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Improving the economics of biodiesel production through the use of low value lipids as feedstocks: vegetable oil soapstock

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Abstract

Semirefined and refined vegetable oils are the predominant feedstocks for the production of biodiesel. However, their relatively high costs render the resulting fuels unable to compete with petroleum-derived fuel. We have investigated the production of fatty acid methyl esters (FAME; biodiesel) from soapstock (SS), a byproduct of edible oil refining that is substantially less expensive than edible-grade refined oils. Multiple approaches were taken in search of a route to the production of fatty acid methyl esters from soybean soapstock. The most effective method involved the complete saponification of the soapstock followed by acidulation using methods similar to those presently employed in industry. This resulted in an acid oil with a free fatty acid (FFA) content greater than 90%. These fatty acids were efficiently converted to methyl esters by acid-catalyzed esterification. The fatty acid composition of the resulting ester product reflected that of soy soapstock and was largely similar to that of soybean oil. Following a simple washing protocol, this preparation met the established specifications for biodiesel of the American Society for Testing and Materials. Engine emissions and performance during operation on soy soapstock biodiesel were comparable to those on biodiesel from soy oil. An economic analysis suggested that the production cost of soapstock biodiesel would be approximately US$ 0.41/l, a 25% reduction relative to the estimated cost of biodiesel produced from soy oil.
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Keywords: Soapstock; Biodiesel feedstock; Transesterification/esterification

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1. Introduction

Biodiesel fuel, which consists of the simple alkyl esters of fatty acids, is presently making the transition from a research topic and demonstration fuel to a marketed commodity. Annual US production in 2001 has been estimated at 57–76 million liters [1], with European production more than 10 times that size [2]. It is predicted that, in the US alone, production will reach 1.3 billion liters annually by 2011 [2].

In addition to meeting engine performance and emissions criteria/specifications, biodiesel will have to compete economically with petroleum-based diesel fuel to survive in the market place. Vegetable oils, partially or fully refined and of edible-grade quality, are currently the predominant feedstocks for biodiesel production. In the US, this is soybean oil, and in Europe it is rapeseed oil, since these are the predominant oilseeds grown in those regions. The prices of these oils are relatively high for fuel-grade commodities. For example, US crude soybean oil prices have generally been in the range US$ 0.48–0.57/kg in recent years, which equates to a cost of US$ 0.40–0.48 for the oil sufficient to produce a liter of biodiesel. Most recently, price spikes have reached as high as US$ 0.77/kg oil. In Europe, the cost of the rapeseed oil typically employed in biodiesel production is roughly 25% higher than that of soy oil in the US. In contrast, US spot prices for petroleum diesel have recently been in the range US$ 0.21–0.24/l. Thus, in the US, the raw material cost of the most typical biodiesel feedstock is substantially greater than the finished cost of the petroleum diesel with which it must compete in the market place. The additional cost of biodiesel synthesis from the oil feedstock further accentuates this discrepancy. In Europe, this price gap between fossil and renewable diesel fuels is less pronounced largely because taxation elevates the price of fossil fuel in that region. Nonetheless, the economic competitiveness of biodiesel is not ensured. Government subsidies are now being considered and enacted in various regions to offset the relatively high cost of biodiesel, and these could help improve the economic competitiveness of biodiesel. However, it is quite desirable to eliminate reliance on such support programs.

These considerations have led to efforts to identify less expensive lipid-bearing materials that could serve as feedstocks for biodiesel production and to devise chemical processes for their conversion to fuels. Thus, animal fats have been converted to biodiesel [3,4], and substantial efforts have been devoted to the development of waste restaurant grease, largely the spent product of the deep fat frying of foods, as a biodiesel feedstock [5–7]. The development of other feedstocks is also of interest, not only to further increase the economic viability of biodiesel, but also to increase the potential supply of this fuel.

'Soapstock'(SS), a byproduct of the refining of vegetable oils, is another potential biodiesel feedstock. It consists of a heavy alkaline aqueous emulsion of lipids, containing about 50% water, with the balance made up of free fatty acids (FFA), phosphoacylglycerols, triacylglycerols, pigments and other minor nonpolar soybean components. SS is generated at a rate of about 6% of the volume of crude oil refined, which equates to an annual US production of approximately one billion pounds. Its market value is approximately US$ 0.11 per kg on a dry weight basis, i.e., about one-fifth the price of crude soybean oil.

Other researchers have reported methods for the production of fatty acid esters from SS [8–10]. However, these have not been implemented to date by industry, perhaps because they