Indian Veterinary Magazine
a monthly Magazine
of the people, by the people, for the people

Vol 2 Issue 10 Oct 2026, 1178-1184 ISSN:3108-1398

# Co-products of the Biofuel Industry as Livestock Feed: Opportunities and Challenges

**Dr. Shubham Nagre[1], Dr. Akash Patil[2*] and Pravin Rakh[3]**

[1,2]Assistant Professor, Department of Animal Nutrition, Shourabh College of Veterinary Science, Kheda, Hindaun City, Rajasthan

[3]Assistant Professor, Department of Veterinary Pathology, Shalinitai Datta meghe veterinary college, Ramtek

***Corresponding Author** : Dr. Akash Patil: e-mail: akashpatilplus@gmail.com

doi.org/10.5281/indianVetmagazine.23296637

## Key Points

- **Biofuel co-products are valuable feed resources:** The production of bioethanol and biodiesel generates co-products such as distillers dried grains with solubles (DDGS), corn gluten meal, glycerol and oilseed cakes that can be used in livestock diets.
- **Nutritional value varies among co-products:** Differences in protein, energy, fibre and antinutritional factors determine their suitability and safe inclusion levels in ruminant, poultry, swine and fish feeds.
- **Proper quality control is essential:** Managing mycotoxin contamination, antinutritional compounds and variation in nutrient composition can improve feed safety, reduce feeding costs and support sustainable livestock production.

***Abstract***

The global drive to expand renewable energy has made biofuels, chiefly bioethanol and biodiesel, an integral part of the energy sector, with conversion of biomass currently the most cost-effective route for producing renewable liquid fuel and contributing about 78 percent of total renewable energy generated worldwide (US EIA, 2010). Since these fuels are largely derived from grains, sugar crops and oilseeds, their processing generates a large volume of co-products that hold considerable value as livestock feed ingredients. Bioethanol manufacture yields corn gluten feed, corn gluten meal, distillers dried grains with solubles (DDGS), vinasse and bagasse, while biodiesel manufacture yields glycerol, fatty acid distillate and oilseed cakes and meals, including those obtained from non-conventional and toxic oilseed plants such as Jatropha and Camelina. These co-products differ widely in their protein, energy, fibre and antinutritional factor content, and consequently in their safe inclusion levels across ruminant, swine, poultry and fish diets. Judicious use of biofuel co-products lowers feed cost, reduces reliance on conventional protein and energy sources such as soyabean meal and maize, and supports a more resource-efficient and environmentally sustainable livestock production system. However, mycotoxin contamination, antinutritional compounds and batch-to-batch variability in nutrient composition need to be carefully managed. This article reviews the major co-products generated by the bioethanol and biodiesel industries, their nutritional composition and their potential and limitations as livestock feed.

**Keywords:** Biofuel co-products, Distillers dried grains, Corn gluten feed, Glycerol, Jatropha meal

## INTRODUCTION

Conversion of biomass into liquid fuel is presently the most cost-effective pathway for producing renewable energy, and biofuels together account for the majority share of renewable energy produced globally (US EIA, 2010). Ethanol and biodiesel, the two principal biofuels produced worldwide, are derived predominantly from grain and sugar crops (ethanol) and oilseeds (biodiesel). The desire to enhance energy security, curb greenhouse gas emissions and stimulate rural development has led many governments to frame policies mandating or incentivizing biofuel blending, such as the Renewable Fuel Standard in the United States and various mandates and tax incentives within the European Union, contributing to a marked rise in global biofuel output.

This expansion has a direct bearing on livestock production, since processing grains and oilseeds for fuel generates large quantities of fibrous, protein-rich and energy-rich residues. Rather than being treated as waste, these residues can be recycled into livestock diets, easing the competition between food, feed and fuel uses of the same raw material. The co-products differ considerably depending on the feedstock and processing route (wet-milling or dry-grind for ethanol; transesterification for biodiesel), so their feed value must be assessed individually.

## CO-PRODUCTS FROM BIOETHANOL PRODUCTION

Ethanol is produced mainly through wet-milling or dry-grind processing of cereal grains, and the process of grinding, liquefaction, saccharification, fermentation and distillation yields a stillage fraction that is further processed into several distinct co-products, namely corn gluten feed, corn gluten meal, distillers grains, vinasse and bagasse (Erickson et al., 2005).

### *Corn Gluten Feed and Corn Gluten Meal*

Corn gluten feed and corn gluten meal are both obtained from the wet-milling of maize grain for starch or ethanol production, but they differ substantially in composition and use. Corn gluten feed is a fibrous, moderate-energy co-product (about 2000 kcal/kg) whose relatively high fibre content helps reduce the risk of rumen acidosis, making it a versatile, cost-effective ingredient for ruminants. Corn gluten meal, by contrast, is a protein-rich, low-fibre co-product with an energy value of about 4000 kcal/kg that serves as an important protein and energy source in poultry rations and is valued in pet food for its high protein digestibility; in some countries it is also used as an organic fertilizer and weed suppressant. Both co-products may carry elevated levels of aflatoxin B1 and therefore require quality monitoring (Feedipedia, 2015, 2018).

| Parameter (% DM) | Corn Gluten Feed | Corn Gluten Meal |
|---|---|---|
| Crude protein | 18–22 | 60–65 |
| Crude fibre | 6–10 | 1–2 |
| Ether extract | 3–4 | 2–3 |
| Lignin | 1–2 | 0.2–0.4 |
| NDF | 31–49 | 5–8 |
| ADF | 8–13 | 2–4 |
| Ash | 6–7 | 2–4 |

*Table 1. Nutritional composition of corn gluten feed and corn gluten meal (Source: Feedipedia, 2015, 2018)*

***Distillers Dried Grains with Solubles (DDGS)***

DDGS is produced by concentrating the thin stillage (condensed distillers solubles) obtained after distillation and drying it together with the coarse distillers grains fraction. As a feed ingredient, DDGS is characterized by a relatively high protein and energy content, a high proportion of rumen bypass protein (about 55 percent of crude protein), and a low starch content that limits the risk of subacute rumen acidosis associated with high-energy rations. It also contains dried yeast cells that supply B-vitamins, improve palatability and support microbial protein synthesis, along with highly digestible neutral detergent fibre that stimulates rumen microbial activity. Its colour ranges from very light to very dark and its odour from normal to smoky, depending on the drying conditions employed (NRC, 2007).

Corn DDGS and rice DDGS differ appreciably in their proximate composition. Corn DDGS typically contains around 38 percent crude protein, 2617 kcal/kg metabolizable energy, 10.7 percent crude fat, 0.29 percent calcium and 6.0 percent crude fibre, whereas rice DDGS contains a higher crude protein content of about 46 percent, 2883 kcal/kg metabolizable energy, 4.5 percent crude fat, 0.73 percent calcium and 4.9 percent crude fibre (BIS, 2024). Because of its favourable nutrient profile, DDGS can be included in the diets of a wide range of livestock species, although recommended maximum inclusion levels vary with species and physiological stage, ranging from about 10–20 percent in poultry diets to as high as 30 percent in growing heifers and pig diets (Kalscheur et al., 2012).

***Vinasse and Bagasse***

Vinasse, the principal liquid by-product of ethyl alcohol distillation from cassava, sugarcane, sweet potato and sweet sorghum, is commonly used to prepare multi-nutrient blocks that improve nutrient utilization and productivity of animals on low-quality roughage-based

diets, and is also used as an organic fertilizer in some countries (Hidalgo, 2011). Sugarcane bagasse, the fibrous residue remaining after juice extraction, consists mainly of cellulose (about 50 percent), hemicellulose (about 27.9 percent) and lignin (about 9.8 percent). Its high lignin content and low levels of soluble carbohydrates and nitrogen give it poor rumen degradability, and attempts to feed sugarcane or sorghum bagasse to livestock have generally proved economically unsuccessful; it is therefore more commonly diverted for use as fuel within the sugar and ethanol industry itself (Kewalramani et al., 1988).

## CO-PRODUCTS FROM BIODIESEL PRODUCTION

Biodiesel is produced mainly from triacylglycerol-rich oilseeds such as soybean, canola, palm and rapeseed through a transesterification process, and this process yields several co-products of nutritional relevance to livestock, including glycerol, fatty acid distillate, and various oilseed cakes and meals such as palm kernel cake.

### *Glycerol*

Glycerol (glycerin) is a colourless, odourless, hygroscopic and sweet-tasting viscous liquid co-product of biodiesel production. In dairy cow diets it is commonly used as an energy source, particularly during the transition period after calving, and as a preventive measure against ketosis; an inclusion level of up to about 15 percent has been recommended, although its methanol content can pose a toxicity risk that is more pronounced in monogastric species (DeFrain et al., 2004). In pigs, glycerine provides an energy value similar to that of maize and can be included at up to about 9 percent for sows, 6 percent for weaners and 15 percent for finishers, while its use in fish diets remains less clear and warrants further study (Schieck et al., 2010). Elevated concentrations of crude glycerin have also been evaluated in beef cattle feedlot diets with respect to performance, carcass traits and ruminal metabolism (Van Cleef et al., 2019).

### *Fatty Acid Distillate and Oilseed Cakes*

Fatty acid distillate, a by-product of vegetable oil refining, is a good source of dietary energy. When reacted with calcium oxide it forms a rumen-protected fat that shields fatty acids from ruminal biohydrogenation; feeding this protected fat augments the oleic, linoleic and stearic acid content of dairy milk fat while reducing its palmitic acid content. Palm kernel cake, another widely available oilseed by-product, has also been evaluated as a partial replacement for cottonseed cake in growing buffalo calves, though its use is limited by antinutritional factors such as phytic acid.

## CO-PRODUCTS FROM TOXIC OILSEED PLANTS

Certain oilseed crops used for biodiesel production, most notably species of Jatropha, contain inherent toxic and antinutritional compounds that constrain the direct use of their co-products as livestock feed.

### *Jatropha Kernel Meal*

The kernel of Jatropha seeds, obtained after removal of the shell, contains about 50–60 percent oil that can be used either as an edible oil or converted into high-quality biodiesel. The defatted kernel meal remaining after oil extraction is an excellent source of nutrients, containing about 60–65 percent crude protein, with essential amino acid levels (except lysine) exceeding those of soybean meal in the case of the non-toxic species Jatropha platyphylla (Makkar et al., 2011). However, the presence of antinutritional factors such as phorbol esters, lectins and trypsin inhibitors in most Jatropha curcas genotypes limits the direct use of the kernel meal as a livestock feed ingredient and generally necessitates detoxification (Makkar and Becker, 2009; Rakshit et al., 2008). Notably, the non-toxic species Jatropha platyphylla is free of phorbol esters, the principal toxin present in most other Jatropha species, making it a more promising candidate for direct incorporation into feed (Makkar et al., 2011).

### *Camelina Sativa Meal*

Camelina sativa, commonly known as false flax and belonging to the Brassica (Cruciferae) family, yields a meal containing about 36–40 percent crude protein that is rich in essential amino acids, including lysine and methionine. Camelina meal can be included at about 10 percent in poultry (layer and broiler) diets. Compared with birds fed a conventional maize-soybean diet, hens fed Camelina meal show an 8- to 10-fold increase in total omega-3 fatty acids and alpha-linolenic acid in eggs, along with a favourable decrease in the omega-6 to omega-3 fatty acid ratio, a recognized indicator of nutritional quality; two large eggs from Camelina-fed hens can supply over 300 mg of omega-3 fatty acids to the human diet (Bean and Leeson, 2003; Cherian, 2009).

## BENEFITS, KNOWLEDGE GAPS AND FUTURE RESEARCH NEEDS

Biofuel co-products frequently substitute for higher-priced conventional feed ingredients. Because DDGS and maize prices are closely linked and their correlation has strengthened in recent years, the availability of DDGS and other co-products buffers livestock producers against fluctuations in cereal grain cost. Being good sources of protein and energy, these co-products can partially replace soyabean meal and maize in ruminant, pig and poultry diets, lowering feed costs while reducing the environmental footprint of both the biofuel and livestock sectors and fostering greater resource-use efficiency.

Nonetheless, several knowledge gaps remain. Batch-to-batch variability in nutrient composition, arising from differences in feedstock and processing conditions, complicates precise ration formulation, and the risk of mycotoxin contamination, particularly aflatoxin B1 in corn gluten feed and meal, requires continuous monitoring. Detoxification protocols for toxic oilseed meals such as Jatropha curcas kernel meal need further refinement and validation across species, and the safe use of glycerol in aquaculture diets remains poorly defined. Long-term studies on animal health, reproductive performance, product quality and life-cycle environmental impact would further strengthen the case for wider adoption of these co-products.

## CONCLUSION

The rapid expansion of the global biofuel industry has generated a diverse array of co-products, ranging from fibrous residues such as bagasse and bagasse-derived vinasse to protein- and energy-dense products such as corn gluten meal, DDGS, glycerol and specialty oilseed meals. When their nutrient composition, antinutritional factors and safe inclusion levels are properly understood, these co-products can serve as valuable and cost-effective alternatives to conventional feed ingredients such as maize and soyabean meal across ruminant, swine, poultry and, to a more limited extent, fish diets. Their strategic use not only reduces feed costs for the livestock sector but also improves the overall resource efficiency and environmental sustainability of the biofuel value chain. Continued research into detoxification techniques, quality standardization and species-specific inclusion guidelines will be essential to fully realize the potential of biofuel co-products as livestock feed.

## REFERENCES

Bean-Hodgins, L., & Leeson, S. (2003). Long-term effects of feeding flaxseed on performance and egg fatty acid composition of Brown and White hens. Poultry Science, 82(3), 388–394.

Bureau of Indian Standards (BIS). (2024). Chicken feeds — Specification (6th ed.).

Cherian, G., & Hayat, Z. (2009). Long-term effects of feeding flaxseeds on hepatic lipid characteristics and histopathology of laying hens. Poultry Science, 88(12), 2555–2561.

DeFrain, J. M., Hippen, A. R., Kalscheur, K. F., & Jardon, P. W. (2004). Feeding glycerol to transition dairy cows: Effects on blood metabolites and lactation performance. Journal of Dairy Science, 87(12), 4195–4206.

Erickson, G. E., Klopfenstein, T. J., Adams, D. C., & Rasby, R. J. (2005). General overview of feeding corn milling co-products to beef cattle. In Corn processing co-products manual: A review of current research on distillers grains and corn gluten. Nebraska Corn Board and University of Nebraska-Lincoln.

Feedipedia. (2015, 2018). Corn gluten feed; Corn gluten meal. INRAE, CIRAD, AFZ and FAO. https://www.feedipedia.org

Kalscheur, K. F., Garcia, A. D., Schingoethe, D. J., Royón, F. D., & Hippen, A. R. (2012). Feeding biofuel co-products to dairy cattle. In Biofuel co-products as livestock feed: Opportunities and challenges (pp. 115–154). FAO.

Kewalramani, N., Kamra, D. N., Lall, D., & Pathak, N. N. (1988). Bioconversion of sugarcane bagasse with white rot fungi. Biotechnology Letters, 10, 369–372.

Makkar, H. P. S., & Becker, K. (2009). Jatropha curcas, a promising crop for the generation of biodiesel and value-added coproducts. European Journal of Lipid Science and Technology, 111(8), 773–787.

Makkar, H. P. S., Kumar, V., Oyeleye, O. O., Akinleye, A. O., Angulo-Escalante, M. A., & Becker, K. (2011). Jatropha platyphylla, a new non-toxic Jatropha species: Physical properties and chemical constituents including toxic and antinutritional factors of seeds. Food Chemistry, 125(1), 63–71.

National Research Council (NRC). (2007). Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids. National Academies Press.

Rakshit, K. D., Darukeshwara, J., Raj, K. R., Narasimhamurthy, K., Saibaba, P., & Bhagya, S. (2008). Toxicity studies of detoxified Jatropha meal (Jatropha curcas) in rats. Food and Chemical Toxicology, 46(11), 3621–3625.

Schieck, S. J., Shurson, G. C., Kerr, B. J., & Johnston, L. J. (2010). Evaluation of glycerol, a biodiesel coproduct, in grow-finish pig diets to support growth and pork quality. Journal of Animal Science, 88(12), 3927–3935.

US Energy Information Administration (EIA). (2010). International energy outlook 2010. U.S. Department of Energy.

Van Cleef, E. H. C. B., Uwituze, S., Alvarado-Gilis, C. A., Miller, K. A., Van Bibber-Krueger, C. L., Aperce, C. C., & Drouillard, J. S. (2019). Elevated concentrations of crude glycerin in diets for beef cattle: Feedlot performance, carcass traits, and ruminal metabolism. Journal of Animal Science, 97(10), 4341–4348.