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Biodiesel and its Production: Renewable Source of Energy

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Abstract

Depletion of fossil fuels at an alarming rate in past few decades in association with global warming has led to the search of an alternative fuel which could fulfill the demand of energy, worldwide. In addition to this, it should also be renewable, sustainable and eco-friendly. Biodiesel has emerged as one of the promising options for replacing conventional fuels. Numerous factors like renewability, non-toxicity, biodegradability, less pollutant emission when compared to conventional diesel are responsible for the overall acceptance of biodiesel as an alternative. It is usually produced from vegetable oil, animal fats, non-edible oil, waste cooking oil, and microorganisms (microalgae, yeasts etc.). The uses of these feedstock, especially non-edible oil, waste cooking oil, and oleaginous microorganisms are cost effective and gained considerable attention in research field. In this respect, numbers of researches are done to investigate the better way of producing biodiesel as an alternative fuel. Accordingly, this review paper examines the latest technologies used for biodiesel production.

Keywords: Biodiesel, Feedstock, Production parameters, Transesterification, Energy sources.

Introduction

The world's total energy consumption has been significantly increasing due to increase in population, which causes enormous impact on environment all over the world. The crude oil import of India has increased steadily in last economic year. Demand of transportation of fuels was 124 billion liters in 2015 and is possible to reach 202 billion by 2024. Based on the international energy outlook 2016 projection, the total world consumption of marketed energy increases by 48% from 2012 to 2040. The fossil fuel demand is facing two major challenges, scarcity of the resources and its negative environmental effect. The environmental effects are additional points to strengthen the concept of replacing the fossil fuels with renewable energy sources. Many researchers are investigating an alternative energy sources, among which biodiesel is getting more importance (Gaurav et al. 2016; Olkiewicz et al. 2016; Mandolesi et al. 2013).

Biodiesel is a biomass derived fuel that is considered to be the most promising petroleum diesel fuel alternative. It is biodegradable, non-toxic, sulphur free, and non-aromatic fuel (Tomić et al., 2015). Chemically, biodiesel is a mixture of monoalkyl ester of long chain fatty acid, i.e. fatty acid methyl ester (FAME) produced from alcoholysis of triacylglycerol from a lipid feedstock (Banković-Ilić et al., 2012). It can be produced from wide variety of resources including, waste cooking oil, animal fats, non-edible plants and microorganisms i.e. microalgae, yeast, bacteria etc. In addition, there are numbers of latest technologies to produce biodiesel in minutes depending on the quality of feedstock (Talebian-Kiakalaieh et al., 2013; Sharma et al. 2008; Datta and Mandal 2016). When it is compared to fossil fuels, biodiesel is far better, as it has no sulphur, having less carbon monoxide, particulate matter, smoke and hydrocarbons and has more free oxygen than petrol diesel (Srivastava and Prasad, 2000). Because of the presence of free oxygen, complete combustion takes place resulting in reduced emission. The production of biodiesel resources can provide energy security to country (Tomić et al. 2015; Banković-Ilić et al. 2012). The best part of biodiesel is that it can be used in any ratio in any diesel engine with little or no necessary engine modification (Talebian-Kiakalaieh et al., 2013).

Biodiesel feedstock

There are various feedstocks for the production of biodiesel which affect various factors including cost, yield, purity and composition (Demirbas, 2009). The various sources include edible oils, non-edible oils, and other sources like waste cooking oils, animal fat, and oleaginous microorganisms (Gurunathan and Ravi, 2015). The most commonly used edible oils are soybean oil (Karmakar et al., 2010; Aarthy et al., 2014; Anr et al., 2016, Hashmi et al., 2016), palm oil (Kaur and Ali, 2013), rapeseed oil

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(Wen et al., 2010; Hu et al., 2011), coconut oil (Abraham et al., 2015), sunflower oil (Bet-Moushoul et al., 2016; Rashtizadeh and Farzaneh, 2013; Rafiee et al., 2013; Istadi et al., 2015), mustard oil (Chen et al., 2012), olive oil (Halek and Delavari, 2013; Dias et al., 2013), peanut oil (Naik et al., 2008; Baskar and Aiswarya, 2015) and canola oil (Takase et al., 2014; Morshed et al., 2011). Soybean oil is one of the major sources of biodiesel in the United States, while palm and rapeseed oil are major sources in Europe and in tropical countries (Singh and Singh, 2010). Non-edible sources are linseed oil (Gurunathan and Ravi, 2015; Karmakar et al., 2010), castor oil (Tomić et al., 2015; Antolín et al., 2002; Luz et al., 2011), stillingia oil (Chinese tallow seed oil) (Zhang et al., 2003; Cea et al., 2015), neem oil (Vallinayagam et al., 2014, Gurunathan and Ravi 2015), jatropha oil (Teo et al., 2015; Tahvildari et al., 2015) and karanja oil (Li et al., 2008; Yahyaee et al., 2013). The oleaginous microorganisms include microalgae (*Scenedesmus obliquus*, *Cholerella vulgaris*, *Scenedesmus dimorphus*, and *Botryococcus braunii*,) and yeast species (*Rhodotorula glutinis*, *Rhodotorula minuta*, *Saccharomvces cerevisiae*, and *Lipomyes starkeyi*). During certain period of time, biodiesel was mostly prepared from conventionally grown edible oils such as rapeseed, soybean, sunflower and palm oil, which severely affected food security, and they are also expensive to be used as fuel and require high arable land for cultivation. The use of non-edible plant oils i.e. waste cooking oil, jatropha oil, neem oil, when compared with edible oils is very significant in developing countries. In last few years, non-edible sources gained more attention towards the researcher for the production of biodiesel due to their high productivity, high efficiency of producing lipid, reduction in raw material price and avoiding competition with the food sources (Vallinayagam et al., 2014; Istadi et al., 2015) and act as substantial source for biodiesel production (Wang et al., 2009). In addition, data reveals that the non-edible oil has higher unsaturated fatty acid and presence of these acid leads to decrease the stability of biodiesel production as it is oxidized rapidly, resulting in poor cold flow properties, which makes it harder to use in colder climate conditions. To overcome these issues, there are other precursors for biodiesel production including microalgae (Gaurav et al., 2016; Singh and Singh, 2010; Yahyaee et al., 2013) and oleaginous yeasts.

Microalgae are new promising sources of biodiesel after edible plant oils. These are photosynthetic microorganisms have simpler structure which allow them to grow rapidly (Li et al., 2008). Some species of microalgae can produce and accumulate hydrocarbons up to 30–70% of their dry weight under optimum conditions, as compared to edible plant oil (Patil et al., 2008; Chisti, 2007). On the basis of climatic condition, it can be grown throughout the year. These microorganisms have ability to grow in small arable land with minimum nutrient requirement (Kong et al., 2007). The harmful gases generated from the petroleum or diesel fuel i.e. high concentration of CO_2, greenhouse gases (GHG), nitrogen dioxide and pollutants in the atmosphere act as nutrients for algae (Negoro et al., 1991). Despite these advantages, high cost and high energy demands for producing microalgae is a major challenge. High temperature and climate condition also lead to significance decline in productivity. Many microalgae can tolerate temperature of up to 15ºC, while increasing temperature above 15ºC or higher causes death of cell. Also, in closed system, when hot days reaches its maximum i.e. up to 50ºC, low productivity of lipid occurs. Whereas, *Rhodotorula* species i.e. (*Rhodotorula glutinis*, *Rhodotorula minuta*, *Rhodotorula mucilaginosa*, *R. rufula*, *R. gracilis*) as oleaginous yeasts are capable of producing and accumulating over 20% of lipids in dry cellular substance (Ratledge and Cohen, 2008; Fickers et al., 2005). These oleaginous microorganisms are unicellular, have higher growth rate and various cheap agricultural raw materials utilization capability. *Rhodotorula* species have the potential application for the industrial lipid production. Certain strains of yeasts (*Metschnikowia gruessii*) accumulate high levels of intracellular lipids (34% oil by dry weight) and have ability to grow in medium containing waste products as growth nutrients (whey and bran) and faster growth rate. Yeast shows advantages in term of its potentially faster growth, high oil content, and high lipid yield in low pH and temperature as compared to microalgae.

Biosynthesis of triacylglycerol in plant and microalgae

Generally, in all plant cells the fatty acid synthesis occurs in an organelle called plastids, whereas in other eukaryotic microorganism it occurs in cytoplasm of the cell. There are two main pathways involved in lipid accumulation in plants, i.e. fatty acid synthesis and triacylglycerol formation.

Fatty acid synthesis in plant and microalgae

In plants and microalgae, glucose is converted into pyruvate in glycolysis cycle, then pyruvate transfer within plastid to form acetyl-CoA with pyruvate dehydrogenase enzyme and then irreversible carboxylation of acetyl-CoA occurs with acetyl- CoA carboxylase to form malonyl- CoA. This malonyl- CoA then produces malonyl- CoA-ACP (acyl carrier protein) with enzyme malonyl-CoA ACP transacylase. Malonyl- CoA-ACP is converted to 3 keto-acyl ACP- CoA with ketoacyl ACP reductase (Figure 1). This 3 keto acyl ACP forms 3 hydroxy acyl ACP-CoA with help of enzyme ketoacyl ACP reductase. In this reaction ketonic group is converted into hydroxyl group (Thelen and Ohlrogee, 2002). In another reaction, 3 hydroxyl acyl ACP-CoA with hydroxyacyl ACP dehydrase form 2,3-trans enoyl ACP/CoA and after that this 2,3-trans enoyl ACP/CoA combine with enzyme enoyl ACP reductase to forms Acyl-ACP-CoA. After the formation of acyl ACP-CoA, the repeated condensation of malonyl CoA, the ACP- bound acyl chain with enoyl acyl ACP reductase, enoylacyl ACP hydratase enzyme, consecutively adding two carbon units to form 16: 0 ACP, then the elongation of 16:0 ACP with the help of enzyme, ketoacyl ACP reductase, ketoacyl ACP synthase, hydroxyacyl ACP dehydrase and enoylacyl ACP reductase, form C18:0 ACP. Further these C18:0 ACP desaturate to form C18:1 ACP, when combine with enzyme called, stromal stearoyl ACP desaturase, this enzyme catalyses the 18:0 ACP to 18:1 ACP, which is the key steps for regulating unsaturation levels of fatty acid in the cells.

Triacylglycerol formation in plant and microalgae

These newly synthesis fatty acids are then exported from plastid as acyl ACP thioesters to enter the eukaryotic glycerolipids synthesis pathway. After entering in endoplasmic reticulum, the acyl ACP CoA is used for the sequential acylation of glyceraldehyde 3 phosphate from dihydroxyacetone phosphate with enzyme glycerol phosphate dehydrogenase, and this glyceraldehyde 3 phosphate produces lisphosphatidate with help of enzyme glycerol 3 phosphate acyl transferase and then lisophatidate with enzyme 1 acylglycerol 3 phosphatidate acyl transferase produces phosphatidic acid, and are then converted to 1,2-diacylglycerol by phosphatidate phosphatase. (Ratledge and Cohen, 2008) Then the third acyl CoA dependent acylation catalyzes by diacylglycerol acyl transferase leads to the production of triacylglycerol (i.e. fatty acid incooperated onto the glycerol backbone.)

Biosynthesis of fatty acid and triacylglycerol in oleaginous yeast

All microorganisms are capable of producing lipids, though only the oleaginous yeast strains have the capability of accumulating lipid inside their cells. Acetyl CoA, is the basic unit of fatty acid synthesis. (Ratledge and Wynn, 2002). The biochemistry of de novo lipid biosynthesis is divided into two distinct parts, the intermediate cellular metabolism and the biosynthesis of triacylglycerol.

The net product of glycolysis is initiated through glucose as a carbon source in cytoplasm of the yeast cell, in which glucose is converted into glycerol 3 phosphate with enzyme, glycerol kinase enzyme, and glycerol 3 phosphate form dihydroxyacetone phosphate with glycerol 3 phosphate dehydrogenase enzyme. After the production of dihydroxyacetone phosphate, itconverts it to pyruvate, that passes through the mitochondrial membrane to mitochondrial matrix. Pyruvate dehydrogenase catalyzes the formation of acetyl-CoA from pyruvate and acetyl-CoA transported via two ways, either enters inside krebs cycle or transported again into cytoplasm to enhance biosynthesis of cellular fatty acids. (Papanikolaou and Aggelis, 2011). In krebs cycle, the acetyl- CoA, that act as the intermediate precursor of intracellular biosynthesis of fatty acid derives from the breakdown of citrate, that has been accumulated inside the mitochondria, i.e. acetyl CoA with the help of enzyme citrate synthase form citrate, these citrate again transported into the cytosol and with help of enzyme, ATP citrate lyase, produces acetyl CoA and these cycle is called as citrate-malate translocation (Mlicˇkova et al., 2004). In this reaction oxaloacetate, is the key ingredient for producing citrate and malate both, when citrate combines with enzyme pyruvate carboxylase it forms oxaloacetate and with malate dehydrogenase it also forms oxaloacetate and these cycle continuous produce acetyl CoA from mitochondria to cytosol.

After that, acetyl CoA carboxylase enzyme, helps in the formation of malonyl CoA from Acetyl CoA. Then further elongation of malonyl CoA produces, malonyl CoA ACP with help of enzyme, malonyl CoA ACP transacylase. These malonyl CoA ACP transported to glycerolipids pathway, where glucose is converted into dihydroxyacetone phosphate via glycolysis and glyceraldehyde 3 phosphate produces from dihydroxyacetone phosphate with enzyme glycerol phosphate dehydrogenase, and this glyceraldehyde 3 phosphate produces lipophosphatidic acid with help of enzyme glycerol 3 phosphate acyl transferase and then lipophosphatidic acid with enzyme 1 acylglycerol 3 phosphate acyl transferase produces phosphatidic acid, and are then converted to 1,2-diacylglycerol by phosphatidate phosphatase (Figure 2). (Mlicˇkova´ et al., 2004).Then the third acyl CoA dependent acylation catalyzes by diacylglycerol acyl transferase leads to the production of triacylglycerol.

Technology for biodiesel production

There are various processes which have been developed for the production of biodiesel from different feedstock. The range of latest or modified technologies has been designed for biodiesel synthesis (Aransiola et al., 2014). The methods include pyrolysis or thermal cracking, Microemulsion, dilution, reactive distillation technology, supercritical fluid methods, catalytic distillation, and transesterification.

Direct use or blending process

The vegetable oil can be used as a fuel in direct injection engines or in blended form. The advantages of this process are, it has a liquid nature-portability, heat content (80% of diesel fuel) and renewability (Kaya et al., 2009). Biodiesel are blend with diesel for reducing the emissions of harmful gases, i.e. CO, SO_2, nitrate compound, polycylic aromatic hydrocarbon and particulate matter.

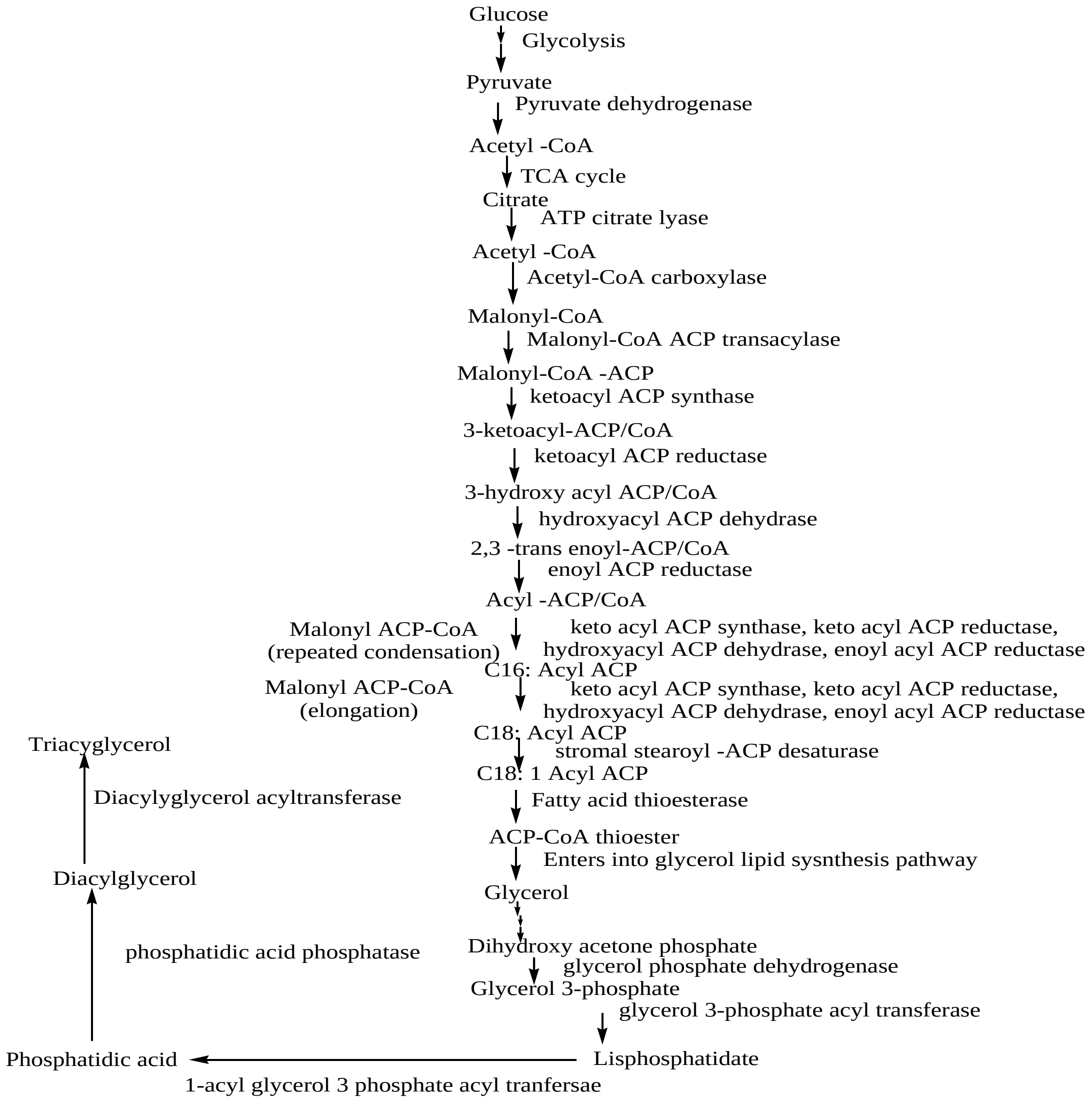

Fig. 1: Biosynthesis of fatty acid and triacylglycerol in plants and microalgae

They are classified into different blend, depending upon their percentage. For example; 100% blend, where pure biodiesel is present, 80% blend (20% diesel and 80% of biodiesel) 20% blend (80% diesel and 20% biodiesel) and 5% blend (only 5% biodiesel mix with 95% diesel). The most common blended biodiesel is B20 which have similar fuel consumption, efficiency as compared with conventional diesel. B20 also reduced particulate emission by 10%, carbon monoxide by 11% and unburned hydrocarbon by 21%, while there is some drawback of B20 blended biodiesel, as it become crystalline in cold temperature and is more critical for fuel engine to work properly. While blending of 5% biodiesel and below has a small impact on diesel engine. The blended biodiesel also have some disadvantage i.e lower volatility, carbon deposits, renewability, reactivity of unsaturated hydrocarbon chains, lower cetane number, oil ring sticking and thickening and gelling of the lubricating oil as a result of contamination by the vegetable oil due which it cannot be used directly in diesel injection engine, it requires modification (Issariyakul et al., 2008; Kansedo et al., 2009; Tiwari et al., 2007).

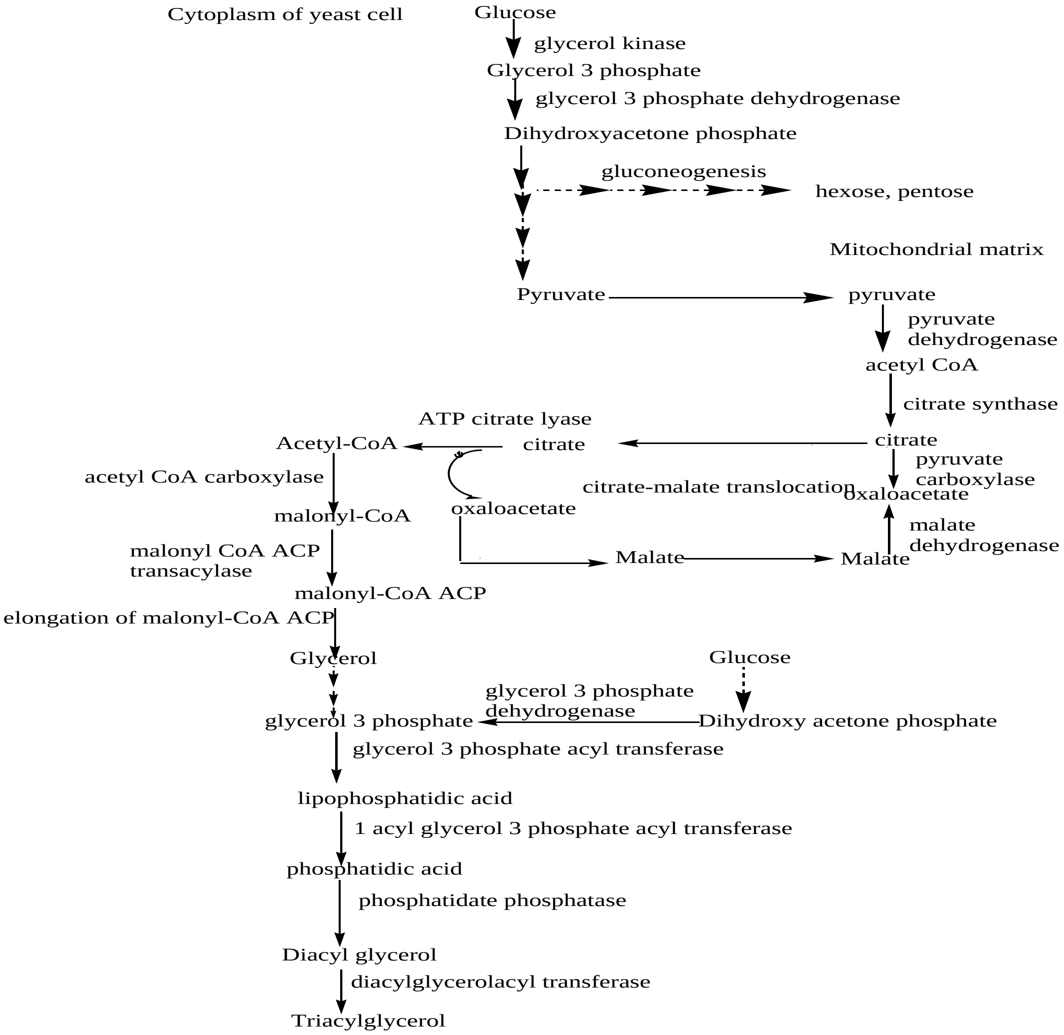

Fig. 2: Biosynthesis of fatty acid and triacylglycerol formation in oleaginous yeast

Thermal cracking or pyrolysis

In thermal cracking or pyrolysis process, organic materials are converted to biofuel in the absence of oxygen at very high temperature. The pyrolysis material can be vegetable oils, animal fats and natural fatty acids. The pyrolysis of vegetable oil ie. (sunflower oil, palm oil, soybean oil etc.) was shown to synthesize petroleum from vegetable oil. Most studies reported that the equipment used in thermal cracking and pyrolysis is way too expensive, while the fuels obtained using this process includes lower flash point, pour point and viscosity. They have considerable amounts of sulphur, carbon, moisture, and sediments (Baskar and Aiswarya, 2015; Aransiola et al., 2014).

Microemulsion

Microemulsion are colloidal dispersion, thermodynamically stable and transparent with diameter range from 100 to 1000 Å. Microemulsion can reduce high viscosity of oil. The oil is mixed with alcohol such as methanol, ethanol, propanol or butanol to form emulsion (Gaurav et al., 2016). All microemulsion can improve spray characteristic. The main disadvantages with the use of microemulsion, there is incomplete combustion, lower cetane number and energy content and the deposition of carbon in engine (Ma and Hanna, 1999).

Microwave technology

Microwave technology can be used to enhance the yield of biodiesel by transesterification process in the presence of catalyst with reduction of reaction time. It was successfully applied to transform waste frying oil into biodiesel (Ayas and Yilmaz, 2013). Microwave irradiation are electromagnetic irradiation with range of wavelength from 0.01 to 1.0 m. Domestic microwave oven operate at wavelength of 12.25 cm and corresponding frequency is 2.45GHz. This technology enhance the chemical reaction because it transfer energy (heat) directly to the reactant and heat transfer is more than conventional process, reactions are fast and can be completed in shorter time (Lidstrom et al., 2014) and makes the separation process easier.

Reactive distillation

Reactive distillation, a multifunctional reactor system involves the integration of chemical reaction and separation simultaneously in a single column. Transesterification of vegetable oil to fatty acid methyl ester (biodiesel) is an equilibrium reaction or reversible process. The easy way to make it irreversible to use excess methanol for high degree conversion of vegetable oil, but in reactive distillation, unreacted or excess methanol was vaporized and vapour are again recirculated in the column and utilized in reactive zone. This technology significantly reduces the methanol to oil ratio and result in an easy separation of biodiesel (Niju et al., 2014). Transesterification of palm oil with methanol in the presence of KOH catalyst was performed in reactive distillation (Prasertsit et al., 2007).

Supercritical technology

Supercritical technology is an innovative approach for non-catalytic synthesis of biodiesel from triglycerides. This technology can be employed for transesterification, esterification and oil extraction (Aransiola et al., 2014; Lee and Saka, 2010). Supercritical fluids (SCF) are fluids when its temperature and pressure is higher than critical temperature (T_c) and pressure (P_c), respectively. Biodiesel can be synthesized by SCF by single and two-step process. In single-step, biodiesel can be directly synthesized by triglycerides through typical transesterification process, while, in two-step SCF process triglycerides are first hydrolyzed into free fatty acid (present in upper portion) and glycerol (lower portion contains water and glycerol) under supercritical water. In the next step; free fatty acid are esterified with supercritical methanol (T_c = 239.4ºC; P_c = 8.1 MPa). In single-step, (methanol and ethanol) and fluid (methyl acetate and dimethyl carbonate) have been employed for biodiesel synthesis. Supercritical methanol was first evaluated for production of biodiesel. Madras et al (Madras et al., 2004) evaluated the synthesis of biodiesel from sunflower oil, and mixed this feedstock with methanol to oil ratio of 40:1 at temperature and pressure of 200-400ºC and 20Mpa respectively. They achieved 96% of fatty acid methyl ester within 40 minutes of reaction time. The main drawbacks of single-step SCF are high temperature, high molar ratio of alcohol to oil ratio and harsh condition consume large amount of energy. To decrease this harsh condition, two-step SCF can be employed for biodiesel production. The major disadvantage of supercritical technology, it requires high energy demand to achieve supercritical condition (Tan and Lee, 2011), corrosion and salt deposition (Wen et al., 2009).

Biox process

The rate of conversion of oil to ester is very slow process due to low solubility of alcohol (methanol) in oil. The use of co-solvent (tetrahydrofuran), increases the rate (speeds up methanolysis), reduces the reaction time and no residue present in ester or glycerol phase (Van Gerpen et al., 2004; Demirbas, 2008; Boocock et al., 1996). Tetrahydrofuran, soluble in alcohol and oil, requires low operating reaction time, after the completion of reaction, biodiesel separation is clean and both alcohol and co-solvent are removed separately (Demirbas, 2008). The Biox process (co-solvent system) can be used for various feedstocks; waste cooking oil, and animal fat. However, due to toxicity and hazard of co-solvent it should be completely removed from biodiesel and glycerol phase. The boiling point of co-solvent is similar to alcohol so recovery of excess alcohol is also difficult.

Catalytic distillation

Catalytic distillation (CD), a green reactor technology which carried out chemical reaction and product separation into a single unit (A. Gaurav et al., 2016). In single unit operation, CD reduces operating cost, save significant energy, increases product yield and productivity due to continuous removal of product from reactive section via distillation (A. Gaurav et al, 2013; B. M. Goortani et al., 2015). The potential advantages of catalytic distillation include; first, the transesterification process is exothermic process and energy liberated during this process can be utilized to drive distillation process. Second, transesterification process is reversible; to achieve the maximum yield (product) the chemical equilibrium should be shifted right towards product. CD removes the product continuously from reaction zone and shift chemical equilibrium towards right (F. Ma, and M.A. Hanna, 1999).

Transesterification

The most widely used technology for biodiesel production is transesterification of oil or fat using alcohol (methanol) in presence of catalyst (Amrik and Gaurav, 2018; Demirbas, 2009; Woodford et al., 2014; Hashmi et al., 2016). Generally, transesterification is reversible with the involvement of three mole of alcohol and one mole of triglyceride to produce one mole of glycerol and three mole of methyl ester, but the simplest way to make it irreversible is to use excess alcohol (Tariq et al., 2012). Alcohols are key substrate in the process of transesterification process and commonly used alcohols are methanol, ethanol, Butanol, propanol and amyl alcohol, but methanol is widely used due to its low cost. Mixing of oil with alcohol unable to form single phase due to poor surface contact between them and reaction to proceed relatively low in absence of catalyst, while in presence of catalyst it increases reaction rate, biodiesel yield and improve the contact between reactant. The catalyst used in biodiesel production are alkali, acid or enzyme (Singh and Singh, 2010; Aransiola et al., 2014; Qiu et al.; 2011). The selection of catalyst depends on free-fatty acid content in fat or oil (Mahmudul et al., 2017; Verma and Sharma, 2016). If free –fatty acid content is low (0.5 to less than 3% of the oil), alkali (NaOH, KOH etc.) (Abbaszaadeh et al., 2012) is better option and while in high free-acid content acid-catalyzed esterification (includes sulfuric acid, hydrochloric acid, slufonic acid and phosphoric acid) followed by alkali-catalyzed transesterification is suitable and to avoid saponification. Alkali-catalyzed reaction is faster than acid-catalyzed reaction (Talha NS, Sulaiman, 2016). Enzymatic catalysts are insensitive to fatty acid content. Enzyme-catalyzed transesterification is mediated by lipase enzyme, produced by microorganisms, plant and animals (Amrik and Gaurav, 2018). This catalysis is employed with wide range of feedstock with high free fatty-acid content. (0.5% to 80%). To increase biodiesel yield and reduce reaction time, transesterification can be coupled with ultra-sound and membrane technology.

Ultrasound-assisted transesterification

Ultrasound-assisted transesterification creates cavitation of bubbles near the boundary of oil and alcohol phase. It increases the mass transfer rate and reaction time which in turn high yield of biodiesel and requires less energy consumption compared to conventional stirring method (Amrik and Gaurav, 2018; Fan et al., 2010). The yield of fatty acid methyl ester (FAME) was greater than 99% during transesterification of canola oil with ultrasound irradiation and reaction time was 50 minutes (Thanh et al., 2010). The major disadvantage of this process is in downstream processing. After the transesterification process, biodiesel is washed with water to remove excess catalyst and generating large amount of waste water. This process increases the purification cost to remove soap, catalyst and glycerin (Santos et al., 2009).

Membrane technology

Membrane technology involves transesterification and separation of products in a single process and it reduces sepration cost. Membrane can be organic or inorganic but inorganic membrane shows excellent thermal stability (Aransiola et al., 2014; Atadashi et al., 2011) and efficiently remove glycerol as soon as they are formed (Aransiola et al., 2014; Ko et al., 2012). Membrane bound transesterification can be used for palm oil, canola oil and yellow grease (Cao et al., 2009). The selectivity parameters of membrane are pore size (0.5 to 0.05µm) and their chemical affinity.

Current scenario of biodiesel production in India

Biodiesel offers several significant benefits in addition to providing energy security and reduced dependency on fossil fuel imports. Some of them are reduced green house gas emissions, good fuel properties for vehicles, increased employment in the agricultural sector etc. Biodiesels are classified into different generations based on the feedstock used for its production. First generation biodiesel used edible oil such as soya bean oil or palm oil as feedstock whereas second generation biodiesel uses non edible oil like Jatropha and Pongamia as feedstock. India depends upon imports of palm oil and other vegetable oils to meet the domestic demand to a large extent. So, in India, they cannot be used for biodiesel production. Whereas, use of non edible oil crops as feedstock does not compete with food requirement and can be easily grown in unused or waste land. Therefore, In India, biodiesel is produced mainly from the non-edible oils extracted from the seeds of plants like Jatropha, Pongamia, Mahua, Sal, Neem etc. Extensive research has shown Jatropha and Pongamia as future hope for biodiesel production in India. The government of India is also making various policies to facilitate biodiesel production. The constitution of National Biofuel Mission (NBM) in 2003 is one example. NBM made an effort on focusing on cultivation of Jatropha and Pongamia crop for large scale production in forest and wasteland and due to which India become the third largest in Asia having highest cultivation area of length about 3 million km which is used for growing the Jatropha and Pongamia crop for biodiesel production by improving its soil erosion and fertility. The annual productivity of biodiesel of around 45,000 tons from jatropha can reach about 2 million tons per year. In 2008, the Ministry of New and Renewable Energy (MNRE) formulated 'The National Bio fuel Policy' which explores job opportunities and rural development associated with biofuel production. This policy also states that the research and development should be focused on the plantation, production and processing of biodiesel. "National Network on Jatropha and Karanja" was formed in 2004 where various institutes such as Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR), State Agricultural Universities (SAUs), The Energy Research Institute (TERI), Central Food Technological Research Institute (CFTRI), Indian Institute of Technology (IIT, Delhi) and Indian Council of Forestry Research and Education (ICFRE) are involved. In addition to the efforts taken by central government at the national level, various state governments are also promoting biodiesel production by formulating various policies and programmes. Further, the new policy also decreases GST from 18% to 12% on the price of biodiesel. With the intention of promoting biodiesel, Government of India is exploring the use of a 5% biodiesel blended with diesel in railways and defense establishments.

Conclusion

The increasing demand for an alternative fossil fuel encourages researchers around the world to seriously consider biodiesel, which is an auspicious renewable source of energy. It is biodegradable, non-toxic, ecofriendly, and emits less pollution, which makes it a more attractive option towards renewable sources of energy. Present review article helps to identify the advance developments and challenges in field of biodiesel. Further, transesterification can be coupled with microwave energy as a heat source or combined with ultrasound helps in higher yield of biodiesel, while enzymatic method for feedstock with high free fatty acids content. Another important concern for large scale production is the selection of feedstock, which is a key parameter in biodiesel production. There are various feedstocks i.e. edible oil, non-edible oils, microalgae, oleaginous yeast, animal fats which act as promising sources for biodiesel production. According to report oleaginous yeast, (*Rhodotorula, Saccharomvces, Lipomyesi*) gaining much more attention due to its higher yield of lipid content as compared to microalgae. In additional to that more investigation is needed to overcome small challenges related with the non-edible feedstock which help to determine the proper method for biodiesel production, to make the production efficient and easier.

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