Renewable and Sustainable Energy Reviews 72 (2017) 246–253

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

The potential of waste cooking oil as supply for the Brazilian biodiesel chain

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ARTICLE INFO

Keywords:
Biodiesel
PNPB
Brazil
Waste cooking oil
Social inclusion
Environment

ABSTRACT

Biofuel production stands out on an international level because of its environmentally sustainable characteristics and the potential to promote rural development in developing countries. Introducing waste cooking oil (WCO) into the biodiesel chain holds the potential to promote social inclusion in urban areas in developing countries as well. In this sense, this paper examines the opportunity for biodiesel production from WCO as a potential source for future energy supply, particularly for biodiesel, and in this case, we will analyze the Brazilian scene. Several related aspects are covered, such as the physical and chemical properties of the WCO and the biodiesel made from it. The process of production is also presented. Lastly, the potential of the supply for this chain and the potential of social inclusion in developing countries, especially in Brazil, are analyzed.

1. Introduction

In a society marked by consumerism and the growing disposability of products, waste generation is getting increasingly worse and therefore has been on the agenda of the main government plenary sessions. Currently, global waste generation is around 12 billion tons/year and the volume expected by 2020 is 18 billion tons/year. The United States and Norway, for instance, produce more than 2.5 kg of waste per citizen/day. In the urban population of Italy alone—about 40 million people—around 89,000 t of waste are produced (i.e., 2.23 kg per capita), with a slight reduction expected (86,500 t) by 2025 [1].

Brazil follows the world trends. According to the Brazilian Association of Public Cleaning and Special Waste Companies [2], in 2014, 215,297 t of solid urban wastes were generated in Brazil, which means an increase of 3.2% compared to 2013. About 40% of solid urban waste is made up of recyclable material, of which only 2% is actually recycled. Compounding this scenario, of this 2%, 40% is returned to the production chain while the rest is consumed in burning energy [3].

Initiatives for the reuse of products at the end of their lifecycle are still scarce and there are no chains organized to replace these products in production cycles on a competitive scale [4]. With oil, these initiatives are no different. However, in Brazil, the recycling of frying oil is gaining importance and attracting investment from companies interested in carrying out the proper disposal of this waste as well as having an outlook toward profit [5].

Waste cooking oils (WCO) can be used in the manufacturing of products in various segments of industry, such as the production of soap, oil paints, and biodiesel [6].

Regarding the production of biofuel, although the production costs worldwide are not competitive compared to those derived from raw fossil materials [7,8], diesel obtained from waste oils is considered an exception [9]. Initiatives for the use of WCO for biodiesel can be found in several countries, such as Australia, China, Germany, Italy, Portugal, the UK, the USA, Austria, and Spain [10].

Brazil also produces biodiesel from WCO; however, the amount of WCO in the energy matrix is still very low. In 2015, only 0.5% of biodiesel was produced from WCO [11,12].

Although it has low usage in the biodiesel chain, WCO has been touted as having the potential to meet the supply chain of biodiesel. WCO are a good alternative for the decentralized generation of power (biodiesel production), which could contribute to solve the fuel supply problems in many isolated rural locations [9,13]. In addition, oil collection can be used for the additional generation of income [14] through the inclusion of collectors [15], which could complement the social proposal for the National Program for the Production and Use of Biodiesel (PNPB) [16] and encourage raw materials with a higher productivity of oil that are alternatives to soybeans [17,18].

It should be noted that one of the initiatives aimed at reducing extreme poverty, particularly in developing countries, is the inclusion of informal collectors in the formal process of collecting solid municipal waste. This inclusion incorporates the training process for popular

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http://dx.doi.org/10.1016/j.rser.2016.11.240
Received 26 November 2015; Received in revised form 28 July 2016; Accepted 21 November 2016
1364-0321/

cooperatives as a way to organize the collectors. Also, the main purpose of these cooperatives is the rational collection of waste [19], added to the generation of income for the population with lower professional qualifications.

According to data from the United Nations Program for Development [20], there are people in the world living under extreme poverty, whose average income less than $1USD per day. The overall goal of cutting extreme poverty to half the level recorded in 1990 was achieved in 2010, five years before the time initially set. However, although the portion of the world's population considered as extremely poor fell from 47% to 22%, more than 1.2 billion people still live in extreme poverty.

Concerning Brazil, the country was one of the largest contributors to the global achievement of that goal. Extreme poverty and hunger were reduced from 25.5% (in 1990) to 3.5% (in 2012), thus reaching the international and national targets according to indicators established by the United Nations (UN) [21].

Regarding the potential for collecting WCO for the biodiesel industry in Brazil, it is estimated that only 2.5% of the oil produced in the country is reused, while the rest is discarded improperly in soils, bodies of water, and sewage systems or else incinerated. It should be noted that one liter of oil can contaminate one million liters of water, because oils and greases are characterized by low solubility and, when excessive, degradation in biological processes is difficult. Oil's low density also leads to the formation of films, obstructing the passage of oxygen to the water, hence increasing the organic load in bodies of water (pollution), having a negative impact on aquatic life [22].

Thus, the reuse of WCO is a way of minimizing environmental impacts [14] and consequently the expenses related to combating pollution generated in the maintenance of basic sanitation systems [23].

Despite the clear benefits from the proper disposal of WCO and even its use in other production systems, the use of WCO for biodiesel production would also allow the redirection of oil *in natura*. While it is currently used for fuel purposes, redirection to the food sector [3] would simplify the discussions about food vs. fuel, a criticism discussed by several authors [24–26].

Therefore, the present paper presents a review about the potential of WCO as a prospective source for biodiesel. In this sense, the paper examines the opportunity of biodiesel production from WCO as a potential source for future energy supply and also, an opportunity to promote social inclusion, particularly for Brazil. Several related aspects were covered in this paper, such as market potential and challenges for the governance and social inclusion in urban areas based on this selective collect, as well technical description, oil treatment and compositions, physical and chemical properties of WCO and its biodiesel.

2. Technical-economic characteristics to determine that this supply is used for biodiesel

2.1. Composition of WCO and biodiesel

WCO contains triglycerides which consist of glycerol and esters of fatty acids. These fatty acids have different numbers of carbon chain lengths that need to be modify tocome shorter carbon chains in order to obtain biodiesel [27]. There are several methods available for biodiesel production from triglycerides: direct blending (dilution), micro-emulsion, catalytic cracking and transesterification [28]. Yaakob et al. [29]detailed the types of transesterification for production of biodiesel from WCO: homogeneous, heterogeneous andenzymatic's catalysed and non-catalytic. However, the alkalicatalysed transesterification is the most used worldwide [28].

About the biofuel production process: part of WCO is transformed into biodiesel (80%), glycerol (10%) and about 10% is discarded [30].

The repeated use of cooking oil by immersion makes it darker and more viscous, with elevated acidity, increased specific heat, and an unpleasant odor. These features reduce the ability to purify it, thereby sacrificing its economic viability [31,32]. The different cooking conditions to which the oil is exposed (as cooking time and temperature) and food (as variations of salt and water contents) can also influence the quality of WCO and the physical properties of its biodiesel [33].

Thus, when WCO is used as a raw material for biodiesel production, further analysis of some of its characteristics is required, such as viscosity, oxidation, water content and mineral salts, and acidity, among others [34]. These changes in the physical-chemical and organoleptic characteristics of the oil are due to thermolytic, oxidative, and hydrolytic reactions [32].

Therefore, before using the WCO for biodiesel production, it must be pretreated [30,35,36]. Pretreatment is carried out to match the oil characteristics to the transesterification process. Filtering and a settling process are required for removal of the solid parts from the WCO, followed by a final heating to eliminate water [30,35].

After pretreatment, the liquid waste becomes a raw material for the production of biodiesel and the process becomes similar to that of oils *in natura* [14]. The liquid part consists of triglycerides and may go through processes such as cracking, esterification, and transesterification, the latter being the most widely used method in biodiesel production [13,17,37].

The process of transesterification of WCO occurs in the following steps: (i) oil is decanted and filtered for the removal of impurities; (ii) the clean oil is put into a stainless steel reactor, where the reaction with alcohol (ethanol or methanol) and a catalyzer (potassium hydroxide or methoxide) takes place; (iii) the reaction product needs to rest in a tank so that the separation phase (biodiesel and glycerin) occurs; (iv) the biodiesel is extracted by a drainage system; (v) after separation, the biodiesel is taken to another tank for stirring, where an earth filter and clarifier is added; (vi) following this process, the biodiesel goes to another tank, where it passes through a filter press to remove earth and other impurities [38].

In pioneering tests in the use of WCO biodiesel conducted by Costa Neto et al. [39] in Curitiba, despite its showing higher viscosity and density than diesel oil, this difference was reduced to a mixture of 20% (B20 mixture). In this mixture, the characteristics had to be very close to pure diesel oil, including in terms of its flash and combustion points. Some authors [14,22,40] also performed well in the production and use of biodiesel produced from WCO. Verma and Sharma [28] present the WCO proprieties by comparing other potential feedstock for the biodiesel sector.

According to the parameters of the Brazilian Agency (Agência Nacional de Petróleo, Gás Natural e Biocombustíveis - ANP), biodiesel that is to be marketed should present the following characteristics: kinematic viscosity at 40 °C of 3.0–6.0 mm^2/s; and acidity index up to 0.50 mg KOH/g [40]. The WCO biodiesel produced by Christoff [14] and Alves et al. [40] was suited to the standards established by the ANP and, in conversion with methanol, obtained a satisfactory yield of 85% and 82.9%, respectively, of pure biodiesel at the end of the process.

In surveys conducted by Çauli et al. [41], the yield of biodiesel produced by residual oil with 4% FFA and pre-dried was 86–94%; applying the same process of transesterification applied to refined soybean oil, the yield obtained was 97%.

WCO has different properties from oils *in natura*, due to the high temperature of the cooking process and the water present in the oil coming from foods. This fact contributes to the occurrence of hydrolysis of the triglycerides, by converting them into free fatty acids (FFA), which causes the change in acidity and viscosity levels, elevating them above the established standards [40,42]. The higher Free Fatty Acid (FFA) content in WCO when compared to oils *in natura*need to be considered for biodiesel production [27,43,44]. The water content in WCO is also higher than oils *in natura*, which also makes the transesterification reaction difficult [27]. The water content should not exceed 0.3% [44]. The presence of water in the oil also slows the