Modeling and experimental validation of Free Fatty Acids (FFAs) removal from crude vegetable oils using fiber reactor technology

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Introduction

A combination of experimental measurements, reactor modeling, and model validation is used to develop a highly efficient approach for removal of free fatty acids (FFA) from vegetable oils. The process revolves around a new reactor concept called the Fiber Reactor™, which is a novel contactor for conducting reactions involving two partially miscible liquid phases that offers from one to two orders-of-magnitude improvement in liquid-liquid mass transfer rates when compared to conventional reactors, such as stirred tanks. The primary objective of this presentation is to describe recent research results that provide further understanding of Fiber Reactor™ performance by investigating intricacies of the engineering technology for application to FFA extraction. Emphasis is placed on comparing the effectiveness of reactive and non-reactive extraction technologies for removal of FFA's from crude vegetable oil by comparing observed mass transfer coefficients, acid removal efficiency and overall cost of operation. Fiber Reactor™ parameters of interest include: fluid pressure drop, fluid flow patterns, fluid flow regimes, liquid-fiber interfacial areas, mass transfer coefficients, heat transfer coefficients, and fiber particulars (material of construction, layout, size, geometry, and surface/wetting properties). Validation of the model-predicted results is also provided using experimental data generated using fiber reactor having diameters of ¼-in and ½-in, respectively.

Materials and Methods

Oil samples were titrated using NaOH 0.1 N, previously standardized. Then the spent volume of hydroxide was the input for the following equation, which provides the % in mass of Oleic acid in the sample.

$$\%FFAs\ as\ Oleic\ Acid = \frac{(mL\ of\ NaOH\ used)(NaOH\ molarity)(MW\ of\ Oleic\ Acid)}{10(Weight\ of\ sample)}$$

A model that predicts the oleic acid concentration is being developed, and is expected to be presented more in-depth, along with the final results of this investigation. The aforementioned model encompasses

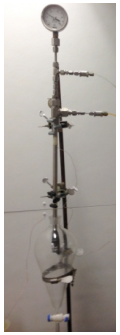

Figure 1. Fiber Reactor

Preliminary results and Discussion

Figure 1 shows the concentration of free fatty acids from the unrefined oil over time. It can be observed that the use of NaOH enhances the removal of FFAs over time (30% more), since the system is used as a titrator.

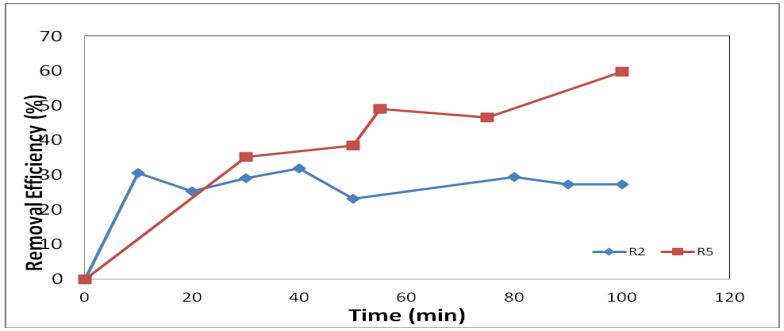

Figure 1. FFAs concentration over time, (R2) Ethanol:Oil 2:1; (R5) Ethanol:Oil 2:1+ 0.01% NaOH.

Significance

Removal of free fatty acids (de-acidification) is the most critical step in the oil purification process due to its economic impact. Currently, alkali refining is the prevalent process for oil de-acidification and its primary drawback is the loss of purified oil due to saponification. Solvent extraction is becoming a promising technology since it operates at mild Temperature (20 to 25°C) and P = 1 atm, therefore consumes less energy. Fiber reactor (FR) technology provides higher interfacial area,which increases mass transfer efficiency for transport of FFA'a from the oil phase to the solvent phase