Renewable and Sustainable Energy Reviews 29 (2014) 120–134

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Conversion of slaughterhouse and poultry farm animal fats and wastes to biodiesel: Parametric sensitivity and fuel quality assessment

Rajat Chakraborty*, Abhishek.K. Gupta, Ratul Chowdhury

Chemical Engineering Department, Jadavpur University, Kolkata, India

ARTICLE INFO

Article history:
Received 8 March 2013
Received in revised form
19 August 2013
Accepted 24 August 2013

Keywords:
Slaughterhouse-poultry farm animal fats
Trans/esterification
Biodiesel
Parametric sensitivity
Process intensification
Biodiesel property

ABSTRACT

Over recent past, animal fat wastes have drawn significant attention for the production of biodiesel all around the globe. The present article provides a comprehensive review on the production of biodiesel from various slaughterhouse animal fats (SHAFs) waste resources viz. beef tallow, pork lard, mutton fat, lamb meat, fleshing oil as well as poultry fats (PFs) and wastes viz. chicken fat, duck tallow and feather meal. Methods of physical-pretreatment of SHAFs and PFs for recovering usable fat and subsequent chemical pre-treatment for reduction of free fatty acids have been enumerated. Biodiesel synthesis processes through both single and two-step trans/esterification employing homogeneous and heterogeneous catalytic routes have been critically assessed. Advantages of reusability of heterogeneous catalysts over their homogeneous counterparts have been elucidated. Besides, parametric effects viz. catalyst concentration, temperature, pressure and alcohol to fat ratios on biodiesel yield along with optimal process conditions have been meticulously presented. Relative merits and demerits of enzymatic and supercritical conversion processes have been highlighted. Current advancements in process intensification technologies have been assessed and comparative appraisals of biodiesel properties produced from various SHAFs and PFs have also been decisively summarized.

Contents

Abbreviations: SHAF, slaughterhouse animal fat viz. BT beef tallow; PL, pork lard; FO, fleshing oil; LM, lamb meat; MF, mutton fat; PFs viz. CF, poultry fats viz. chicken fat; DT, duck tallow; FM, feather meal; MR, molar ratio; HAC, homogeneous acid catalyzed; HBC, homogeneous base catalyzed

* Corresponding author. Tel./fax: +91 3324146378.
E-mail address: rajat_chakraborty25@yahoo.com (R. Chakraborty).

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2013.08.082

1. Introduction

1.1. Selection of biodiesel feedstock

In this modern era, increasing dependence upon fossil-diesel fuel in automobiles and other industries has essentially led to search for alternative sources of energy to replace or supplement depleting petro-fuels from the earth crust [1]. The energy demand of the world will prospectively increase by almost 50% in 2030 and it is important to note that India and China would account for 45% of its usage. Thus, biodiesel could be a very suitable option to cut emissions, to support transportation sector relying heavily on diesel fuels and to maintain an environmentally benign atmosphere. The primary advantage of using biodiesel lies in its biodegradability, renewability and ease of combustion. Reduction of CO_2 emissions and promotion of rural economic development are other bright aspects of using biodiesel as a substitute fuel measure [2]. There are host of feedstocks for biodiesel production; however, judicious selection of feedstock should involve consideration of two vital factors i.e. low cost of production and production in bulk scale; and thus, selecting the cheapest source is crucial for minimizing production cost [3]. The major feedstocks for biodiesel production can be subdivided into following categories as follows [4–18]:

1. Edible vegetable oil: sunflower, soybean, rapeseed, palm, canola, coconut, peanut, mustard and rice bran oil.
2. Non-edible vegetable oil: jataropha, microalgae, safflower oil and linseed oil.
3. Waste recycled oil: waste frying oil and waste acidified oil.
4. Animal fats: (a) slaughterhouse animal fat (SHAF) viz. beef tallow (BT), pork lard (PL), fleshing oil (FO), lamb meat (LM), mutton fat (MF); and (b) poultry farm animal fats/poultry fats (PFs) viz. chicken fat (CF), duck tallow (DT) and feather meal (FM).

Biodiesel, prepared from animal fat-more specifically SHAFs and PFs, is popularly known as 'second generation biodiesel' and has the potential to meet the global energy needs owing to overall cost-effectiveness and acceptable fuel properties.

1.2. High FFA feedstocks: SHAF and PF vs. waste frying oil

Though waste frying oil (WFO), SHAFs and PFs all are FFA rich cost-effective resources, the supply chains of SHAFs and PFs are more centralized than those of WFO due to the availability of WFO only from household kitchen and local restaurants. Moreover, the availability of inedible fat from slaughterhouses and poultry farms is in abundance as compared to that of WFO. Kumar et al. [19] pointed out that animal fat could not be directly incorporated into diesel engines due to its high viscosity. Therefore, efficient technology like trans/esterification could be highly beneficial for fuel property improvement and emission reduction of diesel engines. It was also highlighted that SHAF production in Europe is pretty high making it more attractive to be used as promising feedstock for production of diesel fuel. A detailed comparison revealed that the properties of SHAF biodiesel matched very closely to that of diesel [20]. It was reported that annually, around 2.5 billion pounds of waste restaurant lipids were obtained in form of SHAFs and PFs from restaurants and fast food centers in US [21] with potential for conversion into biodiesel. Nelson and Schrock [22] reported an informative cost analysis illustrating that for a fixed plant capacity, the cost of biodiesel production was highly sensitive to beef tallow (BT) price. Notably, the resource availability analysis predicted that about 4 billion pounds of edible and inedible BT were being produced in slaughterhouses of 11 states of US that could lead to production of 551 million gallons of biodiesel.

Thus, it is apparent that, different SHAFs and PFs e.g. BT, PL, CF, DT, FO, MF, LM, and FM can be very potential source for biodiesel production owing to sustainable availability due to better supply chain and economic feasibility. The present paper primarily attempts to overview the methods of extraction of useable fat from SHAFs and PFs and its subsequent conversion to biodiesel through catalytic, enzymatic and supercritical methods. The parametric effects on biodiesel yield have been critically assessed for both one step and two-step processes. The fuel properties of the product biodiesel derived from various SHAFs and PFs have been comprehensively underlined. Besides, recent advancements in process intensification in biodiesel synthesis have been meticulously presented. This article, thus, aims at providing valuable information to researchers through a comprehensive overview of biodiesel production from low cost-SHAF and PF feedstocks towards further advancement for sustainable development in this promising arena.

1.3. Qualitative analyses of SHAFs and PFs

It [23] was emphasized that usage of low quality feedstocks containing high FFA's and water could cause serious technical difficulties in biodiesel production. Fatty acid profiles of SHAFs viz. PL, BT, FO and PFs viz. CF, mixed fat, DT are presented in Tables 1 and 2 respectively. It is important to note that energy content of biodiesel is a function of energy content of its corresponding feedstock and greater unsaturation in biodiesel leads to a lower heating value [24]. Greater acid number (AN) [25] of SHAF or PF suggests that direct transesterification could lead to formation of soaps; thus, a pre-treatment including esterification with alcohol could reduce the FFA content of the feedstock. Higher value of iodine number in SHAF or PF sample signifies greater level of unsaturation. Kinematic viscosity is another vital property of a feedstock that is a measure of resistance offered to flow and shear [26]. The properties such as acid number, iodine number, kinematic viscosity and higher heating values of SHAFs viz. PL, BT and FO were evaluated and summarized in Table 3.