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Valorization of food waste from restaurants by transesterification of the lipid fraction

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ABSTRACT

Food waste contributes to increase the environmental impact, besides the ethical issue. One interesting way of valorization is its conversion in biofuel, thus helping to boost the concept of circular economy. The target of this work was to find out the feasibility of the use of the oil included in solid food waste (SFW) to produce biodiesel that meets the European biodiesel standard EN 14214. For this purpose, Soxhlet extraction of the lipid fraction of SFW from different restaurants has been carried out. Fatty acid composition was analyzed and potential differences concerning the source of SFW were evaluated through principal component analysis. Results showed significant differences in the oil fatty acid composition depending on the restaurant. However, oil physical and chemical properties were similar, excepting the acid value. Due to the high free fatty acid content (acidity of 11.21 mg KOH/g) of the oil from fine dining restaurant residues, acid-catalyzed esterification pre-treatment to the alkaline transesterification was needed. The fatty acid composition of oils from SFW differs depending on the restaurant, but the range of fatty acid methyl esters (FAME) is similar to that found in vegetable oils, showing a content of oleic acid (C18:1) between 36.39 and 41.57% w/w and linolenic acid (C18:2) of 21.37–38.63% w/w. Several chemical and physical properties of SFW oil biodiesel were analyzed. It was found that biodiesel fulfil the European standard EN 14214, with the exception of FAME yield, oxidation stability and glyceride content. For this reason and to improve biodiesel quality, further reaction optimization study, blending with diesel fuel or the use of additives is strongly recommended. It may be concluded, from this field trial, that oil from SFW from different restaurants may be mixed together and used to produce biodiesel. To corroborate this statement, further diesel engine tests are needed.

1. Introduction

Solid food waste (SFW) comprises food residues and is composed of processed food or discarded edible raw materials [1]. Recently, FAO has reported that more than 50% of the food produced is discarded, reaching over 1.3 billion tons of wasted food per year [2]. EUROSTAT data from 2006 show an annual food waste generation in EU27 of 89 Mt, equivalent to 179 kg per capita. Considering EU population growth by 2020, a production of SFW by about 126 Mt is expected, corresponding to an annual CO_2 related emissions of 240 Mt [1]. These figures demonstrate that SFW has a great impact on environment, food quality, safety and security; a sustainable management of SFW represents a challenge from an economic and ecological point of view. Furthermore, food waste involves a relevant ethical issue, as while food is wasted by developed countries, one billion people die of starvation in the rest of the world [3]. Different sources of SFW production have been identified [1]:

- Manufacturing sector
- Household sector
- Wholesale/retail sector
- Food service sector

In the EU27, 14% of total SFW is provided by the food service sector, reaching 12.3 Mt (an average of 25 kg per capita). Also, there is a significant discrepancy when either EU12 or EU15 is considered, as SFW from food service sector provides 12 kg or 28 kg SFW per capita, respectively. SFW production from food services is caused by inadequate storage, technical malfunction while food is processed in the food chain supply, food safety regulations or excess of food *vs.* request

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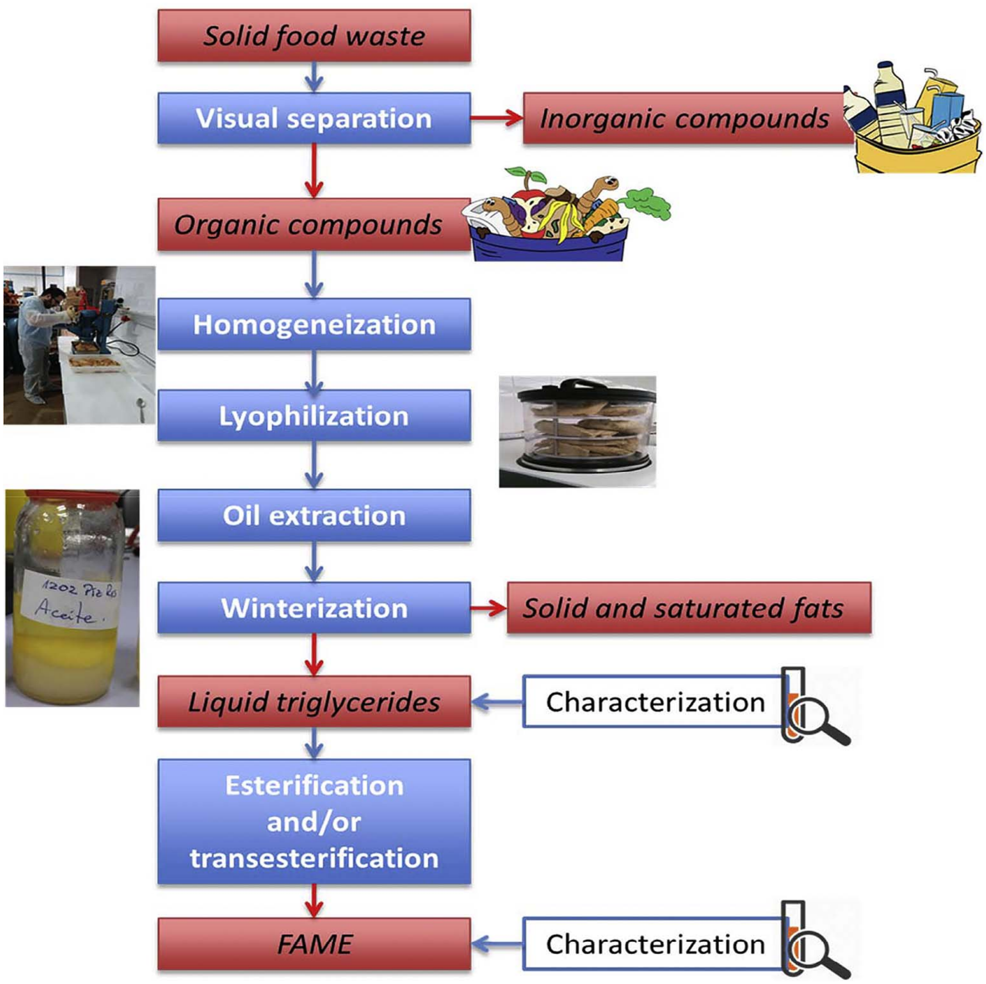

Fig. 1. Experimental layout for biodiesel production.

[3].

The composition of food waste from food service is very heterogeneous and depends on the establishment. It is mainly collected from restaurants, food markets (grocery stores), hotels, cafeterias, caterings and bakeries. Food waste includes different mixtures of food, i.e. meat, vegetable, carbohydrate (rice, potato and bakery products, as donuts and bread), fish, legumes, etc.

The planet is involved in a climate crisis at both global and local level. A change in the energy model, besides the selection of new feedstock and development of efficient conversion technologies to reduce greenhouse gas emissions is needed [4]. In this sense, different protocols as the one in Montreal (1990) or Kyoto (1997) contain legally binding commitments. The EU has developed a strategy for 2020 that includes three objectives, called "20-20-20", in order to reduce greenhouse gas emissions (GHG), to increase renewable energy in final energy consumption and energy efficiency.

In the EU, the industry is the sector that generates the highest amount of exhaust emissions (58%, that is 2.6 Mt) followed by transport (20%, 1.02 Mt). Waste management (including SFW) represents 4% of the total emissions. In this context, increasing the use of alternative fuels is key to reduce GHG emissions. Considering transport, liquid biofuels should have a relevant role. Although, in 2014, 64.1% of produced renewable energy originated from biomass, liquid biofuels for transport only represented 6% of the overall share of renewable energy. At this point in time, SFW is an interesting raw material that may be transformed into biofuels, besides high value-added products through the biorefinery concept. Chemically, food establishments contribute to SFW with lipids, carbohydrates, amino acids, phosphates, vitamins and other types of carbon; the lipid fraction can be converted into biodiesel or fatty acid methyl esters (FAME) by transesterification. For this purpose, a previous extraction of lipids from SFW is needed. This operation can be carried out using a conventional Soxhlet or through supercritical extraction [5].

Before FAME from SFW is produced, is key to analyze the acid value (AV) and moisture content of extracted lipids. In this sense, alkali-catalyzed transesterification using KOH is preferred when triglycerides with low free fatty acid (FFA) content are used. For high FFA feedstock (above 3%), two-step reaction is recommended, combining acid and basic catalyzed transesterification [6,7]. The necessary amount of KOH is supplemented with the necessary amount of catalyst in a second-step transesterification, to neutralize the oil acidity. Also, Thiruvengadaravi et al. [8] proposed an acid esterification pretreatment to reduce AV to 1.3 mg KOH/g in the oil. Yang et al. [9] achieved a biodiesel conversion rate of 98.5% and 97.8% from waste noodles, using both acid and basic catalysts, respectively. Moreover, the viability of biodiesel production from lipid obtained from fungal hydrolysis of SFW was demonstrated in a recent study by Karmee et al. [10]. Authors extracted the lipid fraction with hexane and diethyl ether, after mixing SFW with water, achieving a FAME yield close to 100%.

Biodiesel quality is regulated by the European standard EN 14214. In this sense, several studies [11–15] have demonstrated that the most important physical and chemical properties of biodiesel depend on the fatty acid composition of triglycerides used as feedstock, which constitute the lipid fraction of SFW. However, due to complex thermochemical processes involved during cooking and storage of food, SFW compounds content can undergo several changes. For example, complex structures such as colloidal dispersions and emulsions may take place, while lipids can interact with proteins or sugars [16]. Tree types