Chapter 6
Utilization of Waste Animal Fat for Sustainable Biodiesel Production

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Abstract Rising demand of diesel fuel of this high-traffic world compels us to produce more and more fuel which is not eco-friendly practice, so another way to achieve our goal safely is to produce biodiesel which is not only an alternative but also an excellent substitute. In other words, production of conventional diesel severely affects the environment and economy of country. In Pakistan, the major consumer of this imported petroleum fuel is transport sector. In 2010, this sector produced 8.0 $GtCO_2eq$ of direct greenhouse gas emissions which were about 24% of total energy-related CO_2 emissions. This chapter fundamentally reviews the certitudes and anticipation of biodiesel generation along with its effectiveness in reducing the consumption of petroleum-based fuels and resultant contaminated environment in Pakistan. A wide range of feedstock including animal fats and soybean oil can be efficiently used for biodiesel synthesis.

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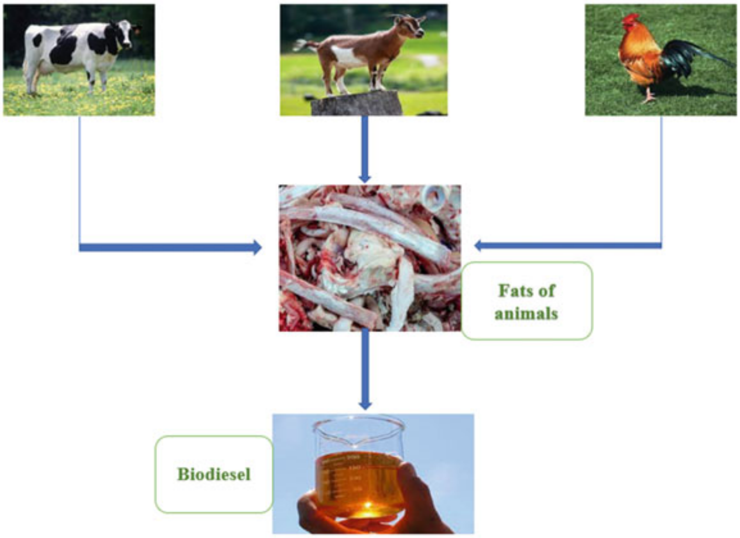
Graphical Abstract



Keywords Biodiesel · Feedstocks · Greenhouse gases · Sustainable energy · Transport sector · Transesterification

6.1 Introduction

Energy constitutes an indispensable entity for the maintenance and uplift of human livelihood standards. The global energy consumption has been doubled over the last three decades, and fossil fuels are the 80% of the total energy (Shirazi et al. 2014). Nevertheless, the energy requirements are gradually increasing owing to rapid economic development and progressively rising human living standards. Consequently, the fossil energy reserves are rapidly running down along with the undesirable emissions of greenhouse gases. Moreover, the abundance of fossil energy resources is confined to only certain regions of the world (Ahmad et al. 2011). Modern transport and communication sector can play a major role in achievement of the economic endeavors and globalization through linked routes. Being essential for the carriage and heavy-duty engines, diesel fuel demonstrated the highest distribution rate among the primary trade products in 2010. Globally, about 30% of the total energy yield is supplied to transportation sector and 80% of it is expended by the road transport. Besides, the road transport receives approximately 60% of global oil supply. In fact, all of the energy used in the transportation sector comes from fossil fuels including gasoline, diesel, LPG, and NG. It mainly derives the fossil fuel-based energy from oil (97.6%), whereas the remaining small amount is contributed by LPG or NG (Ali et al. 2012).

Presently, the world is confronted by a challenging issue of global warming. Therefore, the reduction of progressively increasing CO_2 emissions is recommended for controlling the global warming process and preventing its further exacerbation (Alptekin and Canakci 2010). Historically, fossil fuels have been effectively fulfilling the global energy needs in terms of running vehicles and motor engines and controlling power plants. However, the major emission products of fossil fuel including CO_2, HC, nitrogen oxide (NOx), and volatile organic compound (VOC) have been implicated in causing air pollution, smog, and acid rain (Arbab et al. 2013).

The development of sustainable energy sources offers promising solutions to environmental damage and depletion of decomposing plants and animals. Consequently, there is an awful need to explore authentic, eco-safe, economically feasible, and alternative energy resources. Biodiesel produced from botanical and algal sources is a better substitute to conventional diesel. Chemically, biodiesel is an ester-based oxygenated fuel, comprising of mono-alkyl esters of long-chain fatty acids (Alptekin and Canakci 2010; Atabani et al. 2013a, 2015, 2011).

The unburned total hydrocarbons (HC) and polycyclic aromatic hydrocarbons (PAHs) are withdrawn during biodiesel ignition in the diesel engines (Atabani et al. 2011). Additionally, biodiesel combustion can substantially reduce the emission of carbon monoxide (CO) and particulate matter than fossil-based diesel oil (Atabani and Silva César 2014). In addition being produced using renewable resources, biodiesel saves the environment and people from dangerous air pollution (Atabani et al. 2017). Generally, the efficiency of biodiesel is further improved by mixing 20% v/v or lesser amount of fossil fuel (diesel). Biodiesel has been certified by the Environmental Protection Agency (EPA) based upon the compliance with the qualifications for ASTM D6751 (Atabani et al. 2013b).

Similar to other developing countries, Pakistan also needs vigorous and cost-effective transport and logistic sectors for achieving economic development and enhancing export competitiveness. Therefore, the government is committed to modernize the transport and coordination division through implementing an extensive improvement activity and consistent procedure of change supported by investments in the entirety of its sub-divisions (Atabani et al. 2014a).

Apart from boosting the regional economy, renewable generation of biofuels may also augment the overall energy supply and preclude the environmental deterioration (Arbab et al. 2013; Atabani et al. 2014b). Regardless of a slight diminution in performance, biodiesel can be effectively used in combustion engines and boilers without significant alterations. In addition, the biodiesel nearly release no harmful compounds. Moreover, the physical and synthetic attributes of it are that its utilization either all alone or all blended with oil-based diesel with few specialized changes or no alteration (Atabani et al. 2013c). Several technologically advanced nations used it. For that reason, it is a basic need in the developing countries including Pakistan.

Animal fats are considered as waste and can be obtained from slaughter houses. A minute amount of these fats is used by soap industry, and rest fill up the landfills. It was noticed that percentage of biodiesel and oil produced from mutton fat is higher than those produced from the beef fat. KOH, NaOH, and Na metal were used as a catalyst, and KOH gives higher production of biodiesel as compared to NaOH and Na metal after the transesterification process. Characteristics of biodiesel show that it is an appropriate fuel for vehicles (Balat 2011).

The main sources to obtain animal fats are beef tallow, poultry fat, fish oils, and yellow greases. Beef tallow and poultry fat are the main waste animal fat sources for this purpose. Animal's fat is subtracted from different parts of the animal body, like blood, mesentery, and offal including heart, lungs, and intestines. So the fat can be extracted from these parts of the animal via rendering and then stored in a favorable environment (Balat and Balat 2009). The extracted fats can be converted into the fuel by a reaction called transesterification. The reaction can convert fat into the required product and some other by products on the provision of certain essential conditions like temperature, pressure, and catalyst. The obtained product will be purified from the reaction mixture and stored in a suitable place. The fuel is eco-friendly and sustainable.

6.2 Environment and Climate Change

These days, there is a lot of focus on the environmental issues and to the sustainable exploitation of natural resources. Lack of awareness regarding this matter and proper anticipatory measures may account for high economic and environmental losses in the future. Continuous and widespread contamination is damaging the land, air, and water. Pakistan is predominantly an agricultural country where the availability of natural resources also determines the growth trends of agriculture sector. Therefore, improving the nation's ability is highly essential to accomplish naturally supportable financial advancement and meet the prerequisites of present and future generations.

Pakistan is listed among the highest environmentally vulnerable countries. Urbanization has drastically changed the biological system of cities and provincial zones of the country. The national biodiversity is threatened by prompt depletion of natural resources. However, the government is fully committed to many global conventions and protocols for biodiversity conservation. Moreover, Pakistan has also set the objectives of its economic advancement through Vision 2025.

The most dangerous aspect of nature in the twenty-first century is regarded to be atmospheric changes, which have a variety of effects on the environment and human behavior. Many of these effects, including hurricanes and extremely warm waves, may be life-threatening, whereas spreading of weeds may be less harmful. Regardless of its trivial contribution to the overall emission of GHG, Pakistan may still be influenced by the negative consequences of environmental change.

Excessive ice melting at the glaciers results in dry spells and floods. Extensive rise in the frequency and intensity of unusual climate change coupled with unpredictable storms, recurrent floods, and dry seasons is the major concerns. The projected downturn of Hindu Kush-Karakoram-Himalayan ice sheets on account of perilous atmospheric deviation and carbon residue stores from trans-boundary pollution sources will undermine the natural inflow of water into IRS. Besides, the coastal agriculture, mangroves, and breeding area of aquatic fauna are aggrieved by the entry of aqua saline to Indus delta.

Critical geographical position and socio-economic instability have predisposed Pakistan to the detrimental consequences of climate change (German watch, 2011). Moreover, the deficiency of assets and capabilities for corrective measures will further amplify the circumstances. Atmospheric changes enhance the recurrence and harshness of disastrous incidents, e.g., monsoon rainstorms, swamping, and dry seasons. Terrible dry season of duration of 1999–2003, 2 tornados within thirty days in Karachi/Gwadar coasts in 2008, heavy floods during 2010, 2011, and 2012, land sliding, and GLOFS (chilly lake upheaval floods) in the northern areas represent the obvious manifestations of climate change in Pakistan. Under the 10-year NDMP, the institutional limits of surveillance and forecasting are being improved to combat disasters, by supplanting and introducing the climate observation radars at different regions of the country (Balat and Balat 2010).

6.2.1 State of Environmental Air

Rapidly growing human population, increased number of transport vehicles, random infrastructure, and extensive use of low-quality fuels lead to the environmental contamination in Pakistan. The atmospheric data of various cities revealed 2–3.5 times higher concentrations of suspended particulate matter than the threshold limits. The gradually rising expenditure of energy as a result of expanding industrialization, mechanical traffic, and utilization of chemicals tremendously aggravates the urban air quality. Moreover, privatizing the proprietorship of engine vehicles and lack of successfully implementing the vehicle fitness regulations may further augment the air contamination. Besides, the poor fuel consumption efficiency of motorbikes and auto-rickshaws also corresponds to enormous level of noxious gases (Balat and Balat 2010).

6.2.2 Petro-Fuel Emissions—Health Hazards

Road transport is promptly developing, particularly in metropolitan areas, and has been recognized as a critical source of air contamination, with consequent ill-effects on human health (Banković-Ilić et al. 2012; Basha et al. 2009; Behçet et al. 2015).

Analyzing the aggregate data of 50 countries and 35 urban areas indicated comparable per capita rise in vehicles and salaries, with faster procurement rate of personal cars than commercial vehicles (Fig. 6.1). More interestingly, the per capita rise in vehicles was twofold higher than salaries in countries like China, Pakistan, and India (Bhale et al. 2009).

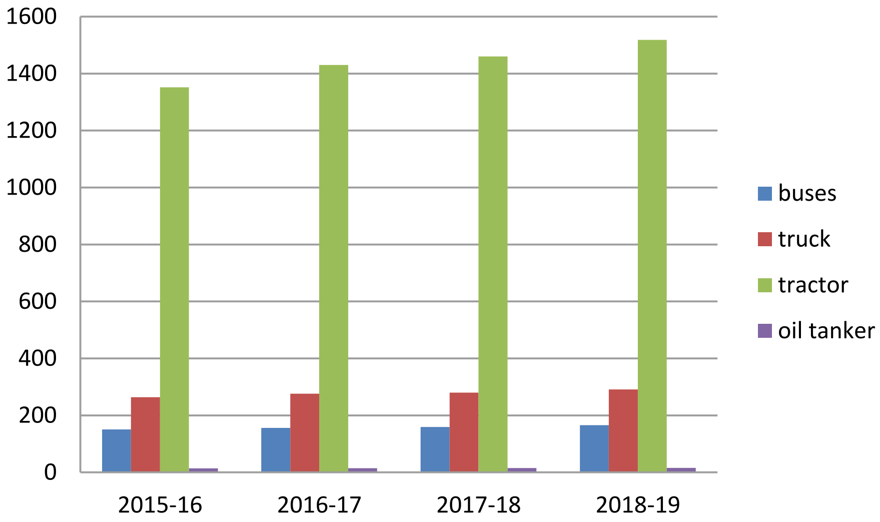


Fig. 6.1 *Source* National Transport Research Centre

Urban transport vehicles are usually fueled by NG, diesel, or gasoline, having different physico-chemical attributes in various regions of the world. Meteorological cosnditions, diverse level of overwhelming polluters (increased number of motorbikes in developing countries), motorways design are regarded as the major confounding factor (Çaynak et al. 2009). Vehicular exhaust emissions are inadequately comprehended and evaluated, particularly in growing nations (Chapagain et al. 2009).

Lead is one of the air contaminants, from human toxicity standpoint. Contrary to industrial regions, the cities of developing countries exhibit relatively higher ambient concentration of fine particulate matter. Diesel-fueled and two-stroke gasoline-powered vehicles are the major sources of fine particulate matter emission. The most noxious air toxins are produced by automobiles. Respiratory problems, pulmonary impairment, pre-term birth, and even mortality are the major consequences of air contamination (Chen et al. 2015). Apart from their diverse toxic effects on human health, these substances are probably carcinogenic (Chhetri et al. 2008) (Table 6.1).

6.3 Potential Feedstock—Biodiesel Achievement in Pakistan

The accessibility and feasibility of feedstock for biodiesel production depend upon the local atmospheric and geological aspects of a country. This wide range of available feedstock can facilitate the advancement of biodiesel industry.

Table 6.1 Health effects of exhaust emissions from automobiles (Cornils et al. 2017; D'Angiola et al. 2010; Demirbas and Biodiesel 2008; Deng et al. 2011)

Exhaust emissions	Detrimental health effects
Carbon monoxide	Besides causing drowsiness, unconsciousness, intra-uterine growth retardation, angina, growth impairment in young children, and death, it also potentiates the toxicity of other pollutants in individuals suffering from respiratory or circulatory disorders
Dioxin	Long-term exposure affects the functions of nervous, endocrine, immune, and reproductive systems
Formaldehyde	Oculo-nasal irritation, coughing, dyspnea, and cancer (as a result of occupational exposure)
Hydrocarbons and other volatile organic compounds	Compounds having low-molecular weight elicit sneezing, coughing, and ocular irritation. High molecular weight compounds may lead to mutagenicity or carcinogenicity
Lead	Inhalation or oral exposure may induce damage to the nervous, circulatory, renal, and reproductive systems; may probably cause hypersensitivity and diminish cognitive ability in children
Nitrogen oxides	Can enhance vulnerability to viral respiratory diseases like influenza and allergic reactions to dust and pollens in asthmatic patients; with typical pathological effects in the form of pneumonia, pulmonary edema, and bronchitis. Most serious health effects are due to their synergistic action with other air pollutants
Ozone	Increased susceptibility to flu and pneumonia; damage to respiratory mucosal membranes associated with coughing and pulmonary dysfunction; exacerbation of asthma, emphysema, bronchitis, and chronic heart disease
PM	Irritation of mucous membranes, pulmonary dysfunction, lung cancer, and death from cardiopulmonary collapse
Polycyclic aromatic hydrocarbons (PAHs)	Lung cancer
Toxic substances	May give rise to birth defects, reproductive problems, and probably cancer. Aldehydes and ketones are ocular irritants, while asbestos and benzene are proven carcinogens

The feedstock for biodiesel generation is selected on the basis of quality, availability, oil contents, physico-chemical properties, and cost. Besides, several biodiesel feedstocks have also been compared in the form of estimated yield and oil contents and have been recorded by several authors (Ali et al. 2012; Atabani et al. 2013c; Falasca et al. 2010; Freedman et al. 1986).

The least expensive one is essential to guarantee low-cost biodiesel production. Generally, the biodiesel feedstocks are categorized into six distinct classes (Gui et al. 2008; Guo et al. 2007; Gurusala et al. 2014).

6.3.1 Edible Vegetable Oils

The utilization of this type of waste results in several issues, like meal versus fuel crisis, significant soil assets destruction, and deforestation. Moreover, the currently raised costs have adversely affected the economic suitability of vegetable oil plants for biodiesel synthesis (Haile 2014; Hajra et al. 2015; Han and Naeher 2006). But their long-term utilization is not feasible in many countries. For example, biodiesel obtained from the entire soybean reserves of USA would hardly meet only 6% of the total diesel requirement (Hoekman and Robbins 2012).

6.3.2 Non-edible Vegetable Oils

Non-edible oils provide potential solutions to diminish the usage of consumable oils for biodiesel generation. Non-edible oil sources are drawing considerable attention owing to their accessibility in numerous areas of the world, particularly the wastelands, lack of competition for food, decreased rate of deforestation, environmental safety, valuable byproducts synthesis, and economic suitability (Hajra et al. 2015; Janaun and Ellis 2010; Kafuku and Mbarawa 2010; Karimi et al. 2015; Karmee and Chadha 2005; Khan et al. 2019; Kondamudi et al. 2009; Kumar and Sharma 2011; Kutzbach 2009; Liaquat et al. 2010; Lim and Teong 2010; Marulanda et al. 2010; Mattingly 2006; Mofijur et al. 2013a, 2013b) (Fig. 6.2).

6.3.3 Waste Cooking Oil

Being an agricultural country, Pakistan depends upon agricultural products for their survival. About 24 kg of edible oil is consumed per capita in Pakistan (Mohammadi et al. 2014). Waste cooking oil is nearly thirty percent effective (Murugesan et al. 2009). Two main suppliers of oil imports to Pakistan are Malaysia and Indonesia (Mohammadi et al. 2014).

Fig. 6.2 Castor oil plant

6.3.4 Microalgae

Microalgae are photosynthetic microbes that are more efficient than plants in converting the daylight, water, and CO_2 into algal biomass. In contrast to edible and non-edible sources, microalgae provide relatively greater oil content. When developed in a farm or bioreactor, the oil production of microalgae is nearly 250-folds more as compared to palm oil yields along with that of soybean oil, respectively. Besides, microalgae are also expected to produce sustainable biodiesel. Nevertheless, the development of effective, large-scale bioreactors of microalgae is big constraints in their commercialization. Ongoing studies have shown that algae grown on flue gas can be used for biodiesel generation (Gui et al. 2008; Oanh et al. 2010; Okona-Mensah et al. 2005; Oliveira 2010). Evaluation has been taken for biosafety and subsequently developed as new feedstock for biodiesel production (Omidvarborna et al. 2015).

6.3.5 Leather Industry Wastes

Waste products of leather industry are another feedstock for biodiesel generation. A large amount of solid and liquid wastes are not properly utilized (Ong et al. 2011).

6.3.6 Animal Fats

Animal fats of potential significance can be easily collected largely from slaughter houses and meat processing units. Moreover, poultry waste products are preferred than animal fats of other types owing to its low cost, ease of processing, and high availability (Fig. 6.3).

Poultry wastes comprising feathers, blood, offal, and trims can provide a cost-effective feedstock for biodiesel generation. Particularly, chicken slaughterhouses lacking the rendering plants are facing issues of proper waste disposal. Consequently, the waste products can be exploited for the extraction of fats.

Chicken oil obtained from waste skin has been successfully used for biodiesel synthesis in India (Razon 2009). Rendering along with heating yields appreciable amount of oil at comparatively less cost than vegetable feedstocks (Sadhik Basha and Anand 2011). Transesterification of chicken fat at a temperature of 60 °C, 1:30 molar proportion, and 24 h reaction time, resulted in 99.01% yield of biodiesel. Moreover, the physico-chemical properties of chicken fat-derived biodiesel like heating, cetane number, and density were comparable to those of ASTM D 6751 biodiesel standards (Sanjay 2015).

Feather meal also constitutes of 2–12% of chicken fats (Sarma et al. 2005). Chicken fats with 2.3% FFA content are recommended for biodiesel synthesis

Fig. 6.3 Animal fat

(Schulte 2007). Besides, pre-treatment significantly enhances the yield of biodiesel from chicken fats. The yield of biodiesel reached to about 91%, following the consumption of supercritical methanol (Sharma et al. 2013). Moreover, chicken fats with a high FFA content (13.45%) were successfully used for biodiesel production after the reduction of its FFA level to less than 1% by means of various acid catalysts (Sharma and Singh 2009). Chicken fat is considered suitable for transesterification and biodiesel formation, owing to its lower FFA content and unsaturated fatty acid profile (Sieminski 2014). Diesel blends of fatty acid methyl ester (FAME) of lard, beef tallow, and chicken fat showed lower NOx emanation levels (3.2–6.2%) in comparison with mixture of soybean oil methyl ester and diesel fuel (Sieminski 2014).

Currently, 40% of the total meat requirement is fulfilled by the poultry sector of Pakistan. There are over 25,000 poultry farms, which provide about 1220 million kgs of chicken meat and 10,000 million eggs per annum.

6.4 Biodiesel Production Methods Flowchart

See Fig. 6.4.

6.5 Biodiesel Production Process

The reactor for biodiesel production consists of following components (Fig. 6.5):

- 1L jacketed glass batch reactor,
- reflux condenser (to recover methanol),
- sampling device,
- overhead mechanical stirrer,
- refrigerator,
- circulating water bath for controlling the reaction temperature.

6.5.1 Pre-treatment Process

In this procedure, moisture is removed from crude oil by placing it in a rotatory evaporator for 1 h at 95 °C under vacuum condition.

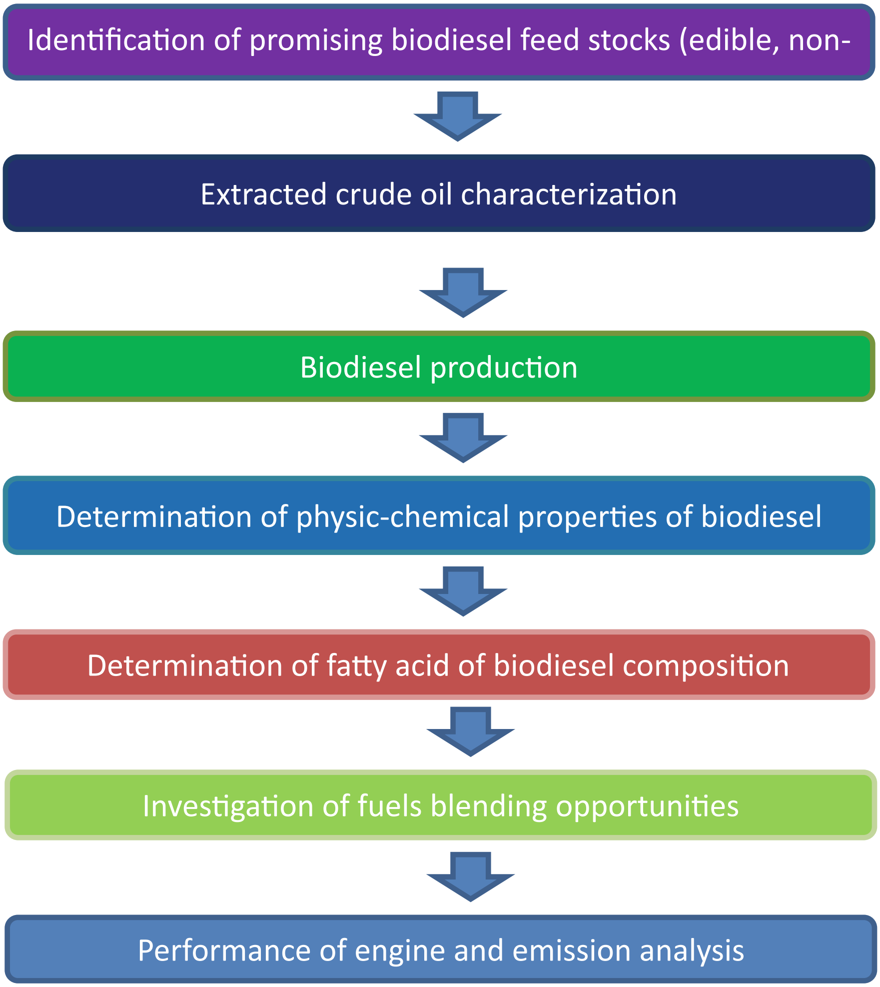


Fig. 6.4 Flowchart of biodiesel production (Arbab et al. 2013; Singh and Singh 2010; Smith et al. 2010; Survey 2014; Usman et al. 2016; Graaf 2012)

6.5.2 Esterification Process

The molar ratio 12:1 (50% v/v) of methanol to crude oils with greater values of acid is maintained during this process. Subsequently, 1% (v/v) of sulfuric acid (H_2SO_4) is taken in a glass reactor and added to the pre-heated oils at 60 °C for 3 h along with stirring at 400 rpm. Once the reaction is completed, the excess alcohol is separated from the mixture by separating funnel. The upper layer comprises sulfuric acid and impurities, whereas the lower layer is placed in a rotary evaporator and heated at

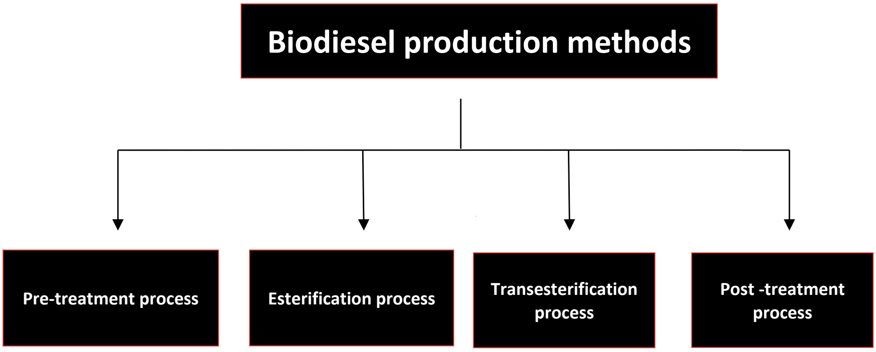


Fig. 6.5 Production of biodiesel can be carried out as follows (Arbab et al. 2013)

95 °C under vacuum conditions for 1 h to remove water and methanol from the esterified oil.

6.5.3 Transesterification Process

Esterified oils and crude oils with low acid values are reacted with 25% (v/v) of methanol and 1% (m/m) of potassium hydroxide (KOH) and kept at 60 °C for 2 h together with stirring at 400 rpm. Upon the completion of reaction, biodiesel is kept in a separating funnel for 12 h to isolate glycerol from biodiesel. The lower layer contains impurities, and glycerol is drawn off.

6.5.3.1 Alkaline-Catalyzed Transesterification

Alkaline-catalyzed transesterification is the most rapid, highly productive, and frequently used procedure for biodiesel production. The abundant methanol is reused and recovered later on. The process of methanol-catalyzed transesterification leads to synthesis of biodiesel and glycerin from free unsaturated fats. The mixing of NaOH with methanol results in the synthesis of sodium methoxide that is subsequently mixed with vegetable oil. The upper layer of the mixture consisting of biodiesel or methyl esters is filtered and washed, whereas glycerin forming the basal layer can be collected and utilized in soap formation.

Moreover, when alkaline catalyst is used, the level of free fatty acid (FFA) declines from a desire limit (running from less than 0.5% to less than 0.3%). Majority of the non-edible oils have greater FFA contents. Therefore, considerable amount of soap is produced by alkaline transesterification method owing to the difficulty in glycerol and ester separation. The typical slow reaction rate of acid-based esterification may necessitate extensive reaction periods to resolve this problem. Consequently, acid-catalyzed transesterification should be followed by alkaline transesterification for biodiesel production from non-edible oils with greater FFA contents.

6.5.3.2 Acid-Catalyzed Transesterification

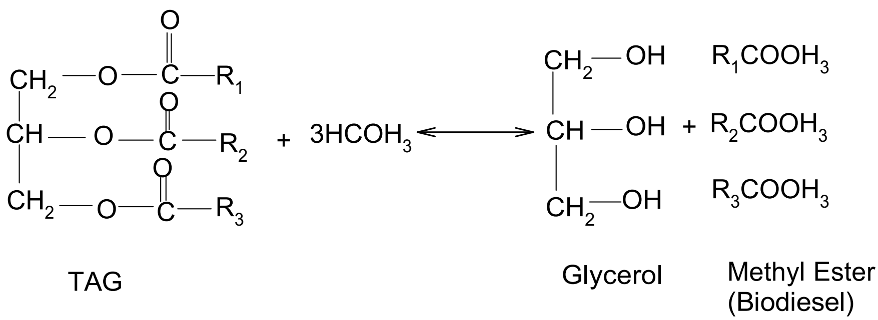
Sulfonic and sulfuric acids are preferred as the Bronsted acids that catalyze the transesterification process (Wyatt et al. 2005; Yue et al. 2010). These catalysts produce extremely high yields of alkyl esters, but the reactions are laborious and typically take longer than three hours to complete (Zhang et al. 2015). According to Pryde et al., methanolysis of soybean oil at 65 °C with 1 mol% H2SO4 and a 30:1 alcohol/oil molar ratio requires 50 h to complete the conversion of the vegetable oil (> 99%), whereas butanolysis at 117 °C and ethanolysis at 78 °C require 3 h and 18 h, respectively, using the same amounts of catalyst and alcohol (Wyatt et al. 2005).

One of the key elements affecting transesterification is the molar ratio of the alcohol to the vegetable oil. Alcohol in excess promotes the development of the products. However, too much alcohol makes it impossible to recover the glycerol; therefore, the appropriate alcohol to oil ratio must be determined empirically while taking into account each particular process.

6.5.3.3 Enzymatic Transesterification

Enzyme-catalyzed transesterification takes place in the presence of lipase enzyme. Hydrolytic enzymes have been used extensively in organic synthesis because of their wide availability and ease of handling. They are reasonably stable and do not require any coenzymes (Zhou et al. 2010).

These investigations all have one thing in common: they optimize the reaction parameters (solvent, temperature, pH, type of microbe that produces the enzyme, etc.) to provide properties that are appropriate for an industrial use. However, compared to base-catalyzed reaction systems, both the reaction yields and the reaction durations are still unfavorable.



6.5.4 Post-treatment Process

This procedure involves the washing of methyl ester, formed in the upper layer, to eliminate the impurities and glycerol. For this purpose, 50% (v/v) oil of distilled water is showered at 60 °C on the surface of the ester followed by moderate stirring. By repeating the procedure many times, the pH of the distilled water becomes neutral. The lower layer is disposed, and upper layer is dried in a flask containing sodium sulfate Na_2SO_4. Further drying is carried out in a rotatory evaporator for the separation of methanol and water from biodiesel. FTIR spectroscopy has been employed to determine the purity of produced biodiesel and the change of crude oil to methyl ester (Arshad 2017a, b; Arshad et al. 2014, 2019; Bano and Arshad 2018).

6.6 Effects of Additives on the Quality of Biodiesel

Biodiesel emulsion containing 83% jatropha biodiesel, 15% water, and 2% surfactants (Span80 and Tween80) has been manufactured by means of a mechanical agitator (Tahir et al. 2019). The resultant fuel was blended with aluminum nanoparticles in the mass parts of 25, 50, and 100 ppm using an ultrasonicator. Afterward, a steady-speed diesel engine was sequentially fueled with jatropha biodiesel, jatropha biodiesel emulsion, and aluminum nanoparticles-mixed jatropha biodiesel emulsion. The performance of biodiesel emulsion was substantially upgraded, while the harmful emissions were highly reduced than pure biodiesel. In addition, compared to pure biodiesel and biodiesel emulsions, biodiesel emulsions with nanoparticles have high performance and reduced emissions.

Biodiesel acquired from *Madhuca indica* is characterized by low-temperature properties (Sharif et al. 2021). The cold flow characteristics of Madhuca methyl ester fuel are less ideal than those of petroleum-based fuel. The low-temperature properties of biodiesel were determined with and without pour point depressants. Besides, the impact of ethanol, lamp oil, and commercial additives on low-temperature behavior of biodiesel was also evaluated. The pour point of biodiesel was significantly decreased, following the utilization of cold flow improving substances. Moreover, the effect of 2% commercial additive was comparable to blending of 20% ethanol. The cloud point of Madhuca methyl ester was decreased from 291 K (18 °C) to 281 K (8 °C) and 278 K (5 °C) upon mixing with 20% ethanol and 20% lamp fuel, respectively. Likewise, the addition of 20% ethanol and 20% lamp fuel reduced the pour point of Madhuca biodiesel from 280 K (7 °C) to 269 K (−4 °C) and 265 K (−8 °C), respectively. The execution and outflow with ethanol blended Madhuca biodiesel and ethanol–diesel-mixed Madhuca biodiesel have also been examined. The mixing of 20% (by volume) ethanol with Madhuca biodiesel accomplished improved burning with 50% reduction in CO emission without influencing the thermal productivity. Moreover, the emanation of NOx was highly decreased following the addition of 20% (by vol.) ethanol into Madhuca biodiesel. Ethanol-added biodiesel represents a sustainable and feasible alternative fuel, having improved low-temperature behavior and better emanation profile.

Several techniques including the utilization of additives (like traditional oil diesel additives such as wax crystalline modifiers or pour point depressants) and mixing with oil diesel and physico-chemical modification of the oil feedstock or the product of biodiesel have been recommended to enhance the cold flow properties of biodiesel (Arshad et al. 2018). The mixing of oil diesel is effective only at lower concentrations of biodiesel (up to 30% volume). Alternatively, the use of huge moieties for disrupting the organized stacking of ester molecules during nucleation of crystals can also diminish the cloud point of biodiesel. For instance, the cloud point is decreased when large moieties are added to the head-group of alkyl ester or incorporated in the tail-group as a side chain. Fractionation and winterization procedures can be employed for altering the unsaturated fat profile of biodiesel or its feedstock. Particularly, the cold flow properties and oxidation stability of biodiesel can be enhanced through the removal of double bond in the ester group and the addition of side chain. However, this can negatively affect the ignition quality and thickness of biodiesel. Acetone has been successfully used for stabilizing the cold flow properties together with improving the flash point criterion and safety of biodiesel (Arshad and Abbas 2018a).

Organic manganese additives are also known to improve the properties of biodiesel acquired from Pomace oil. It has been documented that doping the fuel at a proportion of 12 mol/l oil methyl ester caused a 20.37% reduction in viscosity, 7 °C (129–122 °C) fall in the flash point, and reduced the pour point from 0 to 15 °C (Arshad and Abbas 2018b).

6.7 Current Challenges of Biodiesel Industry

Concerns regarding the future of biodiesel industry are raised due to the long-term dependence on food-grade vegetable oils (edible oils) as feedstocks for biodiesel synthesis. Besides, it also threatens the supply of edible oils to food industry. Moreover, the gradually increasing prices of feedstocks drastically affect the economic feasibility of biodiesel. Therefore, biodiesel generation from non-edible oils, microalgae, and waste products has become the focus of current research in various parts of the world. Much consideration has been dedicated to biodiesel production through the utilization of easily available, non-customary, and non-palatable feedstock collected from wild plants (Arbab et al. 2013; Atabani et al. 2013c; Janaun and Ellis 2010; Singh and Singh 2010). Effective methodologies targeting the monetary aspects of biodiesel generation are essentially required to fulfill the gradually increasing energy needs (Falasca et al. 2010).

6.8 Conclusion

Reliance upon fossil fuels and global climate changes are the main factors which are responsible for economic issues of Pakistan. In Pakistan, transport sector plays major role in consuming the imported diesel fuel; therefore, largest import bills are due to this sector. To overcome these problems, dependence on sustainable energy resources is an excellent and affordable solution. For the production of biodiesel, animal fat waste is the most promising feedstock because it is sustainable, cost-effective, and easily available. In addition, greenhouse gases emissions are less. It was found that biodiesel produces less emissions in auto vehicles. So, the problems related to air pollution and energy security could be resolved not only by producing biodiesel but also by utilizing it in transportation sector. The government of Pakistan is importing too much diesel and oil in order to fulfill the requirements of people. Therefore, it is the need of the day to produce biodiesel from different renewable sources especially animal fat. Production of biodiesel in Pakistan can be promoted by improving production technology of biodiesel or by making governmental policies to introduce biodiesel in transportation sector as a green fuel.

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