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# Critical review on the current scenario and significance of crude glycerol resulting from biodiesel industry towards more sustainable renewable energy industry

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ABSTRACT

Biodiesel production through transesterification of vegetable oils and animal fats is rapidly increasing due to strong governmental policies and incentives. However, corresponding increase in the production of crude glycerol causes mixed effects. Sustainable biodiesel production requires optimization of its production process and drastic increase in the utilization of glycerol. High biodiesel yields and low environmental impacts, with respect to needless waste streams are mandatory. As such, upgrading of crude glycerol to highly pure glycerol and subsequent utilization of the product in producing value-added products are emerging research areas. International crude glycerol market is still at an early and very unstable stage. Globally, future conditions for an international market will largely be decided by supply and demand of glycerol for its utilization in conventional and newly developed industries. This paper highlights the current scenario on glycerol production from biodiesel industry, its global market and its new emerging outlets as commodity chemicals.



**Contents**



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## 1. Introduction

The unexceptional opportunities have created in recent decades to replace petroleum derived materials with bio-based alternatives due to rapid depletion of fossil of fuels and its escalating prices. Petroleum is a non-regenerative source of energy and it is also an important resource of the modern society for its requirement in applications other than power like household products, clothing, agriculture, as a basic materials for synthetic materials and chemicals. Nowadays, fuel crisis has globally flounced the economy in every region, particularly the oil consuming countries due to the rapidly decreasing available global stocks. Due to this serious situation, biodiesel which comes from 100% renewable resources provides an alternative fuel option for future.

The annual biodiesel consumption in the United States was 15 billion liters in 2006. It has been growing at a rate of 30–50% per year to achieve an annual target of 30 billion liters at the end of year 2012 [1]. According to the same report by National Biodiesel Board, there were 105 biodiesel production facilities operating in the United States in 2007, and 77 other facilities were in the planning or construction stage. If all of these facilities are realized, the estimated US biodiesel production capacity will exceed 9.5 billion liters. This level of production will yield nearly 1.2 million metric tons of crude glycerol, the primary co-product of the biodiesel production process.

Purification of crude glycerol to a chemically pure substance results in a valuable industrial chemical. However, purification is costly and the glycerol market is already saturated. Thus, the price of crude glycerol continues to decline and directly affect on biodiesel production cost. This trend will continue as more biodiesel production facilities begin production. According to a report [2], the biodiesel production cost ranges from $0.17 to $0.42 per liter over the last decade. Today, plenty of glycerol stock is available in the world market and its price is declining day by day. The price of pure glycerol varied from $0.50 to $1.50/lb and crude glycerol from $0.04/kg to $0.33/kg over the past few years [3]. The price of glycerol in the market will continue to drop in such an over saturated market. Currently, the main supply of glycerol coming into the market is from the rapidly growing biodiesel industry.

Basically, the continuously high prices of glycerol make it worthwhile for users to be reformulated to some alternative materials such as sorbitol and synthetic glycerol. Meanwhile, sustained low prices encouraged its use in other applications. The impact of the additional huge quantity of glycerol on its prices is not clear. However, it is likely that if new uses for glycerol are not found, the glycerol price may drop to a level that even justify its use as a burner fuel, which cost is usually about 5 cents/lb. This also implies that the overproduction of low grade glycerol would impact the viability and overall economy of biodiesel production [4], market price stability of current crude glycerol as well as environmental concerns due to improper disposal of glycerol [5]. The high biofuel prices and historically low glycerol prices are two main factors that drive researchers to discover new applications of glycerol and provide an ideal platform for chemical and pharmaceutical industries.

The objective of this work is to provide a critical review on the formation and current scenario of crude glycerol resulting from biodiesel production and to provide an insight into the impact of this crude glycerol over the biodiesel production cost itself. The study also provides a view of glycerol market and its new outlets at present and future with respect to the production of glycerol-based value-added products.

## 2. Properties of glycerol

Glycerol, commonly known as glycerin is a major by-product of biodiesel manufacturing process. Generally, approximately 4.53 kg of crude glycerol is created for every 45.3 kg of biodiesel produced [6]. Glycerol is a material of outstanding utility with many areas of application. A unique combination of physical and chemical properties of glycerol makes it technically versatile product which is readily compatible with many other substances and easy to handle. Glycerol is also virtually nontoxic to human health and also to environment [7]. Physically, glycerol is a water-soluble, clear, almost colorless, odorless, viscous, hygroscopic liquid with a high boiling point. Chemically, glycerol is a trihydric alcohol, capable of reacting as an alcohol, yet stable under most conditions. A list of physical and chemical properties which are important for its applications is shown in Table 1 [8]. Glycerol finds application in a broad diversity of end users.

A glycerol molecule has three hydrophilic hydroxyl groups that are responsible for its solubility in water and its hygroscopic nature. Therefore, it is actually has multipurpose substance in many applications. Glycerol can be used as a renewable source for biodegradable products and also find applications in green refinery process. It may have a great environmental value demanded by modern society who favors the non-dependence on depleting sources of petroleum and fossil fuel feedstock.

**Table 1**
Physical and chemical properties of glycerol [8].

| Properties | | Values | |
|---|---|---|---|
| Chemical formula | | $CH_2OH–CHOH–CH_2OH$ | |
| Formula weight | | 92.09 | |
| Form and color | | Colorless and liquid | |
| Specific gravity | | $1.260^{50/4}$ | |
| Melting point | | 17.9 °C | |
| Boiling point | | 290 °C | |
| Solubility in 100 parts | | | |
| Water | | Infinity | |
| Alcohol | | Infinity | |
| Ether | | Insoluble | |
| Heat of fusion at 18.07 °C | | 47.49 cal/g | |
| Viscosity of liquid glycerol | | | |
| At 100% purity | | 10 cP | |
| At 50% purity | | 25 cP | |
| Diffusivity in | | ($DL \times 10^5$ sq cm/s) | |
| *i*-Amyl alcohol | | 0.12 | |
| Ethanol | | 0.56 | |
| Water | | 0.94 | |
| Specific heat in aqueous solution (mol%) | 15 °C (cal/g °C) | | 30 °C (cal/g °C) |
| 2.12 | 0.961 | | 0.960 |
| 4.66 | 0.929 | | 0.924 |
| 11.5 | 0.851 | | 0.841 |
| 43.9 | 0.670 | | 0.672 |
| 100 | 0.555 | | 0.576 |