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Technoeconomic analysis of small-scale farmer-owned Camelina oil extraction as feedstock for biodiesel production: A case study in the Canadian prairies

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ABSTRACT

This study evaluated costs and profitability associated with small scale camelina oil extraction plant in the Canadian Prairies for the purpose of selling camelina oil for further biodiesel production. In this case, *Camelina sativa* is targeted for production on underutilized summerfallow land to avoid displacement of crop lands. Saskatchewan soil zone 7A has the capacity to provide camelina for oil extraction based on small scale capacities of 30,000–120,000 t annum^{-1} and capital investment of $10-24 million. Oil production price is reduced with increased camelina oil content, field yield, plant scale, and camelina meal price. Oil production costs range from $0.39 to $1.88 L^{-1} when camelina meal has a market value of $0.30 kg^{-1}. These results provide an informative basis for investment decisions by farmers and investors vis-à-vis the advancement of farm-adoption of camelina as a dedicated industrial crop, as well as the development of an integrated camelina-to-processing oilseed value-chain.

1. Introduction

Camelina sativa has recently been recognized as a promising and sustainable non-food oilseed crop for biodiesel production in North America (Chen et al., 2015; Yang et al., 2016). Camelina has demonstrated low agronomic input requirements coupled with its ability to grow on marginal land using little moisture, factors which favour adoption in arid regions (Davis et al., 2013; Gugel and Falk, 2006; McVay and Khan, 2011; Newlands et al., 2012). Camelina possesses high seed oil content of 36–44%, twice the oil content of soybean, and over 90% unsaturated fatty acids (Gugel and Falk, 2006; Jiang et al., 2014). These attributes are coupled with camelina's recognized potential to reduce the carbon footprint (Li and Mupondwa, 2014; Shonnard et al., 2010). In fact, the demonstrated feed value of camelina meal also makes camelina an ideal animal feed (poultry, swine and ruminants) given favourable balance of amino acids, high protein and low glucosinolate content (Putnam et al., 1993; Schuster and Friedt, 1998; Zubr, 1997; Zubr, 2003).

The Canadian Prairie Province of Saskatchewan (accounting for 40% of Canada's farmland) has been targeted as a potential supplier of camelina feedstocks (Gugel and Falk, 2006; Séguin-Swartz et al., 2009; Steppuhn et al., 2010). The opportunity includes growing camelina and crushing the seed in the province, and subsequently shipping the crude oil to key markets such as the EU. The EU has experienced significant increase in the demand for biodiesel feedstocks triggered by the 2010 implementation of the EU's Renewable Energy Directive (RED). This directive sets targets for the EU to achieve a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. However, RED policies limit biofuel production from food crops to 7% which means dedicated non-food crops will play an increasingly important role in filling the huge demand gap in feedstock required to satisfy this demand. The EU has also established sustainability criteria under RED for supplying feedstocks such as camelina to this market, since camelina addresses issues related to competition between food and non-food resources, as opposed to traditional feedstock such as canola and soybean which are the

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Table 1
Biodiesel plants in Canada (Biodiesel Magazine, 2015).

Company Name	Location	Prov.	Feedstock	Capacity (L)
Archer Daniels Midland Co.	Lloydminster	AB	Canola Oil	265,000,000
Atlantic Biodiesel Corp.	Dain City	ON	Canola Oil/Soy Oil	170,000,000
Biox Corp.	Hamilton	ON	Animal Fats/UCO/DCO/SBO[a]	67,000,000
Cowichan Biodiesel Co-op	Duncan	BC	Waste Vegetable Oil	200,000
Innoltek Inc.	Thetford Mines	QC	Multi-Feedstock	6,000,000
Methes Energies Canada Inc.	Sombra	ON	Multi-Feedstock	50,000,000
Milligan Biofuels Inc.	Foam Lake	SK	Non-Food Grade Canola Oil	14,000,000
QFI Biodiesel Inc.	Saint-Jean-sur-Richelieu	QC	Multi-Feedstock	19,000,000
Rothsay Biodiesel LLC	Ville Ste. Catherine	QC	Animal Fats/Yellow Grease	45,000,000

[a] UCO-used cooking oil; DCO- distiller corn oil; SBO-soybean oil.

predominant feedstocks used to produce biodiesel in major biodiesel producing regions (Junginger et al., 2014; van de Staaij et al., 2012). Canada's camelina value-chain has an opportunity to access the world's largest biodiesel market that is expected to double in size over the next decade.

These opportunities still require successful adoption of camelina by local farmers on a commercial scale, starting with the ability to plant camelina in marginal areas of Saskatchewan, which would eliminate nearly one million hectares of Canadian Prairie summerfallow, representing a positive land use change while providing farmers with additional revenue crop opportunities. These factors taken together are considered as providing the foundation for a farmer-owned camelina rural biorefinery. A salient feature of Canada's biorefinery strategy is to provide opportunities for farmers and rural communities to participate in and benefit from value-added processing of their farm-produced grains and oilseeds for applications such as bioenergy and other higher-value uses. The strategy includes support for direct investment in value-added processing by farmers through programs such as the Cooperative Development Initiative based on farmer-owned cooperatives. Government funding contribution increases as the level of producer equity investment increases. For instance, the ecoAgriculture Biofuels Capital Initiative, a federal $200 million four-year program, provided repayable minimum 5% of total eligible project costs for projects that process agricultural feedstock. These support mechanisms had led to successful evolution and value-chain integration of farmer-owned small-scale processing business models in Saskatchewan. This includes Milligan Bio-Tech of Foam Lake Saskatchewan, a farmer-owned entity that has emerged as a key player in the production and delivery of biodiesel and related bioproducts to the emerging biodiesel market. Milligan Bio-Tech uses damaged non-food grade canola seed as a feedstock for biodiesel and co-product production to meet on-farm energy requirements and supply surplus to the commercial market. It has a 60,000 metric-tonne (T) cold-press plant producing canola oil for 20 million litres of biodiesel per year, employing 46 staff. It is a small-scale operation oil crushing plant compared to solvent extraction plants such as Cargill' Clavet plant (1.5 million T canola seed annum^{-1}) or Dreyfus JRI's Yorkton plant (850,000 T annum^{-1}). It is also a small-scale plant in comparison to biodiesel plants in Saskatchewan (Table 1) (Biodiesel Magazine, 2015). Pound-Maker, integrated bioethanol-feedlot plant of Lanigan, represents another example of small-scale integrated on-farm production and processing of locally grown feedstocks in Saskatchewan. It is Canada's first integrated bioethanol-feedlot plant established in 1970 by local farmers seeking to diversify and market their grain locally, as well as provide employment for their community. The integrated plant has a feedlot capacity of 28,500 head and a 14.5 million litre ethanol production capacity that requires 40 ha (about 100 t) of grain per day, employing approximately 50 staff from the local area. Farmer shareholders have the first right to deliver grain at prevailing prices and quality specifications. Additional supplies can be sourced from non-shareholders if required.

Hence, farmer-owned small-scale processing of camelina for higher value co-products (oil, meal, and biodiesel) has potential to integrate farmers into the value chain beyond their immediate farm-gate oilseed production, including contributing to farm income diversification, stabilization, and enhancement. In fact, Lardy (Lardy, 2008) reports that small-scale oilseed processing using mechanical presses is becoming increasingly used in other jurisdictions including the USA and Europe to extract straight vegetable oil from oilseed crops for use in biodiesel production and meal coproduct applications as a high-protein, high-energy livestock feed supplements or as a fuel source for pellet stoves, thereby diversifying rural economies.

However, in building business models for small-scale processing of oilseeds like camelina, the profitability of such a production model is not sufficiently clear in terms of capital investment, operational efficiency, and value-chain integration. Studies that have modeled oilseed crushing simply assume it as an input into the production of biodiesel. Hence, most studies skip the technoeconomics of this processing step. The potential small-scale processing of camelina as an alternative model to large-scale high capital intensive solvent extraction in Canadian Prairies requires further elucidation in order to facilitate a market-pull for the emerging opportunity. Hence, this paper's objective is to examine the economics of small-scale camelina oilseed processing as a farmer-owned enterprise in the Canadian Prairie province of Saskatchewan.

2. Material and methods

2.1. Location of production

This study models a small-scale camelina oil extraction plant located in the drier Brown soil zones of southwest Saskatchewan (Fig. 1), which is the target identified by Agriculture and Agri-Food Canada (AAFC) researchers and industry collaborators for the introduction of camelina as a new dedicated bioenergy crop (Falk, 2015; Malhi et al., 2014). The farmer-owned processing plant is proposed to be located in Kindersley, within region 7A of the Brown soil zone which contains 169,295 ha of summerfallow area which can be used by farmers without the displacement of an existing crop in this region (Fig. 2). This figure also depicts concentric circles that represent farmers located within 100–200 km of Kindersley and who could potentially supply the required volume of camelina seed to the processing plant. It is useful to note the relative location of Kindersley with respect to existing large-scale canola oil solvent extraction plants at Clavet (Cargill's 1.5 million T plant) and Yorkton (Dreyfus-JRI 850,000 t plant) both of which are in the Black soil zone and at least 100–200 km away from the edge of the Kindersley supply area.