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A comprehensive review of low cost biodiesel production from waste chicken fat

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ABSTRACT

This paper discusses about the importance of animal fats for power generation particularly from waste chicken fat, advantages of using chicken fat for biodiesel production, different ways of oil extraction from chicken fat and various biodiesel production techniques. A detailed review has been done on the use of novel heterogeneous catalysts for transesterification process such as metal based catalysts and organic catalysts. The factors influencing transesterification parameters like molar ratio, catalyst weight percentage, reaction time and temperature has been collected from several research articles were presented in detail. In addition, the transesterification reaction is studied at different co solvents employed to increase the methyl ester conversion. Also, analyses of relative optimization techniques implementing for transesterification process parameters have been discussed thoroughly. The physico-chemical properties of chicken fat methyl ester such as kinematic viscosity, density, pour, cloud, flash and cold filter plugging point, calorific value and fatty acid compositions of chicken fat methyl ester were compared with different animal fat methyl esters. The study reveals that biodiesel produced from waste chicken fat would be a suitable replacement of edible vegetable oils due to its low cost, ease of availability and the properties of chicken fat methyl ester were within the limits of ASTM D 6751 biodiesel standards. Furthermore, the research work has to be carried out for the improvement of cycles of catalyst reusability, biodiesel purity and cost-effectiveness of biodiesel production process in future.

1. Introduction

Many countries depend on neighbor nations to resolve their energy demands. It is advisable to generate energy from renewable energy sources viz. solar, hydro, tidal, wind, biomass and geothermal, which do not produce vulnerable pollutions to the environment and available plenty. Biodiesel is derived from virgin vegetable oils and animal fats. Biodiesel is low-toxic, biodegradable, carbon-neutral fuel, produces less sulphur content, HC, CO and eco-friendly energy source [1]. Oils derived from palm, peanut, sunflower, olive, rapeseed and soybean come under edible oils whereas jatropha, linseed, mahua, cotton seed and castor oil are non-edible oils which are used for biodiesel production inhibits a good portion of CO_2 that is released during fuel combustion. A study conducted by the National Renewable Energy Laboratory (NREL) in the life-cycle analysis of biodiesel reveals that overall CO_2 emissions were minimized by 78% when compared to petro-diesel was reported by Babcock et al. [1]. The applications of edible oils to produce biodiesel would directly affect the food industry [2]. Even though vegetable oils are mainly used for biodiesel production and some of the major challenges like feedstock procurement, cost of feedstock, transportation and fuel storage for longer periods limits the use of vegetable oils. Waste cooking oil is one of the best options to replace vegetable oil as feedstock for biodiesel production without any environmental degradation [3].

Recently animal fats composed of triglycerides have been utilized for biodiesel production drawn the attention of energy producers. In Brazil rendered beef tallow involves 17% of feedstock for biodiesel production. Leonardo et al. [4] prepared binary mixture of biodiesel blends employed from beef tallow and soybean oil to study the methyl ester properties of mixtures. Although biodiesel is one of the most advantageous renewable fuels and the major obstacle was the high cost of raw materials (vegetable oil and alcohol) that leads to approximately 75 percentage of total production cost is considered to be more expensive than the diesel fuel [5]. The conventional diesel engines use biodiesel without substantial modifications shows lower emissions of particulate matter, sulphur content, hydrocarbon, carbon monoxide due to the presence of higher oxygen content and lower carbon to hydrogen ratio in biodiesel [6,7]. Demand of energy in India is increasing phenomenally each and every year due to more population growth. According to Indian Government statistics, around 700,000 tonnes of

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Nomenclature

gPROMS	general PROcess Modeling System
OCFEM	Orthogonal Collocation on Finite Elements Method
RSM	Response surface methodology
BBD	Genetic algorithm
CCD	Genetic algorithm
GA	Genetic algorithm
FCCD	Face centred cubic design
ANN	Artificial neural network
CCRD	Central composite rotatable design
MAT	Microwave assisted technique
XRD	X-ray diffraction
SEM	Transmission electron microscope
TGA	Transmission electron microscope
TEM	Transmission electron microscope
FTIR	Fourier transforms infrared spectroscopy
EDS	Energy dispersive X-ray spectrometer
TPD-CO_2	Temperature-programmed desorption of CO_2
DSC	Differential scanning calorimetry
BET	Brunauer–Emmett–Teller
KOH	potassium hydroxide
NaOH	sodium hydroxide
KOMe	potassium methoxide
NaOMe	sodium methoxide
TMAH	tetramethylammonium hydroxide
Fe_2O_3	ferric oxide
Al_2O_3	aluminium oxide
$LiAlO_2$	lithium aluminium oxide
Zsm	zeolite socony mobil 5
SiAl	silicon aluminium
NiMo	nickle molybdenum
ZnO	zinc oxide
MnO_2	manganese dioxide
Na_2O	sodium oxide
HHV	higher heating value
CFPP	cold filter plugging point
FAME	fatty acid methyl ester
SHFO	Silurus triostegus heckel fish oil
HC	hydro carbon
CO	carbon monoxide
ASTM	American Society for Testing and Materials

chicken meat is consumed every year [8] and about 77,000 tonnes of chicken fat is discarded due to it creates nuisance to public.

This paper reviews the current literature on the use of waste chicken fat for biodiesel production. Conventional and modern techniques available for oil extraction, transesterification reactors and novel catalysts were also illustrated to achieve higher biodiesel yield with minimum operation time. Fig. 1 depicts the custom of various feedstocks for biodiesel production.

2. Animal feedstocks for biodiesel production an alternate to vegetable oils

Vegetable oils are mainly consumed for biodiesel production for long decades as it can be directly admitted into the engine without any modifications. Edible oil contains long chain alkyl ester fatty acids are converted into short chain viscous alkyl esters which are represented as biodiesel [9]. Animal fats are one of the raw materials collected from waste disposal in markets was available more abundantly than waste cooking oil for the preparation of biodiesel. These animal fats are not suitable for human food chain and used for feeding animals at low cost. Recent trends in the advancement of production of biodiesel from animal fats will definitely save the petroleum fuel for some more decades. Many researchers carried out experiments with different animal fats viz. wastes chicken fat, mutton fat, beef tallow, duck tallow, pork skin and pork lard. Michele et al. [10] evaluated the pilot scale production of biodiesel from beef tallow and got approved by the National Agency of Petroleum (ANP) for checking the quality of fuel. Rafael et al. [11] investigated beef tallow and soybean oil contains 53 mg KOH/g acid number for biodiesel conversion using heterogeneous catalyst sulfonated polystyrene compounds derived from linear polystyrene.

Richard et al. [12] analysed the factors such as raw material availability, energy efficiency and economic factors to convert beef tallow into biodiesel as an alternate to vegetable oils. Chakraborty et al. [13] examined goat tallow using infrared radiation assisted reactor (IRAR) for biodiesel production and highlighted that there was a reduction in reaction time as compared with conventional batch reactor. Abdelrahman et al. [14] conducted transesterification process from Silurus triostegus heckel fish oil through alkaline catalyst and confirmed that physico-chemical properties of the methyl ester were agreed with biodiesel standards. Yahyaee et al. [15] examined fish oil as a potential feedstock for methyl ester conversion by designing a separate extraction machine and compared the oil properties with rapeseed and waste cooking oil. Mata et al. [16] evaluated the purification methods of biodiesel produced from chicken fat, beef tallow and pork lard. It is concluded that animal fats could be efficiently utilized for biodiesel production as a source of non-edible viable feedstock. Table 1 shows the biodiesel production techniques applied for various animal fats. Waste chicken fat was best chosen among animal fats due to its lowest price; easily available in the market and easy to process.

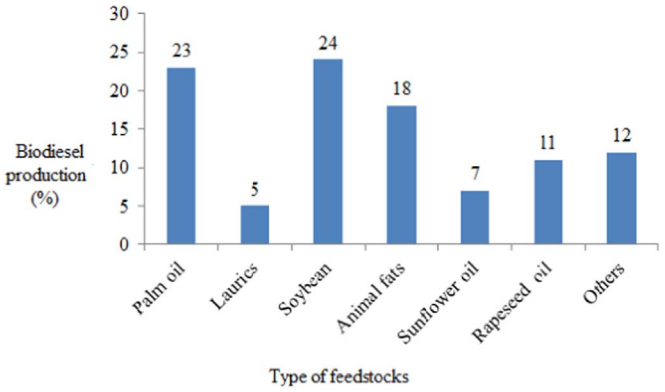

Fig. 1. Production of biodiesel from various feedstocks [3].

3. Merits of waste chicken fat for biodiesel production

- Waste to energy - In India, peoples usually ask for skinless chicken and shopkeepers discard the skin in public drain which leads to hazardous solid waste to the environment. Chicken oil derived from waste skin containing high fat substances is the major feedstock for the preparation of biodiesel [37].
- Non edible oil - After rendering process, the extraction of animal fats by heating techniques produces more amounts of non edible oil, which is inexpensive when compared to vegetable feedstocks [22].
- Contains more energy content- The net calorific value of chicken oil was around 37.91MJ/kg was slightly lower than the petroleum fuels [8].
- More yield of biodiesel - A highest biodiesel yield of 99.01% was attained from transesterification of chicken fat at temperature 60 °C, molar ratio 1:30 and reaction time of 24 h [6].
- Excellent fuel properties- The physico-chemical properties like

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