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Headings of Processing Glycerin Resulted from Biodiesel Synthesis

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Abstract

The recent increase in biodiesel production has brought about concern regarding an oversupply of glycerin to the glycerin market. Biodiesel production has played a large part in these changes and could play an even bigger role in the future of the glycerin market. Therefore, this study presents critically different experimental methods of processing glycerin resulted from biodiesel synthesis.

Key words: *glycerin, biodiesel, microbial fermentation.*

Introduction

Glycerin, a renewable raw material, is a firmly established component in many industrial products. It is obtained as a byproduct when vegetable oils and fats are hydrolyzed or esterified to yield fatty acids, metal salts (soaps), or their corresponding esters.

In the transesterification process, oils and/or fats rich in triglycerides are mixed with an alcohol such as methanol and base such as potassium or sodium hydroxide, resulting in a methyl ester biodiesel stream and a glycerin side stream. This glycerin side stream typically contains a mixture of glycerin, methanol, water, inorganic salts (catalyst residue) free fatty acids, unreacted mono-, di-, and triglycerides, methyl esters, and a variety of other matter organic non-glycerin (MONG) in varying quantities. The methanol is typically stripped from this stream and reused, leaving behind, after neutralization, what is known as crude glycerin. In raw form, this crude glycerin has high salt and free fatty acid content and substantial colour (yellow to dark brown). Consequently, crude glycerin has few direct uses due to the presence of the salts and other species, and its fuel value is also marginal. 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 glycerin may be a costly affair depending on the economy of production scale and/or the availability of a glycerin purification facility.

Purifying Glycerin

One initial step common to all glycerin purification processes is that fat, soap and other organic impurities need to be chemically separated and removed by filtration and/or centrifugation. Final purification is typically completed using vacuum distillation followed by activated carbon bleaching for large operations or ion exchange followed by flash drying to remove water for

smaller capacity plants. Vacuum distillation is very expensive in terms of capital cost and energy consumption, cannot always be carried out continuously and is accompanied by considerable losses of glycerin. In order to separate glycerin from higher boiling point impurities the mixture needs to be additionally subjected to severe thermal stresses that further result in additional losses of glycerin and creates more decomposition products. Because of the high salt content, ion exchange is not economically practical, unless it is used to polish a diluted low salt content glycerin-in-water solution.

HEEPM (High Efficiency Electro-Pressure Membrane) technology is an economical solution for the purification of crude glycerin streams in the biodiesel production industry. HEEPM synergistically combines patented and patents pending high efficiency electrodialysis (HEED) and nanofiltration to purify and recover glycerin. The recovered glycerin, after polishing with ion exchange (if necessary) and water /methanol removal by evaporation, can meet glycerin U.S. Pharmacopeia (USP) standards.

HEEPM technology avoids many of the issues associated with evaporation and distillation such as foaming, carryover of contaminants, limited recovery, and high capital costs. In addition, HEEPM can be integrated easily into existing biodiesel production facilities, and it can be adapted for purification of glycerin at a number of locations within the glycerin waste stream handling process. The robustness of the HEEPM process allows it to be applied prior to or after methanol removal.

Glycerin purification process begins with pretreatment of the glycerin to remove any solids and fouling organics and partially remove colour-causing organics. The HEEPM system configuration is used, with customized automated controls and control logic, providing optimal desalting of the preatreated crude glycerin. The result is a colourless liquid with low salt content [1].

Glycerin Processing

The US biodiesel industry generates millions of gallons of crude glycerin waste each year, and the amount produced is growing rapidly along with the dramatic growth of biodiesel production. There can be many possible ways of converting crude glycerin to various useful compounds. This products are 1,3-propanediol, 1,2-propanediol, dihydroxyacetones, hydrogen, polyglycerols, succinic acid, and polyesters.

Glycerin, when used in combination with other compounds yields other useful products. For example glycerin and ethylene glycol together can be used as a solvent for alkaline treatment of poly fabrics.It can be used as dielectric medium for compact pulse power systems. Glycerin acts as a medium in electrodeposition of Indium-Antimony alloys from chloride tartrate solutions. Biomass is converted to liquid fuel using glycerin that can be blended with gasoline as an alternative fuel. Mixed culture fermentation of glycerin synthesizes short and medium chain polyhydroxyalkanoate blends.

1,3-propanediol can be formulated into composites, adhesives, laminates, powder and UV-cured coatings, mouldings, novel aliphatic polyesters, co-polyesters, solvents, anti-freeze and other end uses. One of the most successful applications has been in the formulation of corterra polymers. As the production is limited and costs are higher, glycerin has become an attractive feedstock for production of for 1,3-propanediol. Microbial fermentation is an important technology for the conversion of renewable resources to chemicals. It can be obtained by microbial fermentation of glycerin**.** Propanediol-based polymers exhibit better properties than those produced from 1,2-propanediol, butanediol or ethylene glycol[2].

To study the glycerin conversion, three types of media were used: a rich medium, a low-nutrient medium (LNM), and when biotin was replaced by yeast extract in the LNM (LNM-YE). To study fermentation at the pilot scale, cultures were carried out using a 20 L reactor with 17 L

useful volume. It was equipped with a boiler to produce steam for in situ sterilization of the culture medium and reactor piping. The culture inoculum consisted of 11 (6% vol) of pH-controlled inoculum culture using industrial glycerin equivalent to 50 g/l of pure glycerin. To determine an adequate nitrogen level for glycerin fermentation by Clostridium Butyricum, NH_4CI was added to LNM in various amounts, and pH-controlled cultures were performed with high concentrations of glycerin corresponding to an initial C/N ratio between 60:1 and 112:1.

Papanikolaou and Aggelis [3] simulated the production of 1,3-propanediol by Clostridium Butyricum from raw glycerin by a Contois-type model. The production of 1,3-propanediol by Clostridium Butyricum was suitable for this type of bioconversion. It was found that the maximum theoretical 1,3-propanediol productivity was comparable with the highest one achieved during growth of various bacterial strains on pure glycerin in batch and continuous cultures. The preculture was carried out in 100 mL conical flasks, filled with 50 mL of medium (the carbon source was 30 g/L of pure glycerin), inoculated with the first post-sporal Hungate-tube culture and incubated at 33°C without agitation for 10-14 h. Batch and single-stage continuous cultures were conducted in a 2 L reactor filled with 0.9 L of medium and inoculated with 0.1 L of preculture. In order to ascertain the anaerobiosis during the first fermentation steps of the fermentor culture, nitrogen gas, at a rate of 0.5 vvm, was infused into the culture medium. The agitation speed was 200 rpm and the pH was adjusted to 7±0.05 by automatic addition of 2 N KOH. The incubation temperature was 33°C. A two-stage continuous culture seemed attractive for achieving simultaneously high product concentration and productivity. The first stage presented a high dilution rate in order to obtain an increased 1,3-propanediol volumetric productivity. The second stage with a lower dilution rate, served mainly to further increase the product concentration. Significant cell growth was observed in the first stage of the culture, where as at the high flow rates significant substrate amounts remained unconsumed in the culture fluid. For both types of cultures, the conversion yield obtained was around 0.55 g of 1,3-propanediol formed per 1 g of glycerin consumed. The highest 1,3-propanediol concentration for single stage process was 35-48 g/L.

Another microorganism that ferments glycerin to 1,3-propanediol is Klebsiella Pneumoniae. The product concentration and productivity of 1,3-propanediol by Clostridium Butyricum was far below the optimum performance on comparing the experimental results with theoretical calculations using Klebsiella Pneumoniae due to the relatively high formation of butyric acid.

Wang [4] studied the conversion of glycerin to 1,3-propanediol with batch and continuous fermentation processes under anaerobic and microaerobic conditions. The 1,3- propanediol conversion rates of both processes were similar, but the productivity of 1,3-propanediol under microaerobic condition was higher than that under anaerobic condition. Wang [5] used the selective hydroxylation technique. The idea was to selectively transform the middle hydroxyl group of glycerin into a tosyloxyl group and then remove the transformed group by catalytic hydrogenolysis. With this approach, the conversion of glycerin to 1,3- propanediol was completed in three steps, namely, Acetalization, Tosylation, and Detosylation. The acetalization of glycerin with benzaldehyde was conducted in benzene. The setup included a round-bottomed reaction flask, a condenser, and a Dean-Stark trap. By using a Dean-Stark trap, the water formed in the reaction could be boiled off from the reaction flask as an azeotrope with benzene, and the reaction could be driven to completion. In this experiment, 100 g of glycerin, 120 g of benzaldehyde (6% excess), and 300 mL of benzene, together with 1 g of *p*-toluenesulfonic acid catalyst, were placed in the reaction flask. The reaction was initiated by bringing the reaction solution to a boiling state, and the volume of the water formed in the reaction monitored the progress of the reaction. Tosylation was carried out in pyridine. The reaction flask was placed in a refrigerator at 5°C to allow the reaction to continue for about 12 h. The progress of this reaction was monitored by the formation of needle-shaped (pyridinehydrochloride complex) crystals. The final step of the conversion was detosyloxylation reaction followed by a hydrolysis reaction. The detosyloxylation reaction removes the tosylated middle hydroxyl group, while the

hydrolysis reaction removes the protection on the first and third hydroxyl groups. This last step yields the conversion target, 1,3-propanediol. It also regenerates the group protection reagent benzaldehyde, which can be recycled back to the acetalization reactor for reuse in the first-step conversion.

Perosa and Tundo [6] converted glycerin selectively to 1,2 propanediol. When glycerin and Raney Ni were heated at 150°C for 20 h in a steel autoclave with 10 atm of hydrogen, conversion reached 12%, with 93% selectivity toward 1,2 propanediol, plus small amounts of ethanol and CO_2. At 190°C, the reaction proceeded faster, with selectivity toward 1,2 propanediol in the range of 70- 80% and ethanol and CO_2 as the sole by-products. At 210°C, the reaction was still faster, but selectivity toward 1,2 propanediol dropped to 48%. The selectivity and rate towards 1,2 propanediol was found to be improved with addition of a phosphonium salt. Dasari carried out reactions in a specially designed stainless steel multi-clave reactor capable of performing eight reactions simultaneously. Each reactor with a capacity of 150 mL was equipped with stirrer, heater and a sample port for liquid sampling. The reactors were flushed several times with nitrogen followed by hydrogen. Then the system was pressurized with hydrogen to the necessary pressure and heated to the desired reaction temperature. The speed of the stirrer was set constant at 100 rpm throughout the reaction. All the catalysts used in this study were reduced prior to the reaction in the same reactor by passing a stream of hydrogen over the catalyst bed at 300°C for 4 h. Copper-chromite catalyst was the most effective catalyst for the hydrogenolysis of glycerin too. The yield of 73% was achieved.

Dihydroxyacetone is used in cosmetics industries as a tanning agent. Garcia [7] investigated the liquid-phase oxidation of glycerin with air on platinum catalysts at different pH. Oxidation of aqueous solutions of glycerin were carried out at atmospheric pressure in a thermostated glass reactor equipped with a stirrer, a gas supply system, an oxygen electrode and a pH electrode . The catalyst was suspended in 300 mL of water under a nitrogen atmosphere and the suspension was heated to 333 K whilst stirring continuously at 1200 rpm. Glycerin was then added and, following a delay of 10 min, air was bubbled through the slurry at 0.75 mL/min. The initial concentration of the aqueous glycerin solution was 1 mol/L. The reaction medium was maintained at a constant pH by addition a 30% sodium hydroxide solution using a pump controlled by a pH meter. The selectivity to glyceric acid was 70% at 100% conversion on Pd/C at pH 11. On Pt/C catalyst, glyceric acid was the main product with 55% selectivity. They found that deposition of bismuth on platinum particles orientates the selectivity towards the oxidation of the secondary hydroxyl group to yield dihydroxyacetone with a selectivity of 50% at 70% conversion.

Bauer [8] investigated the influence of the product inhibition by dihydroxyacetone on gluconobacter oxydans for a semi-continuous two-stage repeated-fed-batch process. The bioreactor system was a combination of a laboratory scale bubble column with a height of 300 mm and an inner diameter of 100 mm and a laboratory-scale stirred reactor having the same dimensions. The total volume of each reactor was 2 L. The reaction volumes were 1.5 L and 1.47 L for reactor stage 1 and reactor stage 2, respectively. Both reaction volumes were kept nearly constant during the repeated-fed-batch experiments by a correctly set concentration of the glycerin feed in order to compensate the loss of broth volume due to evaporation. The pH in reactor 1 was controlled at 5.3. The pH in reactor 2 was not controlled. The temperature was controlled at 30°C. A dihydroxyacetone concentration of 80 kg/m^3 was achieved without any influence of product inhibition. The regeneration capability of the reversibly product inhibited culture from a laboratory-scale bioreactor system was observed up to a dihydroxyacetone concentration of about 160 kg/m^3. At higher dihydroxyacetone concentrations, the culture was irreversibly product inhibited. The reachable maximum final dihydroxyacetone concentration was as high as 220 kg/m^3.

Succinic acid can be used for the manufacture of synthetic resins and biodegradable polymers and as an intermediate for chemical synthesis. Lee [9] has reported the method of production of succinic acid by fermentation of glycerin by using Anaerobiospirillum succiniciproducens. Cells were grown in sealed anaerobic bottles containing 100 mL minimal salts medium containing 5 g/L glucose, 2.5 g/L yeast extract and 5 g/L polypeptone with CO_2 as the gas phase. The medium was heat sterilized (15 min at 121°C) in anaerobic bottle with nitrogen headspace. To the sterile medium, concentrated H_2SO_4 was added to adjust the pH to 6.5. They cultured cells in a medium containing 6.5 g/L glycerin to give a high yield of succinic acid thus avoiding the formation of acetic acid as by-product. The gram ratio of succinic acid to acetic acid obtained was 25.8:1, which was 6.5 times higher than that obtained using lucose as a carbon source. When glucose and glycerin were co-fermented with the increasing ratio of glucose to glycerin, the succinic acid yield decreased, suggesting that glucose enhanced acetic acid formation irrespective of the presence of glycerin. The consumption of glycerin was strongly dependent on the amount of yeast extract added to culture medium.

Clacens [10] studied the selective etherification of glycerin. Etherification was carried out at 533 K in a batch reactor at atmospheric pressure under N_2 in the presence of 2 %wt of catalyst, water being eliminated and collected using a Dean-Stark system. They studied impregnation of mesoporous solids with different basic elements The solvent (methanol) was then rapidly evaporated under vacuum and the solid was calcined under air at 723 K overnight at a heating rate of 1 K/min. The best value to glycerin was obtained over solids prepared by caesium impregnation.

Stumbe and Bruchmann [11] prepared hyperbranched polyesters by reacting glycerin and adipic acid without any solvents in the presence of tin catalysts. Adipic acid and glycerin were charged into a three necked glass reactor equipped with a gas-inlet pipe for N_2 addition and a claisen condenser with vacuum adapter. The mixture was melted at 100°C under N_2 atmosphere with constant stirring. Hyperbranched polyesters obtained had molecular weight of 23,370 g /mol.

Villeneuve [12] carried out enzymatic esterification of glycerin with dicarboxylic acids to produce mono- and/or diesterified glycerin adducts. Reaction of glycerin supported on silica with dimethyl adipate gave a 40% yield of glycerin-monomethyl adipate ester. Best yields of glycerin-mono and diesters (70% and 10%, respectively) were obtained by direct esterification of free glycerin with a diester in a solvent-free system with less than 4 % water present.

Ito [13] did H_2 and ethanol production from glycerin using Enterobacter Aerogenes HU-101. He produced H_2 in continuous culture of self-immobilized cells with a packed-bed reactor. Cultures were maintained at - 80°C with 15% glycerin. A cylindrical glass column reactor was used for the continuous culture. Fresh medium was supplied from the bottom by a peristaltic pump and evolved gas and effluent liquid were discharged from the top of the reactor. Two mL of the seed culture was transferred into the reactor. The cells were cultivated anaerobically at 37°C without controlling pH. The glycerin was diluted with a synthetic medium to increase the rate of glycerin utilization and the addition of yeast extract and tryptone to the synthetic medium accelerated the production of H_2 and ethanol. They reported that yield of H_2 and ethanol decrease with an increase in the concentrations of biodiesel wastes and commercially available glycerin. Moreover, due to a high salt content in biodiesel wastes, the rates of H_2 and ethanol production were much lower than those at the same concentration of pure glycerin. The maximum rate of H_2 production obtained was 30 mmol/L h. Giving a porous ceramics material support to fix cells in the reactor increased H_2 production rate to 63 mmol /L h with a corresponding ethanol yield of 0.85 mol/mol-glycerin Wood reported that chemical engineers from the University of Wisconsin have developed a platinum-based catalytic reforming process operating at moderate temperatures and pressures for hydrogen production from simple biomass-derived molecules glucose and glycerin. The process prevents any steam formation to produce hydrogen only. CO_2 is a by-product.

Another process reported for hydrogen production is the pyrolysis and steam gasification of glycerin. Valliyappan [14] carried out reactions in an inconel, tubular, fixed bed down-flow reactor at atmospheric pressure. He studied the effects of carrier gas flow rate, temperature and different particle diameter of different packing material on the product yield, product gas volume, composition and calorific value. According to him increase in carrier gas flow rate showed insignificant effect on synthesis gas production at 800ºC with quartz chips diameter of 3-4 mm. This increased gas yield from 65 to 72 %wt while liquid yield decreased. Reaction temperature showed linear response for the hydrogen yield increasing from 17 to 48.6 mol% and synthesis gas production increasing from 70 to 93 mol%. Pyrolysis reaction at 800°C, 50 ml/min of nitrogen and quartz particle diameter of 0.21-0.35 mm maximized the gas product yield (71 %wt), hydrogen yield (55.4 %mol), synthesis gas yield (93 %mol) and volume of product gas (1.32 L/g of glycerin).

Uses of Glycerin

Glycerol or glycerin is the most simple polyhydric alcohol, bearing three hydroxy groups on the hydrocarbon chain with three carbon atoms. It is a colourless, odourless, sweet-tasting, syrupy liquid. It melts at 17.8°C, boils with decomposition at 290°C, is miscible with water and ethanol and it is hygroscopic [15]. Glycerin is present in the form of its esters (glycerides) in all animal and vegetable fats and oils.

Glycerin has a lot of uses besides those mentioned above. Glycerin is an important and essential building block in polyethers for urethane polymers. Glycerin based polymers have found some uses, such as in rigid urethane foams. It is used as a humectant (a moistening agent), in tobacco products. In processing tobacco, glycerin makes up an important part of the casing solution, which is sprayed into the tobacco before the leaves are shredded and packed. When processing chewing tobacco, glycerin adds sweetness and prevents dehydration. It is also used as a plasticizer in cigarette papers.

Glycerin is used in cough medicines and anaesthetics, for ear treatments, and in bacteriological media. In cosmetics, glycerin is a favorite in keeping the skin soft and is used in body and shaving creams. It is the basic material in which toothpaste is formed and preserves the desired smoothness and viscosity of the paste. Glycerin acts as a plasticizer and a humectant when used in the production of sheets and gaskets made with ground cork.

It is used in antifreeze fluids for automatic sprinkler systems, defrosting for glass, de-icing, and in electrolytic fluids for making galvanized cloth and lightning arrestors. It is found in cement compounds, particularly in glycerin litharge cements for tubs and sinks, valve repair, still and distilling unit repair and anti-acid corrosion, pipe joint cement, furnace cement, and rethreading compounds. Other uses include embalming fluids, masking and shielding compounds for paint spraying, soldering compounds, high pressure rod packing, lubricants for air brakes, the manufacture of mercury thermometers, engine gauges, electrical equipment, and oil refinery equipment. Glycerin is found in cleansing materials such as soaps and synthetic detergents. It is used as a wetting agent in emulsifiers, wax emulsions, and skin protectives. In laboratory and research work glycerin is utilized in the manufacture of reagent chemicals, basic dyes, and miscellaneous chemicals and insecticides; in asphalt compounds, coal-tar thinners, ceramics, photographic products, fire retardants, modeling clay, leather and wood treatments and adhesives.

Glycerin is also a source of lecithin and of tocopherols (vitamin E). In the production of food, it is used as a solvent, a moistening agent (for example, in baked goods), and an ingredient in syrups. In flavoring and coloring, glycerin acts as a solvent and its viscosity lends body to the product. With candies, glycerin prevents crystallization of sugar. It improves the texture and allows the use of less sugar, in ice cream [16].

Conclusions

The rapidly expanding biodiesel industry collects millions of liters (residual glycerin obtained in this process represent 10% of the weight of the prime material used) of crude glycerin per year as a by-product and most of this glycerin is disposed of as waste glycerin.

This research is based on developing an improved and fundamental understanding of technology that will allow the crude glycerin to be processed.

The study of this methods had been stimulated by two factors, the economical factor (from processing glycerin are obtain many valuable compounds for chemical industry) and the second, is represented by the impact on environment (the problem of disposed of waste glycerin is solved).

References

1. http:// www.eetcorp.com
2. Koller, M., Bona, R., Braunegg, G., Hermann, C., Horvat, P., Kroutil, M., Martinz, J., Neto, J., Pereira, L., Varila, P. – Production of polyhydroxyalkanoates from agricultural waste and surplus materials. *Biomacromolecules* 6(2), 2005, p. 561-565.
3. Papanikolaou, S., Aggelis, G. – Modelling aspects of the biotechnological valorization of raw glycerol: Production of citric acid by Yarrowia lipolytica and 1,3-propanediol by Clostridium Butyricum, *Journal of Chemical Technology and Biotechnology* 78(5), 2003, p. 542-547.
4. Wang, J.F., Xiu, Z.L., Liu, H.J., Fan, S.D. – Study on microaerobic conversion of glycerin to 1,3- propanediol by Klebsielle pneumonia, *Modern Chemical Industry* 21(5), 2001, p. 28-31.
5. Wang, K., Hawley, M.C., DeAthos, S.J. – Conversion of glycerol to 1,3-propanediol via selective dehydroxylation, *Industrial and Engineering Chemistry Research* 42(13), 2003, p. 2913-2923.
6. Perosa, A., Tundo, P. – Selective hydrogenolysis of glycerol with raney nickel, *Industrial and Engineering Chemistry Research* 44(23), 2005, p. 8535-8537.
7. Garcia, R., Besson, M., Gallezot, P. – Chemoselective catalytic oxidation of glycerol with air on platinum metals, *Applied Catalysis A: General* 127(1-2): 165, 1995.
8. Bories, A., Claret, C., Soucaille, P. – Kinetic study and optimisation of the production of dihydroxyacetone from glycerol using Gluconobacter oxydans, *Process Biochemistry* 26(4), 1991, p. 243- 248.
9. Lee, P.C., Lee, W.G., Lee, S.Y., Chang, H.N. – Succinic acid production with reduced by-product formation in the fermentation of Anaerobiospirillum succiniciproducens using glycerol as a carbon, *Biotechnology and Bioengineering,* 72(1), 2001, p. 41-48.
10. Clacens, J.M., Pouilloux, Y., Barrault, J. – Selective etherification of glycerol to polyglycerols over impregnated basic MCM-41 type mesoporous catalysts, *Applied Catalysis A: General,* 227(1-2), 200, p. 2181-190.
11. Stumbe, J.F., Bruchmann, B. – Hyperbranched polyesters based on adipic acid and glycerol, *Macromolecular Rapid Communications* 25(9), 2004, p. 921-924.
12. Villeneuve, P., Foglia, T.A., Mangos, T.I., Nunez, A. – Synthesis of polyfunctional glycerol esters: Lipase-catalyzed esterification of glycerol with diesters, *Journal of the American Oil Chemists' Society* 75(11), 1998, p. 1545-1549.
13. Ito, T., Nakashimada, Y., Senba, K., Matsui, T., Nishio, N. – Hydrogen and ethanol production from glycerol-containing wastes discharged after biodiesel manufacturing process, *Journal of Bioscience and Bioengineering* 100(3), 2005, p. 260-265.
14. Valliyapan, T. – *Hydrogen or syn gas production from glycerol using pyrolysis and steam*, M.S thesis. Saskatoon, Saskatchewan, University of Saskatchewan, Department of Chemical Engineering, 2004.
15. Nenitescu, C. D. – *Chimie Organica*, vol. 1, editura Didactica si Pedagogica, Bucuresti, 1990.
16. http://www.acme-hardesty.com

Direcții de utilizare a glicerinei rezultată la sinteza biodieselului

Rezumat

Dezvoltarea recentă a producției de biodiesel a adus temeri privind o supraalimentare cu glicerină pe piață. Producția de biodiesel a jucat un rol important în aceste schimbări şi ar putea juca un rol şi mai mare în viitor pentru această piață. Prin urmare, această lucrare prezintă în mod critic diferite metode experimentale de utilizare a glicerinei rezultată la sinteza biodieselului.