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Glycerin-A New Energy Source for Poultry[1]

Y.N. Min[1], F. Yan[1], F.Z. Liu[2], C. Coto[1] and P.W. Waldroup[1]
[1]Department of Poultry Science, University of Arkansas, Fayetteville AR, 72701, USA
[2]College of Animal Science and Technology, Northwest A & F University, Yangling 712100, China

Abstract: Glycerin, known as glycerol or glycerine, is the principal co-product of biodiesel production, produced through a NaOH- or KOH-catalyzed transesterification of the triacylglycerols in oils or fats with an alcohol. Glycerin is known to be a valuable ingredient for producing food, soaps, cosmetics and pharmaceuticals. Currently, with plenty of glycerin available to the world market, more uses are expected to develop, especially as a potential energy source for poultry diets, with approximately 4,100 kcal/kg of gross energy. Moreover, glycerin also plays a critical role in body cellular metabolism. Results from different laboratories on the use of glycerin as feed energy source for poultry are discussed in this article. Positive responses are obtained with glycerol content up to 10% in poultry diets. The AMEn also has been measured in several experiments. However, more indices such as carcass performance and blood parameters need to be determined in further studies.

Key words: Glycerin, metabolism, nutrient value, poultry

INTRODUCTION

Glycerin, known as glycerol or glycerine, is the principal co-product of biodiesel production, with 0.35 kg of crude glycerol generated for every 1 L of biodiesel produced (Thompson and He, 2006). Biodiesel is produced through a NaOH- or KOH-catalyzed transesterification of the triacylglycerols in oils or fats with an alcohol, usually methanol (Ma and Hanna, 1999; Van Gerpen, 2005). Through this reaction, the fatty acids are methylated to form methyl alkyl esters (i.e., biodiesel) and the principal co-product from the process is crude glycerol (Ma and Hanna, 1999; Van Gerpen, 2005; Thompson and He, 2006). Approximately 10% of the weight of oil or fat used to produce biodiesel becomes glycerin (Dasari *et al*., 2005) and the U.S. biodiesel industry anticipates glycerin output to be 635 million kg between 2006 and 2015 (Parsons *et al*., 2008). Crude glycerol is commercially of low value due to the presence of impurities. To make it of commercial quality, it should be treated and refined by filtration, chemical addition, and fractional vacuum distillation (Thompson and He, 2006; Willke and Vorlop, 2004).

According to the report from National Biodiesel Board (2007), in the United States, annual production capacity of biodiesel is approximately 5.26 billion L and with another 7.15 billion L/yr of additional production through new construction or plant expansion. Glycerin as a byproduct of biodiesel was supplied in tremendous quantity, with approximately 4.16 x 10^8 kg of crude glycerol (NBB, 2007).

Previously, glycerin has been a valuable ingredient for producing food, soaps, cosmetics and pharmaceuticals (Thompson and He, 2006). Currently, due to its high gross energy of approximately 4,100 kcal/kg (Brambilla and Hill, 1996), more uses are expected to develop, especially as a potential energy source for poultry diets. At the same time, glycerol (1-2-3 propane-triol) or glycerin is not a specific nutrient, but a current energy source similar to carbohydrates (Francois, 1994).

Metabolism of glycerin: Glycerol is a small molecule that plays a vital role in metabolism. It is an important structural component of triglycerides and phospholipids. Glycerol is a precursor to glyceraldehyde 3-phosphate, an intermediate in the lipogenesis and gluconeogenesis pathways, and yields energy through the glycolytic and tricarboxylic-acid pathways (Lin, 1997; Tao *et al*., 1983; Brisson *et al*., 2001).

The glucogenic property of glycerol is well established (Cori and Shine, 1935). The glycerol component can be converted to glucose by the liver (Krebs *et al*., 1966) and kidneys (Krebs and Lund, 1996) and provides energy for cellular metabolism. When the body uses body fat reserves as a source of energy, glycerol and fatty acids are released into the bloodstream. During digestion, triglycerides are hydrolyzed by pancreatic lipase to form free fatty acids and glycerol (Brody, 1994). The resulting glycerol is water soluble and freely enters the portal blood (Sambrook, 1980). Once absorbed, glycerol can be converted to glucose (Emmanuel *et al*., 1983) via glyconeogenesis or oxidized for energy production via glycolysis and citric acid cycle (Rosebrough *et al*., 1980) which can account for 60% of the metabolic fate of glycerol under basal conditions (Robergs and Griffin, 1998). Glycerol also reduces both the Free Fatty Acids (FFA) and the cholesterol levels (Francois, 1994). As an

Corresponding Author: P.W. Waldroup, Department of Poultry Science, University of Arkansas, Fayetteville AR, 72701, USA

energy source, glycerin can also be oxidized, yielding 22 moles of ATP/mol. Due to the sweet taste and small molecular size of glycerin, it can increase feed intake and be efficiently absorbed in the animals' gut. Intestinal absorption of glycerol in rats has been shown to range from 70-89% (Hober and Hober, 1937), with the high absorption rate of glycerol likely due to its small molecular weight and being passively absorbed rather than forming a micelle like that noted for medium and large chain fatty acids with bile salts (Guyton, 1991). In laying hens, the intestinal absorption of glycerol has been shown to more than 97% (Bartelt and Schneider, 2002).

Nutrient values of glycerin for poultry: Glycerin as a byproduct of biodiesel production has been evaluated in diets for poultry as a feed ingredient that provides energy for cellular metabolism (Campbell and Hill, 1962; Lin *et al*., 1976; Lessard *et al*., 1993; Simon *et al*., 1996; Simon *et al*., 1997; Barteczko and Kaminski, 1999; Cerrate *et al*., 2006). Simon *et al*. (1996) suggested that from the point of view of weight gain, feed intake and feed conversion ratio as well as N-balance a supplementation of 5-10% glycerol seems to be beneficial. Simon *et al*. (1996) also indicated that concentrations of 10% glycerol should be included in the diet, as the application via drinking water leads to depression in water and feed intakes. If glycerol is included in the diet, the higher water requirement of the broilers must be considered. Simon *et al*. (1997) concluded that on the basis of the estimated parameters, inclusion of 10% pure glycerol in broiler rations at the expense of corn starch is without adverse effects. The most efficient feeding indices compared to control were obtained in broilers fed a mixture supplemented with 10% glycerol; when broilers were fed with mixtures containing 10 and 15% glycerol a significant increase in the levels of cholesterol, triglycerides and blood glucose were observed as well as a leaner carcass (Barteczko and Kaminski, 1999). Studies from our laboratory (Cerrate *et al*., 2006) reported that the inclusion of 10% glycerol in broiler diets resulted in a decrease in body weight gain, attributed to reduced feed intake related to problems with feed flow (Table 1). In a subsequent trial, glycerin from biodiesel production was effectively used in broiler diets at levels of 2.5 or 5%; furthermore, breast yield was significantly improved by the addition of glycerin (Table 1).

In further studies from our laboratory (Min *et al*., 2008) the combination use of DDGS and glycerin in broiler diets was examined. The results showed that addition of 5% glycerin was acceptable in diets containing up to 30% DDGS. In summary, positive values are obtained with glycerol contents up to 10% in poultry diets; however, more indices such as carcass performance and blood parameters need to be involved in the further studies.

Metabolizable energy content of glycerin: At high inclusion rates, poultry are apparently not able to metabolize all absorbed glycerin. It could possibly be that the enzymatic activation of glycerine by glycerol kinase to glycerine-3-phosphate limits absorption. Dozier *et al*. (2008) indicated that the average AMEn of glycerin was 3,434 kcal/kg, which is similar to its gross energy content. The result of the study also showed that AMEn of glycerin is efficiently utilized by broiler chicken. Table 2 shows the AMEn for different levels of glycerin in broiler diets. Linear regression analysis ($p<0.001$, $r^2 = 0.92$, $n = 24$) revealed that the AMEn value of the crude glycerol for laying hens was 3,805±238 kcal/kg (mean ± SEM; as-is basis) (Lammers *et al*., 2008). In turkey hens, no adverse effects were found on egg production, egg weight, or feed utilization when a pure source of glycerin was used as a source of energy over a 16-week period (Rosebrough *et al*., 1980). Rosebrough *et al*. (1980) also assumed a ME value of 4,200 kcal/kg for dietary glycerol in turkeys, whereas Cerrate *et al*. (2006) estimated a ME value of 3,528 kcal/kg in broilers. Compared with other conventional energy sources, AMEn of glycerin is approximately 40% of poultry oil (Cullen *et al*., 1962; Lessire and LeClercq, 1982) and 36% of corn oil (NRC, 1994) and 10-12% higher than corn and grain sorghum respectively (NRC, 1994). Therefore, glycerin can partly replace conventional energy sources like fats and oils.

Prospects for the further use of glycerin: Pure glycerin is considered as generally recognized as safe for use in animal feed (FDA, 21 C.F.R. 582.1320). Quality variation is a problem when crude glycerin is used as feedstuff. Specific concerns relate to residual levels of methanol,

Table 1: Effects of dietary glycerin levels on performance of broilers (modified from Cerrate *et al*., 2006)

	Trial 1			Trial 2		
Parameter/glycerin level	0	5	10	0	2.5	5
42 d BW (kg)	2.871[a]	2.879[a]	2.706[a]	2.618	2.712	2.709
0-42 d FCR (feed: gain)	1.732[a]	1.709[a]	1.786[b]	1.643	1.625	1.629
Dressing percentage (%)	72.85[a]	72.81[a]	72.17[b]	72.05	72.34	72.08
Breast (% of carcass weight)	26.45	26.72	25.96	25.16[b]	25.80[a]	25.96[a]
Leg quarters (% of carcass weight)	31.05	31.11	31.24	30.11	30.08	29.70

[ab]Means in row with common superscript do not differ significantly ($p \leq 0.05$)

Table 2: Energy balance of broilers fed graded levels of glycerin (modified from Dozier *et al*., 2008)

	AMEn (kcal/kg)		
Added glycerin	7-10 d	21-24 d	42-45 d
0	-	2,984[a,b]	3,012[b]
3%	-	2,946[b]	3,025[ab]
6%	3,621	2,983[ab]	3,039[ab]
9%	-	3,004[a]	3,054[a]
Source of variation, p-value			
Linear	-	0.34	0.03
Quadratic	-	0.34	0.03

[ab]Mean values with a column with no common letters are significantly different ($p \leq 0.05$) as determined by least significant difference comparison

sodium, potassium, fatty acid content and moisture content in glycerol. No specifications for crude glycerol use in animal feed have been published. The FDA addresses methanol under CFR573.640, regulation 21 that requires that as a food additive free methyl alcohol in the methyl esters of higher fatty acids should not exceed 150 ppm or a level shown to be safely used in animal feeds. Recent evaluation of crude glycerol from soy biodiesel production indicates a glycerol content of 76.2% and as much as 7.98% fat, 0.05% protein and 2.73% ash, which was composed of 11 ppm Ca, 6.8 ppm Mg, 53 ppm P and 1.2% Na (Thompson and He, 2006). More concern should be focused on the potential toxic toxicity of methanol, that is to say, chemically reactive formaldehyde and free radicals may damage most of the components of the cells of all animal species (Skrzydlewska, 2003). Moreover, extra NaCl significantly increases water intake, water excretion and litter moisture (Hooge *et al*., 1999). Imbalances in dietary electrolyte balance caused by excessive Na or K and their adverse effect on litter quality also need to be seriously considered (Cerrate *et al*., 2006).

Biodiesel production in the United States is increasing dramatically. The by-product of biodiesel production is crude glycerol, which is approximately 10-12% of the weight of vegetable oil. Increasing biodiesel production will produce an enormous surplus of glycerin, which will significantly lower prices and make it as attractive energy-rich feedstuff for the feed manufacturing industry. Crude glycerol possesses low value due to the presence of impurities. To make it of commercial grade, it should be treated and refined through filtration, chemical additions and fractional vacuum distillation. The refining of the crude glycerol may be a costly affair depending on the economy of production scale and/or the availability of a glycerol purification facility. Glycerol oversupply has led to a decline in its price; the price of refined glycerol was US $1/lb in 1996 and was US $0.50/lb in 2003 (Tyson *et al*., 2004). It has dropped further to an average price of US $0.34/lb (ICIS Pricing, 2007). Alternative uses for the crude glycerol should be explored to make biodiesel more competitive in the growing global market. The use of crude glycerol in poultry feed can save the cost of refining and can compensate in part for the shortage and rising costs of corn, due to excessive use in beverage alcohol production.

Conclusions: In conclusion, based upon results of the studies discussed in this article it can be concluded that glycerin obtained from biodiesel can be an acceptable source of energy for poultry. Glycerin also plays a critical role in body cellular metabolism. If the quality of crude glycerin can be effectively controlled in combination with an acceptable cost, it can partially replace conventional energy sources like corn, fats and oils as a new energy source inclusion in diets fed to poultry.

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