Production of Bio-fuels From Waste Cooking Oil: A review

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Abstract- *Due to high consumption rate of petroleum sources, its reserves are fast dwindling and it is necessary to identify an alternative energy source to supplement conventional fuels. The use of waste cooking oil to produce biodiesel may be an attractive alternative to conventional fuel sources. Biodiesel produced from waste cooking oil is first generation bio-fuel. The biodiesel contributes less to global warming and contains less contaminant in its emission owing to the renewable nature. Recycled waste cooking oil is harmful to human health, if consumed. The possible solution is to convert it into biodiesel. Esterification and transesterification are common processes for production of biodiesel from waste cooking oil. In present review all relevant aspects related to biodiesel production are presented.*

***Key words*: -** Waste cooking oil (WCO), Biodiesel, Free fatty acid (FFA), Esterification, Transesterification, etc….

1. Introduction

Biodiesel comprised of mono-alkyl esters with long chain fatty acids derived from vegetable oils, animal fats, food and non-food based materials (Vicente *et al.*, 2007). Disposal and handling of waste cooking oil has always a big problem. Converting waste cooking oil into biodiesel will help to reduce these problems (Barnwal and Sharma, 2005). Biodiesel is advised for use as an alternative fuel in place of conventional petroleum-based fuel. The reason behind is that biodiesel is renewable, produced from domestic resources and is biodegradable (Mahgoub *et al.*, 2015). Biodiesel is produced from the triglycerides conversion of oils such as those obtained from food base materials like palm oil, soybean, jatropha, rapeseed, sunflower and castor oil (Owolabi *et al*., 2011).

Biodiesel has similar physico-chemical properties like conventional fossil fuel and it can consequently be a substitute of fossil fuel in compression ignition diesel engines (Pasqualinoa *et al*., 2006; Kansedo, 2009). Biodiesel production from first generation feedstocks is interesting area for researchers as an alternative fuel for diesel engine. Biodiesel can also be produced from renewable sources such as vegetable oil, animal fat and used cooking oil. Currently, the cost of biodiesel is high as compared to conventional diesel oil because most of the biodiesel is produced from pure vegetable oil (Seecharan *et al*., 2009). Depending on the origin and production technology of biofuels, these are generally called as the first, second and third generation biofuels, while the fourth generation biofuels make use of novel synthetic biology tools and are just emerging at the basic research level (Aro, 2016).

2. Comparison of different generations of biofuels

Categorization of biofuels is done according to their current or future feedstocks. Based on type of feedstock it is categorized in first, second and third generation biofuels. Comparison of biofuel generations is presented in table 1, which is helpful in understanding raw material type, conversion process type, characteristics of biofuel and production process for first, second and third generations of biofuel.

Table -1: Comparison of different generations of biofuels.

Characteristics	First generation biofuel	Second generation biofuel	Third generation biofuel
Feedstocks	**Food based:** Seed, grain, plants from crop like- sugar cane, wheat, sunflower (Nada, 2013; Sharma *et al.,* 2013).	**Non-food based:** Waste biomass, stalks of wheat, wood, special energy crops (Nada, 2013; Abdullah *et al.*, 2013).	**Non-food based:** Algae (Balan, 2014).
Conversion process	**Chemical conversion:** Esterification and transesterification (Naik *et al.*, 2010).	**Chemical conversion:** Esterification and transesterification. **Thermochemical conversion:** Liquefaction, gasification and pyrolysis (Kaushik *et al.*, 2010; Lali, 2016). **Biochemical conversion:** Photobiological, fermentation and anaerobic digestion (Nada, 2013; Behera *et al.,* 2013).	**Chemical conversion:** Esterification and transesterification. **Thermochemical conversion:** Liquefaction, gasification and pyrolysis (Kaushik *et al.*, 2010; Lali, 2016). **Biochemical conversion:** Photobiological, fermentation and anaerobic digestion (Nada, 2013; Behera *et al.,* 2013).
Production characteristics	Possibility of commercial production, easy production process (Nada, 2013), low cost, increase food based material demand (Naik *et al.*, 2010; Dragone *et al.,* 2010).	Laboratory scale production, high cost (Nada, 2013; Arifin, 2009), non-conventional production process (Naik *et al.*, 2010; Dragone *et al.,* 2010).	Laboratory scale production, high cost (Nada, 2013), non-conventional production process (Naik *et al.*, 2010).
Final products and by-products	**Product:** Biodiesel (Naik *et al.*, 2010). **By-product:** Glycerine	**Products:** Biodiesel, bio-oil, electricity, syngas, hydrogen, ethanol, biogas (Behera *et al.,* 2013).**By-product:** Glycerine	**Products:** Biodiesel, bio-oil, electricity, syngas, hydrogen, ethanol, biogas (Behera *et al.,* 2013). **By-product:** Glycerine

Factors affecting production	**Temperature:** < 70°C (Mathiyazh and Ganapathi, 2011).	**Temperature:** < 70°C (Mathiyazh and Ganapathi, 2011).	**Temperature**: < 70°C (Mathiyazh and Ganapathi, 2011).
	Catalyst: NaOH (< 2.5 wt. %) and H_2SO_4 (< 2 wt. %) (Gashaw and Teshita, 2014).	**Catalyst:** NaOH (< 2.5 wt. %) and H_2SO_4 (< 2 wt. %) (Gashaw and Teshita, 2014).	**Catalyst:** NaOH (< 2.5 wt. %) and H_2SO_4 (< 2 wt. %) (Gashaw and Teshita, 2014).
	Reaction time: < 120 minutes (Jagadale and Jugulkar, 2012).	**Reaction time:** < 120 minutes (Jagadale and Jugulkar, 2012).	**Reaction time:** < 120 minutes (Jagadale and Jugulkar, 2012).
	Methanol to oil molar ratio: < 1:12 (Anita *et al.*, 2010).	**Methanol to oil molar ratio:** < 1:12 (Anita *et al.*, 2010).	**Methanol to oil molar ratio:** < 1:12 (Anita *et al.*, 2010).

3. Diagrammatic representation of conversion processes

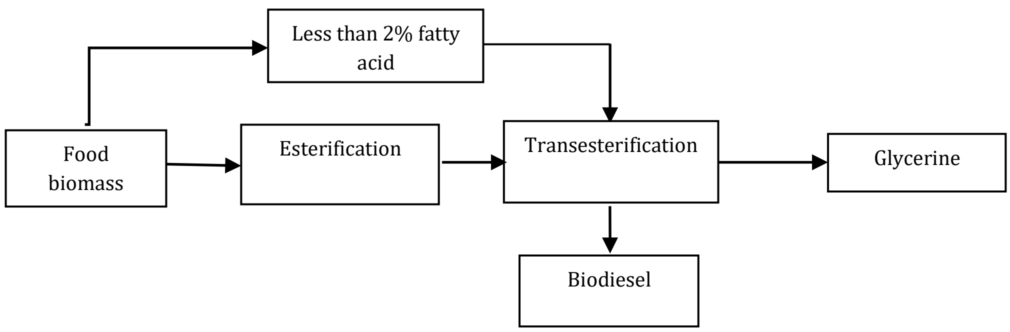


Fig -1: Conversion process of first generation biofuel (Owolabi, 2011).

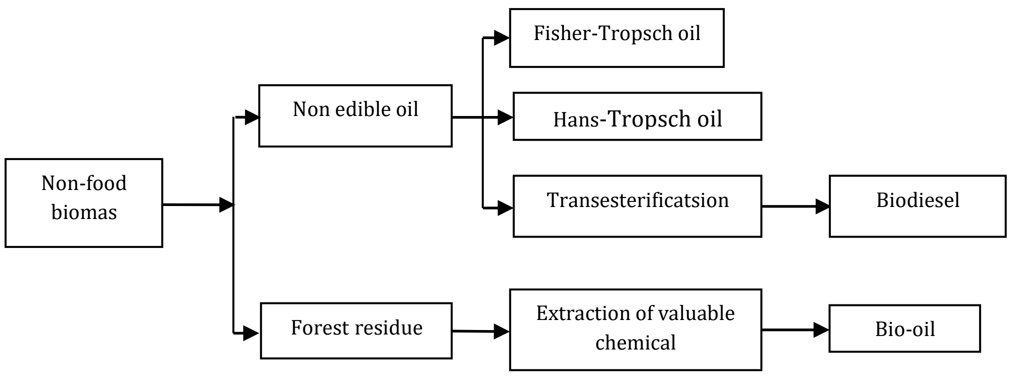


Fig -2: Conversion process of second generation biofuel (Behera *et al.,* 2015).

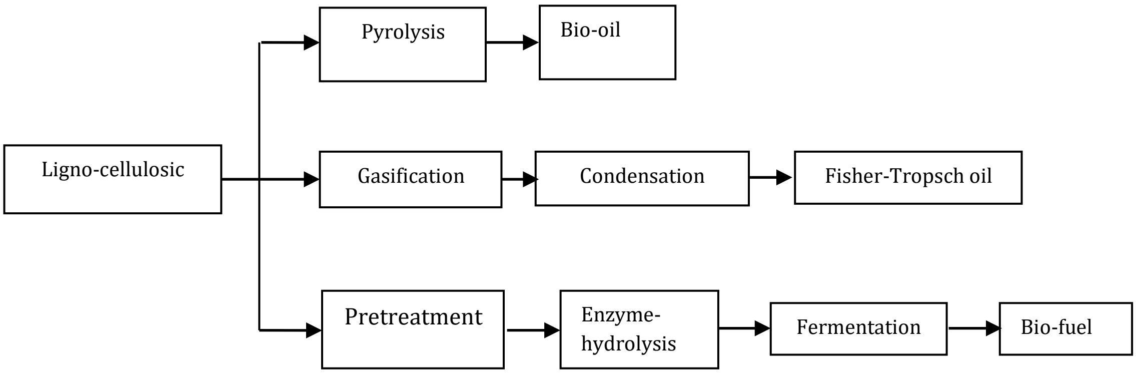


Fig -3: Conversion process of third generation biofuel (Behera *et al.,* 2015).

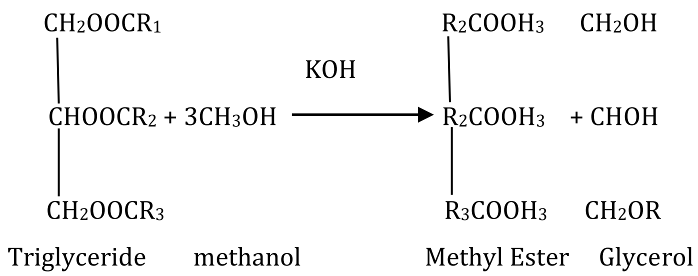
3.1 Mechanism of chemical conversion

First, second and third generation biofuels has similar chemical conversion for production of biodiesel. Chemical conversion consist esterification and transesterification process. Mechanism of chemical conversion is presented below (Hossian *et al.,* 2009).

A. Esterification step:-

$$RCOOH + CH_3OH \xrightarrow{H_2SO_4} RCOOH_3 + H_2O$$

B. Transesterification step:-



4. Properties of biodiesel

Properties of biodiesel are important indicators which are assessed to determine the quality of biodiesel before it takes in use. Standard maximum and minimum limits about biodiesel properties are presented in table 2.

Table-2: Properties of biodiesel.

Properties	Limits		References
	Min.	**Max.**	
Density, Kg/m^3	860	900	(Barabas and Todorut, 2011; Cheetri *et al.,* 2008; Ved and Padam, 2013)
Kinematic viscosity, mm^2/s	2.5	6.0	
Flash point, °C	120	-	
Cetane number	51	-	
Acid value, mgKOH/gm oil	-	0.80	
Water content, mg/kg	-	500	
Methanol and Ethanol, %(m/m)	-	0.20	
Ester contents, % (m/m)	-	96.5	
Free glycerol contents, % (m/m)	-	0.02	

5. Utilization of biofuel

Use of biofuels is still in its initial days and hence relative production cost is higher. However in last decade production and utilization of biofuel increase rapidly. Table 3 shows the global utilization of biofuel and its percentage uses in various areas. India is developing economy and our country splurge a large amount of money from our economy to buy crude oil. Utilization of biofuels in India is very less than developed countries. However efforts are now being made to increase production and utilization of biodiesel in different sectors in India. Table 4 shows efforts of recent utilization of biodiesel in India.

Table-3: Global utilization of biodiesel.

Area	Percentage uses	Reference
Bio Fuel	27%	(Pringle *et al.*, 2011)
Shipping	7%	
Gasoline	13%	
Biodiesel	23%	
Jet Fuel	13%	
CNG and LPG	2%	
Electricity	13%	

Table-4: Utilization of biodiesel in India.

Projects	Amount of biodiesel	References
Shatabadi Express was run from Delhi to Amritsar on 31st Dec. 2002 in association with IOC.	5%	(Dwivedi *et al.*, 2014; Basavaraj *et al.*, 2012).
Lucknow-Allahabad Jan Shatabdi Express was run in association with IOC.	10%	
Council of Scientific and Industrial Research (CSIR) and Daimler Chrysler have jointly undertaken a successful 5000 km trial run of Mercedes cars.	15%	
National oilseeds and Vegetable Oils Development (NOVOD) has initiated test run of Tata Sumo & Swaraj Mazda vehicles in collaboration with IIT Delhi.	10%	

6. Technological development and future scope of biofuel

Research is ongoing to reduce the production cost of biofuels by developing a method to decrease the emulsification during base catalytic transesterification and aqueous-washing of the product for readily recovery of glycerin byproduct. Production of biodiesel from first generation feedstocks by esterification-transesterification process is a traditional commercial process (Nada, 2013). Other technologies such as lab scale batch reactor method (Kawentara and Budimanb, 2013), Pilot Scale Reactor Method (Raqeeb and Bhargavi, 2015), Bubble Column Reactor Method (Raqeeb and Bhargavi, 2015) and Electrolysis Method (Raqeeb and Bhargavi, 2015) are advanced methods for production of first generation of biofuels. However these processes of production of biodiesel are being done at laboratory scale presently and will take time to mature as commercial technology. Microwave irradiation process is also an advanced method to produce biodiesel. It requires less time than other current methods. The main disadvantage of microwave irradiation process is that it requires more energy than other methods (Patil et *al*, 2012). Ultrasonication technique applies to transesterification step in microwave irradiation process (Refaat, 2010). Development of solar biofuels and electro-biofuels by synthetic biology technologies are the future area of first generation biofuels (Aro, 2016).

Second and third generation biofuels are advanced fuels. Modification in new techniques like harvesting algae, adopting biorefinery concept and photobioreactor will be the future of second and third generation biofuel (Behera *et al.,* 2015).

7. Conclusion

Previous studies showed that production of biofuels is possible from waste cooking oil. Bio-fuels can be classified in first, second and third generation biofuels. Production of first generation biodiesel from waste cooking oil could currently is the best way to get biofuel instead of its disposal. Most common first generation biofuel is biodiesel. Second and third generation biofuels production technologies are still in development stage and require an indepth study and research of process economics and process intensification for commercial applications. Esterification and transesterification process is same for first, second and third generation biofuels. Secondary products like glycerol or value added products like biolubricants, greases and polyurethane also have great market potential.

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