

# R-013-025: Energy Beet Research Phase II

## Final Report – Summary

### July 24, 2015

#### FRONT END ENGINEERING

The objective of this research was to conduct experiments to evaluate energy efficient and cost effective methods of extracting soluble sugar from energy beets while minimizing the sugar content of the residual pulp. Energy consumption was also considered since one of the project goals was to qualify the ethanol as an ‘advanced biofuel’ under RFS2.

- Developed an energy efficient front end processing methodology that used only a few simple machines (hammer mill, portable mixer, and basket press) to extract juice from energy beets.
- Frozen beets are more suitable for juice extraction, when compared to fresh or thawed beets.
- Usage of hot water as well as thin juice, instead of clean water for washing between presses, improves overall efficiencies.
- Recommended two pressings with 50°C water between the first and second pressings for frozen beet juice extraction.
- For 19% initial sugar content in whole frozen beets, two pressings results in 16.4% sugar recovered in the juice and 2.6% sugar remaining in the pulp. In other words, 86.3% of the available sugar is recovered for processing and 13.7% of the sugar remained in the pulp. (Note: The maximum sugar recovery occurred with four pressings, where 17.9% sugar is recovered and 1.1% sugar remained in the pulp. However, the increased processing and energy requirements for extraction and evaporation with additional pressings exceeded the value of the additional sugar recovered.)
- For commercial scale continuous processing with two presses of the beet tissue, the researchers estimated capital costs of \$14,462,000 and annual operating cost of \$3,209,000 (without steam costs) for juice extraction. With the capital costs converted to an annual equivalent cost by amortizing them at 8% for ten years, the total annual cost becomes \$5,364,315. For a plant producing 19,000,000 gallons of pure ethanol / year, the theoretical juice extraction costs are \$0.282 / gallon of ethanol; \$7.48 / ton of whole beets \$0.023 / pound of sugar. Since the experimental juice extraction and actual fermentation yields are typically less than theoretical yields, additional beets will need to be processed to match the ethanol plant capacity, and this will result in slightly higher costs than indicated above.

#### COMMUNICATIONS

The primary objectives of the communications work within the energy beet project were to A.) keep key stakeholders – including potential growers, industry partners, rural community business leaders, Economic Development Directors, Advisory Council members, NDSU Extension

Agents, and others –informed; B.) educate stakeholders about the benefits and opportunities of energy beets; and C.) assist management with public meetings and plot trial events.

- Established a project website ([www.beetsallbiofuel.com](http://www.beetsallbiofuel.com)).
- Created multiple power point presentations and hand-out materials.
- Issued Advisory Council status reports.
- Prepared project brochures and plot trial histories.
- Prepared and disseminated news releases for plot trial tours, prospective grower meetings, industry publications and newspaper articles.
- Prepared materials for prospective third-party partners, including Solazyme and Green Biologics.
- Prepared documentation for use with USDA Risk Management Agency.
- Assisted with organizing a meeting to identify five community locations with greatest opportunity for initial energy beet facilities and then with organizing follow-up meetings with prospective growers and other stakeholders in Langdon, Cando, Jamestown, Valley City and Carrington.

### ENERGY BEET CROP INSURANCE

The objectives were to establish A.) that energy beet crop insurance could be made available for producers across North Dakota and B.) the process for accomplishing the task. Farmers will not produce energy beets unless multi-peril crop insurance is available for managing the production risk.

- With the help of Ihry Insurance, Green Vision Group (GVG) communicated with the USDA Risk Management Agency (RMA) in Billings, Montana and met with the RMA headquarters in Kansas City.
- The Product Administration and Standards Division of RMA in Kansas City indicated the following:
  - RMA is open to developing a new policy for energy beets.
  - The policy is conditional on a contract between the growers and an established processor.
  - RMA was very impressed with the field data (plot trial) information developed under the grant and suggested continuation of the trials in areas most likely to support a processing facility.
  - Statewide coverage would not be available initially. GVG must first begin a pilot program where the first plant might be located.
  - The approval process would likely take one year.
  - RMA recommended GVG retain a consulting company which had previously been successful obtaining approval for a new crop policy. The consulting fees would likely range between \$30,000 and \$40,000.
- RMA suggested a ND-based consultant, with whom GVG met. It was concluded that pursuit of a new policy would commence when the energy beet project became site specific.

### ENERGY BEET PLOT TRIALS

The demonstration and yield trials implemented over the course of the project were conducted to determine the potential for energy beet production in areas of North Dakota where the crop is not traditionally grown.

- The potential was primarily measured by assessing the root yields and sugar contents realized from twelve different sites in the ND Drift Prairie region.
- Forty-five site years of data were collected from nine different dryland environments and five different irrigated environments (some sites consisted of both dryland and irrigated trials).
- The average dryland root yield was 25.8 tons per acre, with an average sugar content of 18.8 percent.
- The average irrigated root yield was 32.1 tons per acre, with a sugar content of 17.8 percent.
- All sites produced beets within a common range of root yield and sugar contents, which reflects positively on the crops ability to be a viable commercial option in these new production areas.
- Many of the trials produced acceptable crops even under adverse conditions, including late plantings and drought stress conditions.
- The crop demonstrated tolerance to saline soils; its deep tap root is favorable for improving soil health.
- One challenge identified for future energy beet production is the issue of certain residual herbicides and their impact on beet establishment and performance. However, farmers can readily overcome this issue by reviewing alternative herbicide options similar to farmers in current beet production areas.
- All the factors considered above contributed to the conclusion that energy beets would be an excellent addition to current ND crop rotations.

#### ENERGY BEET SUGAR STORAGE

One of the project goals was to develop a means for long-term feedstock storage to allow processing ethanol from beet sugars throughout the year. Viable storage mechanisms must be cost effective with minimal sugar loss.

- Three methods evaluated for sugar storage included 1) a concentrated, non-purified beet sugar extract (also known as *raw, thick juice*) which could be stored in tanks for summer processing (Phase I research); 2) surface-treated whole beets stored under aerobic atmosphere or in sealed containers, and at either 6°C or 25°C (Phase II); and 3) ensiled beet tissue (Phase II). Phase II research was conducted under the current grant project. Phase I research was conducted under a prior grant project.
  - 1. above): At least 99% of initial fermentable sugars are retained in raw, thick juice stored for 24 weeks under acidic (pH equal to or less than 3.5) and alkaline (pH equal to or greater than 9.5) conditions and solid weight fractions equal or greater than 64.5%. Juice stored under acidic conditions showed greater stability than juice stored under alkaline conditions.
  - 2. above): Solutions of two antimicrobial agents (acetic acid and acidic calcium sulfate) and a plant growth regulator (N6-Benzylaminopurine) applied on the surfaces of beets showed no significant effect on sugar retention at the concentrations evaluated. Beets stored for 24 weeks under aerobic conditions and at 25°C fully retained initial sugars, whereas beets stored at 6°C only retained 56% of sugars. In contrast, beets stored in sealed containers at both temperatures only retained 38% of initial sugars.
  - 3. above): Beet tissue ensiled at some combinations of acidic pH (equal to or less than 4.0) and moisture content less than 67.5% fully retains initial sugars for at least

8 weeks. Moreover, highly acidic conditions (pH equal to or less than 3.0) may break down polymeric sugars into readily fermentable sugars and yield net sugar gains of at most 7%.

- Further economic and life cycle assessments for long-term juice storage as a means to extend processing campaigns seemed appropriate. Equipment for raw, thick juice production is understood and available from multiple manufacturers. NDSU researchers estimated capital and operating costs to produce raw, thick juice (from the juice solution produced by the Front End Processing research) and store it under acidic conditions. This raw, thick juice would represent a half-year supply of fermentable sugars for summer processing at a 19,000,000 gallon per year ethanol plant. The capital cost estimated for evaporation and storage equipment was \$20,681,000, and the operating cost (without labor) was estimated at \$1,353,000. With capital costs converted to an annual equivalent cost by amortizing them at 8% for ten years, the total annual cost becomes \$4,435,000. The theoretical evaporation and storage costs for sugar feedstock to produce 9,500,000 gallons of ethanol during the 'summer' months (½ of the annual supply) are equivalent to \$0.467 / gallon of ethanol; \$12.371 per ton of beets; and \$0.038 / pound of stored sugar. These costs would not exist for the raw juice sent directly to the plant for ethanol processing during the six 'winter' months.