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Technical Feasibility of Small-Scale Oilseed and On-Farm Biodiesel Production: A Vermont Case Study

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Abstract: *This article investigates the technical feasibility of small-scale oilseed* *production and on-farm processing of biodiesel and livestock feed using primary data from two Vermont farms. Results indicate that small-scale production of sunflowers, canola, and soybeans, and on-farm processing of livestock feed and biodiesel are technically feasible, but yields depend on many factors. Increased local expertise, information-sharing among the farm and Extension communities, and improved access to harvesting and processing equipment can improve productivity and efficiency. Additional experience in seed drying and expeller pressing techniques should reduce fat content in the seed meal, improve meal value, and improve oil production efficiency.*

Introduction

Concerns about dairy farm viability, livestock feed costs, greenhouse gas emissions, and fossil fuel reliance have spurred interest in on-farm processing of biodiesel and livestock meal from oilseed crops. This interest is especially high in Vermont, where dairy farming, which accounts for 65% of total farm receipts, has faced severe economic challenges in the last decade (Economic Research Service, 2011). Vermont imports significant quantities of heating oil, diesel fuel, and high-protein oilseed meal for livestock. If Vermont farmers could grow and harvest oilseed crops, press the seeds into vegetable oil and oilseed meal, and process the oil into biodiesel, they could independently produce both liquid biofuel and livestock feed.

The feasibility of farm-scale biodiesel production from oilseed crops has been investigated for oilseed-producing regions of the U.S. by Kenkel and Holcomb (2008); Australia by Carter (2006), Kingwell and Plunkett (2006), and Whittington (2006); and Scotland by Booth, Booth, Cook, Ferguson, and Walker (2005).

Production of oilseed crops is rare in Vermont, however, and small-scale oilseed and on-farm biodiesel production remain largely unproven concepts. Vermont farmers generally have neither the necessary equipment nor experience to raise these crops, and processing oilseeds into biodiesel is an emerging area of knowledge and experience in the Northeast U.S.

This article investigates the technical feasibility of small-scale oilseed production and on-farm processing of livestock feed and biodiesel based on data from two Vermont farms experimenting with these enterprises in cooperation with University of Vermont (UVM) Extension. This research provides needed technical information to farmers, entrepreneurs, and educators who are exploring growing biodiesel feedstocks, processing oilseeds, or producing biodiesel. In addition, this article discusses the role of Extension educators in developing programs for interested farmers.

Data and Methods

The research reported here relies on quantitative and qualitative data from two case study farms in Vermont engaged in the three stages of biodiesel production from local feedstocks: (1) crop production, harvest, and storage; (2) oil and meal production by seed extrusion; and (3) biodiesel production.

Crop yields and production techniques were obtained from field- and small-scale replicated trials of oilseed crops at the case study farms conducted in 2006 and 2007 by UVM Extension specialists Heather Darby and Vernon Grubinger (Darby & Hills, 2007; Grubinger, 2007). Data on the oil and oilseed meal yield and meal nutrient content were also collected from the case study sites.

Crop, oil, and meal yield results are compared to typical yields for the U.S. Results for the nutrient analysis of the oilseed meals are compared to commercial livestock meals. The initial research required entrepreneurship in planning, harvesting, and storage because the farmers and Extension educators had little experience with oilseeds. There were some losses due to weather and birds, and some data were not recorded by the farmer as is commonly encountered with on-farm research. Yet the data reveal the potential and challenges for producing these crops, as well as additional research needs.

Results

Crop Production

Results from UVM Extension field trials indicate that oilseed crops can be grown successfully in Vermont. Although yields were affected by several factors—including the cultivar, weather and soil conditions, rates of germination and emergence, weed pressure (especially for canola and mustard), and bird damage to sunflowers—the data suggest that attaining yields comparable to those typical in higher oilseed-producing regions of the U.S. is possible in Vermont (Table 1).

Table 1.

Crop Yields from 2006 and 2007 Vermont Oilseed Field Trials

Crop	Variety*	Date	Moisture	Yield (lbs/acre)	Typical U.S. Yield

		Plant	Harvest			(lbs/acre)**
2006 trials						
Case Study Farm A						
Canola	Hyola 401	May 9	Aug 25	7.7%	1404	1800
Canola	Croplan 601	May 9	Aug 25	7.9%	1128	1800
Canola	Oscar	May 9	Aug 25	8.3%	996	1800
Canola	Hyola 420	May 9	Aug 25	8.0%	984	1800
Canola	KAB 36	May 9	Aug 25	9.4%	756	1800
Sunflower	IS 6521	May 10	Oct 6	8.0%	2200	2500
Soybean	IA 24, IF 61	May 10	*Crop failure due to wet weather*			
Case Study Farm B						
Canola	Croplan 601	May 19	*Not reported*	13.6%	1750	1800
Canola	KAB 36	May 19	*Not reported*	12.0%	1608	1800
Canola	Oscar	May 19	*Not reported*	11.5%	1363	1800
Canola	Croplan 601	May 29	*Not reported*	13.0%	1200	1800
Canola	KAB 36	May 29	*Not reported*	14.0%	1337	1800
Canola	Oscar	May 29	*Not reported*	12.4%	1000	1800
2007 trials						

Case Study Farm A						
Canola	Croplan 601	May 9	Aug 14	15.2%	792	1800
Mustard	Golden	May 9	Aug 14	11.1%	861	2000
Sunflower	Hysun1521	May 9	Sept 9	7.0%	1643	2000
Sunflower	Seeds2000 Defender	May 9	Sept 9	8.0%	1854	2000
Sunflower	IS 6039	May 9	Sept 9	10.0%	1806	2000
Sunflower	IS 6111	May 9	Sept 9	6.0%	1247	2000
Sunflower	IS 6521	May 9	Sept 9	8.0%	1454	2000
Sunflower	IS 4049	May 9	Sept 9	8.0%	2397	2000
Case Study Farm B						
Canola	Croplan 601	May 23	*Sept 5*	Not reported	3160	1800
Canola	Oscar	May 23	*Sept 5*	Not reported	2600	1800
Canola	Croplan Python	May 23	*Sept 5*	Not reported	3360	1800
Sunflower	Hysun 1521	May 23	October 17	12.0%	1439	2000
Sunflower	Seeds2000 Blazer	May 23	October 17	13.0%	2146	2000
Sunflower	Croplan 803	May 23	October 17	12.0%	1247	2000

Sunflower	Croplan 322NS	May 23	October 17	13.0%	1527	2000
*All seeds were non-transgenic, or non-genetically modified (GMO). **Sources: Kandel, 2010; National Agricultural Statistics Service, 2011; Putnam et al., 2000.						

The greatest challenges to optimizing oilseed crop production in Vermont are lack of familiarity with insects, diseases, and their control methods; scarcity of and lack of familiarity with necessary equipment for harvesting and storage; and inadequate time for crop maturation prior to harvest.

Harvesting oilseeds requires either a combine or a swather, and finding affordable equipment of this type in Vermont is difficult, although used equipment is available from other regions such as the Midwest. Both case study farms are using older-model combines that have been modified for sunflower and canola harvesting.

Obtaining the proper seed moisture in the field prior to harvest is also a challenge in Vermont, where the relatively short growing season and damp autumns make it difficult for oilseed crops to dry down in the field. Oilseed crops generally should be as dry as possible at harvest for optimal handling, storage, and prevention of mold and spoilage. Thus, post-harvest drying must often be performed to assure oilseed quality.

Once harvested, the oilseeds may also need cleaning to remove chaff, weeds, and other impurities that can cause the seed to heat up during storage, reduce the quality of the meal, and trigger mold growth that can reduce oil quality. Early experience at the case study farms has shown that the need for seed cleaning depends on the type of seed, the amount of weeds in the field, the effectiveness of harvesting equipment and techniques in picking up the crop and cleanly separating seed from other material.

Finally, adequate facilities for both initial seed drying and keeping seeds dry in storage are essential. At Study Farm B, harvest moistures have ranged from 13% to 20%, whereas the optimal moisture content for mold-free storage and pressing is approximately 9%. Farmers growing these crops in Vermont will therefore need facilities and equipment for drying or aerating the seeds after harvest. Study Farm B uses aerators placed in bins or bags of seed that have reportedly dried 14 tons of seed from 14% to 9% moisture in three days (R. Rainville, personal communication, October 16, 2008). Study Farm A has installed a solar-powered system using hot water and a heat exchanger for drying seeds stored in a grain bin.

Oil and Meal Production

Early experience with pressing oilseeds at the two study sites has shown that on-farm oil and meal production is technically feasible. The yield and quality of both the oil and meal appear to have strong potential to meet or exceed national averages and be competitive with commercial products, although additional experience with the equipment is necessary to maximize quality and consistency.

Oil and meal yields from 50-lb subsamples of seed grown and pressed at Case Study Farm A are shown in Table 2. The sunflower variety seeded at the highest rate (IS 4049) produced both the highest yield and the highest percent oil content, yielding 119 gallons of oil per acre. Although canola oil yields are relatively low, Grubinger believes that with better growing and harvesting practices, canola seed yields of 1 ton per acre are achievable and that 75 gallons of canola oil per acre could be expected for Vermont (2007).

Table 2.

Case Study Farm A Oil and Meal Yields

Crop	**Variety**	**Moisture**	**Oil content**	**Yield per acre**		**Typical U.S. oil**
				Oil (gall)	Meal (lbs)	yield per acre (gall)*
2006						
Canola	Hyola 401	7.7%	Not reported	26	1205	122
Canola	Croplan 601	7.9%	Not reported	19	985	122
Canola	Oscar	8.3%	Not reported	11	910	122
Canola	Hyola 420	8.0%	Not reported	18	846	122

Canola	KAB 36	9.4%	Not reported	Press malfunction		122
Sunflower	IS 6521	8.0%	Not reported	84	1563	98
2007						
Sunflower	Hysun 1521	7.0%	29%	64	Not reported	98
Sunflower	Defender	8.0%	27%	66	Not reported	98
Sunflower	IS 6039	10.0%	33%	79	Not reported	98
Sunflower	IS 6111	6.0%	29%	48	Not reported	98
Sunflower	IS 6521	8.0%	36%	71	Not reported	98
Sunflower	IS 4049	8.0%	37%	119	Not reported	98
*Source: Kurki, Hill, and Morris, 2010.						

Producing the oil and meal is a technical challenge. Most Vermont farmers will need to purchase a new or used oilseed expeller press, which uses a motor-driven screw to push the seed against a small outlet under significant pressure to extract the oil. Expelling is a continuous method and can reduce meal fat content to 6%-7%, capturing 50%-85% of the available oil. For optimum oil extrusion, the seed must be clean and have a moisture content of 6% to 9%. If the seed is wet, it does not flow through the nozzle well, and if it is too dry, the press grinds the seed to dust.

The two case study farms have taken different approaches to their pressing equipment, each with advantages and disadvantages. Both presses have successfully pressed soybeans and canola, mustard, flax, and sunflower seeds. Study Farm A uses a Swedish-made expeller press (Täbypressen Model 70) that can press 1 ton of seed per day. With an automatic shutoff it can run unattended, but its relatively small nozzle makes it sensitive to jams, interruptions in the flow of seed, and overheating. Depending on feedstock and adjustment, this press can produce 1 to 3 gallons of oil per hour (equating to 23,000-35,000 gallons of oil per year if run 24 hours per day).

Study Farm B purchased both a Chinese-made press (*Anyang* Gemco Energy Machinery Co., Ltd GC-80A) and a German-made press (KernKraft 40), along with a pellet mill. The Gemco press has the capacity to press 4 tons of seed per 24-hour day, and the Kern Kraft press can press 0.5 tons per day. The Gemco press has a larger nozzle that is more "forgiving," obviating the need for seed-cleaning (R. Rainville, personal communication, October 16, 2008), but an operator must be present. Seeds pressed at Farm B are yielding 30% to 40% oil by weight, in line with standards for commercial operations (Journey to Forever, 2008).

Meal from both presses requires pelletizing. Farm B's pellet mill expresses the pellets at 180°F, which reportedly makes the meal less likely to mold. The mill pelletizes 1000-1200 lbs of meal per hour, and has successfully pelletized sunflower seed, canola seed, soybeans, grass, manure, and wood.

Nutrient Value of Oilseed Meal

Samples of soybean, canola, and sunflower meal pressed at Farm A were sent to the UVM Agricultural and Environmental Testing Lab and the DairyOne lab in Ithaca, New York for a comprehensive analysis of their components. Table 3 shows Farm A's seed meal nutrient analyses as compared to typical nutrient values of commercial feeds. The crude protein levels of Farm A's meals compare very favorably with commercial livestock meals. This is important because commercial oilseed meals are fed primarily as a protein source. The amount of fat in Farm A's seed meal samples, however, is very high, at two to twelve times that of the commercial meals. Because too much unsaturated fat can cause digestion problems in ruminants, this may limit the amount of these meals that can be fed to dairy cows, and it indicates that a significant amount of oil is being left in the meal and not extracted by the press (Hutjens, 2001). Complications with meal consistency and content will discount the meal's value as a feed source.

Table 3.

Nutrient Analysis of Case Study Farm A Oilseed Meals (Dry Matter Basis)

	Components (dry matter basis)									
	DM (%)	**CP (%)**	**Fat (%)**	**NEL (Mcal/lb)**	**TDN (%)**	**ADF (%)**	**NDF (%)**	**Ca (%)**	**P (%)**	**Ash (%)**

Soybean meals										
Oct 2006 sample, UVM	87.0	54.4	13.0	1.05	97.8	10.0	12.0	0.37	0.96	5.7
Jan 2007 sample, DairyOne	93.1	40.0	12.9	0.98	92.0	11.5	18.1	0.33	1.12	6.0
Commercial soybean meal, extruded 140ºC*	89.0	46.0	5.5	0.92	87.0	8.0	10.0	0.3	0.68	*not given*
Canola meals										
Oct 2006 sample, UVM	90.5	39.0	23.6	1.12	105.3	25.3	36.3	0.72	1.24	5.9
Jan 2007 sample, DairyOne	89.0	34.7	28.5	1.21	100.0	26.0	34.9	0.7	0.95	5.1
Commercial canola meal, extruded*	92.0	38.0	3.0	0.79	72.0	18.0	36.0	0.3	1.0	*not given*
Sunflower meals										
Oct 2006 sample, UVM	90.9	33.8	17.1	0.98	92.6	36.5	52.3	0.33	1.12	5.3
Jan 2007 sample, DairyOne	95.8	23.2	24.0	1.05	87.0	30.3	50.9	0.37	0.96	5.3
Commercial sunflower meal, with	90.0	34.0	2.1	0.63	57.0	33.0	40.0	0.23	1.03	*not given*

hulls*										

Abbreviations: ADF, acid detergent fiber; Ca, calcium; CP, crude protein; DM, dry matter; NDF, neutral detergent fiber; NEL, net energy for lactation; P, phosphorus; TDN, total digestible nutrients. *Source: Maiga, Marx, Crary, & Linn, 1997

Biodiesel Production

Small-scale biodiesel production operations are relatively easy to establish, and Extension professionals have responded to the interest of farmers and hobbyists with educational publications (Fortson, 2006; Nowatzki, Swenson, & Wiesenborn, 2007; Schumacher, 2007). From a technical perspective, on-farm biodiesel production in Vermont is no different, requiring adequate, heated space for the operations; the necessary equipment; careful space and site planning; safety measures; and processes to optimize productivity and quality.

Neither of the case study farms' new biodiesel production facilities was fully operational at the time of the research data collection, although Farm A has been making biodiesel with smaller and older equipment for several years. Farm A's new biodiesel facility has a batch capacity of 400 gallons and is located in the same building as its oilseed processing facility. The facility was designed in cooperation with an engineering firm to ensure that safety concerns and environmental issues associated with biodiesel production were addressed. Farm B's biodiesel building houses both oil presses, the pellet mill, and a BioPro 190 biodiesel processor with Incosept technology and T76 dry wash columns. Farm B's facility can process 100 gallons of biodiesel per day.

Conclusions & Implications

Farm-scale production of oilseed crops, vegetable oil and meal, and biodiesel in Vermont is technically feasible. Data from UVM Extension field trials show that oilseed crops in Vermont can attain yields comparable to national averages, especially as access to harvesting equipment and experience with harvesting techniques improve. Farm-scale expeller presses appear to produce meal and oil of adequate quality for on-farm use or sale to other farmers. Additional experience in drying seeds to the correct moisture and fine-tuning the pressing process will help reduce fat content in the meal and improve the efficiency of oil production.

As more Vermont farmers experiment with oilseed crops, the development of local expertise among the farm and Extension communities should help new growers. Farmers, processors, and other business owners involved in oilseed crop production should continue to build networks for developing and sharing local expertise in harvesting, processing, distribution, and sales.

Many economic issues remain, including the cost of equipment, optimizing the size of operation, the relative value of the meal compared to commercial products, and comparison of the cost of the end product with commercial diesel fuel. In addition, meeting regulatory requirements for on-farm fuel production may impose costs. As with any new product development, however, testing ideas, sharing information, and ingenuity will likely enable Extension to assist other farmers in producing their own diesel fuel and livestock feed.

The experiences of these case study farms indicate the challenges and cooperation that have characterized this research. Farmer initiative, entrepreneurial spirit, engineering trial and error, researcher inquisitiveness, and sharing of ideas among farmers, Extension educators, and others have combined to make these farm experiments work. While they have shown the feasibility of oilseed and biofuel production in Vermont, the experiments also indicate the need for greater exploration of the remaining technical and economic questions. Through additional cooperative research, interested farmers and UVM Extension are continuing to work on finding the answers.

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