Feedstuffs Reprint

Crude glycerol potential described

While glycerol can be an attractive alternative energy source for animal feed, it has its own limitations in terms of lower energy content than oils and fats, impurities and possible effects on the metabolic activity of the animals.

By **MOHAN DASARI***

THERE is currently a lot of focus on the use of crude glycerol as a source of carbohydrate in animal feed. Currently, there are still a number of unanswered questions regarding the safety, handling and efficacy of using this byproduct. We need to be very careful and fully understand the pros and cons of feeding crude glycerol.

A few of the questions are: What is the effect of glycerol on animal metabolism and overall animal health? What is the effect on meat or egg quality? What is the effect of impurities present in crude glycerol? Will the current feeding equipment work with inclusion of crude glycerol?

Let's take a closer look at the current glycerol market, the chemical nature of glycerol and the potential physiological effects of feeding crude glycerol on animals.

Glycerol is a colorless, odorless, viscous liquid widely used in pharmaceutical, food, personal care and many other industries. Also commonly called glycerin or glycerine, it is a sugar alcohol and, fittingly, is sweet-tasting and of low toxicity. Fats and oils contain about 10% bound glycerol, which is released as a free-glycerol byproduct during biodiesel production.

Glycerol market

The U.S. production of biodiesel has increased exponentially from 500,000 gal. per year in 1999 to about 500 million gallons by the end of 2007, generating 50 million gallons of low-value crude glycerol per year (Figure).

This burgeoning worldwide industry produces millions of gallons of crude glycerol per year as a byproduct, most of which is disposed of as a low-value product because refining glycerol is not feasible for small-scale production.

As the supply of oils to be converted to biodiesel is becoming increasingly competitive, the very survival of the biodiesel industry will depend on the value of its byproducts. This means that new uses and markets must be found for the main byproduct: glycerol.

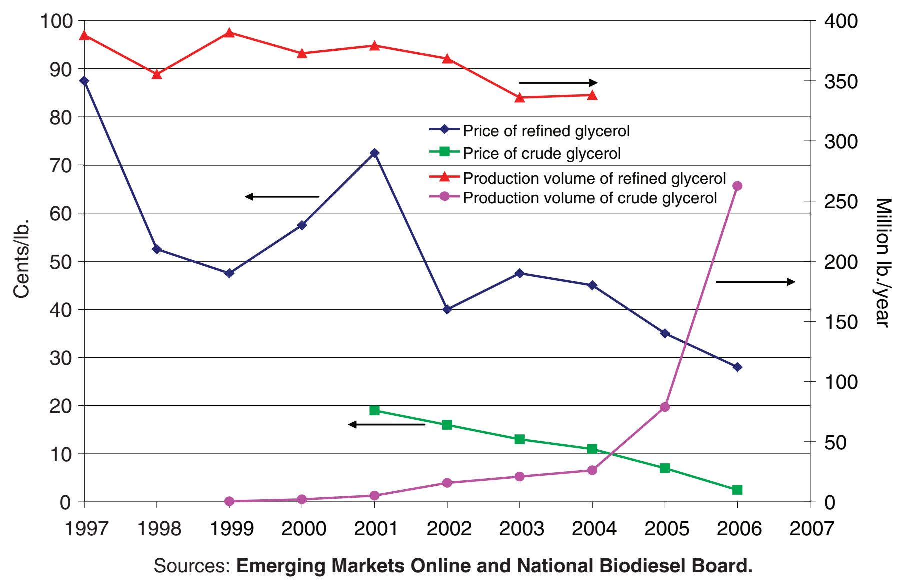
While pure glycerol has numerous industrial applications, the uses of crude glycerol are highly limited due to its composition.

Crude glycerol derived from biodiesel production possesses very little value because of its impurities. The primary impurities in glycerol include spent catalysts, salts after neutralization, residual methanol, methyl esters, oil/fat, soap and free fatty acids.

On the other hand, high-purity glycerol is a very important industrial feedstock. Its applications are found in food, drug, cosmetic and tobacco industries. Glycerol is a very versatile chemical and can be used as a starting material for several industrial chemicals like propylene glycol (antifreeze, cosmetics), epichlorohydrin (plastics, resins, paints) and polyglycerols (solvents, cosmetics, food additives).

Further refining crude glycerol will depend on the economy of production scale and/or the availability of a glycerol purification facility. Larger-scale biodiesel producers refine their crude glycerol and move it to markets in other industries. It is generally treated and refined through filtration, chemical additions and fractional vacuum distillation to yield various commercial grades. If it is used in food, cosmetics and drugs, further purifications are needed such as bleaching, deodorizing and ion exchange to remove trace impurities.

Market prices and production volumes for refined and crude glycerol



Sources: **Emerging Markets Online and National Biodiesel Board.**

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Purifying crude glycerol to that stage, however, is costly and generally not economically feasible for small- to medium-sized plants.

Currently, with plenty of glycerol available to the world market, prices and U.S. exports have declined and will continue to drop due to an overly saturated market and new supplies of glycerol entering the market from the burgeoning biodiesel industry. However, in view of the numerous applications of glycerol, the current trend in prices may only exist for three to four years before all crude glycerol is diverted from the animal feed industry to use in an industrial chemical application.

Glycerol as animal feed

One area that is drawing attention lately is the use of crude glycerol as an animal feed ingredient. With the increase in the corn prices and the glut of crude glycerol in the past years, the very real possibility of using biodiesel crude glycerol to replace corn is being investigated.

According to the 2004 *Code of Federal Regulations* (§582.1320) for glycerol, "This substance is generally recognized as safe when used in accordance with good manufacturing or feeding practices."

Glycerol is a polyhydroxyl alcohol (polyol), or a sugar alcohol. However, from a nutrition standpoint, glycerol is considered a carbohydrate. The experts seem to disagree as to whether glycerol should be considered a carbohydrate or a simple energy source. The reason for this argument is that glycerol does not affect blood glucose or insulin levels in humans like a normal carbohydrate.

In the past, the food industry considered glycerol to be a food additive or a preservative as it was used only to maintain the quality/texture of the food more than as a nutritional/energy source. However, as of today, the Food & Drug Administration regards glycerol as a carbohydrate.

As a carbohydrate is consumed, blood glucose levels will increase, which triggers the pancreas to secrete insulin. Insulin triggers liver cells to convert glucose to glycogen, which gets stored in liver or skeletal muscle cells while the excess glucose is used for triglyceride synthesis. Some of the glycogen will again convert back to glucose at later stages, as necessary, and will be used by the animal as energy source.

Analysis of crude glycerol obtained from different biodiesel manufacturers showed that the digestible energy value of 85% crude glycerol is about 1,600-1,650 kcal/lb. with a metabolizable energy content in the range of 1,500-1,580 kcal/lb.

Table 1 shows the range of energy content of crude glycerol samples obtained from four different sources. While glycerol can be an inexpensive source of energy, it should also be noted that the energy content is about 2.5 times lower than the metabolizable energy content in some vegetable oils, which is about 4,000 kcal/lb.

With the surge in ethanol production resulting in high corn prices, inexpensive crude glycerol is being seen as a potential substitute for corn. While glycerol can be used as a pure energy source instead of corn, glycerol being a carbohydrate/sugar alcohol can be a replacement for the starch part of the corn, but not the fat, protein and fiber portions. So, appropriate substitutions for fat, protein and fiber are essential to formulate a balanced diet.

Prior to the high influx of crude glycerol to the market, several studies were done, dating back to the early 1970s, to evaluate glycerol as a feed ingredient in diets of animals (Fisher et al., 1971). Glycerol is generated in the body during the breakdown of triglycerides to fatty acids. In addition to the glycerol present in the animal diet, the predominant source of glycerol is adipose tissue.

Depending on the energy state and energy need of the animal, glycerol is either metabolized in the liver to supply energy to the liver cells whenever needed or enters the gluconeogenesis pathway in order for the liver to produce glucose for use by the rest of the body. Hence, any excess glycerol fed as a part of the animal diet can induce physiological and biochemical adaptations, especially in the liver.

In view of its metabolism, glycerol can be considered a rapidly metabolizable carbohydrate source. Glycerol is metabolized at a fast rate to alpha-glycerophosphate, an intermediate, which plays a key role in the formation of triglycerides and phospholipids. This will result in an increase in the lipid content and, thus, the mass of liver. Hence, the increase in glycerol content in the feed may also affect the triglyceride metabolism in animals.

This is consistent with the observations of studies by Narayan et al. (1975 and 1979) on the effect of dietary glycerol on rat liver and serum lipids. The studies found that the glycerol treatment resulted in an increased liver mass after 21 weeks. The cholesterol esters and lipid levels in the liver and serum showed a significant one- to two-fold increase. It was also suggested that dietary glycerol might stimulate hepatic lipogenesis and speed up the induction of fatty acid desaturases, resulting in changes in liver fatty acid composition and in altered membrane permeabilities.

Despite its high absorption in the animal gut, excess glycerol in the diet may only be partially metabolized in the body, with the rest excreted in the urine. This effect is more pronounced at higher glycerin inclusion rates.

In the U.S., subacute ketoacidosis affects 30-50% of all dairy cows (Hutjens, 1996).

1. Energy content range in crude glycerol from four different sources

Component	Range
Glycerol content, %	82-88
Total digestible nutrients, %	81.0-83.5
Net energy for gain, kcal/lb.	600-640
Net energy for lactation, kcal/lb.	840-880
Net energy for maintenance, kcal/lb.	870-910
Digestible energy, kcal/lb.	1,600-1,650
Metabolizable energy, kcal/lb.	1,500-1,580

2. Comparison of methanol and glycerol content in crude glycerol obtained from different sources

Sample	Glycerol (wt%)	Methanol (ppm)
CG1	86.3	<100
CG2	72.2	11,500
CG3	88.3	<100
CG4	78.9	400
CG5	82.0	580
CG6	84.6	200
CG7	94.0	<100

Glycerol is a glucogenic substance and prevents ketoacidosis in high-yielding dairy cows by increasing the supply of glucose precursors (Johnson, 1955). These glucose precursors increase the glucose production in the liver and thereby reduce the need to mobilize the fat to meet the energy demands.

Kristjan Bregendahl, assistant professor of poultry and nutrition at Iowa State University, fed up to 15% crude glycerol to laying hens and found that the apparent metabolizable energy in crude glycerol is 1,725.9 kcal/lb. (3,805 kcal/kg) and was used in high efficiency by the hens. Bregendahl saw no adverse effects on egg production, egg weight, egg mass or feed consumption in a 10-day, short-term study with 48 hens.

Cerrate et al. (2006) formulated diets consisting of 0, 5 and 10% glycerol in a typical broiler diet and found that including 5% in the diet had no adverse effect on bodyweight, feed intake, feed conversion and dressing percentage, while there was a decrease in all of the above characteristics with 10% glycerol inclusion in the feed compared to the control.

Brian Kerr, Agricultural Research Service research leader, in his studies on both nursing and finishing pigs, showed equal growth performance between a glycerol-supplemented diet and a conventional diet.

Schroder et al., in studies on sheep, substituted glycerol up to 10% for starch sources and found no negative effects on the rumen environment, nutrient turnover and whole-tract digestibility of organic matter constituents.

Impurities

While glycerol seems like a good replacement for animal feed ingredients as a pure energy source, producers must be wary of some of the implications of the impurities present in the crude glycerol.

Methanol is one of the reactants in the production of biodiesel from fats and oils. Excess methanol is typically used to drive the biodiesel (transesterification) reaction forward, and the unreacted methanol finally ends up in the glycerol phase due to its polar nature.

Most of this methanol is recovered via distillation and is recycled to the beginning of the process. Not all methanol can be stripped out of the glycerol phase using a flash distillation technique that results in low levels of methanol, typically in the parts per million range, remaining in the glycerol. This problem will be more pronounced in small biodiesel facilities that use simple batch distillation/evaporation techniques for economic reasons.

According to the 2005 *Code of Federal Regulations* (§573.640) for methyl esters of higher fatty acids, "The food additive meets the following specifications: (1) free methyl alcohol not to exceed 150 parts per million; (2) unsaponifiable matter not to exceed 2%."

Table 2 shows the comparison of seven different samples of crude glycerols obtained from biodiesel manufacturers in the U.S. Four of the seven crude glycerol samples tested had a methanol content higher than the FDA allowable contaminant level. More importantly, samples CG5 and CG6, obtained from the same biodiesel manufacturing plant on two different days, have two different methanol contents.

It should be noted that currently, multiple different types of process technologies and feedstocks are used to produce biodiesel in the U.S. Each combination of process technology and feedstock may result in different grades and/or qualities of crude glycerol being generated as a generally unregulated byproduct.

The results in Table 2 show the variability in the crude glycerols that are available in the market.

At a recent seminar, FDA's Center for Veterinary Medicine and various industrial boards concluded that potential contaminant levels in crude glycerol, particularly methanol, with levels higher than 150 ppm could be considered unsafe for animal feed unless biodiesel manufacturers had data on the safety of the product at higher levels.

Methanol is intoxicating but not directly poisonous. It is toxic due to its breakdown (toxication) by the alcohol dehydrogenase enzyme in the liver by forming formic acid and formaldehyde, which cause blindness from destruction of the optic nerve.

Depending on the catalyst used for the biodiesel reaction, the crude glycerol may contain 6-8% inorganic salts. High levels of sodium or potassium in the diet may result in electrolyte imbalance in animals.

There may also be some problems associated with the texture of the feed and handling the feed using the traditional feeding mechanisms with the addition of glycerol. Glycerol is highly viscous and, due to its chemical nature, has a tendency to absorb and retain moisture. These properties of glycerol may create flowability issues in dry feed used in self-feeders. On the other hand, glycerol can act as a good binding agent in the case of pelletized feed.

Conclusions

While glycerol can be an attractive alternative energy source for animal feed, it has its own limitations in terms of lower energy content than oils and fats, impurities and possible effects on the metabolic activity of the animals.

It is strongly recommended that the consumers of crude glycerol for use as animal feed should be aware that unregulated glycerol that is a byproduct of biodiesel can pose a potential danger to the animals when the quality of the crude glycerol is not monitored properly.

The industry needs to more fully understand the effects of feeding crude glycerol before it is included as a regular part of an animal diet. Additional long-term studies on the effect of crude glycerol on animal metabolism are necessary in order to make any long-term feeding recommendations.

Practicing nutritionists will be able to give the best guidance on glycerol use and recommendations on a product testing protocol.

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