Application of TiO₂ nanoparticles for eco-friendly biodiesel production from waste olive oil

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ABSTRACT

An environmentally benign, simple, and efficient process has been developed for biodiesel production from waste olive oil in the presence of a catalytic amount of TiO₂ nanoparticles at 120°C with a conversion of 91.2% within 4 h. The present method affords nontoxic and noncorrosive medium, high yield of biodiesel, clean reaction, and simple experimental and isolation procedures. The catalyst can be recycled by simple filtration and reused without any significant reduction in its activity.

Introduction

Biodiesel is known as a nontoxic, renewable, and environment-friendly biodegradable fuel that is free from sulfur and aromatic compounds. Also, the combustion performance properties of biodiesel have been considered to be better than conventional fossil fuels (Catarino et al. 2017). Storage, transportation, and handling of these fuels are simpler than diesel fuels due to a higher flashpoint. Biodiesel is normally produced as fatty acid methyl esters (FAME) or fatty acid ethyl esters (FAEE) by the transesterification of triglycerides (present in vegetable oil, algal oil, or animal fat) and methanol or ethanol, respectively (Chopade et al. 2012; Ramachandran et al. 2013). Due to the high viscosity and low volatility of pure vegetable oil, the fuel lines and fuel injectors would clog and the piston heads would experience increased fouling (Shahid and Jamal 2011). Blending of oil with petroleum diesel, pyrolysis (thermal cracking), emulsification, and transesterification have been found as the different procedures to reduce the viscosity of triglycerides (Strayer, Blake, and Craig 1983).

Titanium dioxide (TiO₂) nanoparticles (TNPs) have attracted extensive research interest because of their novel properties such as chemical stability, large surface area, nontoxicity, and low production cost (Chen and Mao 2006). A large number of diverse applications that include solar dye-sensitized solar cells (Xu et al. 2010), photocatalysts (Baram et al., 2011), orthopedic and bioimplant applications (Kar, Raja, and Misra 2006), solid-phase extraction adsorbents (Kefi et al. 2011), solar energy applications (Mor et al. 2006), and photo-electrochemical cells for the solar generation of hydrogen (Gong, Lai, and Lin 2010) have been found. The heterogeneous catalysts present three main advantages such as recyclability, simple workup and purification of the products, and reduction in the water to wash the product phases (Chouhan and Sarma 2011).

In continuation of our studies to develop environmentally friendly synthetic methodologies (Khaligh and Mihankhah 2015; Mihankhah, Delnavaz, and Khaligh 2016), herein, we report the application of TNPs as a reusable catalyst in the promotion of the biodiesel production from waste olive oil in order to waste management.

Experimental

The transesterification reactions were carried out in a 250 mL stainless steel high pressure Parr reactor. Each reaction was performed with a 4:1 volume ratio (30:1 molar ratio) of methanol to waste olive oil in the presence of 200 mg of TNPs. The feedstock for the transesterification reaction was waste cooking or frying olive oil. Olive oil was obtained from Rodbar city in Guilan province (IRAN). The anhydrous methanol was purchased from Sigma-Aldrich (99.8% purity) and was used without further processing. TNPs were purchased from Degussa (Evonik) with defined shape and size; further, the characterization of TNPs was carried out by XRD and SEM in order to determine their formation, size, and morphology behaviors. In a typical synthesis method, 23 g of TiO₂ powder, P25 Degussa, was mixed with 200 mL of 18 M of aqueous solution of KOH. The mixture was heated in a Teflon-underlined steel reactor with constant stirring at 150°C for 24 h. The reaction product was washed with deionized water through repetitive centrifugation at 4500 rpm for 15 min in an Eppendorf centrifuge. The washing was repeated several times until the supernatant attained pH = 7 and the conductivity of the supernatant reached 15 µS/cm⁻¹. Conductivity measurements were carried out using Thermo Fisher Scientific/Eutech Instrument PC700 pH/mV/Conductivity meter. The instrument conductivity ranges from 0 to 2000 µS and 0 to 200.0 mS. The instrument has a full scale resolution of 0.5% and an accuracy of ±1%. Before