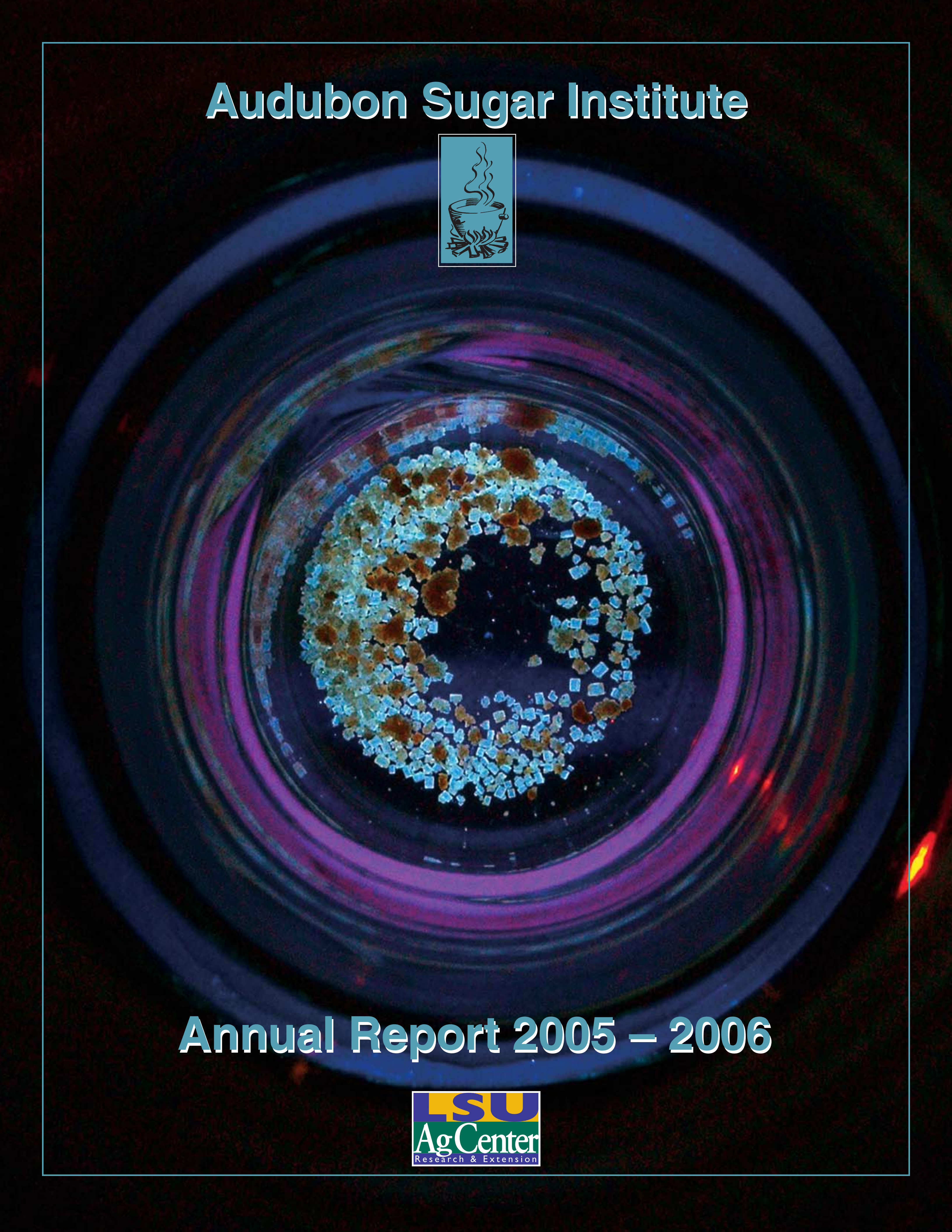
Audubon Sugar Institute



Annual Report 2005 – 2006

LSU AgCenter
Research & Extension

AUDUBON SUGAR INSTITUTE

Audubon Sugar Institute

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On the Cover: Raw sugar, illuminated with ultraviolet light (300 nm) will fluoresce, revealing impurities called "proto-colorants" that can evolve into colored materials. The more highly colored regions are aggregates held together with molasses. The colorant materials in the molasses "quench" fluorescence and appear "dark" under ultraviolet light. Removing or inhibiting these contaminants could lead to the direct production of white sugar; this could potentially increase the profit share of the Louisiana sugar industry. Photo by Lee Madsen.

Louisiana State University Agricultural Center
William B. Richardson, Chancellor
David J. Boethel, Vice Chancellor and Director of Research
Paul D. Coreil, Vice Chancellor and Director of Extension

Produced by LSU AgCenter Communications

AUDUBON SUGAR INSTITUTE

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Mission Statement

To foster a center of excellence for applied and original sugar research, which exceeds the expectations of our stakeholders in Louisiana and the international sugar industry, through innovative research, technology transfer and education.

Goals of the Audubon Sugar Institute

Goal 1
To enhance the productivity and profitability of the Louisiana sugar and other sugar process-related industries.

Goal 2
To improve the practice of sugar manufacture through education and technology transfer.

Goal 3
To conduct research toward a diversified sugar process industry.

Goal 4
To attract, retain and develop a world-class staff to serve our stakeholders.

Goal 5
To encourage use of low environmental impact technologies in sugar processing.

Audubon Sugar Institute Advisory Board

(As of March 2006)

VICE CHANCELLOR'S FOREWORD

It would be difficult to look back on 2005 without commenting on the devastation that hurricanes Katrina and Rita left after their passing through Louisiana. Agriculture was especially hard hit with virtually every commodity suffering losses, with sugarcane among those that sustained some of the most severe losses. The LSU AgCenter also felt the impact of the storms with losses to infrastructure and crops on the research stations, extension offices destruction and many personnel with damaged homes and property.

The AgCenter administrators are extremely proud of how the organization immediately stepped up to help the citizens of our state, while trying to get our units operational. It would be impossible in the limited space I have for this message to list the numerous examples of how our personnel contributed to the recovery in the aftermath of the storms and are continuing to do so. I will mention, however, that the Audubon Sugar Institute opened its doors to house personnel from the Sugarcane Processors Research Institute (SPRI) who were displaced when the USDA-ARS Southern Regional Research Center (SRRC) in New Orleans had to close because of the flooding of its facility. In fact, AgCenter faculty members also took in 38 USDA scientists and staff from the SRRC into their offices and laboratories to allow them to continue their research programs. The collaboration and hospitality shown by the Audubon Sugar Institute faculty and staff is appreciated.

In 2005, sugarcane remained one of Louisiana's most important agriculture commodities, with a farm gate value of $293.5 million and value-added revenue of $187 million. These statistics rank sugarcane as the leading row crop in the state and, once again, reinforce the fact that the industry is a critical component to economic development in Louisiana. Likewise, sugarcane continues to be an important focus area within the LSU AgCenter. Among the programmatic areas within the Louisiana Agricultural Experiment Station (LAES), the number of scientist years devoted to sugarcane (12.3 SYs) ranks as the highest for a single commodity. Research efforts on the crop can be found in the departments of Agricultural Economics and Agribusiness, Biological and Agricultural Engineering, Agronomy and Environmental Management, Entomology, Food Science, Human Ecology and Plant Pathology and Crop Physiology; research stations – Iberia and St. Gabriel; and the Audubon Sugar Institute.

Dr. David J. Boethel

During the past year, the industry has become much more interested and involved in pursuing opportunities for value-added entities associated with sugarcane – ethanol production, cogeneration of electricity, bagasse mats as planting substrates for plants used in coastal restoration and erosion protection of levees and roadsides, products for diagnostic use in sugar mills and the development of a sugar-based "nutraceutical" product that has potential for poultry feed with positive anti-diabetic properties. Research directed at finding a better biocide for sugar mills discovered that a cold sterilant has application for infection control in hospitals and now is being considered for commercialization.

ASI scientists have produced ethanol from bagasse. Although the amounts made are measured in milliliters rather than gallons, breakthroughs are occurring, and pilot plant studies have begun. The findings have resulted from the collaborative project with MBI International. This research has been greatly aided by the special grant from the Department of Energy. These are just a few examples of the programs where ASI scientists are making progress on bringing greater value to sugarcane.

The traditional role for ASI has not been ignored as value-added interest has grown. The ASI faculty continue to research ways to improve sugar mill efficiency. Mills have become more efficient than five to 10 years ago when natural gas usage was virtually nonexistent. Sugarcane is rarely washed at the mills, except under special circumstances, and dextran, once a major problem, is handled routinely on the floors of the mills. It is estimated that sugar recovery has increased by 10 pounds sugar per ton of cane processed by close attention to processing losses. Certainly, the mill operators have searched for innovation, but ASI scientists have become a resource for problem solving. They have visited mills to make their expertise available, have conducted short courses to train sugar engineers and presented seminars to give the industry the chance to hear the progress of their research projects. This outreach effort is a conscious attempt to bring the latest technology and knowledge to the sugarcane industry. We are convinced that these education programs can help your programs, and please do not miss the opportunity to participate.

As I begin my third year as vice-chancellor and director of the Louisiana Agricultural Experiment Station, I want to thank the American Sugarcane League for the continued financial support provided by the Dedicated Research Committee and the base support provided to the sugarcane breeding program and the Audubon Sugar Institute. The ASCL through its funding of projects helps us focus our research on the most important needs of the industry. Thanks also are in order for the ASI Advisory Board for the same role you play for ASI. I remain enthusiastic about the future of ASI and the programs being conducted by the unit.

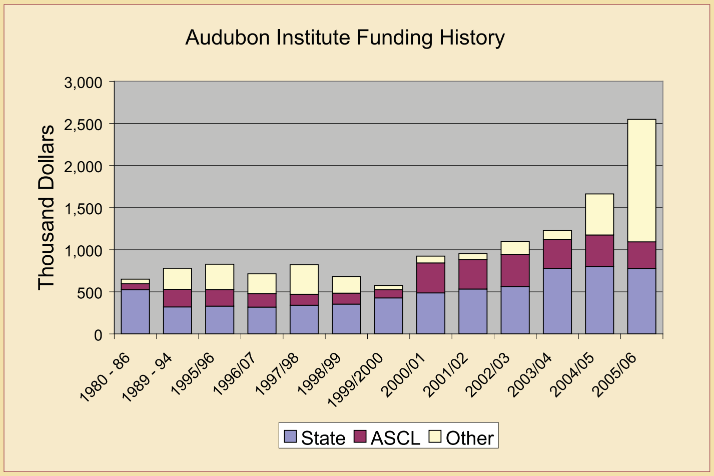
If, as you read the annual report, questions arise, please call on Dr. Rein and his staff to clarify any issues. Better yet, we would welcome you to visit ASI to learn more about the contributions being made on behalf of the industry. Although the LSU AgCenter and the sugarcane industry face some challenges, both have been partners with long histories of serving the citizens of Louisiana. I am confident we will continue to do so for many years.

HEAD OF INSTITUTE'S REPORT

We were fortunate to escape any ill effects from hurricanes Katrina and Rita that caused so much havoc in Louisiana. Our work was little affected, and, in fact, we have been able to provide some office and lab space for personnel at the Sugar Processing Research Institute Inc. (SPRI), who have temporarily lost their premises in New Orleans, and to a displaced scientist with the USDA. The major effect we felt was financial – state money through the LSU System was cut, and our funding through the American Sugar Cane League was reduced as resulting bad sugar crops affected their revenue severely.

We were fortunate, however, to see much increased funding from the U.S. Department of Energy (DOE), which increased from $0.5 million in the previous year to $2.5 million in 2005/06. We continue to share this with MBI International (Michigan Biotechnology Institute) in Lansing Mich., but the funding has enabled us to expand both in terms of people and equipment. We are particularly pleased to have Dr. Benito Stradi join us as an assistant professor dedicated to this project. We have now filled all the space available in our premises at St. Gabriel; we would not have been able to expand our endeavors in this way at our old campus location.

Our funding history is shown in the graph. Ensuring that we have enough funds to execute research is an important and time-consuming process. We are fortunate to have Melati Tessier at Audubon to handle so much of the management and administration of our grants so efficiently.



There is a great deal of interest in the state and the nation in using agricultural biomass for fuel, chemicals and power. I believe sugarcane processing has huge advantages relative to other options, and we are excited to be working in these areas at this time. It is most appropriate for us, and I think we have the ability to make good progress with our people and equipment resources.

The sugar crop in Louisiana was again well below average, largely due to weather-related factors. Another mill, Cinclare, has crushed its last cane, so that six mills have now closed in the last six years. We have made a concerted effort to have regular contact with all the mills. In most cases, our contact has been well received, and slow-but-steady improvements in processing efficiency are evident.

Dr. Peter Rein

Last year we ran the BE4342 course in Sugar Process Engineering as an intersession course covering two and a half weeks. It seemed to be a success, and we had five delegates from overseas participate. Our short course on ethanol production run by Jaime Fingerut from Brazil was very successful; we plan a follow-up course in August 2006.

The past year has been one in which we have been able to consolidate, despite the expansion of our activities in the sugarcane biomass utilization area. This has been helped by a low turnover of staff. Features of this consolidation include:

- *Our analytical lab, under Brian White's energetic leadership, has expanded in scope and capability and is now well resourced to meet our analytical resources.*
- *Our engineering team, lead by Julie King, has worked well together and provides a valuable service in enabling much of the experimental work in progress. In addition the team has got the troublesome HVAC system under control and reduced our utility usage down to less than half what it was previously, a huge cost saving.*
- *Our pilot plant equipment is slowly but surely all being recommissioned and is proving its usefulness in our biorefinery project.*
- *Our biorefining project is now becoming more focused, and we have made some progress up a steep learning curve.*

Apart from the biorefining project, our other research work has made good progress. Two of our research associates are registered for graduate study: Lee Madsen for a Ph.D. in chemistry and Stella Polanco for an M.S. in chemical engineering. We are steadily building up our knowledge and skills base in all aspects of sugar processing.

We are again grateful to the American Sugar Cane League for supporting our efforts in many ways.

My thanks are also due to those in Audubon who work hard to promote our Institute and help us achieve our objectives.

RESEARCH REPORTS

Louisiana Mill Tests

Seventeen mill extraction tests (on 12 tandems) were conducted during the 2005 crop. The tandems tested were 5-, 6- or 7-mill tandems. Prepared cane and bagasse samples leaving each mill in the tandem were collected and analyzed for pol, moisture and fiber content. Ash content also was determined on prepared cane and last mill bagasse samples. Preparation index was measured on the prepared cane samples using the Louisiana method. Tandem and individual mill pol extraction values were calculated using the following equation:

$$E = \frac{100\,(\text{Pol \% fiber in feed} - \text{pol \% fiber in discharge})}{(\text{pol \% fiber in feed})}$$

Results are shown in Table 1.

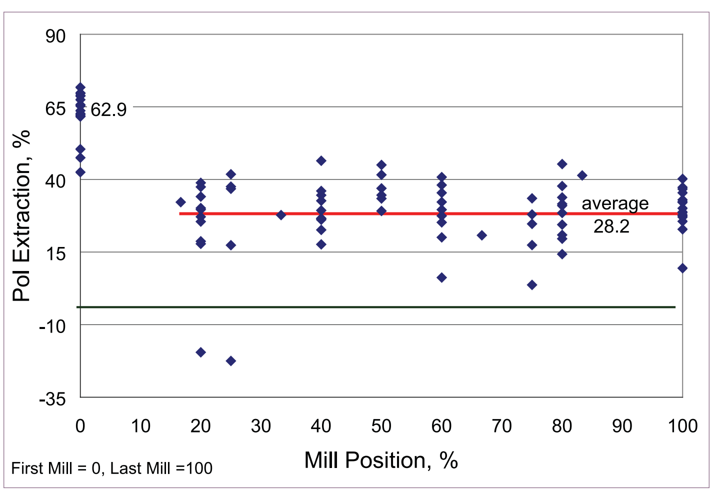
Table 1. Results of milling tests during 2005 crop.

	Average	Maximum	Minimum
Fiber % prepared cane	11.6	13.2	9.8
Pol % prepared cane	12.3	13.6	11.0
Ash % prepared cane	2.4	4.8	0.8
Moisture % bagasse	53.6	61.7	50.3
Pol % bagasse	3.0	5.0	1.9
Ash % bagasse	4.2	7.3	1.9
First mill pol extraction, %	62.9	71.7	42.5
Tandem pol extraction, %	92.4	95.6	84.2
Reduced pol extraction, %	91.7	95.3	84.5

The average pol extraction of all first mills tested was 62.9 percent with the following mills in the tandem each averaging about 28 percent pol extraction. The individual data points and overall averages are shown in Figure 1.

Overall, wide variations were in all of the milling parameters. Most of the factories have one or more mills that perform poorly, indicated by increasing moisture and/or low individual mill extraction.

Figure 1. Individual mill pol extraction through the tandem.



A Comparison of Mill and Diffuser Juice

From the time that diffusion was first introduced as a viable alternative to milling, there has been considerable speculation as to whether the raw juice from a diffuser is inferior to that from mills, in terms of the subsequent recovery of sugar in the boiling house. It was considered that the high temperature and long residence time to which the cane is subjected in the diffuser could lead to the extraction of additional impurities. The Enterprise mill has both a mill tandem and a diffuser of similar capacities, allowing for a reliable comparison. The mill and diffuser processed cane from the same cane supply area, so the comparison is not affected by cane quality issues.

Weekly composite raw juice samples from the parallel milling and diffuser extraction systems at Enterprise mill in Louisiana were collected during the 2004 and 2005 grinding seasons. Comprehensive analysis including HPLC sugars, polysaccharides, anions and color were undertaken. Table 2 contains some of the key parameters derived from these analyses.

Table 2: Comparison of mill and diffuser Juice from Enterprise

	2004		2005	
	Diffuser	Mill	Diffuser	Mill
True Purity, %	87.2	87.4	87.2	87.1
Color, IU	13489	12158	12175	11062
Starch, mg/kg solids	684	1,572	402	760
Fructose/Glucose ratio	1.03	1.06	0.99	0.99
Dextran, mg/kg solids	464	477	270	543

Juice purity (Figure 2) and monosaccharide/ash ratios in both raw juices are very similar, despite the higher extraction in the diffuser, indicating that no difference in recovery of sugar from the juices is expected. Under Louisiana conditions, the color of the juice from a diffuser is about 10 percent higher than that from a milling tandem as illustrated in Figure 3. This is less than the seasonal variation of up to 30 percent in color shown for both mill and diffuser raw juice.

Figure 2. The comparative study done on diffuser and mill juice collected from Enterprise Factory showed very little difference in true purity.

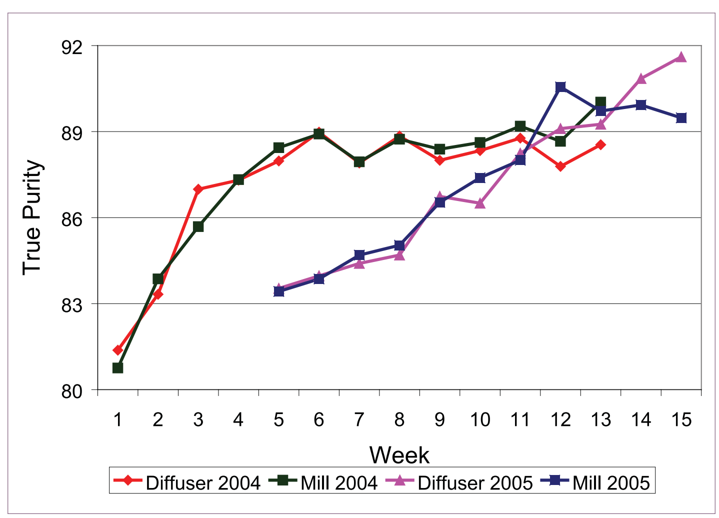
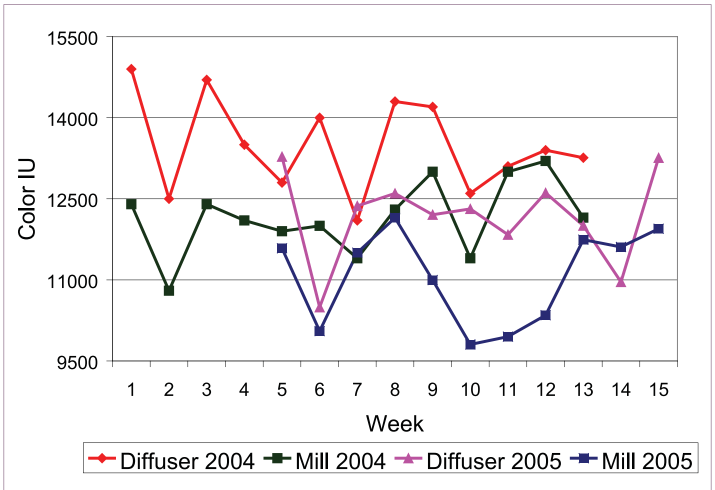
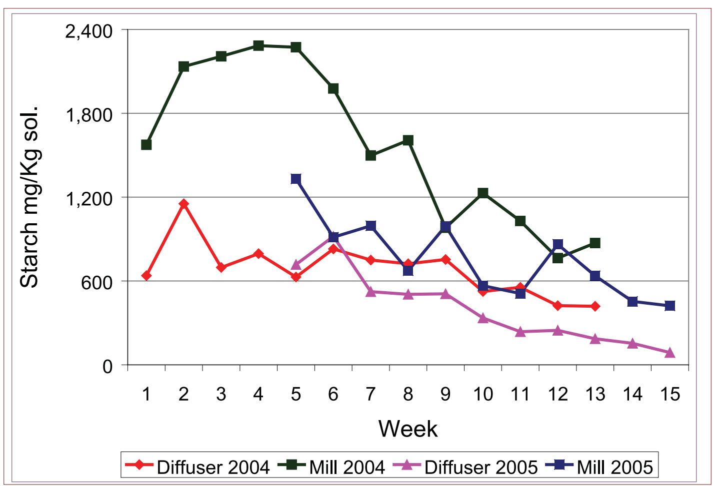


Figure 3. The color in diffuser juice was approximately 10% higher than in mill juice.



The starch and dextran content is significantly lower in diffuser juice than in mill juice, despite the fact that dextranase was added into the milling tandem. The dextran level is clearly affected by climatic conditions, being significantly higher when the temperature is higher and during wet weather. These conditions promote the activity of *Leuconostoc* both between harvesting and grinding and in the milling tandem. Starch levels are slightly higher in both sets of juice at the beginning of the season, which is assumed to be due to cane quality. Figure 4 plots the starch data for the two seasons.

Figure 4. Starch analysis on diffuser and mill juice revealed much higher starch content in mill samples.



Reducing Sugar Losses in Filter Cake

Despite an improvement in 2005, residual sugar in filter cake remains a source of significant loss of revenue for the industry. Table 3 summarizes the sugar loss in filter cake over the last four years.

Table 3. Survey of residual sugar in filter cake.

Year	Pol % cake	Filter cake produced, lb/t cane
2002	4.2	150
2003	4.1	109
2004	4.1	129
2005	3.3	111

To assist the industry to improve the situation, a program was undertaken in 2004 and 2005 to study various aspects of juice clarifier and filter operations. In a 2004 survey of clarifier mud composition, an important finding was the high levels of bagacillo determined in clarifier underflow in a number of mills in relation to the total suspended solids (Table 4). The bagacillo in mixed juice negatively affects mud settling, mud volume and pol loss in filter cake. Unlike other industries, most Louisiana mills only screen mixed juice on cush-cush screens with 1.5 mm aperture.

Table 4. Bagacillo ratio (dry weight of bagacillo/dry weight of non-bagacillo suspended solids)

Minimum	0.6
Maximum	1.3
Average	0.9

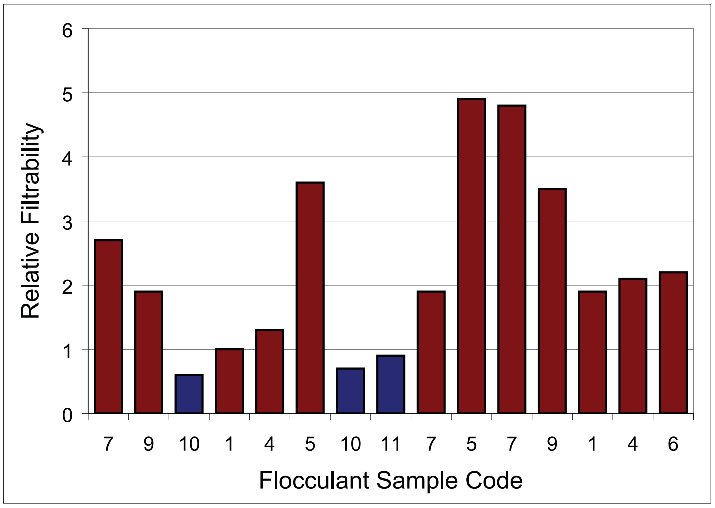
Figure 5. Equal weights (0.5 g) of dry soil (left) and dry bagacillo (right).

Because of its fluffy texture, bagacillo adds disproportionately to the volume of the cake. For comparison, equal weights of dry soil and dry bagacillo are arranged side by side in Figure 5. The bagacillo that underwent heating and liming is especially spongy, absorbing nearly 20 times its weight of juice. Finer screening of mixed juice with 0.8 mm screens is common elsewhere, and it would be expected to reduce the bagacillo ratio in the clarifier mud to around 0.3, reduce the amount of filter cake by 30 percent and provide an additional 16 lb bagasse per ton of cane. Additional benefits would be expected from the reduction in mud volume within the clarifier, better mud settling and better sweetening off of the filter cake on the filters. It is expected that even with finer screening the residual bagacillo would still be sufficient to provide porous enough cake but it is possible that the optimization of the flocculant addition would become more critical than it is now.

A series of laboratory tests were carried out with a number of commercial flocculants – both anionic and cationic – and their effect on filtration rate of clarifier mud was measured. The high molecular weight anionic flocculants represented by burgundy bars in Figure 6 were found superior to the cationic flocculants (blue). As a matter of fact, the same flocculants that are effective in the juice clarification stage also were found effective for mud conditioning. At 10 mg/L flocculant on mud volume, the filtration rate was increased with respect to the control (no flocculant) by up to five-fold.

Improving cake porosity by optimizing the addition of flocculant does not increase the amount of filter cake (unlike bagacillo), yet increases the processing rate (flow of juice through the cake) and lowers the filter cake pol (flow of wash water through the cake).

Figure 6. Effect of various anionic (burgundy) and cationic (blue) flocculants on relative filterability of clarifier mud (10 ppm flocculant on mud volume).



Filtrate Clarification

Juice clarification is an important step in cane sugar production. Suspended solids and some dissolved compounds are separated from mixed juice forming a mud that is de-sweetened in vacuum filters. The filtrate, representing about 20 percent of mixed juice, is normally returned to the mixed juice tank before clarification. The reason for this return is the high turbidity and suspended solids content in filtrate. To avoid recycling, further clarification is necessary to obtain a clear solution. This can be done by a flotation clarification system.

Using pilot plant equipment, experiments were done in two Louisiana sugar mills during the 2004 and 2005 seasons. The filtrate was mixed with appropriate flocculants and fed at a controlled flow rate to the clarifier. Mud formed in the clarifier was separated from the clarified filtrate. Air was injected to promote mud separation. Using 15 mg cationic flocculant/kg filtrate and 3 mg anionic flocculant/kg filtrate, the clarified filtrate was clear, and the mud formed was bulky and thick (figures 7 and 8).

Some results from the trials are presented in Table 5.

Figure 7. Clarified filtrate.

Figure 8. Mud removed from clarifier.

Reductions of 79.1 percent and 68.9 percent were achieved respectively in turbidity and suspended solids. An increase of 1.1 points in purity and a decrease of 14.8 percent in color were also observed. These tests showed that some significant advantages of filtrate clarificationi can be achieved – avoiding the return of filtrate to the main clarifier (increase in clarifier capacity, less sugar destruction because of recirculation); increasing the quality of filtrate; better processing operation after the clarifiers; and increasing sugar recovery (estimated 0.2 percent).

Table 5. Filtrate composition before and after clarification.

Filtrate	Brix	Color IU	Turbidity NTU	pH	Susp. Solids mg/l	True Purity	Dextran mg/kg DS	Lactic Acid mg/kg DS	Calcium mg/kg DS
		1-day Average					Single Sample		
In	9.3	11220	1,400	6.9	1,680	87.6	283	814	3,720
Out	10.6	10560	292	6.2	522	88.7	247	819	2,950
Reduction			79.1 %		68.9 %				

Direct White Sugar Production

Cane white sugar production involves a complex system of extraction, purification and crystallization in two separate processing steps: from cane sugar to raw sugar in raw sugar mills and from raw sugar to refined sugar in sugar refineries. This separation is due to the presence of specific impurities in sugar juice, mainly high molecular mass colorants that have a high affinity for sugar crystals. Therefore, if these compounds are not properly removed in sugar mills the raw sugar product has a residual color without the characteristics of a white sugar.

Producing white sugar directly in the sugar mill has advantages such as elimination or minimization of the refining process and increased revenue to the raw sugar mill. Attempts have been made to apply new technologies such as membrane filtration. This technology is promising, but it is not usually economically viable for this purpose. In our novel approach, clarified juice is decolorized with granular activated carbon (GAC) in two columns in series, followed by demineralization and/or softening.

During 2005 season a pilot plant (Figure 9) was installed in one Louisiana sugar mill to decolorize and soften the clarified syrup. GAC was placed in two columns of 15 L and 30 L capacity. The first column is a guard column to protect the second column from suspended solids carried over with the juice. Before the second column, juice was contacted with hydrogen peroxide. After passage through the GAC columns, juice was treated with cationic and anionic resins in a mixed bed column, to remove hardness in solution and reduce juice color. The installation worked continuously for two months with clarified juice at a flow rate of 1 BV/h (on total carbon). Average composition of clarified juice was: Brix 14.3; color 9070 IU, turbidity 212 NTU, ash 3.5 g/100 g solids, pH 7.2. Average composition of final treated liquor was: Brix 13.9; color 1680 IU; turbidity 165 NTU, ash 4.0 g/100 g solids; pH 6.0. A reduction of 81.4 percent in juice color was obtained (75.6 percent on carbon columns and 24.1 percent on resins). A turbidity decrease of 22.1 percent and hardness (calcium and magnesium) reduction of 88.5 percent was observed (Figure 10 and Table 6).

One of the most unique and promising aspects of the system involves the method of GAC regeneration. Normally, GAC is regenerated at a high temperature in special kilns. In a new regeneration process (NRP) developed at Audubon, a special solvent regeneration is used. In this process, regeneration is performed using a novel solution of solvents and other chemicals after the columns have been washed. The process was performed on the GAC columns every five days. Regeneration of the ion exchange resins was performed every three to four days using a conventional solution of NaOH and NaCl.

Figure 9. Pilot plant for clarified juice decolorization and decalcification.

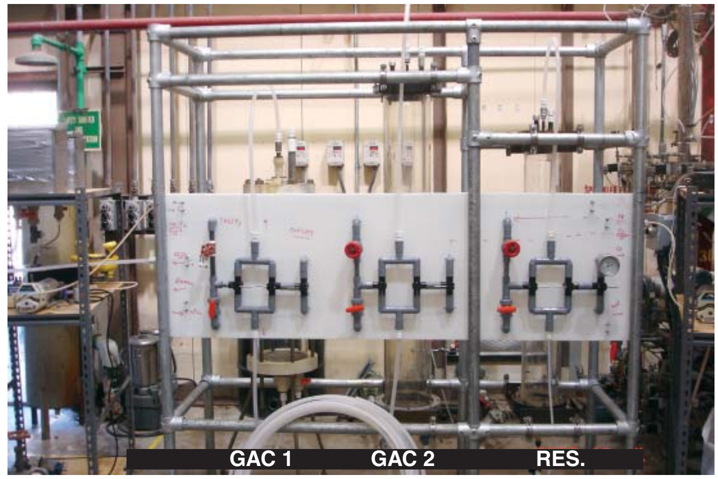


Figure 10. Samples of clarified juice (from left to right): before the first GAC column; after the first GAC column; after second GAC column; and after resins column.

A comparison of this new regeneration process (NRP) with other chemical processes is presented in Figure 11. The high regeneration capacity of this process will allow the application of GAC in the sugar industry without requiring the expense of a regeneration kiln.

From these results it appears that the proposed decolorization process (granular activated carbon and ion exchange resins) is efficient enough to process clarified juice to white sugar directly in raw sugar mills (see Figure 12).

Table 6. Composition of clarified juice before and after treatment.

	10 Cycle Average					Single Sample	
	Brix	Color IU	Turbidity NTU	Ash g/100 g DS	pH	Purity	Ca+Mg mg/kg DS
Clarified juice	14.3	9070	212	3.48	7.7	87.4	4,240
Juice after first GAC column	14.3	6870	191	3.67	5.9	88.6	4,460
Juice after second GAC column	14.1	2220	187	3.92	5.6	88.2	4,350
Juice after resin column	13.9	1680	165	4.04	6.0	89.0	489
Reduction		81.4%	22.1%				88.5%

Figure 11. Attenuances of regeneration effluents using three regeneration methods.

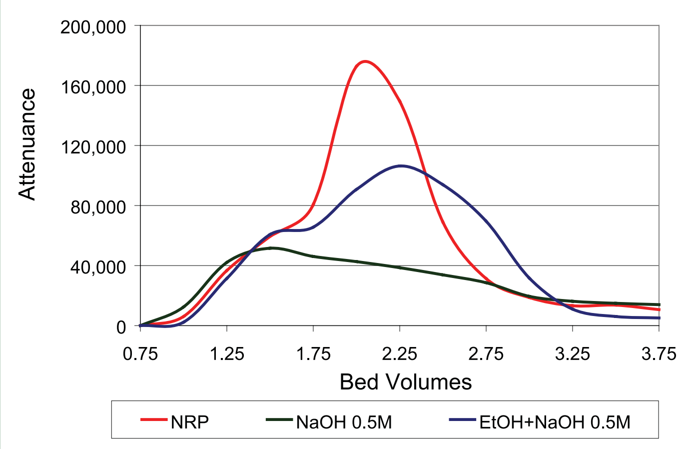
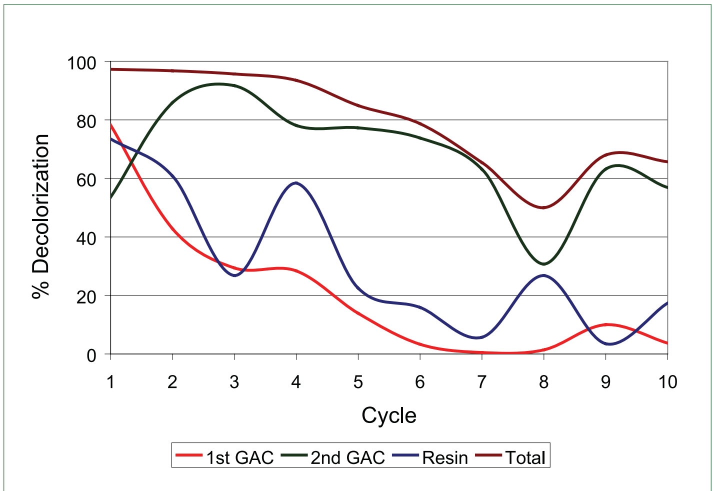


Figure 12. Decolorization through GAC and Resin columns.



Mud Filtration and Sweetening Off With Membrane Filter Press

A pilot-sized membrane filter press (H. Putsch & Co. Inc.) was placed in a Louisiana mill (Figure 13) and operated on the clarifier mud taken from a mud conditioning tank. From 10 ppm to 20 ppm flocculant were added and 25 to 40 gallons of mud processed per cycle ranging from 15 to 30 minutes – and was completed when the chambers became full, and a feed pressure of about 90 psig was reached. The moisture of the cake was reduced to below 50 percent by inflating the rubber membranes with air. Based on the test results, it is estimated that for a 10,000 tcd mill, a total filtration surface of 260 m^2 will be needed, corresponding approximately to 80 1.2 m x 1.2 m plates. It is noteworthy that this filtration area requirement is seven times less than the lowest estimates quoted by Hugot for industrial plate and frame press installations in Cuba in the 1930s. It is believed that this is the result of the application of efficient modern day flocculants used in this work, while the classical textbook refers to industrial operations well before synthetic flocculants became available. This difference also matches well the filterability improvement from addition of flocculants found in the vacuum filter studies.

Figure 13. View of the pilot scale membrane filter press.

Evaluation of Several Agents for Potential to Inhibit Nonenzymic Browning During the Production of Sugar from Clarified and Decolorized Sugarcane Juice

Several adjuvants were evaluated for potential to either promote or inhibit the formation of color. It was noted during preliminary tests that mixed dithiocarbamate (mDTC) mill biocide can promote non-enzymic color formation. It is known that sodium bisulfite (NaBS) will inhibit browning, but residual sulfite in sugar is undesirable. N-acetyl cysteine (NAC), a modified amino acid was tested as an FDA approved alternative.

Cleaned, whole-stalk sugarcane was crushed using a Farrell 3-roll mill. The juice was clarified by hot-liming and back-adjusted to pH 7.0 using H_3PO_4. The mud was coagulated via the addition of 5 mg/kg conventional anionic flocculant. The juice was filtered, after addition of bagacillo, through a fine screen.

Samples of this juice were treated with varied quantities of mDTC, NAC, or NaBS. These juices were subject to a multiple effect evaporator simulation (MEES) whereby they were brought, in three steps, to about 67 percent DS under conditions of decreasing pressure.

The second portion was decolorized via passage at two bed volumes per hour through GAC and a mixed bed ion exchanger. The resulting liquor was subjected to the treatments as the clarified juice and an identical MEES.

Syrups from both clarified and decolorized juices were subject to an accelerated storage test (AST) whereby they were sealed and incubated at 95 C for 8 hours with periodic sampling.

MEES and AST products were assayed for refractometer Brix, pH, sugars, levulinic and formic acids by high pressure liquid chromatography (HPLC) with differential refractive index detection, 5-hydroxymethyl-2-furaldehyde (HMF) and 2-furaldehyde via HPLC with diode array detection and ultraviolet-visible spectrophotometry. Fractions were taken from the final MEES syrups; these were subject to fractionation, and several proto-colorants were tentatively identified via gas chromatography with mass-selective detection. Results are shown in Figure 14.

For clarified juice, there was a small, but significant increase in color across the MEES. In several of the cases, the color increased slightly across the first and second “effects” and decreased across the third. Decolorized juices were less stable, mDTC applied as cited

exhibited +45 percent and +101 percent of the color formed relative to the control. Samples made to contain NAC or NaBS exhibited an inhibition of color formation that amounts to –24 percent and –56 percent, respectively, of the color formed in the control. The most significant increase in color in all cases occurred across the first "effect."

AST results of the different MEES syrups were interesting as shown in Figure 15. After incubation, the decolorized juices all increased in color, but the effects were different from those in the MEES, with mDTC levels 1 and 2 registering color increases of only 86.2 and 75.1 percent, NaC 73.2 percent and NaBS 72.34 percent of the control.

The tentatively identified compounds found conformed to that which is known for caramel, including maltol isomers, HMF and other furanoid derivatives.

Figure 14. Final color of clarified (CJ) and decolorized juices (unlabeled) rendered to syrup during the MEES tests.

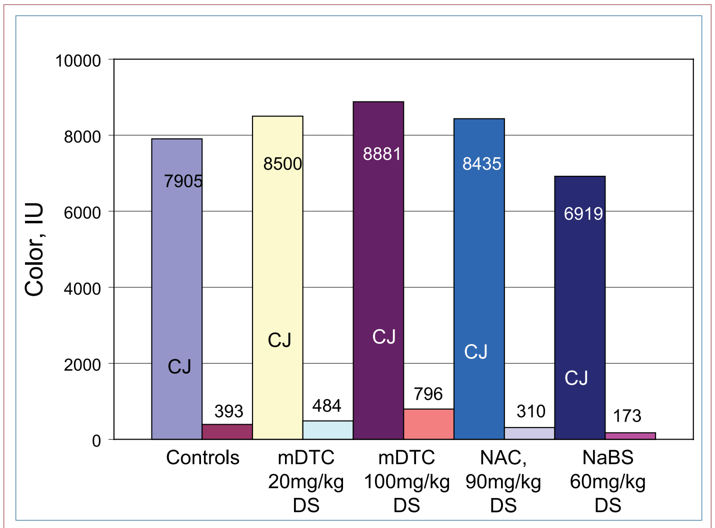
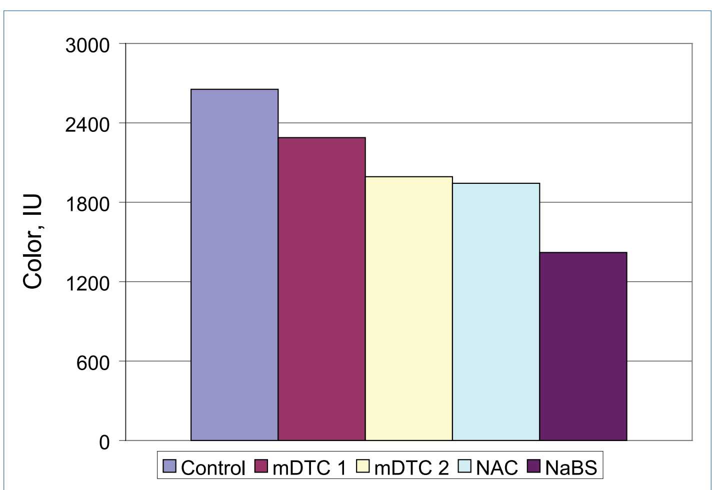


Figure 15. The final color of the syrups prepared from decolorized juice and subject to accelerated storage tests.

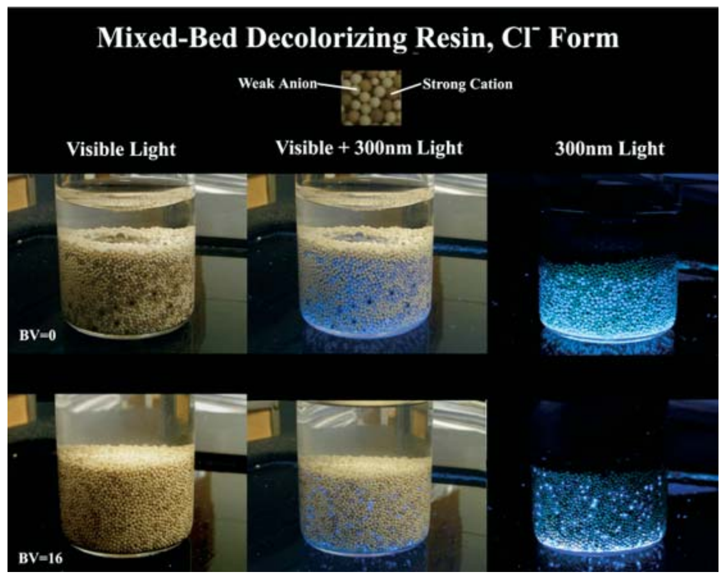


Effect of Colorant Loading on the Fluorescent Properties of Ion Exchange Resin

Sixteen bed volumes of clarified sugarcane juice were passed through a decolorizer comprised of, sequentially, a column of activated carbon and a mixed-bed ion exchanger (Cl^- form). The visual properties under long-wave ultraviolet light (300 nm) were noted, and it was determined that this method may have potential use for online testing of resins employed in a pilot or industrial scale decolorizer.

It appears that the fluorescence of the cationic resin is quenched by adsorption of colorant or precursor materials. This quenching, which can be seen in Figure 16, could be used to monitor resin beds for breakthrough allowing for optimization of regeneration protocols.

Figure 16. Mixed-bed ion exchanger, virgin material, top, and after 16 bed volumes of clarified juice, as seen under visible light (left), visible light with 300 nm UV light (center) and 300 nm UV light only (right).

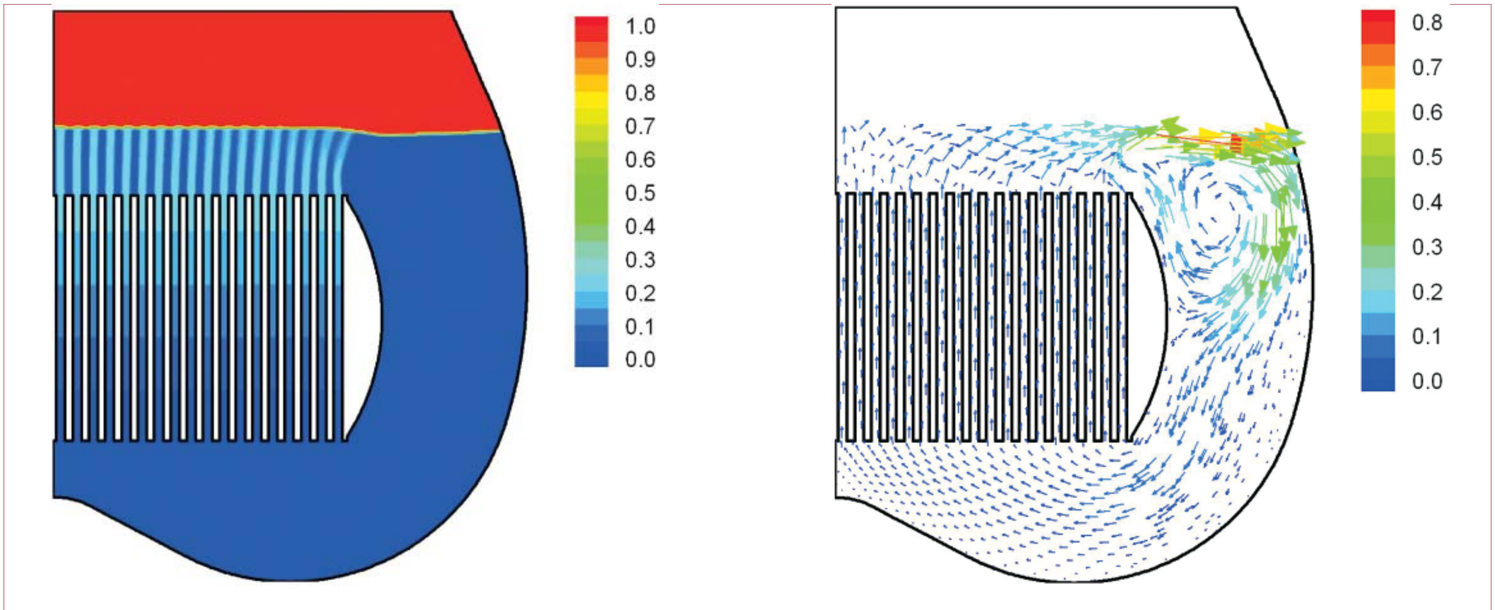


Numerical and Experimental Study of the Flow in Vacuum Pans

Measurements of the massecuite velocity in a continuous vacuum pan were performed at the Enterprise sugar mill using insertion flow sensors to determine the velocity in the bottom and the downtake, elucidating the flow patterns and providing an estimate of the circulation rate. The flow has been simulated applying the Eulerian-Eulerian multiphase CFD model (Fluent). A reduction in the interfacial momentum interaction is necessary to obtain agreement between measurements and computations.

Figure 17 presents the contours of volumetric fraction and massecuite velocity vectors predicted numerically, showing velocities at the bottom similar in magnitude to those measured with the insertion flow sensors. No stagnation zones are indicated, and the most notable feature is the development of a vortex that occupies a significant part of the upper-downtake region. The predicted vortex is reasonable due to the sharp turn that the geometry of the crystallizer imposes on the flow at this location, and its existence was confirmed with the measurements at the downtake and previous observations in a lab-scale facility.

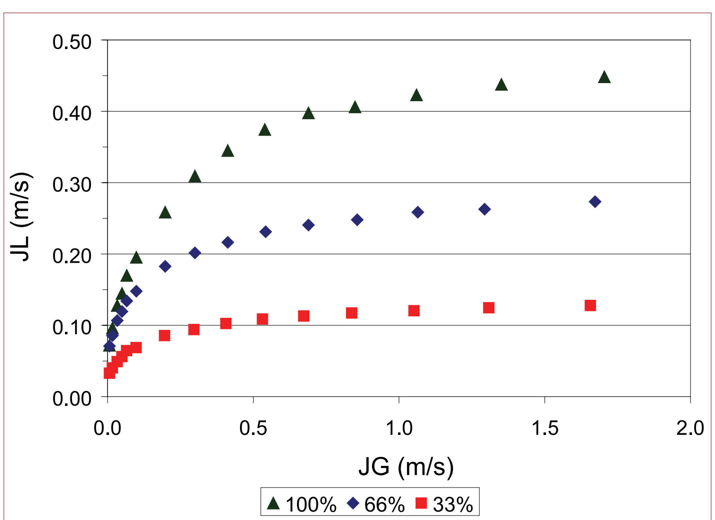
Figure 17. Contours of volumetric fraction (left) and liquid velocity vectors (right) in a continuous vacuum pan predicted using CFD.



The results have shown that a numerical solution that represents the flow in vacuum pans reasonably is possible as long as the momentum interaction between the gas and liquid phases is specified properly. An experimental facility has been constructed to study the transfer of momentum between gas and liquid in buoyancy-driven vertical channel flows. Data from this study are being used to seek relations applicable in the modeling of the vapor-massecuite momentum interaction. Figure 18 presents some preliminary results that illustrate the increase in circulation, in terms of the liquid flux, as the gas flux (analogous to evaporation) is higher. The circulation produced displays an asymptotic behavior, with a progressive decay in the transfer of momentum as the gas flow is raised.

The interfacial transfer of momentum appears to be more effective within the bubbly regime, while a progressive loss in the capacity to produce circulation occurs as the gas flux increases and transition to the slug and churn regimes occur. This phenomenon is probably the reason behind the reduction in momentum interaction required during the CFD simulations and suggests that regimes such as slug and churn are potentially present in calandria tubes. The development of these regimes would explain the fluctuating character of massecuite boiling, as well as the higher performance observed with short calandria tubes, while longer tubes would be more susceptible to develop slugs and churns, losing the ability to produce circulation and consequently affecting the heat transfer and crystallization rates.

Figure 18. Circulation in terms of the liquid flux vs. gas flux determined in the experimental facility at three different levels of frictional resistance (analogous to circulation vs. evaporation).



Experimental Study of Sugar Boiling

When massecuite circulates rapidly within a pan, the good mixing of the contents of the pan lead to homogenous conditions of temperature, mother liquor supersaturation and good quality sugar crystals. The rate of circulation is directly related to the rate of heat transfer. This is because the heat transferred from the steam-heated calandria to the massecuite leads to boiling and generation of vapor bubbles in the tubes. The difference in density between the boiling massecuite in the tubes and the massecuite in the downtake is the driving force for circulation, which causes upflow in the tubes and downflow in the downtake. Circulation is affected by the hydraulic resistance of the channel through which flow takes place, the physical properties of the fluid and the amount of vapor formed.

Thus far, modeling and experimental work has been done looking at massecuite flow patterns making an assumption of constant vapor generation and uniform vapor generation in every tube. An experimental test rig where flow is induced by generation of vapor bubbles in the massecuite has been designed that will determine the variables affecting heat transfer and boiling inside the calandria tubes. The goal is to be able to predict the heat transfer and rate of vapor generation as a function of the fluid properties, the geometry of the tubes, the massecuite head above the tubes and the rate at which massecuite arrives at the entrance of each tube, to optimize the crystallization process.

Visualization studies will be conducted to elucidate the characteristics of natural convective flow boiling in the calandria tubes and identify the flow patterns. Variables such as void fraction, pressure drop and heat transfer coefficients will be measured. This is a joint research project between ASI and the Mechanical Engineering Department at Louisiana State University.

Reducing Sugar Color With Hydrogen Peroxide

Dosing hydrogen peroxide directly in the vacuum pans is sometimes done to reduce massecuite viscosity and sugar color. That way, peroxide contacts or reacts with all color bodies that are in the massecuite. Treating only the 5 percent of color that eventually adheres to the outside and becomes part of the sugar should in theory reduce the peroxide requirement twenty-fold with a comparable decolorization effect. This concept has been tested in a series of experiments. A set of commercial sugar samples was obtained from two sulphitation mills in Colombia and the sugars were treated with 100 mg hydrogen peroxide/kg sugar. The color of the sugar was reduced by 18 percent on average, from 223 IU to 182 IU (Table 7).

Table 7: Color reduction using hydrogen peroxide on commercial sugar samples from Colombia.

Sample	Color before treatment, IU	Color after treatment, IU	Color reduction, IU	Color reduction, %
C	226	202	24	11
D	201	159	42	21
E	236	187	49	21
C	235	197	38	16
D	217	172	45	21
E	240	198	42	18
F	180	179	1	0
G	204	162	42	21

Application of 3000 ppm hydrogen peroxide to an 1,800 IU Louisiana raw reduced its color to 822 IU, a 56 percent reduction. Similar reductions were found by bleaching affined raws, producing bleached sugars with 214-266 IU. The color of all bleached and unbleached sugar increased after six months of storage but the color advantage of bleached sugars was preserved.

In another set of tests in a Louisiana mill, 1700 ppm (mg/kg sugar) of hydrogen peroxide was diluted in 1 L water and applied directly in a Western States batch centrifuge with a manually operated sprayer. The centrifuge operation was as follows: acceleration in 50 seconds to1200 rpm followed with a 2-second wash, followed by spinning for 80 seconds at 1200 rpm. The peroxide spray was applied over about 10 seconds immediately following the 2-second wash. The color of the sugar (average of three tests and three controls, Table 8) was reduced from 919 IU to 277 IU, a 70 percent reduction. Adding a few ppm of sodium hydroxide to the hydrogen peroxide offsets the small pH drop that results from bleaching with hydrogen peroxide alone. Pol reading exceeding 100 is due to residual dextran or other dextrarotatory compounds incorporated into the sugar crystals.

Table 8: Results of hydrogen peroxide treatment on Louisiana raw sugar.

	H_2O_2 Treatment	Control	Change
Color, IU	277	919	-642
Pol	100.2	99.6	0.6
Ash, %	0.09	0.22	-0.13
Invert, %	0.09	0.13	-0.04

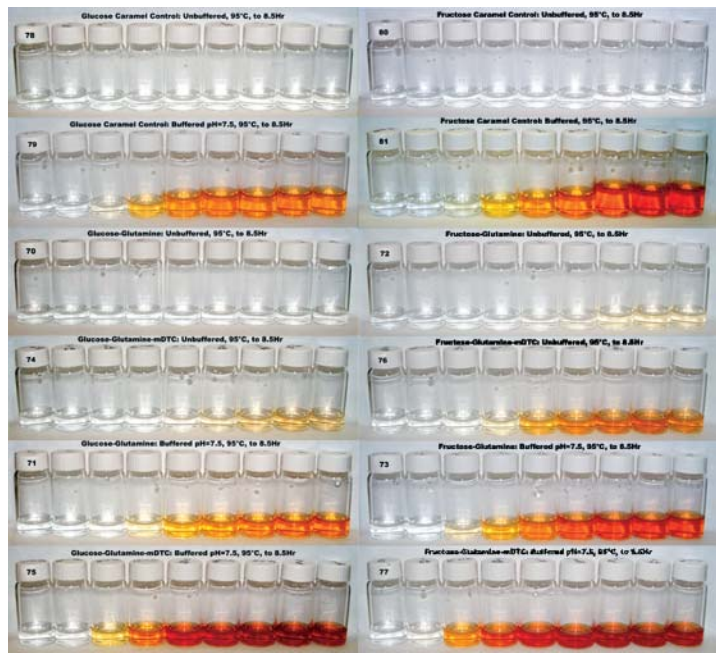
High Brix Colorant Models

Effect of Temperature and Dry Solids Loading on the Kinetics Involved With Carameloid and L-Glutamine Related Maillard Reaction Products

Carameloid and melanoidin-type colorants evolved from the reaction of synthetic syrups were evaluated for behavior under conditions of varied temperature and solids loading. Constituents, in accord with cane-syrup, viz. sucrose (95 percent): glucose (5 percent), sucrose (95 percent): fructose (5 percent) and sucrose (90 percent): glucose (5 percent): fructose (5 percent) systems were similarly evaluated both with (0.5 percent) and without added amino acid and, with or without buffering, at pH 7.5.

It was found that under normal cane sugar processing conditions, fructose is the most reactive constituent, followed by glucose with respect to nonenzymatic browning processes generally regarded as carameloid and/or melanoidin. Similarly, as seen in Figure 19, fructose leads toward more rapid hydrolysis of sucrose than glucose, with commensurate formation of ICUMSA color.

Figure 19. Mixtures of glucose or fructose with and without mDTC, and with or without buffering at pH 7.5. Each set is run with or without l-glutamine at 500 mg/kg dry solids.



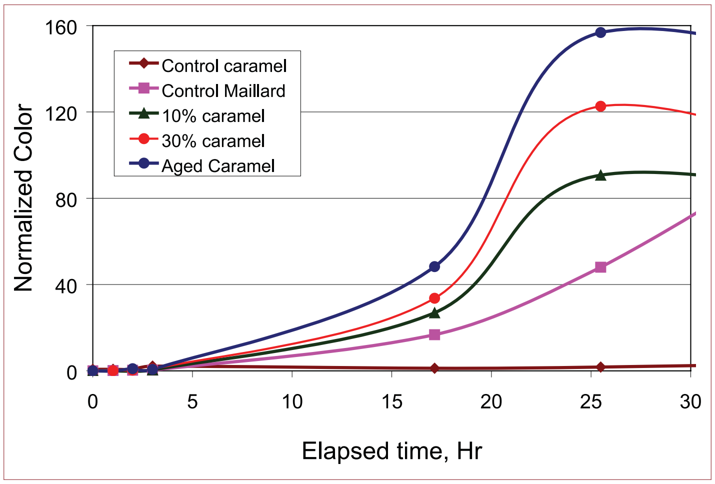
The Influence of an Induction Period on Color Formation in Model Maillard Reaction Systems

Research toward the economical production of white sugar is not exclusively limited to the realm of color removal. Recognition of the chemical behavior of colorant groups has led to several ideas that are potentially useful in the manufacture of product sugars of low color. Of these, the inhibition of color formation is of significant interest because producing less color in process can extend the cycle times for polishing carbon decolorizers (while increasing economic feasibility).

One such realization involves a chemical induction period prior to the rapid onset of color formation (and concommittent destruction of sucrose) in caramel and "Maillard" system models. During this induction period, little color is formed, and sucrose levels remain stable. After this period, however, colorant production accompanies the rapid destruction of sucrose. This study aims to investigate colorant induction in model systems toward process modifications that could lead ultimately to the production of low color sugar.

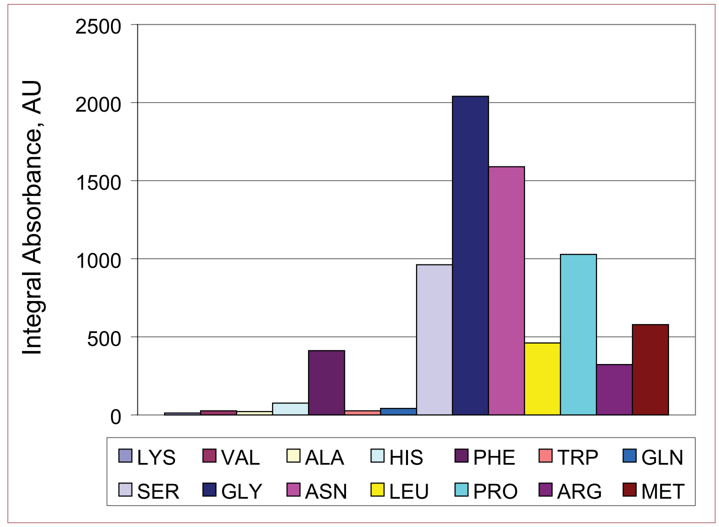
It was found that Maillard reaction models developed color more quickly, relative to controls when spiked with "active caramels" (caramel with a strong fluorescence at 300 nm, but very little, if any absorbance at 420 nm). Samples spiked with active caramel develop 40 percent -50 percent more color (see Figure 20), and at a much greater rate than the controls. This suggests that the inductive phase was bypassed, yielding a more rapid condensation of reactive intermediates into color bodies. In light of this, it may be useful to reevaluate recycling low-grade sugar regarding both color and massecuite purity.

Figure 20. Rates of color formation increase with an increase in added active caramel at 50% Brix at 90 C.



"Sorption index" or the integral absorbance value can give us an idea of the total amount of material spawned by a given amino acid in a Maillard reaction; this may allow us to determine which acids are most problematic in nonenzymic browning reactions during the processing of sugar from cane. These indexes are demonstrated in Figure 22.

Figure 22. Sorption indexes for the Maillard reaction products resulting from the named amino acids, as desorbed from carbon, measured as total absorbance between 250 nm and 600 nm.



Adsorption and Desorption of Various Glucose Melanoidin Colorant Mixtures Onto Activated Carbon

Glucose melanoidins were prepared with several amino acids including L-lysine (LYS), valine (VAL), alanine (ALA), histidine (HIS), phenylalanine (PHE), tryptophan (TRP), glutamine (GLN), serine (SER), glycine (GLY), asparagine (ASN), leucine (LEU), proline (PRO), arginine (ARG), and methionine (MET). These reactions were maintained at 75 C in 50 percent D-(+)-glucose with various amino acids added at 1.0 % dry solids (DS) for 10 hr. The pH value was maintained at 7.0±0.1 by periodic addition of 0.1N NaOH.

Each mixture was taken up into aqueous solution and adsorbed onto activated carbon (0.59±0.069 g product/g carbon) at room temperature until the mother liquor ceased to qualitatively fluoresce under long-wave ultraviolet (300 nm) irradiation (UV-depleted material). The mother liquor was removed, the carbon was washed, dried and desorbed with N,N-dimethylformamide (DMF, see Figure 21) at room temperature. Samples of the starting material, UV-depleted material and desorbate were subject to analysis via UV-VIS spectrophotometry from the wavelengths of 200nm-700 nm.

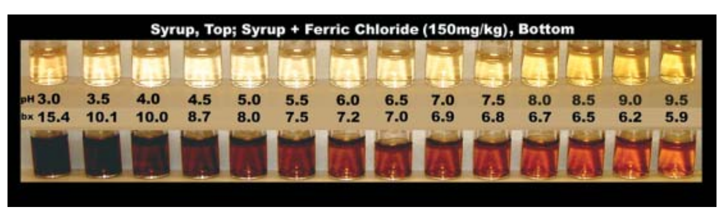
Figure 21. Ability of DMF and Dimethylsulfoxide to desorb cane colorants from carbon.

Influence of pH on Color in Syrup

Syrup produced from whole-stalk cane was diluted to 15 percent Bx, adjusted to pH 3.0 and titrated to pH 10.00 with 0.01N NaOH. The pH was evaluated against equivalents of NaOH added, and UV-VIS spectra were taken from 200 nm-700 nm. A sample of the same syrup was treated with 150 mg/kg of ferric chloride for comparison. Both syrup titrations are given in Figure 23.

From this work, it appears that the so-called "phenolic iron" complexes exhibit significantly more color at low pH. This is contrary to the "non-complexed" phenolic materials commonly found in the cane juice. Excess iron entering the system during processing can add a significant amount of color to processing liquor under acidic conditions. This increase in color may not necessarily be made obvious by rendering the solutions alkaline (pH 8.0-8.5).

Figure 23. Diluted syrup titrated with 0.01N NaOH; syrup, top and syrup fortified with $FeCl_3$, bottom. Brix and pH are equivalent for each set.



Bagasse Boiler Operations for 2005

During the 2005 crop, 64 boilers were tested and 108 boiler tests were conducted. Current boiler operations in Louisiana mills are being investigated to provide suggestions for improving efficiency. Operating conditions such as steam pressure, steam flow and boiler feedwater temperature were noted. Flue gases were analyzed for temperature and oxygen concentration using a Testo 300 XL flue gas analyzer. Bagasse samples were collected during each test and analyzed for moisture and ash content. Excess air, boiler efficiency and pounds steam produced per pound of bagasse burned were calculated using a program written for a similar study conducted in the early 1990s. This project will be continued for another year, and preliminary results are summarized in Table 9.

Table 9. Summary of 2005 boiler test results.

	Average	Maximum	Minimum
Preheated air temperature (F)	458	595	312
Flue gas temperature, (F)	457	631	334
Oxygen % flue gas (v/v)	7.5	16.1	0.7
Excess air, %	65	319	0.8
GCV Efficiency, %	55	62	38
Lb steam produced per lb bagasse burned	1.9	2.3	1.1
Moisture % bagasse	54.9	61.7	50.3
Ash % bagasse	4.3	10.0	1.7

The average flue gas temperature of 458 F is high, and the overall boiler efficiency of 55 percent is low. If the flue gas temperature were lowered to 300 F, boiler efficiency could be increased to 62 percent and produce 13 percent more steam (but would require economizers).

Bagasse quality is low, as shown in Table 9. If bagasse with 50 percent moisture and only 3 percent ash were available with the existing flue gas temperature of 457 F, boiler efficiency would increase to 60 percent, thereby providing 9 percent more steam.

Statistical Analysis of Rheological Properties of Final Molasses

Weekly final molasses composite samples were collected from all Louisiana sugar mills and one Hawaiian sugar mill during the 2004 season (October–December). These samples were analyzed in the Audubon Sugar Institute Analytical Lab for the most important components, including starch, dextran, entrainment of air and apparent viscosity at 40 C. Previous work has shown that final molasses is a shear-thinning non-Newtonian fluid that can be described by the Power Law models $\tau=K\gamma^n$ and $\mu=K\gamma^{n-1}$: τ is the shear stress, K the consistency, γ the shear rate, n the flow behavior index and μ the apparent viscosity. The final molasses data was processed using SAS/STAT (v. 9.1.3) statistical software. Using correlation analysis and multiple linear regressions with stepwise selection methods, models were built to explain the flow index and consistency variation with respect to possible independent variables. The models confirmed previous work that showed that consistency variation is strongly affected by true solids (dry substance). The degree of aeration of the sample (volume of air or other gas) was also found to be a highly significant factor. Out of the other variables considered, only dextran effect was statistically significant. The variation in flow behavior index was affected by the same variables (true solids, entrainment of air and dextran). Starch concentration in these samples did not demonstrate a significant effect on either consistency or flow behavior index. The air entrainment on molasses was on average 11 percent by volume with a range of 1 percent to 30 percent.

Final Molasses, Syrup and Juice Survey Results for the 2005 Grinding Season

Audubon continued the final molasses survey for the 2005 season to assess actual losses in final molasses more accurately. Over the past six seasons, ASI has evaluated how it handles and analyzes these samples and worked to improve every aspect of the final molasses survey to increase both accuracy and turn around time. The 2005 season was one of the best for sample turn around and accuracy.

The average weekly Target Purity Differences (TPD) values for 2005 are plotted with the weekly averages from the previous two seasons in Figure 24. Expected trends from startup and liquidation continued. Table 10 contains the average target purity, TPD, F/G ratio, F+G, (F+G)/ash ratio and ash for the past six seasons. The TPD was lower for 2005 and total reducing sugars were higher. In Table 10, it can be seen that the F/G ratio has dropped from 1.68 in 2000 to 1.25 in 2005.

Figure 24. Target purity differences in molasses over the last 3 years.

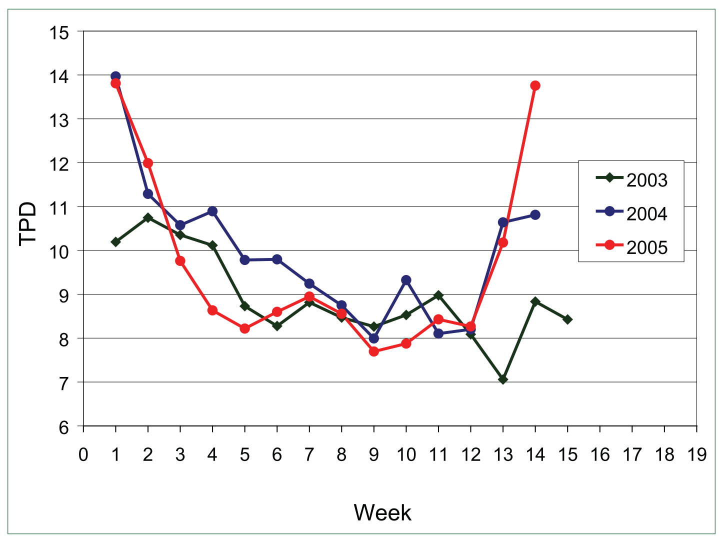


Table 10. Final Molasses Survey Data Summary for 2000-2005.

	2000	2001	2002	2003	2004	2005
TP, %	35.5	33.3	34.0	33.6	34.3	32.6
TPD	10.2	10.5	10.4	8.9	9.9	8.9
Ash, % Brix	18.9	16.8	17.1	17.3	17.1	15.8
F+G	15.7	18.8	16.9	18.2	16.2	19.9
F/G	1.68	1.41	1.44	1.33	1.35	1.25
(F+G)/Ash	0.78	1.14	1.00	1.07	0.97	1.28

Plotted in Figure 25 are the average fructose plus glucose-to-ash ratios for the past three seasons. Lower F/G ratios indicate that Maillard reaction has been decreased, improving exhaustion conditions. The lower F/G ratio and the higher total reducing sugars resulted in the lowest Target Purity since the reintroduction of the final molasses survey in 2000. A comparison of juice and syrup data for 4 mills is illustrated in Table 11.

Figure 25. Reducing sugars to ash ratio in molasses for the last 3 years.

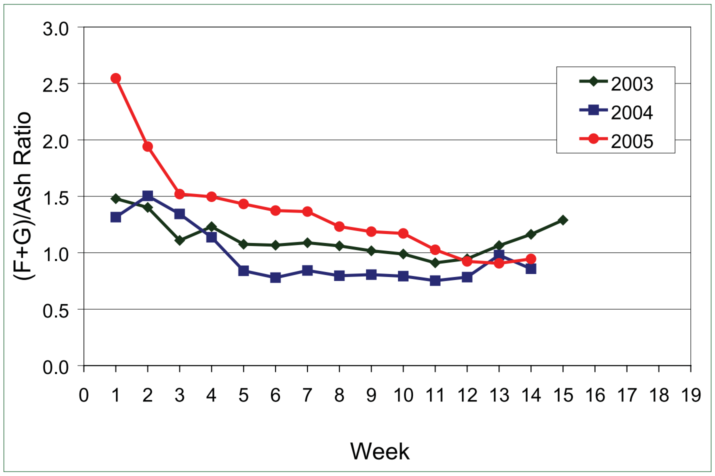


Table 11. Comparison of Juice and Syrup Data for 2004 and 2005 Seasons.

	Season	True Purity	Pol/Sucrose Ratio	F/G Ratio	Ash % Brix	(F+G)/Ash Ratio
Juice	2004	88.2	0.97	1.12	4.1	1.05
	2005	87.0	0.96	0.96	4.4	1.23
Syrup	2004	88.0	0.97	1.07	3.7	0.94
	2005	86.4	0.97	0.96	3.7	1.28

The 2005 season was dryer and cooler than the 2004 season. Both the 2005 and the 2003 were dry seasons compared to the other four of the last six. Lower ambient temperatures and little rain made 2005 less demanding on the processors in some respects. The cane, however, was not as mature in the beginning of the season resulting in the lower juice purities for the 2005 season as seen in Table 11. The continued downward trend in the F/G ratio can be attributed to better factory control. It is certain that favorable weather conditions did contribute to the lower TPDs in 2003 and 2005, but overall the mills are improving.

Pretreatment and Enzymatic Conversion of Sugarcane Trash to Fermentable Sugars and Ethanol

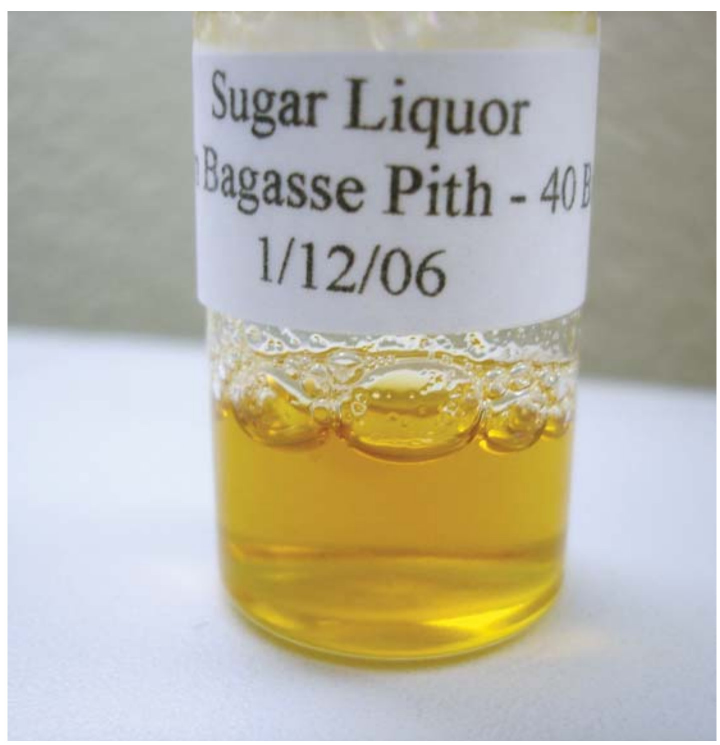
Converting sugarcane biomass, leaves, tops and bagasse to higher-value chemicals or fuels is the key to exploiting more fully the potential of sugarcane. Cane varieties now exist that can further augment the biomass yield by a factor of two or more. After combine-harvesting whole cane, the leaves and tops can be separated from the billets by entrainment with air. Significant benefits to the mill accrue from not milling the trash – but the processing or disposal of the hundreds or thousands of tons of separated trash per day at a mill poses a considerable challenge. The cost of transporting the extra trash to the mill is an important consideration and must be carefully balanced against the benefits.

Cellulose and hemicellulose of sugarcane biomass can be converted to fermentable sugars and ethanol with an acid as in the Dedini process or with enzymes as in the preferred process followed at the National Renewable Energy Laboratory, a unit of the U.S. Department of Energy. Before enzymatic hydrolysis, biomass must be pretreated to make the holocellulose accessible to the enzymes. Acid pretreatment has been more common, but alkaline pretreatment was found by some to give higher sugar yield. In addition, in acidic conditions some hemicellulose hydrolysis is unavoidable, exposing the monosaccharides to acid degradation, lowering the sugar yield and increasing toxicity of the hydrolysate liquor for ethanol-producing yeast. Higher chemical requirements in the alkaline pretreatment to neutralize acetic and other organic acids released from the biomass limit the choice of alkali in an industrial setting. Lime is favored because of its low cost, benign environmental impact and familiarity of the sugarcane industry with its use. The objective of this program has been to build on the previous work at Texas A&M University with lime pretreatment, but, in conceptualizing the process, employ only such unit operations that have a reasonable chance of acceptance by the sugarcane industry by avoiding the following:

a) chemical recovery,
b) specialized equipment to handle high pressures or very corrosive,
c) reduction of biomass size beyond what is readily achieved with present-day sugarcane factory equipment.

Until now, the pretreatment conditions used are impregnation with hydrated lime followed by short duration steam treatment and hydrolysis with industrial enzymes. The product is a mixed sugar (glucose + xylose) liquor that can be fermented to ethanol or purified and concentrated to make a feedstock for other higher value conversions. Results to-date indicate yields of about 350 kg sugars from 1 metric ton of sugarcane leaves (dry basis), or more than 135 kg sugars from one metric ton of leaves at 60 percent moisture.

Figure 26. A mixed glucose/xylose sugar liquor prepared from bagase pith by lime/steam explosion pretreatment and enzymatic hydrolysis, partially decolorized with activated carbon and concentrated to 40 Brix.



Erosion Mats From Bagasse

Industrial erosion blankets for temporary soil protection during road construction and for levee and coastal erosion abatement range from $0.4/m^2 (straw and wood based) to $2/m^2 for polypropylene and up to $3/m^2 for imported coconut fiber products. At 0.3–0.5 kg/m^2 this is equivalent to about $0.8 to $2.0/kg on a dry weight basis. Taking the estimate of $0.8/kg for the potential bagasse-based products, that indicates about $0.4/kg bagasse at 50 percent moisture, making it potentially an attractive commercial product for the sugar industry. A further advantage is expected from savings on shipping other low density products from out-of-state or even overseas manufacturers.

A simple prototype process has been developed and is being tested that consists of four principle operations:

- Cooking bagasse with dilute soda ash in an open steam-heated vessel.
- Fiberizing a portion of the cooked whole bagasse in a standard disk refiner.
- Blending refined and nonrefined bagasse, forming the mat.
- Drying and rolling mats to produce rolls that are 1.2 x 2.4 m, 1.8 x 3.6 m, etc.

Figure 27. Cooked whole bagasse.

Figure 28. Cooked whole refined bagasse: 1 pass, 0.0005 m plate gap, 0.2 m diameter Bauer single disk refiner.

Figure 29. A 1.2 m wide mat-forming machine.

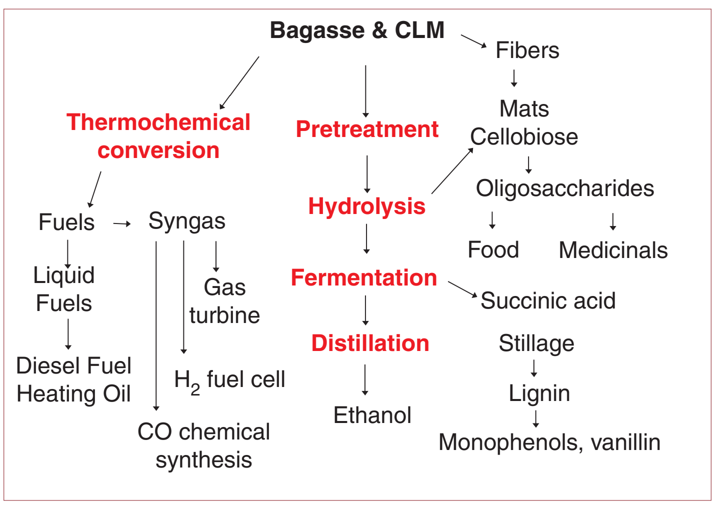
Figure 30. Mats drying.

Figure 31. Partially rolled 1.2 x 2.4 m dried mat.

SUGARCANE BIOREFINERY PROGRAM

A sugarcane biorefinery will convert bagasse (lignocellulose) and molasses into fuel and other products. With the support of the U.S. Dept. of Energy, we have been pursuing this vision for approximately two years, and a preliminary blueprint is taking shape. The research outline is shown in Figure 32. The focus is on producing a range of potentially saleable products, with sugarcane bagasse and/or cane leaf material (CLM) as feedstocks. Overlying the individual research areas is a macroscopic view, produced by computational economics for computing the effect of changes in the global economy and prices upon the wealth level of nations. Our contribution is toward a solution of the largely sparse matrix systems that provide insight into macroscopic global changes in the economy.

Figure 32. Research outline of the Audubon Sugar Institute Biorefinery program.



Products that can be produced without hydrolysis of lignocellulose to sugars are hydrogen and syngas, ethanol from synthesis gas and other products (geotextiles for erosion control). Hydrogen and syngas production research follows along the lines of other numerous studies in the area of gasification. Our task is to take sugarcane bagasse and produce a syngas with a tunable amount of hydrogen. We are in the process of assessing the possible gasifier technologies to choose the most suitable for sugarcane.

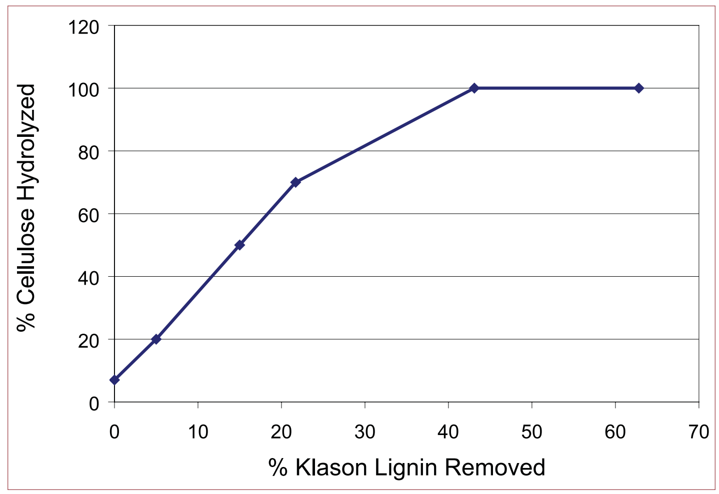
The gasifier gas can then be directed to a turbine for electricity or to a pipeline for use as a chemical feedstock. The production of ethanol is strongly pursued in the platform using enzymatic hydrolysis followed by fermentation; however, there is an additional route for taking the synthesis gas to ethanol and other liquid fuels using the Fisher-Tropsch process. Other product development is focused on the use of the sugarcane fibers to produce erosion control products.

Products from the sugars found in lignocellulose that are being investigated are ethanol, cellobio-oligosaccharides, lignin-derived compounds such as monophenols and plastics, and compounds derived from use of alcohol stillage, i.e. succinic acid, aconitic acid. Some of these processes are at the laboratory stage and others have moved to small pilot stage.

A key to the production of sugars from lignocellulose is a method for separating lignin from cellulose. Bagasse requires the removal of 40 percent of the lignin before all the cellulose is available for enzymatic conversion to glucose (Figure 33).

A modification of the AFEX process is being used in a small-scale pilot system to produce sufficient treated bagasse to conduct pilot-scale hydrolysis/fermentation experiments. The treated bagasse is enzymatically hydrolyzed and the sugars fermented to alcohol.

Figure 33. The effect of lignin removal from bagasse on enzymatic cellulose hydrolysis.



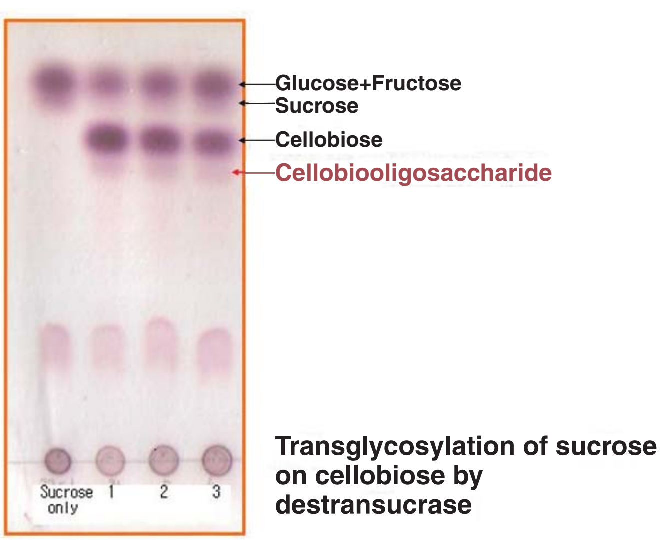
Ammonia treatment of bagasse at ASI, equipment and team members, Maintenance Repair Master Michael Robert and Assistant Professor Dr. Benito Stradi.

Products other than alcohol have a significant role in the economic viability of a biorefinery. Cellobiose is normally produced in small quantities during cellulose hydrolysis. It has been found possible to simply modify the hydrolytic process, increasing the quantity of cellobiose produced, at the expense of glucose production. Use of a modified dextran production system allows us to convert the cellobiose into non-nutritive food additives.

A major component of lignocellulose is the polyphenol, lignin. Several of the treatment options that are under investigation produce liquid streams containing high concentrations of monophenols. Table 12 lists some of the more common monophenols found as a function of treatment process. Optimization to produce selected monophenols may yield commercially viable quantities of fine or bulk chemicals from what would normally be considered a waste material, without reducing the ability to produce ethanol from the sugars present in biomass.

Dr. Chung with hydrolysis reactor.

Figure 34. TLC profile of a cellobio-oligosaccharide produced from cellobiose and sucrose.



Sucrose: Cellobiose; **1** 1:2, **2** 1/1, **3** 2/1

The raw sugar mill is a nascent biorefinery, with infrastructure already in place for collecting and processing biomass (sugarcane). Adoption of selected "add-on" processes, depending on the economics for individual operations, can lead us to a future where bagasse will become increasingly valuable, not a "waste" material for disposal.

Table 12. Common monophenols found in liquid streams produced by different chemical treatments of bagasse.

	Organosolv	Ethanol	NaOH	Ox-B
Chlorinated Phenols	X			X
Substituted Phenols	X	X	X	X
Benzofuran	X	X		
Benzophenone	X	X		
Ethanone	X	X		X
Mequinol	X	X		X
Propenic acid	X	X	X	X
Vanillin	X	X	X	X

Faculty members and co-PIs of Audubon's biorefinery project, Drs. Donal Day and Benito Stradi explain to post-docs and graduate students the safety and operating procedures to conduct a pilot-scale process to pretreat and ferment sugarcane bagasse to produce ethanol.

Factory Reports, Lab Analyses and Cane Sampling

One factory that was changing to a new manufacturing report format requested discussions on input data that should be used, methods for calculation of the report and results that should be shown on the report. Report calculation formulas were provided, and, after discussions, a more useful and accurate manufacturing report format was adopted.

Discussions on the expected accuracy and interpretation of the reported figures were requested by two factories. In particular, these factories were interested in comparing their operations with those at other factories that were processing cane of different quality.

One factory asked for help in using the manufacturing report to pinpoint undetermined losses. In the absence of accurate juice (and bagasse), sugar and final molasses weights it is quite difficult to definitively establish the undetermined losses. Many of the manufacturing reports contain pol and solids balances, as well as theoretical calculations on the quantity of sugar and final molasses that should be produced. In the absence of accurate process weights, however, the theoretical calculations serve only to highlight inconsistencies in the reported figures. For most factories, control of undetermined losses is best done by maintaining sanitary milling conditions, good control of juice pH to limit inversion and monitoring the sugar that is lost in cane wash water and condenser water.

A few factories requested that analyses be performed on freshly collected samples to validate the results being obtained. In general, the results being reported by the factory were found to be valid. One factory was interested in lowering the losses in filter cake. The filter cake was analyzed and found to contain adequate bagacillo. The primary reason for the high pol in filter cake was the lack of adequate filter wash water. Once the filter wash water was increased, the pol in filter cake was substantially reduced. The lack of adequate filter wash water is common in Louisiana.

The core lab operations at a factory were reviewed and suggestions were made to improve the accuracy of the results. It should be noted that periodic review of the core lab operations are important as improper core lab operations generally result in the under-reporting of the true TRS figure. For example, using wet glassware dilutes the sample and reduces the pol percent cane figure, and inadequate drying of the residue samples in the oven results in over-prediction of the fiber in cane, which, in turn, lowers the calculated TRS. Poor press sanitation can lower the purity and pol of the juice, and, in this regard, it is recommended that a few drops of biocide be added to the cane that is pressed to sanitize the internal press piping.

Mill and Boiler Tests

Because several factories have installed or are considering installing larger mills, there was a lot of interest in determining mill performance. Several factories requested the mill testing method to be able to conduct their own tests on a periodic basis.

Two factories installed new boilers for the 2005 crop. All new boilers installed are required to be tested for actual emissions. Emission testing of the boilers was conducted prior to the official boiler tests to assist factories in adjusting combustion for minimum emissions. During the official boiler tests assistance was provided in recording test data and checking of measured gas flows with calculated gas flows to ensure that reported data was reasonable.

Running viscosity measurements in his lab is Associate Professor Dr. Harold Birkett, who has been involved since 1977 with much of the extension services provided by this department for the Louisiana sugar industry.

Electrical Power Generation

During the 2005 crop, and primarily as a result of the disruption caused by hurricanes Katrina and Rita, the cost of natural gas doubled. Dry weather, coupled with special efforts by factory personnel to minimize gas usage, resulted in record low gas consumption for the state's sugar factories in 2005. At the same time, however, many factories purchase all or most of their electricity from local utilities, and the cost of electricity reached record levels in 2005. As a result, a few factories were interested in discussing the installation of turbo-generators to produce some or all of their electricity.

The newer boilers installed at several factories have been designed for higher operating pressures than the older boilers in the factory. The higher-pressure boilers provide the ability to operate topping turbines driving generators that can be used to provide all or most of the factory's electrical requirements. The exhaust from the topping turbine can enter the lower pressure live steam header. This arrangement does not materially alter the factory's steam balance while providing electricity.

Pan Design Details

Some modifications for a 3,000 ft^3 batch pan were recommended to improve its performance. Larger condensate outlet pipes were installed and modifications to the feed arrangement and a steam circulation system were recommended. The pan boiled much better as a result.

Assistance was given to a mill wishing to increase the size of the pan by increasing its diameter. This led to an increase in capacity and heating area. It was shown that the downtake also needed to be increased in size to achieve good circulation.

A modification to the feed system on an A continuous pan was recommended. The modification eliminated previous problems of blocking of the feed lines feeding in from the bottom of the pan.

Modified C massecuite discharge piping options and sizing were performed for two factories.

Miscellaneous

Some factories are expanding their evaporator station (often with equipment available from closed factories) and asked for help in calculating the expected evaporator capacity increase and steam consumption decrease for various possible scenarios. This information was provided to two factories this year.

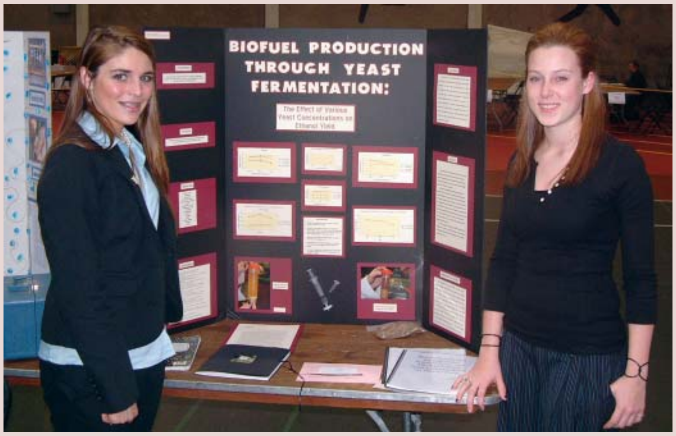
Other factories are considering the production of high pol sugar. One factory was interested in improving the quality of the product sugar by remelting all the C sugar and graining for the As and Bs. Calculations were performed for the proposed boiling system. This scheme requires only a small increase in pan capacity and steam, but does require the installation of cutover tanks to develop the high grade grain.

Work on the filter station identified a poor vacuum as a major cause of poor performance. It was also established that too much bagacillo was coming to the clarifier with the raw juice and that control of flocculant addition to individual filters could be improved.

Calculations were undertaken for a mill reconfiguring its heater station following the installation of a plate heater. Liquid velocities, areas and pressure drops were investigated to arrive at practical heater arrangements.

Some factories and growers have inquired about the quality of high fiber cane. Direct analysis of unfertilized high fiber cane (L79-1002) was performed at start and end of crop to determine fiber, pol and Brix content. The results are summarized to the right. Of interest is the low pol content and juice purity of this unfertilized cane.

High School Student Involvement at ASI



Wallis Watkins and Bridget Tiek

Wallis Watkins and Bridget Tiek, sophomores at St. Joseph's Academy in Baton Rouge, placed second with their project involving alternative energy at the 2006 Regional Science Fair at LSU. For several months they worked at Audubon conducting experiments to determine how much ethanol could be produced from the treated substrate through SSF (simultaneous saccharification and fermentation) and to determine the optimal yeast loading for fermentation. Their project was mentored by Drs. Donal Day, Matt Gray and Chang-Ho Chung.

Wayne Roy, Iberville Parish District 13 councilman, appointed Sheneka Kelley, a student from East Iberville High, to spend two summer months at Audubon Sugar Institute to assist in Web development and library coordination. She was mentored by Chardcie Verret and Melati Tessier. Training in the analytical lab also was provided to help foster interest in pursuing a science career. This summer student program is sponsored by Iberville Parish to help under-represented and underprivileged youth within the parish. It provides not only technical training and job skills but promotes higher education.

L79-1002 Cane tested on 10/05/05

Handcut Cane. Trash % gross cane = 16.3 %.
Stalk Weight = 0.4 lb

Sample	*% Fiber*	*Brix*	*Pol*	*Purity*	*% Ash*
Clean Stalks	20.83	9.02	3.93	43.57	1.64
Trash	49.43	9.85	0.05	0.51	7.51

L79-1002 Cane tested on 11/29/05

Handcut Cane. Trash % gross cane = 17.1 %.

Sample	*% Fiber*	*Brix*	*Pol*	*Purity*	*% Ash*
Clean Stalks	22.05	10.66	5.18	48.59	2.43
Trash	47.82	10.16	0.47	4.63	5.39

ANALYTICAL CAPABILITIES

Audubon currently has nine operational liquid chromatograph (LC) systems. Three units are older ion chromatography units, one set up for cation analyses and the other two for anion analyses, including organic acids. One of these older units for organic acid analysis will be replaced with a new unit that is on order now. Audubon also has an ion exchange chromatography unit used for alcohol, sugar and oligosaccharide analyses. Three high pressure liquid chromatograph (HPLC) systems are used for routine sugar analyses on juice, syrup, molasses, bagasse hydrolysates and other project samples as required.

A reverse phase HPLC system was purchased with funds from a Louisiana Board of Regents grant. This unit is a state-of-the-art Agilent 1100 LC with a diode array detector (DAD) and an ESA evaporative light scattering detector (ELSD). The DAD allows for analyses of samples over a wavelength range of 190 nm to 950 nm simultaneously. The attachment of the ESA ESLD allows for the determination of nonchromophoric components present at levels too low for a refractive index detector to detect. The Agilent system is utilized mostly for color studies and analysis of high molecular weight compounds.

An Agilent 6890 gas chromatograph (GC) has also been purchased and installed. The 6890 GC has been used mainly in analyses of alcohols. Additionally, six Agilent 5890 GCs were donated to Audubon. Two of the donated GCs have been installed and a license for the Agilent software has been purchased to control them. One of the 5890s has a thermal conductivity detector that is ideal for gas analyses. This unit has been set up to analyze components of syngas produced from biomass. The other unit has been set up to analyze for phenolic compounds that are removed from treated bagasse. Recently, another GC was donated that is designed for online measurements. This GC will be coupled directly to a syngas biomass reactor. Because of hurricane Katrina, Audubon has had access to a GC/MS that belongs to Dr. Richard Eaton who was displaced and is working at Audubon until he can return to his laboratory at the USDA building in New Orleans. The use of this instrument has been of great value to Audubon especially on the color and DOE projects.

Other instrumentation includes a refractometer with 0.01 Brix resolution and temperature compensation capabilities, a polarimeter with 0.01°Z resolution at either 589 nm and 880 nm wavelength for sucrose by polarization and a conductivity meter with temperature compensation for determination of conductivity ash. Audubon has a Near-Infrared (NIR) Transmittance Spectrophotometer. This unit will be used for molasses survey samples for the 2006 season. Another NIR spectrophotometer was donated, but has yet to be evaluated for performance or use.

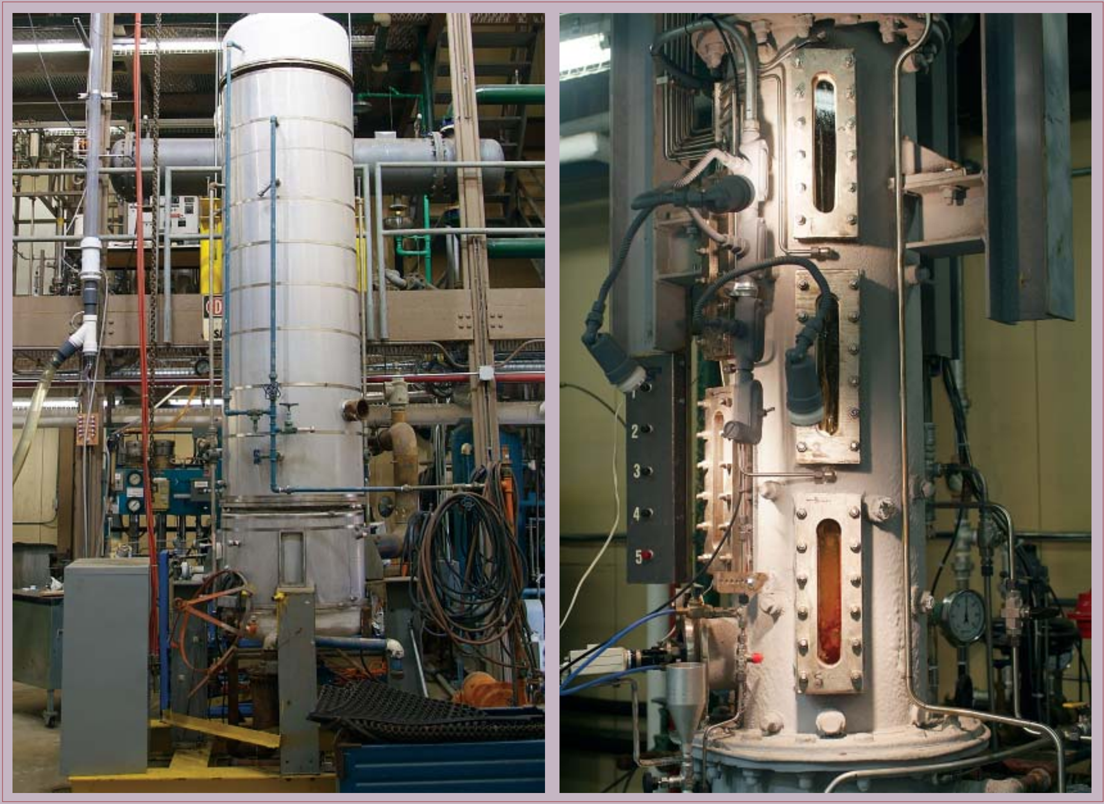
Audubon has been able to acquire over the last few years several new analytical instruments. Included in these purchases are a new refractive index detector and two new LC systems. Some used equipment has been purchased as well, including eight auto-samplers and a refractive index detector. Audubon has also been the beneficiary of several instrument donations from the Lyondell Corporation. Although some of the donated and existing analytical equipment is dated, all are capable of producing adequate results. Audubon is fortunate to have analytical personnel with the talent and knowledge to maintain and operate all this equipment to provide accurate and timely results.

Audubon acquired additional lab equipment through grants and donations from the private sector.
With the expanded capabilities in the analytical lab, Audubon's team of chemists led by Brian White (r) are able to enhance their skills using state-of-the-art instrumentation.
With White are Research Associates Chardcie Verret (l) and Stella Polanco.

SHORT COURSES

Audubon Sugar Institute continued its short course program in 2005, offering Spring and Fall sessions to coincide with the off-crop season. These courses qualified for Continuing Professional Development for registered professional engineers but were designed to increase knowledge of people at all levels in the sugar industry. A new course in Ethanol Production in the Cane Sugar Mill was introduced, bringing in guest speaker Mr. Jaime Finguerut, of CTC (Centro de Tecnologia Canavieira, formerly Copersucar), Brazil. The aim of this course was to gain more insight to the Brazilian technology and learn the opportunities that exist for the Louisiana sugar industry to expand its profitability.

All courses offered at Audubon Sugar Institute can be viewed online on our Web site at www.lsuagcenter.com/audubon/. Courses offered in 2005 included:



Audubon's pilot facility includes this 75 cu ft evaporator (left) and a 14 gallon vacuum pan (right). Pilot scale equipment such as the vacuum pan provides an excellent tool for hands-on training in our short course program.

An Introduction to the Technology of Sugar Production – Two days

A comprehensive overview of all cane processing operations was covered in this introductory course to provide an understanding of the process from growing cane to final product. The topic also covered the important aspects that affect sugar production and factors taken into account in running a mill efficiently.

Technology Refresher: Improving Raw Sugar Factory Operations and Profitability – Two days

This was a refresher course introduced in 2002 for individuals involved in the operation or the design of raw sugar mills to enhance their technical skills and get up to date with important issues that affect the efficiency and profitability of raw cane sugar production.

An Introduction to Sugar Refining – Two days

A comprehensive coverage of the important aspects in sugar refining was offered for individuals new to the sugar refining industry and for suppliers to or customers of the sugar industry. The course materials offered participants better understanding of issues related to capacity, costs, losses and product quality.

Ethanol Production in a Cane Sugar Mill – Three days

Participants gained from this course the basic understanding of ethanol manufacture and an update on the Brazilian technological developments to exemplify how ethanol production fits in a cane sugar mill, the opportunities that exist and the economics. An overview of the basic fermentation technology, possible feedstock and factors that affect product yield was covered. The course also briefly discussed the process for potable alcohol, dehydration of ethanol for fuel use and handling and blending as a gasoline extender.

Continuous Vacuum Pan Boiling – One day

A detailed understanding of continuous pan boiling and its comparison with batch processing was the main objective of this short course. The implications of converting from batch to continuous operation were examined, and advantages and disadvantages associated with making a change on different grades of boiling were evaluated. This course also encompassed the factors that affected process parameters and, ultimately, product quality.

Introductory Sugar Boiling – Three days

This class offered individuals with little or no experience in sugar boiling an overview of the sugar boiling process. It not only provided an understanding of the principles involved but also taught how to boil pans and allowed hands-on trials in making sugar on ASI's pilot plant.

Bagasse Boiler Operation – Two days

The course objective was to provide boiler plant operations personnel an understanding of the role of the boiler plant in the raw sugar factory and the factors that affect boiler capacity, efficiency and air emissions. Emphasis was given to bagasse boilers, although discussions also covered natural gas boilers. Combustion calculations and use of charts and tables to estimate boiler efficiency were also incorporated to the course materials.

Bench Chemist – Four days

This course was developed to suit newly employed bench chemists in a raw sugar factory who were unfamiliar with sugar mill analyses. A brief overview of the process involved in raw sugar manufacturing and why the analyses done are important was given. Hands-on training included handling of a sample mill to obtain juice and bagasse samples, performing the various analyses, calculating the results and maintaining and calibrating the lab instruments.

Chief Chemist – Four days

This course was designed for chemists, process engineers and managers who needed to understand how factory manufacturing reports are calculated, interpreted and checked against theoretical considerations. The training involved hands-on report calculations, use of computers in the preparation, correction and checking of the reports and use of the report data to analyze factory operations.

DEGREE PROGRAM

The education program at Audubon Sugar Institute is offered at both graduate and undergraduate levels in the form of Sugar Engineering as an area of specialization or a minor in conjunction with other engineering degree majors.

Currently, Audubon Sugar provides part-time work in the analytical lab and factory for undergraduate students minoring in Sugar Engineering, and graduate assistantships to LSU students pursuing their master's degree or Ph.D. in Chemical Engineering, Biological Engineering, Chemistry, Mechanical Engineering and Food Science. With the increased number of research projects approved for funding and added space at the new facility, Audubon has enhanced its capability for more graduate students to attain expertise in a variety of aspects of sugar processing.

Sugar Engineering Courses

Two Sugar Engineering courses introduced by Audubon Sugar four years ago have continued to be offered by the College of Engineering. They are a course in Sugar Process Engineering, which teaches all the background to sugar processing (BE 4342) and Sugar Factory Design (BE 4347), which introduces the student to the detail of equipment design in a factory. Prerequisites to these courses are listed on our website at www.lasuagcenter.com/audubon.

The interdisciplinary graduate program at Audubon is joined by Research Associate Lee Madsen who is pursuing a Ph.D. in Chemistry.

Research Associate Stella Polanco is undertaking an M.S. in Chemical Engineering.

Minor in Sugar Engineering

The objective of this program is to produce a graduate ideally suited to the operation and management of a sugar producing facility. In all cases, the student is encouraged to work as a part-time student at ASI, with maximum exposure to sugar processing at every opportunity.

A set of courses has been prescribed so that students studying in biological, chemical or mechanical engineering may earn a minor in Sugar Engineering, by choosing the two sugar courses described above and their electives to meet the requirements. If possible, the student should also choose a design project in a sugar engineering related topic, which is overseen by the staff of the Audubon Sugar Institute. Sugar Process Engineering should preferably be taken in the junior year.

To earn the minor, students in the College of Engineering must complete 18 hours of required courses with a grade of C or higher. Visit our Web site at www.lsuagcenter.com/audubon for the list of required courses.

Another option involves spending the fall semester at an operating sugar mill for an internship, yielding 3 credit hours (allowed for in BE 3249). The internship could substitute for one of the required courses.

Master's Degrees in Chemical, Mechanical or Biological Engineering Specializing in Sugar Engineering

Students are recruited to earn a master's degree in Chemical, Mechanical or Biological Engineering. This program is targeted at people who have a first degree and wish to gain some specific sugar processing expertise through further study.

Following the thesis option, the master's degree academic requirement is 24 credit hours in the nominally 21-month program. The course requirements include the Sugar Process Engineering and Sugar Factory Design courses listed above. Depending on the first degree of the individual concerned, the student would be encouraged to choose electives appropriate to supporting a strong sugar expertise.

A thesis is required related to a relevant sugar processing topic. In all cases, the student would be encouraged to take on a research assistantship in ASI for the duration of the course. The student would be given maximum exposure to sugar processing at every opportunity.

Sugar Engineering Courses as Intersession Courses

As an alternative to the regular semester class, BE 4342 was offered as an Intersession course for the first time in 2005. This option is also open to outsiders, through a Continuing Education program and is scheduled in the form of an intensive 18-day period of lectures to enable participation by both domestic and international working professionals. Several students and Audubon personnel enrolled in Chemistry, Biological Engineering and Chemical Engineering degree programs at LSU and delegates from the sugar and sugar-related industries in Brazil, Jamaica and Reunion Island attended this class. The syllabus included two field trips to a sugar mill and a refinery, a final project that used the pilot plant equipment, a test and a final exam. The intersession option also is offered in the 2006 schedule of courses.

SOCIETIES & CONFERENCES

Representation on Technical Societies and Research Institutes

ISSCT (International Society of Sugar Cane Technologists)
Honorary Lifetime Member: P.W. Rein
Co-Products Section Committee: D.F. Day
Processing Section Committee: M. Saska

SPRI (Sugar Processing Research Institute)
P.W. Rein (Member of Board of Directors)

International Sugar Journal
M. Saska (Referee), L. Bento (Referee)

American Chemical Society
D.F. Day, L. R. Madsen, B.E. White

American Society of Microbiology
D.F. Day, C.H. Chung, G. Dequeiroz

American Institute of Chemical Engineers
P.W. Rein, M. Saska, M.A. Tessier

American Society of Mechanical Engineers
J. W. King

American Society of Advancement of Science
D.F. Day

Institute of Food Technologists
D.F. Day, G. Dequeiroz

Society for Industrial Microbiology
D.F. Day

Southern Region Development Committee – USDA
D.F. Day

Sugarcane Biomass

Dr. Luis Bento, professor, received the Frank Chapman Memorial Award for best poster at the 2005 Annual Sugar Industry Technologist Meeting in Dubai, UAE. His poster was titled "Decolorization of Sugar Solutions with Oxidants and Ion Exchange Resins." The award was presented by SIT executive committee member, Michael Donovan.

Meetings, Conferences and Workshops Attended

April 2005
ASI Annual Conference (all staff and faculty)

May 2005
Biotechnology Conference, Denver (P.Rein, C.Chung, M.Gray)
SIT, Dubai, UAE (L.Bento)

June 2005
ASSCT, Panama City Beach, Fla. (P.Rein, D.Day, H.Birkett, M.Saska, J.King, B.White, L.Madsen, C.Verret)

July 2005
International Biorefinery Workshop, Washington D.C. (P.Rein)

October 2005
Foxboro Users Conference, Houston (P.Rein)

November 2005
Biomass Peer Review Meeting, Washington D.C. (P.Rein, D.Day)

February 2006
ASSCT (La. Division) Baton Rouge, La (all staff and faculty)

VISITORS

International Visitors to the Institute

April 2005
Jose Agostinto (Portugal); Nauman Khan (Pakistan)

May 2005
Laurent Corcodel (Reunion); Ézio Oliveira (Brasil); Danilo Piccolo (Brasil); Ricardo Steckelberg (Brasil); Marrington McDonald (Jamaica); Mike Inkson (UK)

June 2005
Jaime Finguerut (Brasil); Mullapudi Narendranath (India); Peter Twine (Australia); Carla Guimarães (Portugal); Mike Cox (S. Africa), Muzi Ninela (S. Africa); Rob Scott (S. Africa)

August 2005
Benito Stradi (Costa Rica); Martin Scheable (Germany); Bernard Prior (S. Africa)

December 2005
Leopold Briones (Germany); Yan Mingyi (China); Qi Rong (China); Yang Jai Ju (China); Yang Wanshan (China); Ye Li Na (China); Dr. Chi (China)

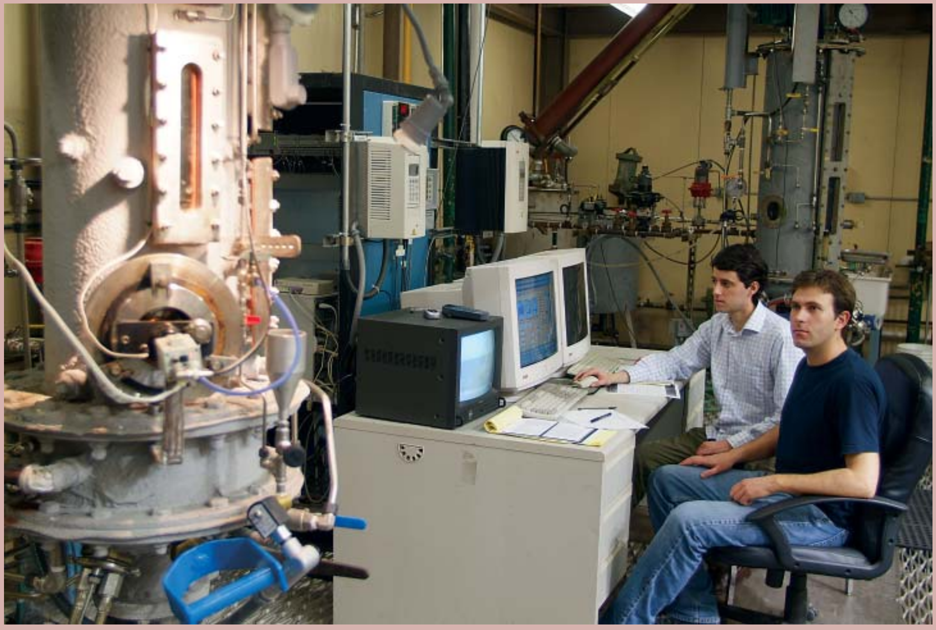
February 2006
Alexander Prauge (Germany); Henrique Amorim (Brasil); Emmanuel Duffaut (Spain); Doug Emek (Canada); Young-Hwan Moon (Korea)

March 2006
Mario Mendez (Brasil); Oscar Nishimura (Brasil)

Visiting Researchers

Young-Hwan Moon is a Ph.D. candidate from the Biochemical Division of the School of Biological Sciences in Chonnam University, Seoul, Korea and is a student of adjunct professor Dr. Doman Kim. Moon was at Audubon throughout February 2006 on an informal exchange program to study lignin separation techniques at Audubon and impart his knowledge on isolating cellobio-oligosaccharides from biomass.

Antonio Ferreira and Pedro Martins have been performing sugar boiling experiments using Audubon's pilot vacuum pan No. 1 to study impurity transfer into crystals during growth. Particular emphasis is given to the relationship between growth conditions (supersaturation, impurity levels, growth rate, etc.) and color transfer. Crystal growth curves, relating growth rate and supersaturation are expected to be obtained following previous work in this field. Kinetically active impurities such as glucose, fructose, dextran and starch will be studied in terms of their effect on the growth rate and on color transfer.



Pedro Martins (l) and Antonio Ferreira observe crystal growth in one of Audubon's pilot scale vacuum pans.

Improvements to the vacuum pan No. 1 have been made to achieve full automation of the cycle. This will allow systematic crystallization experiments according to the boiling schemes used in industry.

Antonio Ferreira is at Audubon for three months, supported by a Ph.D. scholarship from the Portuguese Foundation for Science and Technology. Pedro Martins is funded by Audubon and by the Portuguese Fulbright Commission for an eight-month stay.

Dr. Richard Eaton is a research microbiologist at the U.S. Department of Agriculture Southern Regional Research Center (SRRC) in New Orleans. Displaced by Hurricane Katrina, he was temporarily relocated in Arkansas for a brief period before seeking refuge at Audubon Sugar Institute.

The goal of his research at SRRC is to eliminate the earthy/muddy off-flavor chemicals, geosmin and 2-methylisoborneol (MIB), from farm-raised catfish. While a Katrina refugee at the Audubon Sugar Institute, he has been reviving his existing bacterial cultures and isolating new bacterial strains and testing them for their potential to convert MIB and geosmin to tasteless/odorless products.

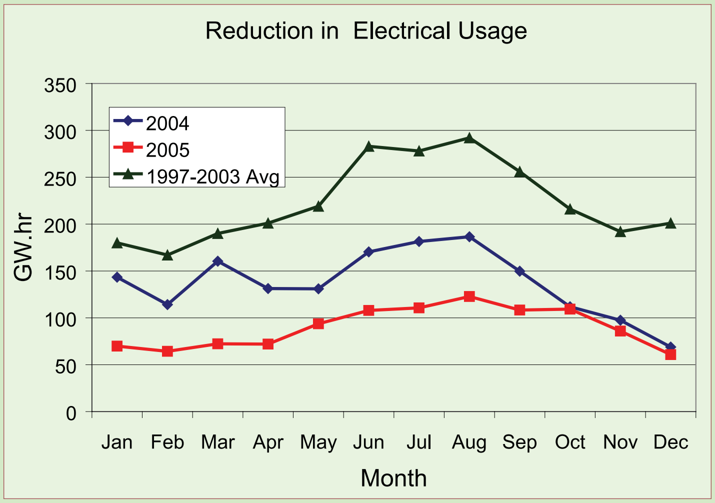
FACTORY MANAGER'S REPORT

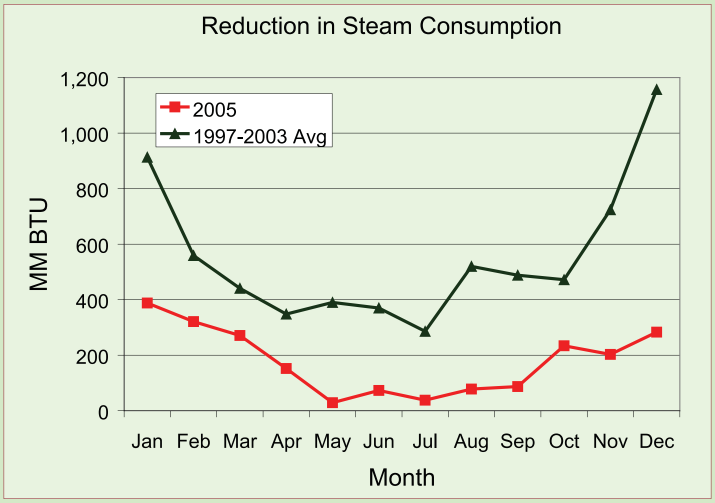
The Year: The second year at our new facility has been spent enhancing the operation of the building systems. The number of emergency equipment repairs has gone down in 2005 because of the implementation of a preventative maintenance program in 2004. That program has given us more time to plan our maintenance and upgrades. In addition, we have addressed two major sources of energy consumption.

Reduction of Electrical Consumption: A problem we faced was the high energy consumption of a building designed without the use of air recirculation to supply the heating and air conditioning system. The graph below illustrates the reduction in electrical consumption that has been achieved at the new facility over the last two years. The highest consumption represents the average electrical usage from 1997 through 2003 when the Syngenta Corporation occupied the building. It can be seen that in 2004 we managed to lower the consumption rate considerably, and in 2005 we reduced it even more. In fact, 2005 consumption was reduced from the 1997-2003 rates by an average of 133 GW.h per month. That represents a monthly savings of more than $9,400.

The reduction in electrical consumption during 2004 and 2005 can be attributed mainly to two changes. One was slowing down the airflow through the building. This was done by shutting down approximately one third of the 43 fume hoods on the building roof and installing variable speed drives on the main air handlers to slow down and optimize fan speeds. The other change was to carefully schedule operation of the heating and air conditioning system by shutting down air handlers during unoccupied hours and cutting off the reheat system on days it was not needed.

Reduction of Steam Consumption: Another problem is the high cost of steam, which we purchase from the Syngenta Corporation. The graph below compares the average steam consumption from 1997 through 2003 to the steam consumed in 2005. The 2005 consumption was reduced from the 1997-2003 average by 145 million BTU per month. That represents a monthly savings of more than $2,100. The steam savings are also attributed to more efficient operation of the heating and air conditioning system, which utilizes steam to preheat and reheat the building air supply.





This covered extension was built in 2004 to accommodate equipment brought from the previous facility that could not be placed in the pilot plant.

Maintenance Repairer Master, Michael Robert, refurbished this 500 liter fermenter and completed the utility tie-ins to provide the capability to operate a pilot-scale operation of fermentation processes developed in the lab.

Library

Audubon Sugar Institute is grateful for the numerous sugar process engineering books donated this year by Mr. Americo Mariota of Florida. Approximately 250 books relating to analytical chemistry were recently donated by Lyondell Chemicals in Lake Charles, Louisiana. This generous donation along with about 170 new catalog additions this year has significantly expanded Audubon's collection of more than 4,000 books and journals. Our library offers a wide selection of reference material for researchers within the department and many others related to the industry. Local and international journals and periodicals that are available date as far back as 1930 to the present.

Publications 2005-2006

Barazza, J.M., Primera, E.J., Saska, M. (2006). Tecnologias para la generacion de Energia a partir de la biomasa: Co-liquefaccion de residuos del corte de la cosecha de cana con carbon. Proc. Colombian Congress of Chemical Engineers, Manizales, Colombia.

Bento, L. S. M. (2005). Utilization of infrared images to inspect C-massecuite. Processing. Proc. Sugar Ind. Technol. Conf. 64, 255

Bento, L. S. M., Rein, P. W., Sabliov, C., Boldor, D., Coronel, P. (2005). C massecuite re-heating using microwave. J. Amer. Soc. Sugar Cane Technol. 26, 1.

Bento, L.S.M, Cuddihy J., Simoneaux W. (2006). Filtrate clarification. Amer. Soc. Sugar Cane Technol. LA Division Annual Meeting, February 2006.

Birkett H., Stein J (2006). Louisiana milling and boiler efficiencies 2005. Amer. Soc. Sugar Cane Technol. LA Division Annual Meeting, February 2006.

Chung, C.H. (2006). Production of Glucooligosaccharides and mannitol from *Leuconostoc mesenteroides* B-742 fermentation and its separation from byproducts. J. Microbiol. Biotechnol., 16, 325-329.

Day, D. F., Chung, C. H. (2005). A Nutraceutical. US Patent pending, filed May 2003.

Day, D. F., Chung, C. H. (2005). Chemical Oxidation for Cellulose Separation, US Patent pending, filed March 2005.

Day, D.F., Rein, P.W. (2006). Overview of the Audubon Sugar Institute Biorefinery Project. Amer. Soc. Sugar Cane Technol. LA Division Annual Meeting, February 2006.

DeQueiroz, G.A., Chung, C.H., Lee, Y.J., Day, D.F. (2005). Process of turning sugarcane bagasse into cellulose and lignin derived products. 35th Amer. Soc. Sugar Cane Technol. Meeting, Panama City Beach, FL, June 22-24.

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FACULTY & STAFF

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Lanelle Mabile, Administrative Coordinator.

Carla Gilley, Administrative Assistant.

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Chardcie Verret, Research Associate: B.S. Chemistry (Southern University)

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Michael Robert, Maintenance Repairer Master.

Lamar Aillet, Maintenance Foreman.

FACULTY & STAFF

Faculty and Staff

Dr. Luis Bento, Professor: B.S. Chemical Science (Coimbra University, Portugal); Licenciate in Engineering, Chemical Engineering (University of Porto); Ph.D. Chemical Engineering (Minho University, Portugal).

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Drs. Peter Rein and Donal Day

Dr. Matt Gray, Post-Doctoral Researcher: B.S. Chemistry (Simon Rock College, Massachusetts); Ph.D. Chemical Engineering (Dartmouth College, New Hampshire).

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Dr. Ioan Negulescu, Professor, Dept of Human Ecology LSU: M.S. Polymer Engineering & Science (Technical University, Iasi, Romania); Ph.D. Technology of Polymers (Technical University, Iasi, Romania).

Staff Changes

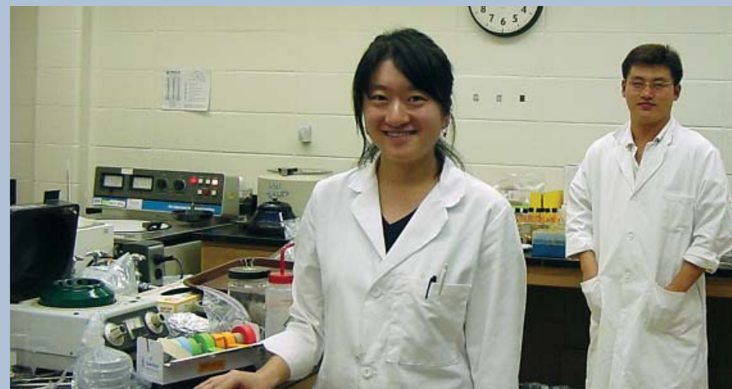
Jane Crawford, retired December 2005.

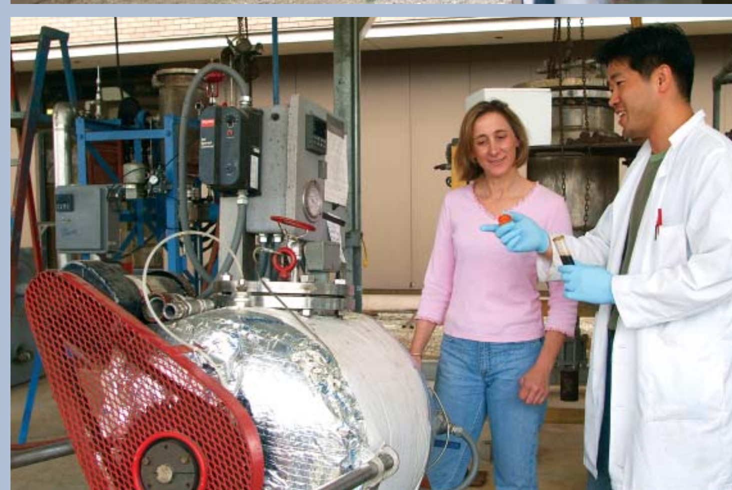
Carla Gilley, Administrative Assistant: joined March 2006.

Ligia DiSilva, Temporary Research Associate: Oct. 5, 2005 –Jan. 6, 2006

FACULTY & STAFF

Staff and Students of Audubon Sugar Institute





Aerial view of Audubon Sugar Institute (ASI), Saint Gabriel, Louisiana, taken in May 2006.

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