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Optimization of biodiesel production from animal fat residue in wastewater using response surface methodology

Sary Awad *, Maria Paraschiv, Edwin Geo Varuvel, Mohand Tazerout

École des Mines de Nantes, Département Systèmes Energétiques et Environnement, (DSEE), GEPEA, CNRS-UMR 6144, 4 rue Alfred Kastler, BP20722, 44307 Nantes Cedex 03, France

HIGHLIGHTS

▶ Biodiesel was obtained from waste water animal fat residue.
▶ Two-step acid-catalyzed transesterification process was employed.
▶ Operating parameters were optimized by response surface methodology.

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ABSTRACT

Animal fat residues (AFR) from waste water were used as feedstock to produce biodiesel by a two-step acid-catalyzed process. Treatment of the AFRs with 5.4% (w/w) of 17 M H_2SO_4 at a methanol/AFR ratio of 13:1 (50% w/w) at 60 °C converted more than 95% of the triglycerides into fatty acid methyl esters (FAMEs) with an acid value (AV) of 1.3 $mg_{KOH}/g_{biodiesel}$. Response surface methodology indicated that a lower AV cannot be reached using a one-step acid catalyzed process. Thus a two-step acid catalyzed process was employed using 3.6% catalyst and 30% methanol for 5 h for the first step and 1.8% catalyst and 10% methanol for 1 h in the second step, resulting in a yield higher than 98% and an AV of 0.3 $mg_{KOH}/g_{biodiesel}$. The product thus conforms to the European norm EN14214 concerning biodiesel.

1. Introduction

Biodiesel is a promising biofuel because its physical and chemical properties are similar to those of diesel fuel (Demirbas, 2008; Balat and Balat, 2008) and because its oxygen content enhances combustion and reduces hydrocarbon and particulate matter emissions (Demirbas, 2005; Rahimi et al., 2009; Basha et al., 2009).

Most of the produced biodiesel in the world is from vegetable oils, namely rapeseed oil in Europe and Canada and soybean oil in USA (Karmakar et al., 2010). Since biodiesel production from these sources can lead to competition with food production, other feedstock for biodiesel need to be explored. Animal fat residues (AFR) collected from fat traps are a cheap source of lipids that can be used to produce biodiesel. Andersen and Weinbach (2010) have estimated that in Norway 2.5 tons of AFR per 1000 households per year could be collected. Assuming that the European Union has the same potential as Norway, with 501 million households, the EU-27 has a potential to collect 1.25 million tons of AFR that could be transformed into 1250 million liters of biodiesel. The problem with AFRs is their high content of free fatty acids (FFA). Using an alkali catalyzed process, the FFA will be transformed immediately into soap. An acid-catalyzed reaction will be 4000 times slower than an alkali-catalyzed process and requires higher amounts of alcohol and catalyst and higher temperatures (Sharma and Singh, 2009; Lam et al., 2010; Agarwal, 2007). In order to solve this problem, an acid-catalyzed pre-esterification step is required to decrease the FFA level to 1% (West et al., 2008; Tiwari et al., 2007; Dias et al., 2009). This process is usually followed by an alkali-catalyzed process due to its reaction speed. Optimization of these reactions requires a large number of experiments and a mathematical tool that can predict the effect of each parameter of the reaction and their interactions. Response surface methodology has been successfully applied to the optimization of biodiesel production from different raw materials using different types of catalysts (Yuan et al., 2008; Bautista et al., 2009; Tiwari et al., 2007; Ghadge and Raheman, 2005).

In the present study, biodiesel production from AFR using a two-step acid catalyzed reaction was studied. The first step of reaction was optimized using response surface methodology. The produced biodiesel was analyzed and compared to European norm EN14214.

* Corresponding author. Tel.: +33 (0) 2 51 85 82 88; fax: +33 (0) 2 51 85 82 99.
E-mail address: sary.awad@gmail.com (S. Awad).

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