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Economics of small-scale on-farm use of canola and soybean for biodiesel and straight vegetable oil biofuels

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ABSTRACT

While the cost competitiveness of vegetable oil-based biofuels (VOBB) has impeded extensive commercialization on a large-scale, the economic viability of small-scale on-farm production of VOBB is unclear. This study assessed the cost competitiveness of small-scale on-farm production of canola- [*Brassica napus* (L.)] and soybean-based [*Glycine max* (L.)] biodiesel and straight vegetable oil (SVO) biofuels in the upper Midwest at 2007 price levels. The effects of feedstock type, feedstock valuation (cost of production or market price), biofuel type, and capitalization level on the cost L^{-1} of biofuel were examined. Valuing feedstock at the cost of production, the cost of canola-based biodiesel ranged from 0.94 to 1.13 $\$ L^{-1}$ and SVO from 0.64 to 0.83 $\$ L^{-1}$ depending on capitalization level. Comparatively, the cost of soybean-based biodiesel and SVO ranged from 0.40 to 0.60 $\$ L^{-1}$ and from 0.14 to 0.33 $\$ L^{-1}$, respectively, depending on capitalization level. Valuing feedstock at the cost of production, soybean biofuels were cost competitive whereas canola biofuels were not. Valuing feedstock at its market price, canola biofuels were more cost competitive than soybean-based biofuels, though neither were cost competitive with petroleum diesel. Feedstock type proved important in terms of the meal co-product credit, which decreased the cost of biodiesel by 1.39 $\$ L^{-1}$ for soybean and 0.44 $\$ L^{-1}$ for canola. SVO was less costly to produce than biodiesel due to reduced input costs. At a small scale, capital expenditures have a substantial impact on the cost of biofuel, ranging from 0.03 to 0.25 $\$ L^{-1}$.

1. Introduction

Declining crude oil resources, volatile petroleum markets, the quest for energy security, and the impact of petroleum fuel use on global climate change have spurred efforts to identify and develop alternative renewable energy sources [1–4]. Utilization of vegetable oil-based biofuels (VOBB) including straight vegetable oil (SVO) and derivatives thereof such as biodiesel have emerged as renewable alternatives to petroleum fuels [5,6]. Biodiesel is a mixture of monoalkyl esters resulting from a chemical reaction between an alcohol and vegetable oil in the presence of a catalyst [7]. SVO refers to chemically unaltered vegetable oil produced by an oilseed crop. In this study, VOBB refers to SVO and biodiesel collectively as biofuels derived from agriculturally produced oilseed crops with reference to SVO and biodiesel made specifically when necessary.

Societal concerns about climate change and food availability suggest that alternative energy systems should exhibit

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a positive net energy balance, net reduction of life cycle emissions, and marginal impact on food supply in addition to being economically viable. Numerous studies have suggested that more total energy is produced than consumed in the biodiesel production process [1,8–10]. However, others have asserted that biodiesel production requires more total energy input than is produced in the resulting biofuel [11]. Alternatively, SVO was shown to be more energetically efficient than biodiesel for certain feedstocks and production settings [12]. VOBB's exhibit reduced emissions compared with the petroleum fuels they displace. Biodiesel for instance exhibited a 41% decrease in greenhouse gas emissions compared to diesel fuel [1]. However, the magnitude of the reduction will vary based on feedstock production practices and engine design [13,14]. The emission profile of SVO is substantially different than that of biodiesel. While it is generally agreed that SVO increases carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons, and particulate matter emissions relative to biodiesel, there is significant discontinuity in the literature as to how it compares with petroleum diesel [15–21]. The magnitude of the reduction in greenhouse gas emission is dependent on multiple factors including SVO chemical composition, engine type, and engine configuration.

Beneficial environmental characteristics and political impetus have led to recent increases in US biodiesel production. An estimated 2.65×10^9 L (7.0×10^8 gal) of biodiesel were produced domestically in 2008, an increase of 56% over 2007 [22]. Large-scale biodiesel facilities, ranging in capacity from 1.89×10^7 L yr^{-1} (5.0×10^6 gal yr^{-1}) to 3.79×10^8 L yr^{-1} (1.0×10^8 gal yr^{-1}), have accounted for virtually all of the measureable increase in total biodiesel production [23]. Despite recent increases in the production of VOBB, their contribution to aggregate energy use remains very small [24].

Numerous researchers have cited the cost competitiveness and quality of biodiesel as major impediments to broader commercialization [25–32]. For instance, Bender [25] found the cost of biodiesel ranged from 0.30 to 0.69 \$ L^{-1} for differing feedstocks and production scales citing a petroleum diesel price of 0.18 \$ L^{-1}. Haas et al. [27] estimated the cost of biodiesel to be 0.53 \$ L^{-1} compared with petroleum diesel prices ranging from 0.20 to 0.25 \$ L^{-1}. For the majority of VOBB production systems including those noted above, the most prominent expense is feedstock acquisition. Haas et al. [27] found that feedstock costs constituted 88% of the total cost of biodiesel when using degummed soybean oil, which is consistent with previous findings [25,32]. From a fuel quality perspective, it is important that commercially produced biodiesel meets or exceeds the established quality standards ensuring safe use [30,33]. There are occurrences where sub-specification biodiesel has resulted in mechanical detriment and degradation of public perception of the biofuel [34].

Traditionally, research analyzing the economics of VOBB production has focused on large-scale biofuel production facilities, though there is a growing literature surrounding the economics of small-scale biofuel production [35]. Currently, it is not sufficiently clear whether the benefits associated with VOBB's can be maintained or enhanced through a reduction in scale e.g., on-farm biofuel production. Diverting relatively little land area to the production of oilseed crops, certain agricultural operations could displace a substantial amount of their diesel fuel and livestock feed requirements by producing them on-farm. On-farm production of required inputs reduces producer exposure to volatile market swings, thus mitigating certain production risks. If biofuels and livestock meal are produced on-farm at a discount compared with commercially available substitutes, substantial savings could accrue enhancing profitability. Furthermore, replacing non-renewable petroleum fuels with low carbon biofuels produced on-farm could reduce total farm-based emissions. Additionally, on-farm production of biofuel and livestock meal progresses toward a more closed-loop agricultural system where energy and nutrients are cycled in close proximity to their origin.

While the physical construction of a small-scale on-farm biofuel production system may differ in the level of sophistication, the fundamental components of each are similar. Fig. 1 illustrates the processes common to a generic small-scale biofuel production system. In the upper Midwest there are numerous potential oilseed feedstocks including soybean, canola, camelina, brown mustard and sunflower [36–38]. The appropriateness of a particular oilseed feedstock for biofuel production depends on agronomic suitability (e.g.,soil type, amount of precipitation, nutrient requirements), oil content, and meal nutritional characteristics. Following feedstock production or purchase, the oilseed is first conditioned to remove any debris that may hinder or cause mechanical damage in the oil extraction process. The oilseed is then crushed using a mechanical oilseed press removing approximately 70–80% of the total oil producing crude vegetable oil and livestock meal. Meal is most commonly fed to livestock as a protein and energy supplement while the crude vegetable oil is processed into biodiesel or SVO. There are numerous ways to process crude vegetable oil into biodiesel at a small scale. The most common method is base catalyzed transesterification.

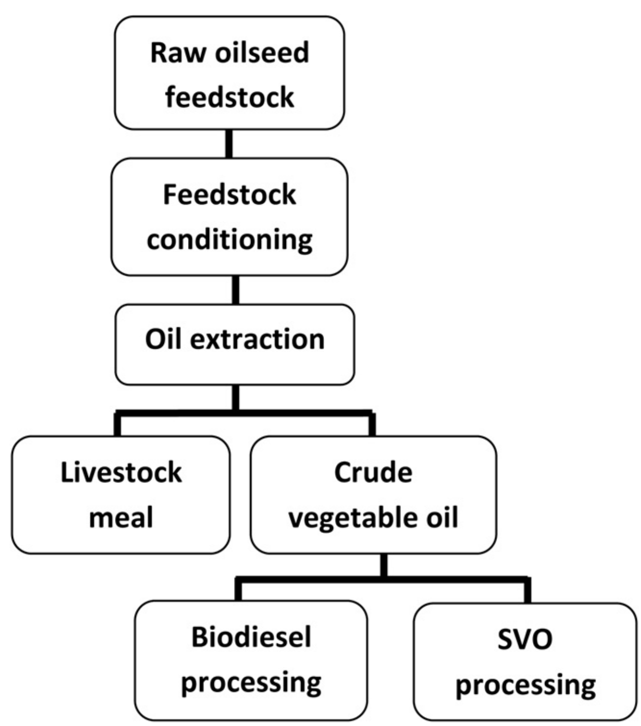

Fig. 1 – Small-scale on-farm biofuel production flowchart.