and there is relatively little information on the feeding of DDGS to sows (Monegue and Cromwell, 1995; Wilson et al., 2003; Hill et al., 2005).

When bio-diesel is produced, the glycerin is separated from the fatty acids in tri-glycerides. The glycerine can be used as an animal feed, but at this time, very limited research with this ingredient has been completed (Lammers et al., 2007).

Recently, reviews that concentrated on parts of the issues related to feeding DDGS to swine were published by the co-investigators and the PI (Shurson et al., 2004; Kerr et al., 2007; Stein, 2007). However, there are no reviews available that has systematically summarized all the research conducted with all the co-products from the biofuels industry.

### **Objectives:**

The objective of this work was to conduct an exhaustive literature review of all published information related to the feeding value to pigs of co-products from the bio-fuels industry. Specific aims of the review included:

- a. A characterization of co-products from the bio-fuels industry that is available for feeding pigs.
- b. Organization of co-products into related areas (i.e., DDGS, DDG, Liquid co-products, HP co-products, glycerine, etc.).
- c. Summary of all data related to the composition of co-products from the bio-fuels industry.
- d. Summary of results related to the digestibility of energy and nutrients in co-products from the bio-fuels industry.
- e. Summary of performance results from experiments using co-products from the bio-fuel industry.
- f. Recommendations for using co-products from the bio-fuel industry.

### **Materials and Methods:**

Search engines were used to search for literature published in peer-reviewed publications, abstracts, and conference proceedings. Literature that was published in a thesis or research reports from universities or private

companies were included where available. Results published throughout the world were included and results using all types of co-products were used.

After the compilation of the literature, publications were organized according to the specific aims. Summaries were made for co-products produced from wheat, sorghum, corn, and oilseed. Each publication was critically reviewed and the quality of the work was assessed. Results were summarized according to the specific aims and written into a publication for peer-reviewed publication.

## **Results:**

Results have been summarized in tables according to the objectives. An extensive discussion of these results is provided in Appendix A.

### ***Objectives a and b: Characterization of Co-products from the bio-fuels industry and organization into related area.***

- 1.1 Distillers dried grains with solubles
- 1.2 Distillers dried grains
- 1.3 High protein distillers dried grains with solubles
- 1.4 High protein distillers dried grains
- 1.5 De-oiled distillers dried grains with solubles
- 1.6 Enhanced distillers dried grains with solubles
- 1.7 Corn germ
- 1.8 Glycerin
- 1.9 Liquid co-products
- 1.10 Other distillers co-products
  - 2.10.1 E-corn
  - 2.10.2 High lysine E-corn
  - 2.10.3 Glutenol

### ***Objective c: Summary of all data related to the composition of co-products from the bio-fuels industry***

The chemical composition of the co-products from the ethanol industry is provided in Tables 1, 2, and 3, in Appendix A.

***Objective d: Summary of results related to the digestibility of energy and nutrients in co-products from the bio-fuels industry.***

The digestibility of amino acids, phosphorus, and energy in co-products from the ethanol industry are presented in Tables 4, 5, and 6 in Appendix A. Pure glycerin contains approximately 4.3 Mcal GE/kg, but most glycerin is sold as a feed grade glycerin containing only 86% glycerin, 3% NaCl and 10% water. This product contains approximately 3,625 kcal GE/kg. The DE and ME in feed grade glycerin (86% pure glycerin) is 3,344 and 3,207 kcal/kg, respectively.

***Objectives e and f: Summary of performance results from experiments using co-products from the bio-fuel industry and recommendations for use of these products in diets fed to pigs.***

A summary of performance results of nursery and growing-finishing pigs fed DDGS are provided in Tables 7 and 8 of Appendix A. From these tables, it is concluded that up to 30% DDGS may be included in diets fed to both nursery and growing finishing pigs without changing pig performance or carcass composition. Data from feeding DDGS to sows indicate that up to 50% DDGS can be included in diets fed to gestating sows and at least 30% may be included in diets fed to lactating sows. There are a few data from research in which liquid co-products were fed to pigs and these data are presented in Tables 9 and 10 of Appendix A. It appears that inclusion of both condensed distillers solubles and corn steep water may reduce the performance of pigs fed liquid diets. There is, therefore, a need for more research in this area to design feeding programs that can be utilized these co-products without changing pig performance. There are no data on feeding glycerin to sows, but growth performance and carcass composition in growing-finishing pigs is not changed if up to 15% glycerin is included in the diets. For nursery pigs, at least 6% glycerin may be included in the diet.

**Discussion:**

The review of literature revealed that there is an extensive database related to the composition of DDGS, the digestibility of energy and nutrients in DDGS, and the use of DDGS in diets fed to pigs. Most of this

literature is related to the use of DDGS that is produced from corn, and there is only limited information available about the use of sorghum DDGS and wheat DDGS. Likewise, for most other co-products from the bio-fuels industry, very few data have been published and for many co-products, no data are available. There is, therefore, a great need for continued research in this area as the industry changes and continues to fractionate the co-products and produce more different co-products. For these co-products to be effectively included in diets fed to pigs, research needs to be conducted.

One of the results of this literature review is that conclusions about the effects of including DDGS in diets fed to all categories of pigs can be drawn. As is shown in some of the results tables, it is possible to include up to 30% DDGS from corn in diets fed to weanling pigs from 3 weeks post-weaning without changing pig performance. If sorghum DDGS is used, only 20% should be used. It is also possible to include up to 30% DDGS in diets fed to growing-finishing pigs without negatively impacting growth performance or carcass composition. There are, however, also a number of studies that showed that DDGS negatively impacted growth performance, and based on the available literature, it is not possible to identify factors that led to these different results. It is, however, recommended that diets that contain DDGS be formulated on the basis of standardized ileal digestible lysine and digestible phosphorus. Crystalline sources of lysine and possibly tryptophan should also be used if DDGS is included in the diet to prevent the level of dietary crude protein to increase when DDGS is used.

For gestating and lactating sows, at least 50 and 30% DDGS can be used without negatively impacting sow or piglet performance. It is possible that greater concentrations of DDGS can be included in diets fed to sows, but research to investigate that possibility has not yet been conducted. There are no data on the possibility of using wheat DDGS or sorghum DDGS in diets fed to sows.

There is limited information about the use of co-products other than DDGS. However, the literature review showed that HP-DDG may be used in diets fed to growing and finishing pigs as a complete replacement for soybean meal if diets are supplemented with crystalline amino acids. It has also been shown that up to 10% corn germ may be included in diets fed to growing finishing pigs without negatively impacting pig performance.

For deoiled DDGS, it was shown that nursery pigs may tolerate up to 30% in the diet, but for growing-finishing pigs, only 10% can be included if performance is to be maintained.

One of the intriguing questions about DDGS is reports that indicate that feeding DDGS may improve intestinal health. Although the research in this area is not conclusive, it has been shown in some experiments that DDGS provides some protection against enteric diseases. This is clearly an area that deserves more research in the future.

Increasing quantities of glycerin is being produced from the biodiesel industry. Glycerin may be included in diets fed to weanling and growing-finishing pigs in amounts of 6 and 15%, respectively, but there are no data available for feeding glycerin to sows.