Technoeconomic Evaluation of On-Farm Biodiesel Production from *Camelina sativa* in the Southeastern United States

11th Annual World Congress on Industrial Biotechnology
Track 2: Algae, Specialty Crops, and Biomass Supply
Advances in Oilseeds
Tuesday, May 13 10:30am-12:00pm

Kevin R Caffrey, Matthew W Veal, Mari S Chinn
North Carolina State University
Biological & Agricultural Engineering
What is *Camelina sativa*?

- **Plant Characteristics**
  - Agronomic
  - Fatty acid profile
- **Chemical composition**
  - Antioxidants
  - Other phenolics & flavonoids
- **Potential Markets**
  - Industrial Applications
    - Drying oil
    - Cosmetics & dermatological
    - Biofuels
  - Food & Feed
Project Objectives

• Construct Realistic Process Flows
• Calculate Feasible Product Values
• Determine Biodiesel Production Costs
• Investigate On-Farm Processing
  • Scenarios designated by farmgate product
    • Scenario 1: Grain
    • Scenario 2: Oil
    • Scenario 3: Biodiesel
Process Model
Operation Costs

- Standardization
  - March 2014 US $
  - June 1, 2009 to May 30, 2012
- Cultivation (High Cost & Realistic)
  - Land use, equipment, inputs
- Transportation
  - Freight transport, distances
- Industrial Operations
  - Crush: soybean margins
  - Biodiesel: soybean margins, no tax incentive
- On-Farm Operations
  - Extraction: seed cleaner, extruder, centrifuge
  - Biodiesel: springboard biodiesel unit
Product Valuation

• Grain
  • U.S. canola, Canadian canola
  • Corrected for oil content
• Oil
  • U.S. soybean, U.S. canola, Canadian canola
• Meal
  • U.S. soybean, U.S. canola, Canadian canola
  • Corrected for protein content
• Biodiesel
  • Average U.S. sales price
• Crude Glycerol
  • Low value market ($0.11/kg)
• Seed Trash
  • No value assigned
Agronomic System Costs

High Cost ($731/ha)
- Land 27%
- Planting 12%
- Fertilizer 33%
- Harvest 16%
- Herbicide 9%
- Storage 3%

Realistic ($486/ha)
- Land 24%
- Planting 18%
- Fertilizer 34%
- Harvest 24%
- Herbicide 0%
- Storage 0%

33% Savings

Agronomic Unit Production Costs

<table>
<thead>
<tr>
<th></th>
<th>High Cost</th>
<th>Realistic</th>
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<tbody>
<tr>
<td>Grain ($/kg)</td>
<td>$0.40</td>
<td>$0.27</td>
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<tr>
<td>Oil ($/kg)</td>
<td>$1.07</td>
<td>$0.71</td>
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<tr>
<td>Oil ($/L)</td>
<td>$0.98</td>
<td>$0.65</td>
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**Processing Operation Costs**

- **Grain (112/ha)**
- **Oil (520/ha)**
- **Biodiesel (619/ha)**

Proportion of Processing Costs:
- **Transportation**
- **Oil Extraction**
- **Biodiesel Production**

Farmgate Product Processing Cost:
- Grain ($112/ha)
- Oil ($520/ha)
- Biodiesel ($619/ha)
# Breakeven Production Costs

<table>
<thead>
<tr>
<th>Scenario 1: Grain</th>
<th>Scenario 2: Oil</th>
<th>Scenario 3: Biodiesel</th>
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<tr>
<td>High</td>
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<table>
<thead>
<tr>
<th>Grain ($/kg)</th>
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<td>$0.40</td>
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<td>$0.50</td>
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<table>
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<tr>
<th>Oil &amp; Biodiesel ($/L)</th>
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<td>$0.00</td>
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<tr>
<td>$0.05</td>
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<td>$0.15</td>
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<td>$0.35</td>
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<tr>
<td>$0.40</td>
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<tr>
<td>$0.45</td>
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</table>

**Legend:**
- Oil
- Biodeisel
- Grain

**Source:**
- [NC State University](https://www.ncsu.edu)
Breakeven Production Costs

Scenario 1: Grain
Scenario 2: Oil
Scenario 3: Biodiesel

Realistic Agronomic Production System
Sensitivity Analysis Parameters

- Single Parameter - coefficient of variation
  - June 1, 2009 to May 30, 2012
- Products
  - Grain (3)
    - U.S. soybean, U.S. canola, Canadian canola
  - Oil (8)
    - U.S. soybean, U.S. canola, Canadian canola, corn oil, inedible tallow, edible tallow, white grease, yellow grease
  - Meal (3)
    - U.S. soybean, U.S. canola, Canadian canola
  - Biodiesel
- Agronomic Inputs
  - Nitrogen (5)
    - Anhydrous ammonia, nitrogen solution (30%), urea (44-46%), ammonium nitrate, sulfate of ammonium
- Grain Characteristics
  - Yield
  - Oil content
- Fuel Costs
  - Diesel
  - Electricity
Sensitivity Analysis of Farm Profitability

**Grain**

- Grain ($/kg)
- Yield (kg/ha)
- Nitrogen ($/kg N)
- Diesel ($/L)

**Oil**

- Oil ($/kg)
- Meal ($/kg)
- Yield (kg/ha)
- Nitrogen ($/L N)
- Oil (%)
- Diesel ($/L)
- Electricity ($/kWh)

**Biodiesel**

- Biodiesel ($/L)
- Meal ($/kg)
- Yield (kg/ha)
- Nitrogen ($/kg N)
- Oil (%)
- Diesel ($/L)
- Electricity ($/kWh)
Operational Comparisons

- **Agronomic Costs**
  - Margins similar to winter wheat

- **Industrial**
  - Crushing
    - $0.16/kg profit over soybean margins ($0.03/kg)
  - Biodiesel
    - Net loss without tax incentive

- **On-Farm**
  - Oil Extraction
    - Costs $0.28/kg more than soybean margins ($0.03/kg)
    - Extruder ($0.16/kg), Seed Cleaner ($0.08/kg), Centrifuge ($0.07/kg)
  - Biodiesel
    - $0.23/kg greater than industrial margins ($0.04/kg)
Additional Product Valuation

- Omega-3 Fatty Acids
  - Priced as DHA: $12.61/kg grain products ($0.75/kg)
- Phenolics & Flavonoids
  - Additional high value markets
- Extruder Meal
  - Oil included: $0.45/kg meal ($0.39/kg)
- Crude Glycerol
  - Proportional with futures: $0.15/kg crude glycerol ($0.11/kg)
- Cover Crop Valuation
  - Net cost of hairy vetch/rye: $79/ha
- Advanced Biofuels
  - Iso-parrafin rich jet fuel
Major Conclusions

• Agronomic production can be profitable
• Improved cultivation methods required for Southeast
• Oil extraction cost is the major inhibitor to on-farm processing
• Farmgate product has the greatest impact on farm profitability
• High value products represent important markets
• System parameters are interconnected
Multi-Parameter Volatility

US Biodiesel

Canadian Canola

US Diesel Retail Price

Crush Product Value

Oil
Meal
Oil+Meal
Soybean

March 2014 US $/L

March 2014 US $/kg

Date

Date

Date

Date

Oct-07 Feb-09 Jun-10 Nov-11 Mar-13

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$0.00 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00

$0.00 $0.20 $0.40 $0.60 $0.80 $1.00

$0.00 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00

$0.00 $0.25 $0.50 $0.75 $1.00 $1.25 $1.50 $1.75 $2.00

Iowa
IL/IN/OH
US Average
Oil
Meal
Seed

Crush Product Value

Iowa
IL/IN/OH
US Average
Oil
Meal
Oil+Meal
Soybean
Acknowledgement

- USDA AMS - Richard Tanger & Samuel Jones