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Short Communication

Edible oil mill effluent; a low-cost source for economizing biodiesel production: Electrospun nanofibrous coalescing filtration approach

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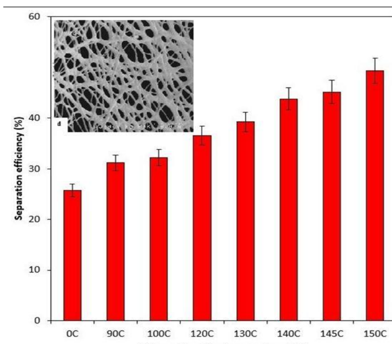
HIGHLIGHTS

- EOM as a low-cost and emerging source for biodiesel production.
- Improving coalescing filtration using electrospun nanofibrous for oil recovery.
- Thermal treating of filters improve the coalescing efficiency.

GRAPHICAL ABSTRACT



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ABSTRACT

Biofuels have increased in popularity because of rising oil prices and the need for energy security. However, finding new raw sources for biodiesel production is still challenging. The oil which comes from wastewater effluent generated in edible oil mills (EOM) can be considered a low-cost, widely available, emerging and interesting source for biodiesel production. This study tries to improve the coalescing filtration by using electrospun nanofibrous filters for oil recovery from the EOM effluent. In order to improve the separation efficiency of the filters, thermal treatments (90ºC to 150ºC) were used. Results indicate that oil recovery using coalescing filtration is a promising method for providing a new source for making biodiesel production more economical.

1. Introduction

A biofuel is a fuel that is produced from living organism, or more specifically made through biomass conversion (Mohammadi et al., 2011; Long et al., 2013). Biomass refers to recently living organisms, most often plants or plant-derived materials or even algae (Chisti and Yan, 2011; Bridgwater, 2012). Biofuels have increased in popularity because of rising oil prices and the need for energy security (Shirazi et al., 2013a). Among the various developed bioenergy sources such as bioethanol, biobuthanol or, biogas, biodiesel has attracted great interest due to its various advantages (Hasheminejad et al., 2011).

During the last couple of decades, biodiesel, which is an alternative to petro-based diesel, has attracted an increasing deal of attention. This has been due to its remarkable emission characteristics which means less carbon

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monoxide, sulfur compounds, particulate matter and unburned hydrocarbons (Shirazi et al., 2013a). Major strategies are now being considered to use biodiesl at the commercial scale. These strategies focus on increasing the production quality, creating novel feedstock in order to increase potential production quantity, enhancing fuel performance and other economizing strategies such as simultaneous production of value-added by-products. It is worth noting that one of the most challenging problems in the way of economizing biodiesel production is finding an available and low-cost source (i.e. vegetable oil for biodiesel manufacturing via transestrification, which is the most common method for methylesterification) (Hasheminejad et al., 2011; Chisti, 2013). In other words, using agricultural crops or algae is not economical yet, due to the rising global demand for water (Shirazi et al., 2012a). Therefore, using alternative and cheaper sources (i.e. oil) for biodiesel production is a critical subject. Recently, the waste cooking oil (WCO) produced in restaurants and fast-food places is being investigated as a versatile oil source for biodiesel production (Yaakob et al., 2013). It is worth noting that the wastewater effluent generated in edible oil factories contains ~4000 mg/L of crude oil (Rupani et al., 2010); and can therefore be worth investigating as an emerging and interesting source of raw material (i.e. vegetable oil) for biodiesel production. However, prior to any downstream processing, this crude oil should be recovered from the wastewater stream. In this regard, coalescing filtration is one of the most practical separation methods which has effectively been used for treatment of oily wastewaters (Viswanadam and Chase, 2013).

Liquid-liquid coalescing filtration is utilized to accelerate the merging of droplets to form fewer droplets, but with greater diameters (Eggers et al., 1999). The settling or rising of the larger droplets downstream of the coalescer element then requires considerably less residence time. Fig. 1 shows a three steps approach into how droplets coalescing works. The coalescing medium is the most important parts of a coalscer which, as can be seen, captures several droplets and forms larger drops.

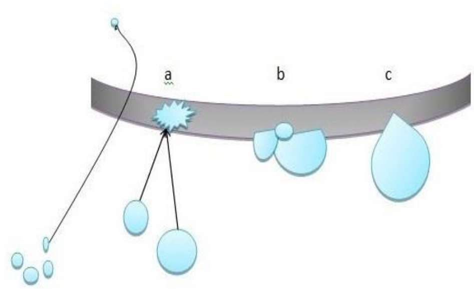


Fig.1. Three steps of droplets coalescing on a fiber a) collection of individual droplets, b) combination of several small droplets into larger ones and c) rising of the enlarged droplets due to density difference

Currently, electrospinning method has been used to prepare coalescing mediums. This is a simple and practical method that creates fibers ranging from microns to nano in regards to their size; through an electrically charged jet of polymer solution or melt (Mirtalebi et al., 2013). In this study, an electrospun nanofiber based filter has been used for oil recovery from simulated wastewater effluents, generated in an edible oil mill (EOM) through coalescing filtration.

2. Materials and methods

Electrospun polystyrene filters were prepared using a self-made electrospinning set-up, equipped with a high voltage system (Gamma high voltage power supply, ES60P-5W, USA) (Fig. 2).

A 20wt.% solution of polystyrene (Sigma-Aldrich, USA) in *N, N*-Dimethylacetamide (DMA) (Merk, Germany), was used as the polymer dope. The polymer solution was electrospun at a rate of 0.1mL/min. Then an 18kV high voltage was applied between the needle (as the spinneret, 18gage) and the stainless steel collector, with 17cm distance. The nanofiber mat was then kept in a fume hood for 48h to dry in environmental conditions. The electrospinning set-up was then run for 30min to prepare each filter in the ambient pressure and temperature. Nanofibrous filters were thermally treated at 90 to 150ºC using a vacuum oven for 30min.

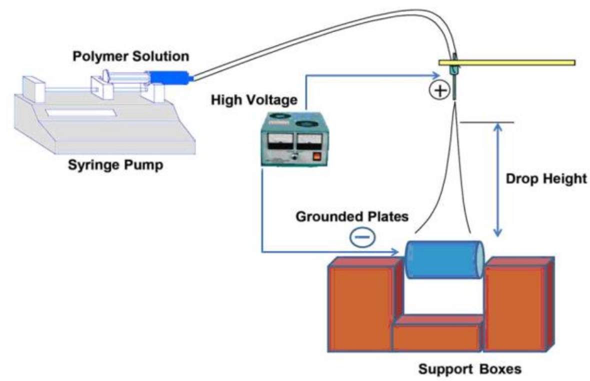


Fig. 2. A general scheme of the electrospinning set-up applied in this work

Scanning electron microscopy (SEM) (HITACHI S-4160, Japan) and atomic force microscopy (AFM) (DUALSCOP 95-200E, DEM, Denmark) were used for morphological and topographical observations.

A CILAS-1064 particle size analyzer and TOG-TPH analyzer (D3921-96 ASTM) were used to evaluate the performance of nanofibrous polystyrene filters for oil recovery from wastewater.

A lab-scale filtration set-up (Fig. 3) was made and used for coalescing the filtration experiments. The nanofibrous filters with an effective area of ~79 cm^2 were placed in the horizontal dead-end module. Sunflower oil (Behshahr Co., Iran) was used to prepare the wastewater emulsion (~3000 mg/L oil in distilled water). This mixture was agitated by a mixer (IKA, Germany) with 3000 rpm at least for 30 min.

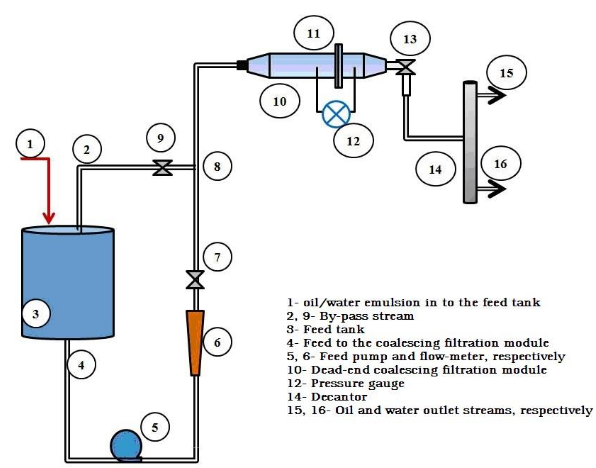


Fig.3. A general scheme of the experimental coalescing filtration set-up

3. Results and discussion

3.1 Morphological and topographical observations

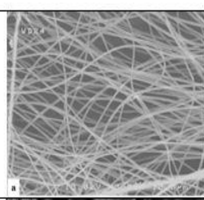
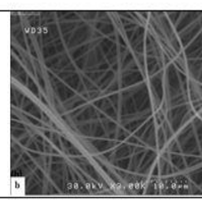
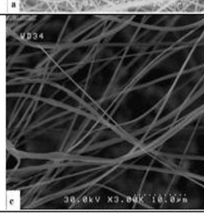
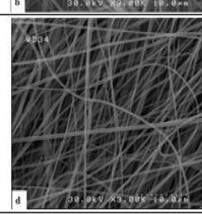
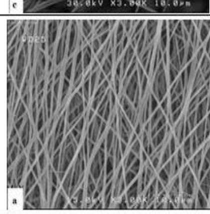
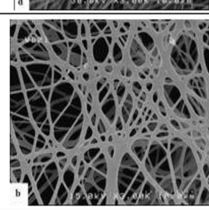
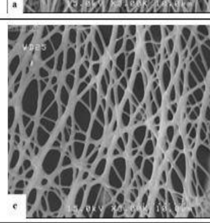
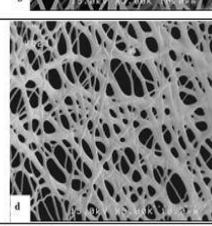
Table 1 shows the SEM images of the electrospun filters, before and after thermal treatment. As it can be observed, there was no significant change in the morphology of the electrospun filters when they were heated from 90 to 120ºC; however, after a 130ºC thermal treatment, the fibers started to merge together. The morphology change can be observed after 140ºC heating. With an increase in the temperature from 140 to 150ºC, as it can be observed, the morphology of the nanofibrous filters changed, significantly. In other words, using a thermal treatment led to the creation of a more uniform structure (i.e. pore size and its distribution). It is completely well-known that having a uniform pore structure and regular pore size distribution can directly affect the filters/membranes performance. Further discussion in this regard can be found in earlier works (Shirazi et al., 2013b; Shirazi et al., 2013c).

3.2 EOM recovery from wastewater

In order to evaluate the performance of the electrospun filters for oil recovery from synthesized EOM effluent, it is necessary to have something as a control solution. In this study, the natural decantation of water-oil emulsion (via phase separation) was used as control. Thus, a solution containing 3000 mg/L of sunflower oil mixed in distilled water was prepared and stored in a sealed graduated cylinder (100 mL, A-class; MERIANFIELD, Germany). A phase separation of the immiscible phases was monitored every 8 h. It was observed that after about 90 h the oil and water phases separated, completely. However, it should be mentioned that even after 90 h, a creamy layer was observed between the water (i.e. the polar and lower phase) and the oil (i.e. the non-polar and upper phase). It should be stated that the natural decantation of the water-oil emulsion, through gravitation settling, for the EOM effluent is time consuming and not practical at the industrial scale. Therefore, to use this oil for biodiesel production, the proposed separation process should be accelerated.

Fig. 4 shows the separation values (%) of the electrospun filters (based on the heating temperature) when used for coalescing filtration of the EOM effluent. As it can be observed, separation efficiency significantly increased through the application of thermal treatments (i.e. filters modified by higher heating temperatures). In other words, using thermal treatments led to an increase in the efficiency of the coalescing separation of the dispersed oil droplets from the water, as the phase continued. This can be explained by the fact that the coalescing of the dispersed droplets (Fig. 1) (i.e. sunflower oil droplets in this study) is a function of pore structure of the applied filter. It means that having a uniform pore structure (i.e. circular pores) and more regular pore size distribution can potentially increase the coalescing efficiency.

Table 1
SEM images of electrospun nanofibrous polystyrene filters before and after thermal treating

Before thermal treating		90ºC thermal treating	
100ºC thermal treating		120ºC thermal treating	
130ºC thermal treating		140ºC thermal treating	
145ºC thermal treating		150ºC thermal treating	

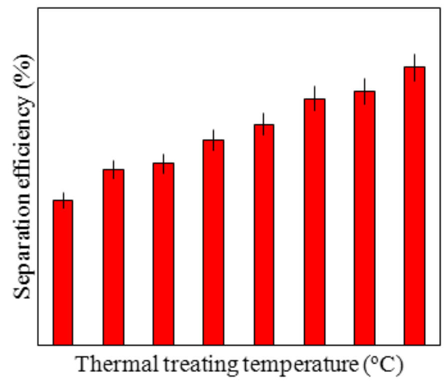


Fig. 4. The effect of thermal treatments on the separation efficiency of the oil-water emulsion

4. Conclusions

In this study it was found that the natural phase separation of the oil-water emulsion was time consuming and relatively completed after 90h, therefore, this cannot be used at the industrial level. The impact of thermal treatments on the morphology and separation efficiency of nanofibrous filters for oil-water coalescing separation was significant. Thermal treatments of between 90 to 130ºC had negligible effect on the morphology, however, slight increases were observed in the oil-water separation phase. Coalescing filtration can be effectively used for oil recovery from the EOM effluent, especially when an electrospun filter is used. Generally speaking, the results of this study can open a new window into to finding a novel source for biodiesel production through oil recovery from a low-cost and available sources.

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