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Feasibility of On-Farm or Small Scale Oilseed Processing and Biodiesel Production

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Background

The rapid increase in biofuel production has had obvious impacts on the agricultural sector. The production of ethanol, the dominant biofuel in the U.S. has had significant impact on feed grain prices. A recent study by the Center for Agriculture and Rural Development projected that ethanol expansion is likely to continue under a long-run equilibrium corn price of $4.05/bu is achieved (Tokgoz et al., 2007). Corn producers, and owners of crop land in the grain belt region appear to be early beneficiaries from the ethanol boom. Other groups of producers, such as pork and poultry producers, are generally considered to be disadvantaged by higher feed prices. Many producers have also invested in ethanol and other biofuel projects. Not surprisingly, these investments have also been concentrated in the grain belt region. Producers in non-ethanol producing areas are often interested in benefiting from the new "biofuel economy".

The desire to participate in the perceived value-added opportunities of biofuel production has led to increased interest in small scale oilseed processing and biodiesel production. Biodiesel can be produced from a wide range of oilseed feed stocks. An oilseed based biodiesel operation is a technical possibility for producers in most regions of the U.S. The rapid increase in fuel expense has also contributed to the interest in small scale biodiesel production. Farm diesel prices have increased over 300% since the mid-1990s and have risen over 100% in the last three years (DOE-EIA, 2008). While fuel costs represent only 10% of the cost of production for most crops, they are a highly visible component. On-farm oilseed processing and biodiesel production is often considered as a possible strategy to mitigate the impact of rising fuel prices. Several states have also developed specific incentives to benefit producers who produce biofuels for their own consumption.

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The processing of extracting oil from oilseed crops and producing biodiesel and feed coproducts is not technically complex and can be conducted at a farm scale level. As in most industrial processes there are significant economies of scale to biofuel production. However there are several factors which could help to justify small scale biodiesel production. There is substantial variation in the local basis for oilseed crops. A producer's opportunity cost for diverting oilseed crops to a processing operation may therefore be substantially below the national or regional price level. A farm-scale oilseed processing/biodiesel production facility may also use farm infrastructure and/or labor which has low out-of-pocket costs. Many producers can also use the meal feed coproducts from oilseed processing in livestock operations or have opportunities to sell them in local markets. On-farm processing also eliminates transportation and retailing costs for both the fuel and the feed coproducts if used on-farm.

In light of the current interest in small scale oilseed processing/biodiesel production, there is a need to determine whether a farm-based or small scale operation could be economically feasible. This study examines the feasibility of a small scale integrated oilseed crushing and biodiesel production operation. The analysis considers alternate oilseed feed stocks and a range of biodiesel prices.

Oilseed Processing

Oil can be extracted from oilseed crops using either chemical (solvent) or mechanical systems. Solvent-based systems typically involve the use of hexane which is an environmentally sensitive and potentially explosive substance. The entry level price for a new solvent plant is over $10 million. Mechanical extraction systems include simple expellers (often called cold presses), pre-heated expellers and extruder-expeller systems. The process of heating oilseeds significantly increased the extraction efficiency. Heat pre-treatment also assists in deactivating enzymes and can improve the protein quality and texture of the meal, relative to that of a mechanical cold press.

Extruder/expellers compress the oilseed to very high pressure using friction as a source of heat to raise the temperature to approximately 135º C. The heat deactivating the enzymes and destroys micro-organisms. The compressed material then expands rapidly as it leaves the extruder. The expansion ruptures the starch cell structure, facilitating the release of the oil. After leaving the extruder the extruded oilseed is immediately processed in a screw press (Anderson, 2004). The extrusion step increases oil yield relative to a cold pressing system. In addition, the seeds have a very short dwell time at high temperature and the temperature and dwell time can be manipulated to improve the digestibility and quality of the meal. The meal from extruder/expeller system generally has a higher level of bypass protein, a desired property in dairy cattle rations.

Because of its relative simplicity and relatively high extraction efficiency, most small scale oilseed processing operations use the extruder-expeller technology. A flow chart of the process is provided in Figure 1.

Biodiesel Production

Biodiesel can be produced by chemically combining several types of natural oils or fats with an alcohol to form alkyl esters of fatty acids (Ryan, 2004). Fatty acid alkyl esters that meet stringent transportation fuel quality standards are generally known as biodiesel. Biodiesel can be used in pure form (B-100) or blended with petroleum diesel. Blends as low as 2% (B-2) have been demonstrated to be sufficient to create lubrication advantages, while blends are up 20% (B-20) can be used in most diesel engines without modification. Biodiesel has an oxygen content of approximately 11% (by weight). This oxygen in biodiesel improves combustion and therefore reduces hydrocarbon, carbon monoxide, and particulate emissions but tends to increase nitrogen oxide emissions. Biodiesel has better lubrication properties (lubricity) than current low-sulfur (500 ppm sulfur by weight) petroleum diesel. This lubricity advantage has become more important since ultra-low-sulfur petroleum diesel (15 ppm sulfur by weight) was introduced in 2006. A one or two percent volumetric blend

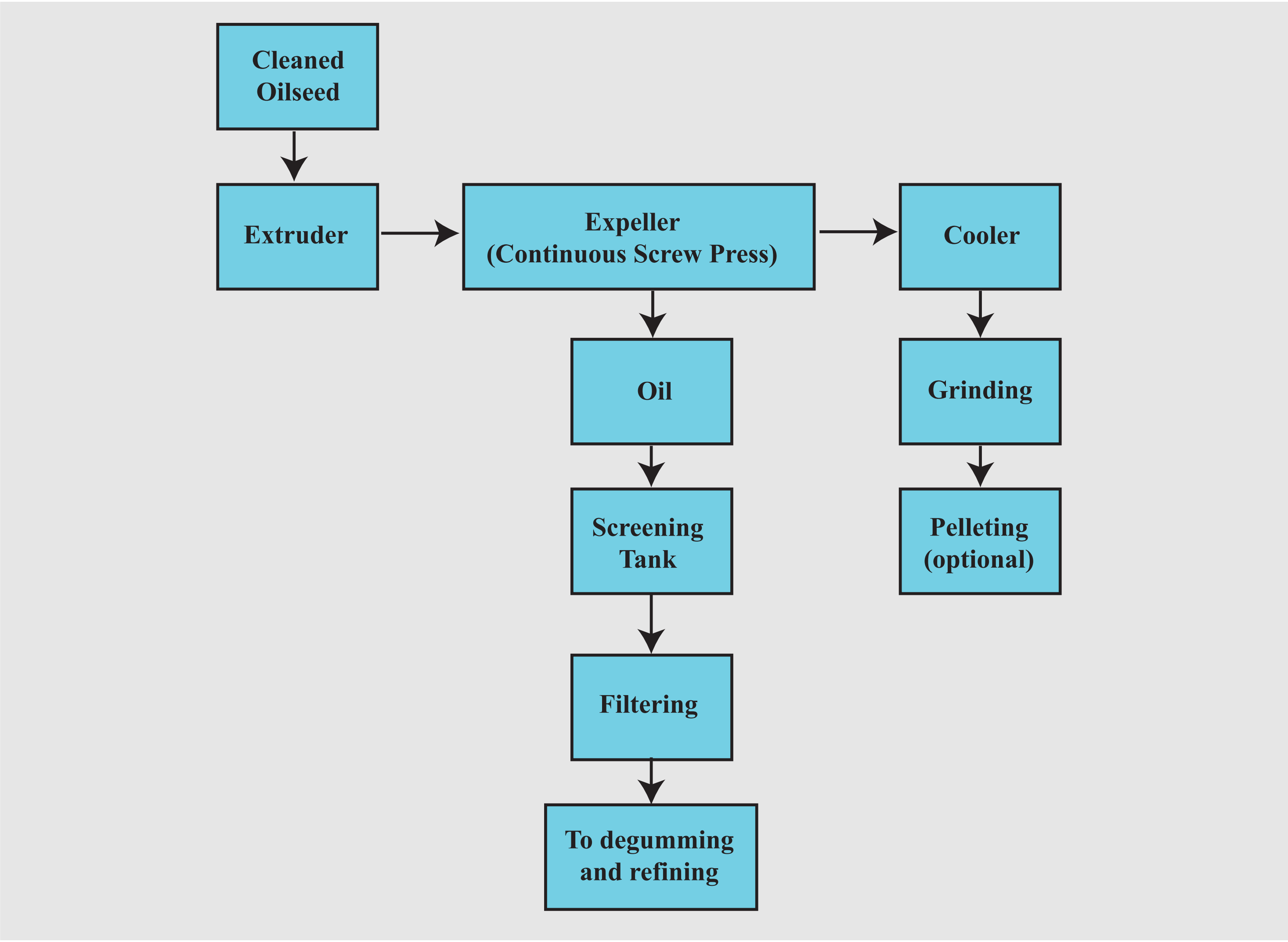

Figure 1. Extruder/Expelling Processing Flowchart

of biodiesel in low-sulfur petroleum diesel improves lubricity substantially. This lubricity advantage increased the demand for biodiesel demand as a fuel additive.

The most common production process for biodiesel is base catalyzed transesterification, a relatively simple process which has a conversion yield of around 98%. Crude vegetable oil contains triglycerides which are glycerine molecules three long chain fatty acids attached. (Vegetable oils vary in the nature of the fatty acids which can in turn affect the characteristics of the biodiesel.) In the transesterification process, the triglyceride is reacted with alcohol (usually methanol or ethanol) in the presence of a catalyst which is usually a strong alkaline like potassium hydroxide or sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol.

The biodiesel production process (Figure 2) begins by mixing of alcohol and catalyst which is typically sodium hydroxide (caustic soda) or potassium hydroxide (potash). The alcohol and catalyst are mixed or agitated and then transferred to a closed reaction vessel where the oil is added. The system after adding the oil from here is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around 160°F) to speed up the reaction and process is closed to the atmosphere to prevent the loss of alcohol.

The reaction produces two basic products: glycerin and biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. Glycerin has a higher density than biodiesel and can be gravity separated by simply drawing off the bottom of the settling vessel. A centrifuge can be used to separate the glycerin and biodiesel more rapidly. The biodiesel is purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage. Prior to use as a commercial fuel, the finished biodiesel must be analyzed using sophisticated analytical equipment to ensure it meets any required specifications.

The glycerin separation contains unused catalyst and soaps. Mineral acids are used to neutralize the glycerin before it is routed to the evaporator where water and alcohol are removed. These steps yield an 80-88% pure glycerin that can be sold as crude glycerin. The glycerin can also be distilled to 99% or higher purity and sold into the cosmetic and pharmaceutical markets.

Baseline Scenario

Equipment lists and cost quotations for “bare bones” systems for oilseed crushing and biodiesel production were estimated by the food equipment engineer at the Food and Agricultural Products Center at Oklahoma State University. The oilseed processing system had a capacity of approximately 1 ton per hour or around 2,000 tons/year if operated on an 8 hour day basis. The biodiesel equipment had an annual capacity of approximately 250,000 gallons/year which was a fairly close match to the protected oil yield from the crush operation using a high oil content oilseed such as canola. This production level would likely exceed the needs of most producers but could be a practical size for a small group of producers or cooperative. Operating costs for the biodiesel and crushing systems were based on the chemical inputs required for each gallon of throughput and from the electrical costs of the systems.

Results and Implications

The equipment compliment including a extruder-expeller with a 10 HP electric motor, associated conveying systems, two 500 gallon biodiesel reaction/settling tanks, methanol tank and various transfer and metering pumps was estimated to cost $341,369. No costs were included for a building or installation. The processing operation was assumed to be 50% debt financed at a 7.5% (Lawrence, 2008) interest rate. Electricity costs were estimated at $.08/KW (Sperry, 2008) and no expenses for operator labor were included. The meal feed coproduct was assigned a value of $300/ton (University of Missouri, 2008) which, at current price levels, represents the high end of the retail price for a 35-40% protein supplement. The biodiesel produced was assigned a value of $3.00/gallon and no subsidies were considered. While obviously optimistic, this price might be appropriate for producers in states with specific subsidies for on-farm production of biodiesel. An opportunity cost value of $.11/lb (Neuens, 2008) was assigned to the canola seed processed. The scenarios considering sunflower and soybeans used values of $.15/lb and $8.00/bu (Neuens, 2008) respectively.

At the (admittedly optimistic) baseline assumptions the canola processing/biodiesel operation had an internal rate of return of 5.71%. It should be emphasized that this analysis assumed use of existing land and buildings and placed on value on the farm operator labor. At this level of returns even a producer with excess labor availability would be better served by paying down existing farm loans rather than investing in the processing operation. The sensitivity of the returns to the implicit value of the biodiesel and meal feed coproduct are provided in Tables 1 and 2. The analysis indicates that on-farm processing might be attractive at biodiesel values above $3.10/gallon and/or meal values above $320/ton.

Canola seed has an oil content of approximately 40%. The analysis of sunflower seed which has an oil content of 44% and a slightly higher farm value (opportunity cost) yielded similar profitability levels. However the on-farm processing of soybeans (which have an oil content of approximately 20%) was not projected to be profitable at biodiesel prices below $3.50. Because the extracted oil and biodiesel is the more valuable on a per pound basis relative to the meal feed

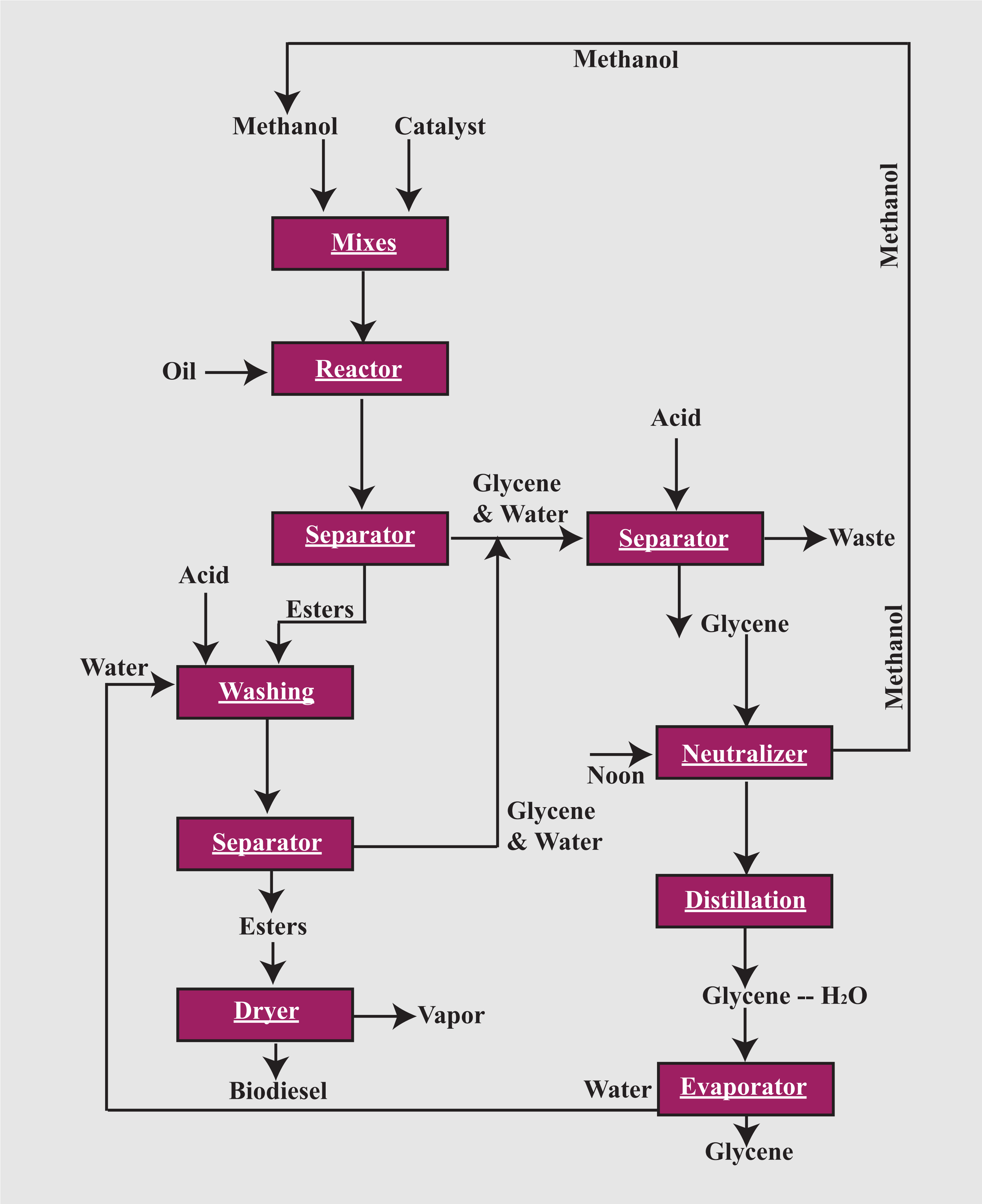

Figure 2. Biodiesel Production Process

Table 1. Sensitivity of Canola Processing Return to Biodiesel Value						
	Biodiesel Price					
Economic Variable	$2.90	$3.00	$3.10	$3.20	$3.30	$3.40
Internal Rate of Return	Neg	5.7%	15.7%	24.2%	40.2%	47.9%
Return on Assets	-3.3%	4.4%	12.1%	19.7%	27.4%	35.0%
Return on Equity	-6.4%	8.8%	24.2%	39.5%	54.8%	70.0%

Table 2. Sensitivity of Canola Processing Return to Meal Value						
	Meal Price					
Economic Variable	$280	$290	$300	$310	$320	$330
Internal Rate of Return	Neg	0.3$	5.7%	10.7%	15.3%	19.6%
Return on Assets	-3.1%	0.7%	4.4%	8.1%	11.9%	15.7%
Return on Equity	-6.2%	1.3%	8.8%	16.3%	23.8%	31.3%

Table 3. Breakeven Oilseed Crop Values at Various Biodiesel Prices					
	Biodiesel Price				
Economic Variable	$2.50	$2.75	$3.00	$3.25	$3.50
Breakeven Canola Price $/lb	0.082	0.097	0.113	0.130	0.146
Breakeven Sunflower Price $/lb	0.074	0.091	0.108	0.125	0.143
Breakeven Soybean Price $/bu	5.30	6.00	6.70	7.40	8.10

coproduct, the profitability decreases as the oil content of the feed stock crop decreases.

Grain market prices, which represent the opportunity cost of processing oilseed into biodiesel are obviously one of the key factors in determining the feasibility of an on-farm crushing and biodiesel production operation. Current (spring 2008) oilseed prices are at historic highs. Processing $12/bu soybeans or $.21/lb canola or sunflowers into biodiesel would require a biodiesel value of over $4.75/gallon to breakeven. The breakeven oilseed crop price for various biodiesel price levels is provided in Table 3.

Conclusion

Interest in on-farm or small scale processing of oilseed crops into biodiesel is likely to cycle with fuel prices. The results of this study indicate that an on-farm canola processing/biodiesel operation is not profitable at current biodiesel and meal feed prices. However the returns are sensitive to the value of biodiesel and to a lesser extent the value of the meal feed. Producers who placed a high value on the biodiesel produced either because of its value in replacing purchased fuel or through state-specific incentives might find on-farm processing of a high oil content crop such as canola or sunflowers profitable. On-farm processing of soybeans (the predominant oilseed crop in the U.S.) is much more difficult to justify. Because of the lower oil content, a soybean based processing operation is unlikely to cover even the direct production costs at reasonable biodiesel values.

The results summarized in this report were developed using the "On-Farm Oilseed Processing Feasibility Template" developed by Oklahoma State University. The template which is incorporated into a Microsoft Excel spreadsheet allows the user to customize the analysis to meet their particular situation and to consider a wide range of sensitivity analysis. A full report of the feasibility study and the feasibility template are available free of charge by contacting Phil Kenkel, Department of Agricultural Economics, Oklahoma State University, phil.kenkel@okstate.edu.

References

Anderson, D. 2004. "A Primer on Oils Processing Technology." F. Shahidi, ed. In Vol. 5 of *Bailey's Industrial Oil and Fat Products*, 6th edition. Hoboken, NJ: John Wiley & Sons, Inc.

Lawrence, J. Personal Communication. Loan Officer, CoBank, Wichita Office, January 2008.

Neuens, G. Personal Communication. Oilseed Purchase Manager, Producers Cooperative Oil Mill, Oklahoma City, January 2008.

Ryan, D. 2004. "Biodiesel- A Primer." National Center for Appropriate Technology, ATTRA Publication #IP263. Available at http://attra.ncat.org/attra-pub/PDF/biodiesel.pdf.

Sperry, S. Personal Communication. Director of Public Relations, Oklahoma Association of Electrical Cooperatives, Oklahoma City, January 2008.

Tokgoz, T., A. Elobeid, J. Fabiosa, D. Hayes, B. Babcock, T. Yu, F. Dong, C. Hart and J. Beghin. 2007. "Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets." Center for Agricultural and Rural Development, Staff Report 07-SR-1010, Iowa State University, May.

University of Missouri Extension Service. 2008. "Byproduct Feed Price Listing." Available at http://agebb.missouri.edu/dairy/byprod/bplist.asp.

U.S. Department of Energy, Energy Information Administration. 2008. "Weekly Diesel Prices-All Types, March 1994-January 2008." Available at http://tonto.eia.doe.gov/oog/info/wohdp/diesel.asp.