

**Contract No. R-013-025**  
**“Energy Beet Research – Phase II”**  
 Submitted by Green Vision Group, Inc.  
 Principal Investigator: Lloyd Anderson

**PARTICIPANTS**

<b>Sponsor</b>	<b>Cost Share</b>
Syngenta Seeds, Inc. and Betaseed, Inc.	<u>\$ 271,050</u>
Subtotal Cash Cost Share	\$ 271,050
Green Vision Group, Inc. and Heartland Renewable Energy	<u>\$ 229,050</u> (in-kind)
Subtotal In-kind Cost Share	\$ 229,050
North Dakota Industrial Commission	<u>\$ 500,000</u>
Total Project Cost	\$1,000,100

Project Schedule – 33 months	Project Deliverables:
Contract Date – July 23, 2012	Status Report: April 30, 2012 v
Start Date – January 1, 2012	Status Report: August 31, 2012 v
Completion Date – February 28, 2015*	Status Report: December 31, 2012v
	Status Report: April 30, 2013 v
	Status Report: August 31, 2013 v
	Status Report: December 31, 2013 v
	Status Report: April 30, 2014 v
	Final Report: February 28, 2015*v

**OBJECTIVE/STATEMENT OF WORK:**

The objective of this project is to finalize a cost effective and energy efficient plant design and advance development for North Dakota’s first 20 MGY energy beet biofuel plant.

The project will involve the following tasks:

- 1) Engineering design and evaluation of alternative front end technologies and equipment for processing whole energy beets prior to ethanol fermentation.
- 2) Continue statewide energy beet yield trials in 2012 and 2013 crop years.
- 3) Qualify energy beets for federal crop insurance in North Dakota.
- 4) Stakeholder communication activities.
- 5) Scale up and expand whole beet and juice storage research.
- 6) Project Management

The front end engineering study will provide design parameters for preprocessing equipment that will extract juice prior to ethanol production. Regional yield information will demonstrate the suitability of sugar beet production in non-traditional areas and qualify energy beets for federal crop insurance in advance of commercial production so growers and agricultural lenders have adequate risk management tools available. The communication program will inform producers, community leaders, investors and the renewable energy industries leading to commercial economic development opportunity. The Phase II of beet juice storage study will take bench scale laboratory results from Phase I and conduct demonstration scale evaluations needed for feedstock storage (both whole beets and juice) and plant design to construction of a commercial facility (Phase III).

## **STATUS:**

### **August 31, 2012 Report**

The following summary report for the period April 1, 2012 through July 31, 2012 was provided:

The energy beet grant project consists of primary research activities for front-end engineering, feedstock storage, and plot/yield trials along with crop insurance and communication/education objectives and project management.

**FRONT-END ENGINEERING:** NDSU activities consisted primarily of research experiment design and test equipment specifications for extracting maximum energy beet juice (sugar) in a cost efficient manner with minimum energy consumption. The project's goals are to qualify its product as an advanced biofuel under RFS2 and to compete in the commodity ethanol markets. Actual research will begin during fall, 2012 when beets will be available.

**FEEDSTOCK STORAGE:** NDSU reported on the successful Phase I juice storage research at scientific society meetings. Phase II research work plans for storing whole energy beets for 12 months without degradation or significant sugar loss were updated for implementing during fall, 2012 when beets will be available.

**PLOT/YIELD TRIALS:** NDSU, in partnership with Syngenta and Betaseed, established a combination of 14 dryland and irrigated plot trials across the non-traditional sugar beet growing areas of ND. Most of the trials were planted April 23-24, within the targeted window for planting. Excellent weed control was achieved with the 'Roundup Ready' energy beets. The combined effect of 2012 low rainfall and high temperatures at many of the trial locations will provide an opportunity to evaluate energy beets grown under challenging conditions. GVG, NDSU, Syngenta and Betaseed representations made plot trial and project development presentations at the Carrington, Minot, Langdon, Colgate, Hannaford, Williston, Spiritwood, Litchville and Oakes plot tours during July.

**CROP INSURANCE:** GVG engaged Ihry Insurance for assistance in qualifying energy beets for crop insurance. The Risk Management Agency (RMA) informed us that all sugar beets will be under review in 2013. Once the final 2012 plot tour results are available, the information and request for insurance qualification will be submitted to RMA in Kansas City, which will not work on the request until 2013.

**COMMUNICATIONS/EDUCATION:** The promotion of eleven plot tours was the primary activity during the period. A grower brochure, grower budget and history of prior beet root yields and sugar content were prepared for use with the plot tours. Media attention was received from Ag Week, Farm & Ranch Guide, Successful Farming and local newspapers and radio stations. An Advisory Board meeting was held at the Carrington Research Extension Center and presentations were made to agricultural associations.

**MANAGEMENT:** In addition to activities identified above, key management activities included attendance at the Advanced Biofuels Leadership Conference in Washington, DC; meeting on LCA for RFS2 with EPA in Washington; attendance at Fuel Ethanol Workshop in Minneapolis; communications with Solazyme, ROPA, Amity and Putsch; monitoring European research which will impact the project; and multiple meetings with researchers, sponsors, funding sources, communities and others engaged in the project.

### **December 31, 2012 Report**

The following summary report for the period August 1, 2012 through October 31, 2012 was provided:

**FRONT-END ENGINEERING:** NDSU activities consisted of final experimental design, contract execution with GVG (Sept 10, 2012), recruiting for supporting lab research personnel, and sourcing and negotiating on purchase and lease alternatives for required research equipment. NDSU and GVG personnel participated with an energy beet display in the NDSU Extension Service booth at the Big Iron Farm Show at the RRV Fairgrounds.

**FEEDSTOCK STORAGE:** NDSU obtained ten tons of 2012 harvest sugar beets for storage research over the next year's timeframe. The first set of experiments consists of 630 units of whole beets to be tested for various combinations of surface treatments (antimicrobial agents and senescence inhibitor), modified atmospheres (various aerobic and anaerobic conditions) and temperatures, along with 'controls'. The experiments will be tested for various properties at five different intervals over a year's time.

**PLOT/YIELD TRIALS:** GVG, NDSU and the seed company sponsors made plot trial and project development presentations at the Harvey and Turtle Lake plot tours during August. The environmental conditions during the latter part of the growing season generally experienced a continuation of the trend for below average rainfall at most trial sites. The dates of first frosts (not severe) were normal. The plot trial harvests conducted by NDSU, Syngenta and Betaseed personnel occurred in early October. Preliminary results for the irrigated trials include a range of from 31 to 44 tons per acre; the dryland trials ranged from 20 to 33 tons per acre. The average energy beet sugar content was 19.1% across all sites. The two top sugar producing trials were 17,774 pounds per acre (dryland) and 17,256 pounds per acre (irrigated). The sugar content percentages tend to be higher for dryland than for irrigated production.

**CROP INSURANCE:** GVG was waiting for 2012 plot trial results so that the information could be presented to RMA in Kansas City.

**COMMUNICATIONS/EDUCATION:** The principal communication/education events included the completion of the plot tours in August; energy beet booth at Big Iron; and a presentation at the ND Agricultural Bankers conference in Fargo. The principals also considered renaming and rebranding the development project. Since the principals are also associated with an early stage effort to develop a US energy beet association, consideration of rebranding has been delayed.

**MANAGEMENT:** In addition to activities identified above, other key management activities included meetings to consider: the use of stillage for fertilizer production; fermenting whole beets rather than extracted juice; alternative harvesting systems; methods and costs for traditional beet storage; follow-up on European whole beet storage research; and sources of and availability of pipelines for natural gas supply. Management continues to be active in networking and communications with many individuals and organizations across ND and elsewhere.

### **April 30, 2013 Report**

The following summary report for the period November 1, 2012 through March 31, 2013 was provided:

**FRONT-END ENGINEERING:** NDSU acquired and installed a 700 cubic foot freezer for storing frozen sugar beets obtained from ACSC during March. Dr. Anand Kumar Pothula was hired as Project Research

Associate for the front-end research project. A basket press for juice extraction was obtained from Italy. The hammer mill (May delivery) and lab equipment were ordered. The research will be conducted at the NGPRL in Mandan, ND.

**FEEDSTOCK STORAGE:** NDSU completed its experimental setup of 420 beet storage units in December, 2012. The experiment was reduced from a planned 630 storage units to fit available resources and storage space. Beet tissue samples from sugar beets stored for two, four and twelve weeks have been collected and analyzed for dry weights and industrial sugars. Samples will also be obtained at twenty-four and fifty-two weeks, with the current set of trials being completed in December 2013.

**PLOT/YIELD TRIALS:** The seven 2012 dryland trials averaged 26.0 tons per acre during the year despite below average rainfall at many of the locations. NDSU has documented dryland root yield and sugar content levels very comparable to sugar beet performance in the traditional Red River Valley production region. The average yield across five 2012 irrigated trials was 36.2 tons per acre. During 2013 NDSU, along with Betaseed and Syngenta, will conduct fourteen trials in the ND counties of Foster, Stutsman, Barnes, Wells, Griggs, Dickey, Steele, Cavalier, Towner, Ward, McLean and Williams. Nine sites will be dryland and five sites will be irrigated. Project agronomists have been reviewing site selection to verify herbicide history and determining needs for fertilization, residue management and seedbed preparations.

**CROP INSURANCE:** GVG compiled four years of energy beet root yield and sugar content history by ND County for submittal to the Risk Management Agency. During May GVG will present the data to Mr. Johnson at RMA in Kansas City and determine the next steps for obtaining energy beet crop insurance.

**COMMUNICATIONS/EDUCATION:** The principal communication/education events included the January Advisory Council Meeting; two presentations at NGPRL by Dr. Cannayen; and presentations to the Rolette County Commissioners and the McLean, Sheridan and Oliver County Soil Conservation District. In addition there were several press releases / news articles in agricultural publications and newspapers.

**MANAGEMENT:** In addition to activities identified above, other key management activities included conferences with Green Biologics as a potential industrial sugar customer; continued research on global developments related to whole beet storage and front end processing; Board meetings with NDSU, Syngenta and Betaseed; attendance at the Renewable Fuels Association National Ethanol Conference; meeting with Cenex Harvest States on ethanol marketing; and meeting with other industrial sugar developers on potential cooperation for crop insurance and EPA pathway applications.

### **August 31, 2013 Report**

The following summary report was provided for the period April 1, 2013 through July 31, 2013:

The energy beet grant project consists of primary research activities for front-end processing, feedstock storage, and plot/yield trials along with crop insurance and communications/education objectives and project management.

**FRONT-END ENGINEERING:** The balance of the research equipment was received, installed, and modified as necessary for the sugar extraction research. Preliminary results were obtained and the process was demonstrated to GVG/HRE and other NDSU representatives. The project was presented to approximately 700 stakeholders at the NGPRL Friends and Neighbors Day in July.

**FEEDSTOCK STORAGE:** Samples from sugar beets stored for two, four, twelve and twenty four weeks have been collected and analyzed for dry weights and industrial sugar contents. Based on results to

date, it was concluded that temperature has a significant effect on sugar preservation, but the impact of surface treatments and storage atmosphere did not have a specific benefit. High standard deviations in test results contributed to the conclusions. The research samples planned for a 52-week analysis will be terminated. Research results were presented at the July ASABE International Meeting and also submitted as a published paper.

**PLOT/YIELD TRIALS:** Thirteen plot trials (8 dryland and 5 irrigated) were established at eleven locations in ND. Cool, wet weather conditions delayed the plantings, with twelve completed in mid-May and one in June. One planned site did not get planted due to weather conditions. Initial plant stands were favorable at all sites, but residual herbicide effects have affected several sites, resulting in one being abandoned. Consequently, twelve of fourteen planned plots will mature to harvest. With the dry, hot weather during the summer months nearly all the dryland sites are experiencing moisture stress which presents another opportunity to test beet performance under challenging conditions.

**CROP INSURANCE:** The meeting which had been planned for May with RMA was delayed due to the retirement of GVG's primary contact person. The meeting was rescheduled for September 10, 2013 in Kansas City, when GVG will present its data on the energy beet production trials and ascertain the necessary steps and timing to secure crop insurance.

**COMMUNICATIONS/EDUCATION:** The primary communications activities included updating stakeholders through multiple meetings and presentations and partnering with NDSU and others on press and news releases. These releases included information on successful plot trials in dry conditions, feedstock storage research, and the impact of herbicide carryover on beets. The planning for tour dates and publicity for the 2013 plot trial tours was also done during this period.

**MANAGEMENT:** In addition to activities identified above, other key management activities included Board meetings with NDSU and others; attendance at ABLC and meeting with EPA in Washington during April; attendance at FEW in St Louis in June; meetings with Plant Sensory Systems; arrangements for preparing and submitting an industrial sugar sample to Green Biologics; meeting with WBI Energy on natural gas supplies in ND; and work with NDSU associates on their research objectives.

### **December 31, 2013 Report**

The following summary report for the period August 1, 2013 through November 30, 2013 was provided:

The energy beet grant project consists of primary research activities for front-end processing, feedstock storage, and plot/yield trials along with crop insurance and communications/education objectives and project management.

**FRONT-END ENGINEERING:** Preliminary research on mechanically pressing sugar (solution) from frozen, thawed and fresh beets has been conducted. The relationship between time and juice extracted has been determined. Multiple pressings of the cake (with water added) resulting from the first press have been run to determine the incremental sugar extracted with each subsequent press. Research beets from the 2013 crop year were obtained and stored. 2013 beets were also crushed for the storage research to be conducted by ABEN in Fargo. Beet juice was extracted for treatment and shipment by ABEN to Green Biologics for fermentation research in their laboratories. The project was presented via vendor booth at Big Iron in Fargo.

**FEEDSTOCK STORAGE:** A one-year experiment for the evaluation of ensiling techniques for beet feedstock was initiated. Beets were ensiled at normal moisture content (75%) and at reduced moisture content (65%) which is typical for other ensiled plant materials. In addition, the pH for the ensiled beets

will be tested as a variable. 'Control' beets were stored at their normal pH. Other research samples were stored at reduced pH levels which were achieved by adding sulfuric acid. The research results will be monitored and analyzed for fermentable sugar content over 12, 24 and 52 weeks of time. Ultimately, the samples will be fermented to evaluate the effect of storage conditions on ethanol yield.

**PLOT/YIELD TRIALS:** Twelve plot trials were harvested in late September or during October. The 2013 trials again experienced challenging conditions, including late plantings, limited rainfall, heat stress, soil salinity and herbicide residues. The dryland yields ranged from 14.5 to 29.5 tons/acre, with an average of 23.1 tons/acre. The dryland sugar content ranged from 16.4 to 18.4%, with an average of 17.7%. The irrigated yields ranged from 28.1 to 43.9 tons/acre, with an average of 34.7 tons/acre. The irrigated sugar content ranged from 15.8 to 18.4%, with an average of 17.0%. Given the results and conditions, the industrial beet performance reflected good adaption across the non-traditional production areas.

**CROP INSURANCE:** A GVG principal met with RMA in Kansas City in September. RMA was receptive to the crop insurance request for industrial beets, and suggested that the project engage the services of a firm with experience in getting new crop approval for crop insurance.

**COMMUNICATIONS/EDUCATION:** The primary communications activities included updating stakeholders through multiple meetings and presentations and partnering with NDSU and others on press and news releases. Other activities included a written Advisory Council update, assisting with the plot trials, and assisting with a stakeholder meeting in Carrington to focus on initial plant site locations and herbicide carry-over issues for industrial beets.

**MANAGEMENT:** In addition to activities identified above, other key management activities included Board meetings with NDSU and others; engagement with NDSU research activities, presentations at plot trials, a focus on EPA timelines, meeting with Minn-Dak Sugar Coop., and focusing of crop residue carry-over issues and initial plant location analysis so that the project can commence with prospective producer education and determination of grower interest.

#### **April 30, 2014 Report**

The following summary report was provided for the period December 1, 2013 through March 31, 2014:

The energy beet grant project consists of primary research activities for front-end processing, feedstock storage, and plot/yield trials along with crop insurance and communications/education objectives and project management.

**FRONT-END ENGINEERING:** The first phase of the current year's research to mechanically extract sugar from fresh, freshly frozen, long term frozen, and thawed beets was completed. Four sequential presses of the beet material were applied to each condition of beets, with cold water washes in between the serial presses. Long term frozen beets yield the best extraction results. The next phase of experiments will include hot water washes (up to 70 degrees C), energy consumption measurements, and the effect of beet particle size. The research process and results were presented at four conferences during the reporting period.

**FEEDSTOCK STORAGE:** A one-year experiment to evaluate ensiling techniques for beet feedstock storage was initiated November, 2013. Hammer milled samples were stored unaltered, or adjusted for moisture content and pH. Sample analysis dates were set for February 12, May 7 and November 19, 2014. The stored materials will be analyzed for fermentable sugar content, and ultimately samples will be fermented for ethanol yield.

**PLOT/YIELD TRIALS:** Although the plot trials to be conducted under the REC grant were completed in 2013, NDSU's Research Extension Centers will continue with several dryland and irrigated trials in 2014. These trials are not funded via REC grant monies. The seed company cooperators for the 2014 trials include Syngenta, Betaseed and SES VanderHave.

**CROP INSURANCE:** Crop insurance implementation requires the final selection of the first facilities site, which has not occurred.

**COMMUNICATIONS/EDUCATION:** The primary communications activities included updating stakeholders through multiple meetings and presentations in Valley City, Jamestown, Carrington, Cando and Langdon during the reporting period. GVG and NDSU partnered on multiple press and news releases to create awareness of meetings and presentations which occurred in December, 2013 and January and March, 2014. In addition, Power Point presentations were updated and plot trial result exhibits were prepared for the multiple engagements with various stakeholders.

**MANAGEMENT:** In addition to activities identified above, other key management activities included multiple meetings with NDSU and others; engagement with NDSU research activities; multiple presentations to various stakeholders and prospective growers at Valley City, Jamestown, Carrington, Cando and Langdon during the period; and coordinating seed supplies from Syngenta, Betaseed and SES VanderHave for 2014 plot trials. GVG also engaged in initial efforts to start a grower's organization to focus on specific decision needs of the prospective growers.

**'ADVANCED BIOFUEL' APPLICATION AT EPA:** During March, 2014 the EPA issued a Program Announcement suspending for six month all studies on pathway applications for designations under RFS2.

A no-cost extension was requested and granted extending the date for submission of the final report to February 28, 2015.

## 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 sited 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.

This contract has been closed. Copies of the full status reports are available in the Industrial Commission files.

Updated 8/10/2015