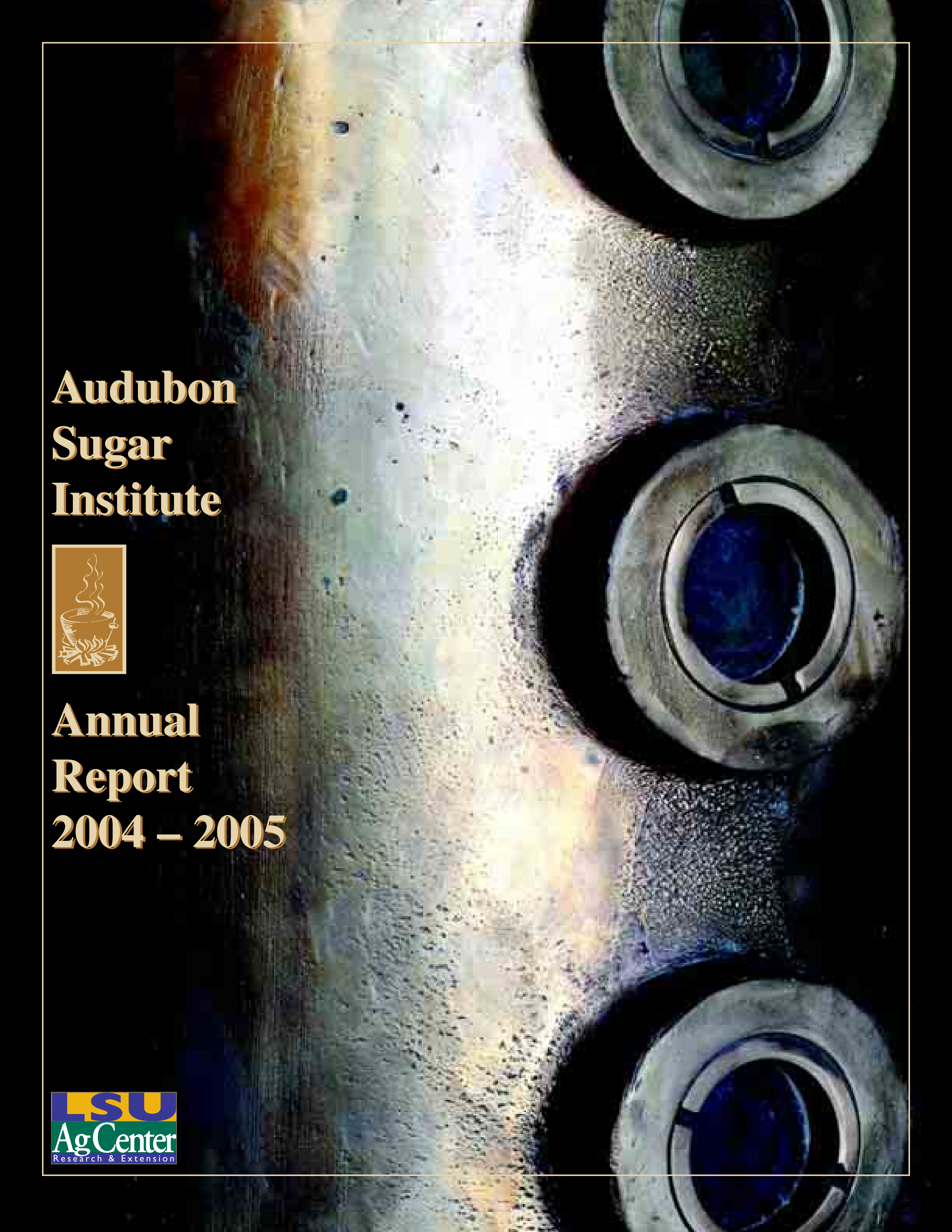

# Audubon Sugar Institute

# Annual Report 2004 – 2005

LSU AgCenter
Research & Extension

# AUDUBON SUGAR INSTITUTE

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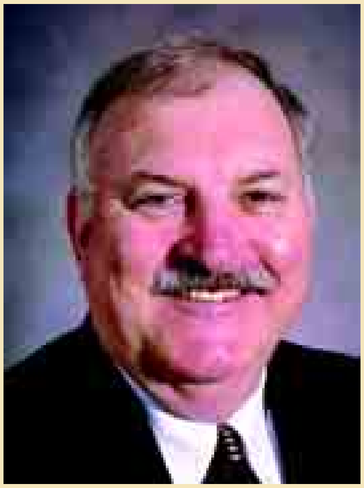
**Louisiana State University Agricultural Center**
William B. Richardson, Chancellor
David J. Boethel, Vice Chancellor and Director of Research
Paul D. Coreil, Vice Chancellor and Director of Extension

Produced by LSU AgCenter Communications

# Vice Chancellor's Foreword

*In 2004, acres of sugarcane grown and harvested, number of producers, tons of sugarcane per acre, and sugar produced per acre were reduced relative to 2003. Concern about marketing allotments and proportionate shares, lingering effects of harvest equipment disruption of fields in 2002, delay of factory starting dates due to deluges from tropical storms, intermittent periods of drought and excessive rainfall, and rust disease exacerbated by climatic conditions favorable to the pathogen collectively contributed to the problems faced by the sugar industry last year. However, sugarcane retained its position as the leading row crop in Louisiana with a farm gate value of $303 million and value-added income of $194 million. Clearly, these statistics illustrate the critical role sugarcane plays in the economics of agriculture in our state, and, when the multipliers associated with jobs (production and mills) and infrastructure are added, the major role the crop plays in economic development is evident as well.*

*Last year marked the first complete year that the faculty and staff of the Audubon Sugar Institute occupied the research facilities on Highway 75 at St. Gabriel which resulted from the generous donation of the Syngenta Corporation. Although some facets of the equipment and pilot plant are not fully online, a great deal of the challenge of moving an entire research unit and "restarting" facilities that had not been operational for some time has been met. The improvement over the former ASI facilities is immeasurable, and the new location and buildings offer the opportunity for expansion.*



David J. Boethel

*Undoubtedly, some of the problems experienced in the production phase of the sugarcane industry contributed to the closing of two processing mills in 2004. These events are discouraging, but the LSU AgCenter is committed to continue its research and outreach programs to address the problems facing the industry, both in sugar production and in sugar processing.*

*ASI is tasked to focus on sugar processing to enable sugar factories to become more efficient through research and transfer of the technology which emerges from that research. Over the past several years, the ASI faculty members have frequented the mills across Louisiana to accomplish the mission of the organization. ASI also focuses on research to develop a diversified sugar processing industry through the creation of value-added products. Over the past two years, value-added research has been greatly aided through special grants from the Department of Energy. The AgCenter is joined in this research thrust with a new partner, the Michigan Biotechnology Institute. Dr. Peter Rein, in his message in this annual report, elaborates on this initiative. The potential outcomes of this collaboration are exciting, and we must thank the Louisiana congressional delegation for its support of this enhanced value-added research effort.*

*The LSU AgCenter, like the sugar industry and our long-time partner, the American Sugar Cane League, faces budget challenges. The grants awarded by the ASCL Dedicated Research Committee to our scientists are becoming more critical each year for our programs to remain viable. We appreciate the confidence the ASCL has placed in our research and extension faculty by funding projects deemed important to the sugar industry. We view this support, as we hope the League does, as an investment in the future of the industry. Advancements in research followed by educational programs to stimulate adoption of new technology remain vital to sustain an industry that has been a mainstay in the economy of Louisiana for over 200 years. As always we welcome you to visit the ASI to learn more about the programs being conducted by our scientists on behalf of the sugar industry.*

***ON THE COVER***

*Visitors to Audubon Sugar Institute are greeted by this brass structure that is 5 feet, 5 inches tall and 15 inches in diameter that graces the front lobby of the facility. It is a vacuum pan with eight sight glasses on each side and 22 3/8-inch machine-flanged bolts on each joint. The walls and flanges are 5/8-inch cast brass. Built in 1954 by Oil City Brass Works, the equipment cost $563.19. This was higher than the original quote because of two increases in the price of bronze ingots that year. It had been kept in storage after the sugar factory ceased full-scale production. In 2004, Audubon's factory personnel polished the brass and brought it out for display.*

# Head of Institute's Report

*Audubon Sugar Institute completed its first full year in the new facilities at St. Gabriel. It has been a busy time, with a significant proportion of our people and money resources committed to getting things operational and dealing with problems. Routine maintenance of the building and its HVAC system are going to absorb more of our effort than anticipated. The task of getting all our equipment operational, particularly in the pilot plant, is incomplete.*

*In spite of the problems, I believe that all concerned would agree that it has been a good move for Audubon. Although travel to and from the main campus 12 miles away consumes more time, the benefits far outweigh the disadvantages. It is a pleasure to have a facility we can show with pride to visitors. It also gives us room for expansion, which has made it possible for us to extend our program of work substantially.*

*We hosted an Opening Ceremony at our new premises in August 2004. We were fortunate indeed to have Senator Mary Landrieu address the gathering and appreciated the presence of other dignitaries including LSU System President Dr. Bill Jenkins and AgCenter Chancellor Dr. Bill Richardson. It was an opportunity for us to recognize formally Syngenta's generous donation of the research facilities to Audubon, and to recognize the efforts of Senator Landrieu in securing the substantial Department of Energy research funding we enjoy. It was a great occasion and we gave our guests a tour of our new building and showcased the research work in progress.*

*The DOE funding is being used to develop the concept of a Sugarcane Biorefinery, aimed at substantially augmenting the value that can be extracted from the sugarcane crop. In this endeavor we are working together with the Michigan Biotechnology Institute, a collaboration which is of great value to us, with its substantial background in biomass treatment and experience and contacts in securing federal funding. It is a good organization to work with, and we are sure that this partnership will bear fruit as we continue this endeavor.*

Dr. Peter Rein

*Our efforts in sugarcane biomass utilization are timely in the context of the Louisiana sugar industry. Sugar production was down substantially, even lower than reduced crops of the previous two years, and two more Louisiana mills have closed as a consequence of the financial hardships. Our plan to develop a biorefinery has a large number of different activities planned as part of the overall project. The base case assures ethanol production, but other options will be investigated; we are optimistic that we can help the industry to maximize its profitability in the future by developing more valuable products to boost revenue.*

*We have almost completed our first year on the project and a summary of what we have achieved so far is contained in this report. DOE funding was $500,000 for financial year 2004-05 and increases to $2.5 million in 2005-06. This has made it possible to augment our research staff, and we welcome Drs. Chang-Ho Chung and Giovanna DeQueiroz as new post-docs, both of whom received their doctorates under Audubon's supervision. In addition, Dr. Matthew Gray, a recent graduate from Dartmouth, has joined us as a post-doc; Joy Yoshina is also involved in the project as a research associate.*

*The LSU AgCenter is also facing cost pressures leading to budget cuts. We have been fortunate in securing some lucrative grants, in addition to the DOE funding, mainly from the Louisiana Board of Regents. These are applied to more conventional sugar processing research and involve collaboration with the LSU chemistry, mechanical engineering and human ecology departments. The American Sugar Cane League continues to support Audubon with some research funding, and we are most grateful.*

*During the year two Ph.D. students and two M.S. students completed their degrees. We have taken on some new graduate students to replace them. Staffing has been stable, and, in addition to the people hired for the biorefinery project, we have Chardcie Verret in the analytical lab and Ron Giroir as electrical/instrumentation engineer.*

*The future looks good for Audubon in spite of financial challenges to the AgCenter and the Louisiana sugar industry. We will consolidate in our new facility at St. Gabriel. We will increase our numbers and expand our research, both in conventional sugar processing and in biomass processing. We rely on the support of the local sugar processing industry, and will continue to do what we can to help improve profitability in a challenging environment.*

*My thanks are due to those of the staff of Audubon who have worked hard to help us achieve our objectives and to those at the AgCenter who help us in our efforts to run an effective organization.*

## Sugar Loss in Cane Washing and Cane Wash-water Composition

In an ASCL-sponsored program, cane wash-water composition was monitored at two mills. In addition to sucrose that was determined by high performance liquid chromatography (HPLC), mud concentrations in the water samples were determined. Coarse cane fragments were first removed from the wash-water samples by screening with a 0.2-mm screen. Fifty mL of the screened samples were then centrifuged with a high-speed laboratory centrifuge, and the concentration of the fine suspended soil solids was determined by drying of the centrifugation sediment.

Three rounds of sampling gave the following range of results for sucrose and mud concentrations in the cane wash water:

The sugar losses appear somewhat lower than those reported in previous ASI annual reports, perhaps reflecting the short time the cane is actually in contact with the water in the type of wash tables.

| Sucrose (mg/L) | Mud (mg/L) | Mud: sucrose | Sucrose loss (t/d) | Sucrose loss (kg/t cane) |
|---|---|---|---|---|
| 300 – 1,000 | 600 – 2,000 | 1.4 – 4.8 | 11 – 27 | 1 – 3 |

When washing is stopped, mud is brought into the mill with the cane; most of it is then eliminated with an appreciable amount of sucrose entrained with it in the filter cake. At typical values, a filter cake with 65% moisture and a pol of 2% to 4%, the mud:sucrose ratio in the filter cake is in the range of 10 to 20. Therefore, from a losses point of view, if mud:sucrose ratio in wash water is less than about 10, consideration should be given to temporarily suspending cane washing. The mud:sucrose ratio in the wash water may provide a simple but useful cost-benefit criterion for cane-washing operation because its low value indicates high sucrose loss relative to the amount of mud removed.

Figure 1. A typical Louisiana sugarcane wash table.

## A Novel Biocide

Testing of a novel biocide developed at ASI was conducted to obtain EPA registration as a sporocide. It is now approved by the EPA for use in a national emergency, such as a bioterrorism event. Full product registration is yet to come. This compound is highly oxidative and has a wide range of uses beyond a biocide. Its oxidative power is both an advantage and a disadvantage. The compound is a cold sterilant. It will kill bacterial spores in less than an hour. The best cold sterilant commercially available takes more than 10 hours to achieve the same results. It is very effective at cutting through biofilms. Figure 2 shows the test point of a biofilm on a sugar wash table and the bacterial recovery from this sample point after a single application of the biocide. Figure 3 shows the effective use of the biocide. Because of its oxidative capacity, it is not suitable for application to a sugar stream, because it will also oxidize the sugar in solution. This has become a commercial project in the hands of licensees of the technology.

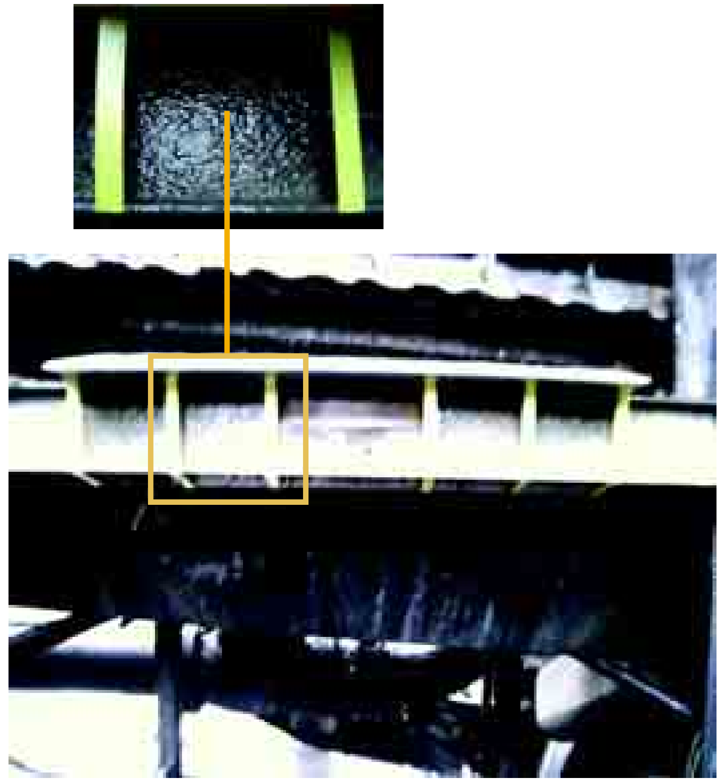


Figure 2: A 5-mm-thick biofilm on sugar mill wash table before treatment and the location where sprayed with biocide.

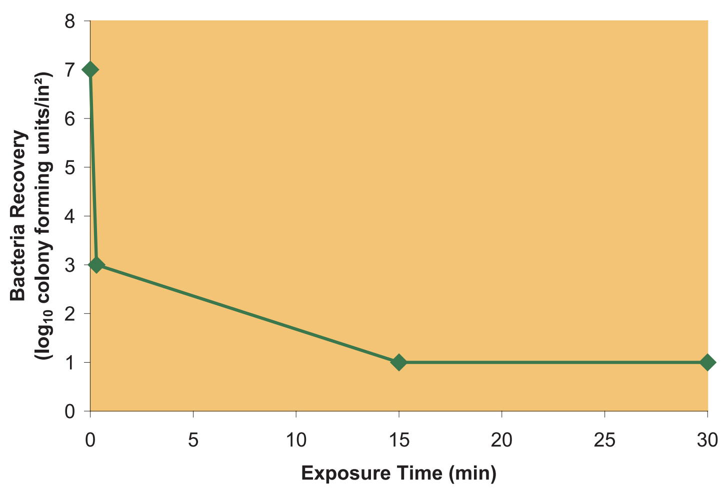



Figure 3: $Log_{10}$ numbers of bacteria recovered per square inch as function of time after spray with biocide.

## Replacement of Lime with Soda Ash in Juice Clarification

Lower hardness, level of soluble calcium salts in clarified juice, is expected to lead to reduced evaporator scaling, lower viscosity and higher boiling rates in low-grade sugar crystallization. In 2003, the replacement of lime with soda ash (sodium carbonate) in juice

clarification was found to produce clarified juice with 30% to 50% lower calcium levels compared with standard clarified juice. No processing problems were noted in 2003 with soda ash clarified juice, except that the turbidity was substantially higher when clarification was done with soda ash. Therefore, one of the objectives in 2004 was to optimize the flocculant type and dosage rate in soda ash clarification.

Laboratory tests in October and November 2004 with 11 commercial and experimental flocculants at a 5 ppm level revealed significant differences in the settling rate, mud volume and clarified juice turbidity among the individual flocculants. Table 1 shows some results.

Table 1: Turbidity Measurements of Soda Ash Clarified Juice.

| Raw Juice pH | Final pH After Soda Ash | Clarified Juice Turbidity (NTU) | | Factory Clarified Juice Turbidity (NTU) |
|---|---|---|---|---|
| | | Flocculant 1 | Flocculant 2 | |
| 6.2 | 8.7 | 17 | 110 | approx. 70 |
| 5.7 | 7.5 | 28 | 95 | approx. 40 |

The laboratory tests clearly showed that, with a properly chosen flocculant, clarified juice can be produced with a turbidity comparable or even lower than that now produced in the mills in liming clarification. The mixed juice pH is somewhat higher than one would expect in raw juice because of the recycled limed filtrate in the hot raw juice that could not be avoided. The calcium levels determined by HPIC were reduced from 0.23% – 0.42% dry solids in factory-clarified juice to 0.16% – 0.25% dry solids in soda ash clarified juice. Based on the favorable results of laboratory tests, a full-scale factory trial was organized at a Louisiana mill. The test results were affected by an unrelated mill shut down in the course of the trial and a higher-than-anticipated consumption of soda ash. The determination of calcium and silicon levels by atomic absorption in raw juice, clarified juice, syrup and other samples taken in the course of the testing is under way. As expected, the first results indicate lower calcium levels in soda ash clarified juice. Silicon removal appears negligible in either lime or soda ash clarification.

## Optimizing Mud Filter Operation

A simple laboratory procedure was developed and demonstrated that can be applied by the mills to monitor clarifier and filter feed conditioning. In a survey of five Louisiana mills, the suspended solids content in the untreated clarifier mud ranged between 7% and 18%. Of the suspended solids in the clarifier mud, nearly half by weight was bagacillo that passed the large-opening cush-cush screen with raw juice. In the limited number of samples that were tested, little if any difference was found between the cake filtration resistance of untreated mud and the actual filtrate feed. This indicates inadequate conditioning of the mud before filtration. Because the bagacillo content appears adequate even before adding any additional dry bagacillo, emphasis should be placed on proper choice and dose of the secondary flocculant. Published recommendations in the Cane Sugar Handbook for optimum levels of added dry bagacillo and total suspended solids in filter feed appear to have been derived from tests with mixed juice and clarifier mud with much lower levels of suspended solids than found in Louisiana mills and may not be accurate for our conditions.

Figure 4: Internals of a sugar mill vacuum filter.

## Determination of Residence Time in Evaporators Using Zinc Chloride as a Tracer

Current ASI programs related to evaluating heat transfer and flow conditions within evaporators and vacuum pans prompted measurements of residence time in individual evaporator effects. Relatively straightforward modifications of Robert vessels are possible to promote plug flow-like fluid pattern and increase the evaporator capacity. Zinc chloride was found to be a suitable tracer in previous testing of low-grade crystallizers. The tests on the first effects in two mills revealed large deviations from the relatively narrow residence time distribution reported from SRI tests in Queensland. Although our tests may have been affected by the flow rate and juice level fluctuations during the tracer tests, the wide distribution of residence times may be a sign of significant short-circuiting and recirculation within the vessels. This points to the need to reconsider issues of juice inlet distribution and other design aspects of the existing industrial evaporators.

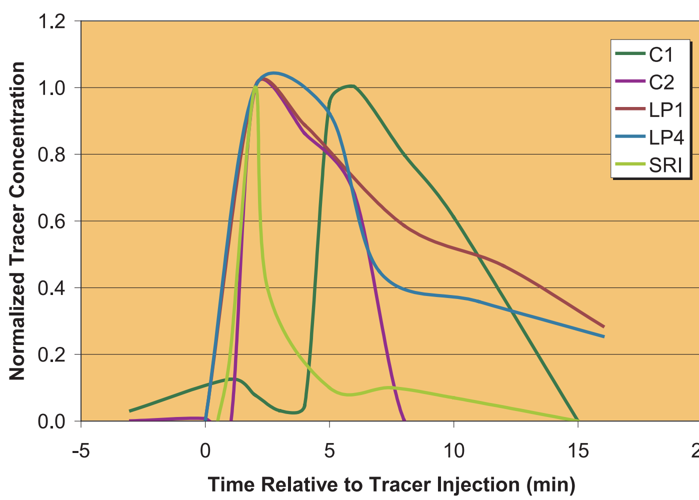



Figure 5: Residence time distribution measured in evaporator vessels. Two tests each in sugar mills C and LP and compared with tests reported by Sugar Research Institute, Australia.

## Online Measurement of Evaporator Heat Transfer Coefficients

The project started at St James mill last season was continued. The aim of the project was to develop a low-cost system to determine the heat transfer coefficients for the mill's large quadruple effect evaporators in real time. The model is based on minimal instrumentation, using only two volumetric flow meters, one microwave Brix probe and nine RTD temperature measurements, and is inexpensive for a mill to install. The measurement points are shown in Figure 6.

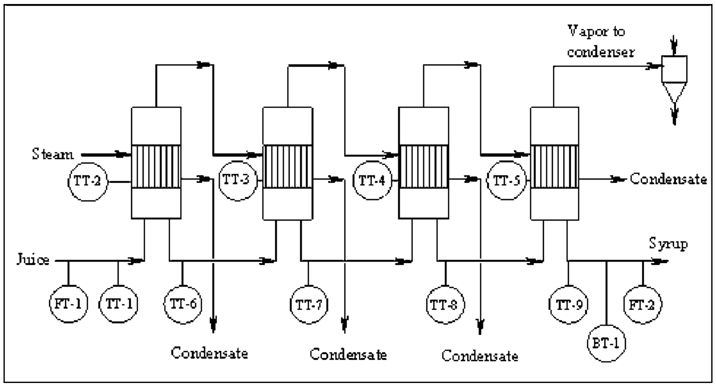



Figure 6: St. James quadruple effect evaporator arrangement and measurement points.

The fluid flow within the vessel contributes significantly to heat transfer, and good feed distribution is essential. In 2003, the evaporator vessels had single central inlets covered with feed distribution plates. This could lead to flashing up the downtake, affecting circulation, and leading to short-circuiting from inlet to outlet. Therefore, the feed arrangement was modified for the 2004 season to a feed ring distributing the feed around the periphery of the vessel. After these modifications, there was an increase in the heat transfer coefficients for all the bodies except the last one. This anomaly is explained by the fact that this vessel was not being cleaned satisfactorily. Once the final effect vessel was cleaned sufficiently, the calculated value was similar to the value obtained in the 2003 season. The average heat transfer coefficient values measured in the two seasons are shown in Table 2; the heat transfer coefficient data for the 2004 season are shown in Figure 7.

Table 2. Average values of heat transfer coeffiecients.

| Effect No. | 2003 | | 2004 | |
|---|---|---|---|---|
| | kW/(m².K) | BTU/(h.ft².°F) | kW/(m².K) | BTU/(h.ft².°F) |
| 1st | 2.4 | 420 | 2.6 | 460 |
| 2nd | 2.5 | 440 | 2.8 | 490 |
| 3rd | 2.3 | 405 | 2.7 | 475 |
| 4th | 0.4 | 70 | 0.4 | 70 |

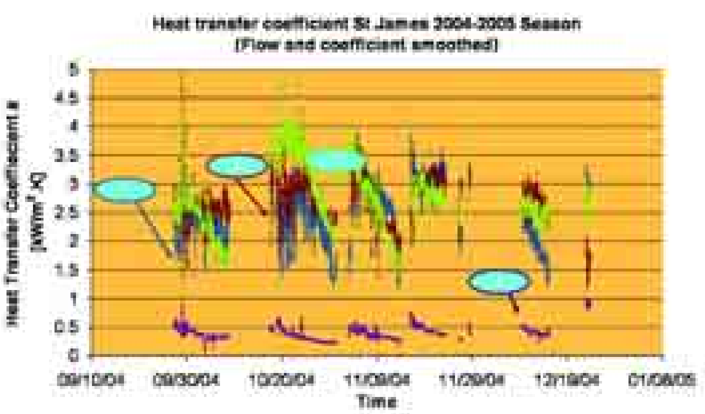



Figure 7: St. James mill heat transfer coefficient data for the 2004 season.

It is clear that the major the bottleneck is the last vessel, where a higher temperature difference and high degree of scaling are evident.

Attempts were made to model the scaling behavior of the evaporators. From the literature, a number of models for the time dependence of heat transfer coefficients were found. Most of them are generally of the form as follows:

$$\frac{1}{k^n} = \frac{1}{k_o^{\,n}} + a_o\theta$$

where $k_0$ is the value of the heat transfer coefficient with clean tubes and θ represents time in days. From the literature, the exponent n has the value 2 when the evaporators run with a constant temperature difference and 1 when operated at constant heat flux; the latter is probably closer to the case of sugar mill evaporators. The data from the 2003 and 2004 seasons were processed, and the results for the 2004 season are summarized in Table 3. The negative values for $a_o$ that occur in the second effect are in periods where little scaling was seen in the first few effects and is zero for all practical purposes. It is clear from this data that the final effect scales quickest, followed typically by the third and first effects.

Table 3: Regressed time dependent model constants for the each effect during 2004, (n=1).

| | Constant ($a_o$) in equation for each effect | | | |
|---|---|---|---|---|
| Data Period | Effect 1 | Effect 2 | Effect 3 | Effect 4 |
| First | 0.000 | -0.005 | 0.006 | 0.167 |
| Second | 0.010 | 0.019 | 0.030 | 0.220 |
| Third | 0.011 | 0.004 | 0.014 | 0.197 |
| Fourth | 0.001 | -0.001 | 0.018 | 0.125 |

The value of the clean heat transfer coefficient ($k_o$) depends on the operating conditions and liquid properties. A number of different models have been proposed for the heat transfer coefficient, as a function of different variables. The heat transfer coefficient data from the first 24 hours after the vessels were cleaned was used to compare with these equations. The data from the first through fourth effect are combined for regression analysis. For the data to be used for design and estimation purposes, the parameter $k_o$ needs to be determined.

None of the correlations proposed are free from scatter. Of the correlations used in prediction of the clean heat transfer coefficient, the correlation that appears to be most repeatable and consistent is that of absolute temperature over Brix, also referred to as the Swedish formula:

$$k_o = 0.16\,\frac{t_L + 273.15}{B_L}$$

where $t_L$ is the liquid temperature (°C) and $B_L$ the brix of the liquid.

Through evaluating the heat transfer coefficients online, an assessment of the performance of individual effects was achieved. The results showed if a vessel was cleaned adequately during the cleaning cycle, the final two effects are the effects with significant scaling problems, and the first effects do not need to be cleaned as often. Less frequent cleaning is expected to save mill downtime and cleaning chemical costs.

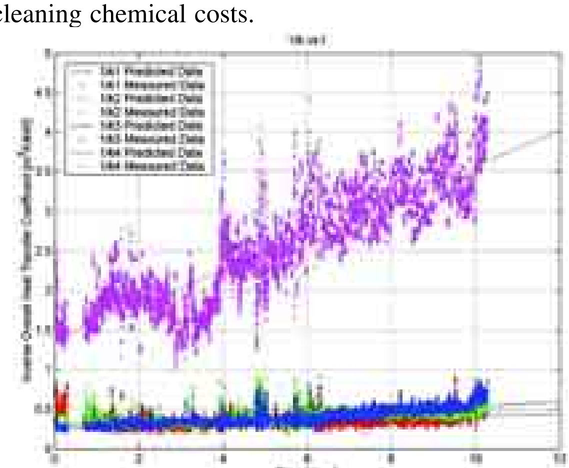


Figure 8: Regression for time dependence of scaling from 2004, n=1.

# Numerical and Experimental Study of the Flow in Vacuum Pans

This project is being developed with the LSU Mechanical Engineering Department.

## Lab-scale Study

A lab-scale test rig is being used to study the circulation mechanism, providing information about some flow features and data for the verification of the CFD modeling. Particle Image Velocimetry (PIV) has been applied in the characterization of the flow field; it is an optical technique based on the use of a pulsed laser to track the position of tracer particles. For the numerical analysis, the commercial CFD code FLUENT has been applied, using the multiphase Eulerian-Eulerian approach, which is the most appropriate considering the complex interaction between the phases.

Initial simulations overpredicted the liquid velocity and circulation rate, although some qualitative agreement between the flow patterns was noticeable. Adjustments to the computation of the interaction of momentum between the phases, specifically the drag coefficient of the gas bubbles, through the use of correlations more suitable for the particular conditions, and correction of the drag for high gas volumetric fractions, have produced numerical results that are in reasonable agreement with the experimental data. For example, the velocity vectors measured and numerically predicted for the bottom region, where only liquid is present, are similar in direction and magnitude (Figure 9), obtaining comparable circulation rates and flow patterns.

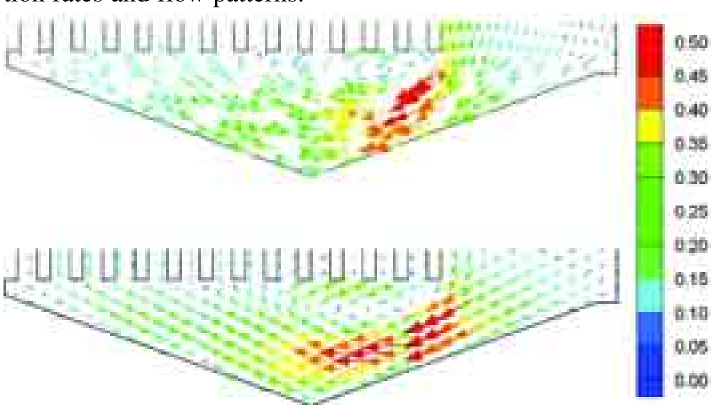



Figure 9: Liquid velocity vectors at the bottom region of the test rig predicted numerically using CFD (top), and measured using PIV (bottom) [m/s].

The simulations applying different momentum exchange models are, in general, comparable to the experimental data from a qualitative point of view, but not from a quantitative point of view. The experience with the lab-scale test rig indicates that, if the exchange of momentum between the gas and liquid phases is solved properly, a satisfactory numerical solution of the entire flow-field will become feasible.

## Full-scale Study

The massecuite velocity was measured in a 160 m³ Fletcher Smith Continuous Vacuum Pan (CVP) at the Enterprise sugar mill using commercial insertion flow meters, whose design is based on the hot wire anemometry technique. The CVP has 12 cells, and measurements were performed in the second and eleventh cells, below the corner of the lower calandria tube sheet, where all the circulating liquid passes before entering the tubes and the velocity is expected to be approximately horizontal. Therefore, the integration of the velocity profile is expected to give a reasonable figure for the circulation. Liquid velocities up to 0.35 m/s were recorded, which are in agreement with values reported previously using the same technique in an SRI-CVP in Australia.

A velocity profile skewed toward the calandria tube plate was obtained along the line of measurement, indicating that the movement of the liquid phase is faster near the bottom calandria tube plate and slower toward the bottom of the vessel (Figure 10), and agreeing qualitatively with CFD predictions. The circulation in the eleventh cell is only 36% of the value determined in the second cell, showing the strong effect of viscosity.

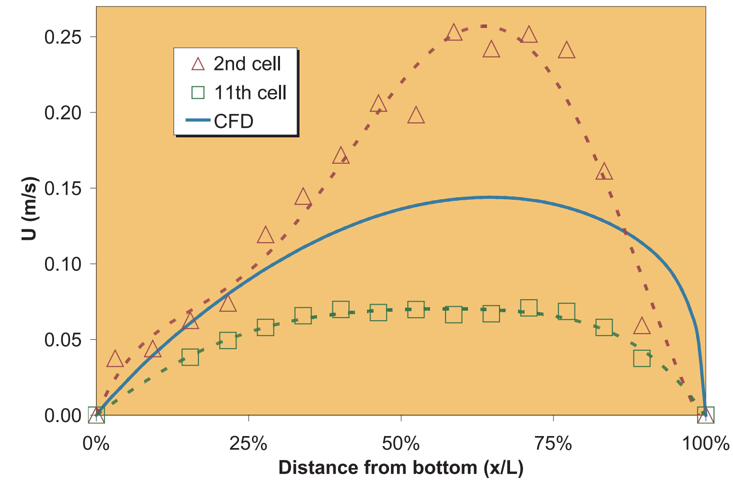



Figure 10: Velocity profile underneath the corner of the calandria measured and predicted using CFD [L: Distance between shell and calandria].

As expected, the measurements showed consistently higher circulation after the cleaning and illustrated the strong interaction between circulation and heat transfer, which decay together as scaling takes place (Figure 11).

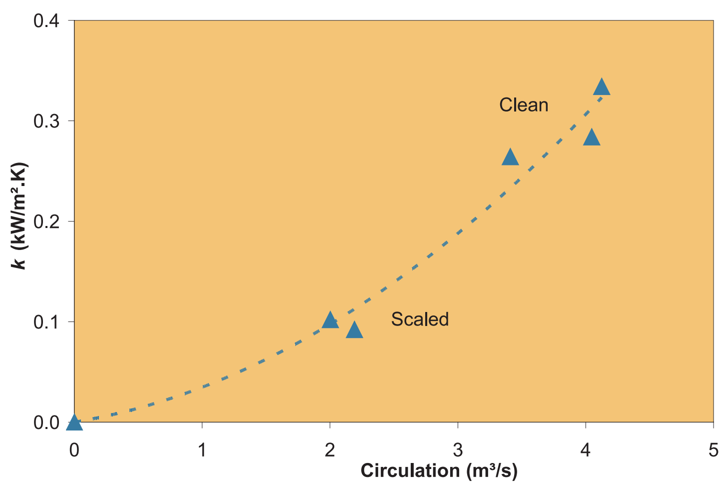



Figure 11: Circulation in the second cell and vacuum pan overall heat transfer coefficient.

# Low Grade Station Operations and Equipment Evaluation

During this study (2001-2004 crops) data were gathered on pans, crystallizers, reheaters and centrifugals to monitor low grade station operations and evaluate equipment. Some of the results are:

## Vacuum Pan Heat Transfer Coefficients

Table 4 summarizes the heat transfer coefficients for batch and continuous pans on A, B and C massecuites. In general, the batch pans had significantly higher heat transfer coefficients and were operated on steam at 6 to 10 psig higher than that of the continuous vacuum pans. Batch pan coefficients are evaluated from calculated evaporation rates over the whole batch pan cycle. Continuous pan values are calculated from condensate flow rates.

| Type | Calandria Steam Pressure (psia) | Massecuite Temp (deg. F) | Heat Transfer Coefficient (BTU/(hr.ft².F) |
|---|---|---|---|
| A Batch | 24.2 | 155.8 | 84.5 |
| A Continuous | 10.2 | 155.0 | 56.3 |
| B Batch | 21.6 | 162.5 | 57.1 |
| B Continuous | 14.4 | 159.0 | 29.5 |
| C Batch | 20.3 | 144.3 | 34.1 |
| C Continuous | 14.4 | 154.1 | 28.7 |

Table 4: Heat transfer coefficients for various pans.

## Effect of Massecuite Brix on Cyclone (Nutsch) Purity

Figure 12 shows the effect of massecuite Brix on the hot C cyclone (Nutsch) of the massecuite out of the pan at striking. Each Brix unit increase lowers the hot cyclone purity by about 2.5 purity points.

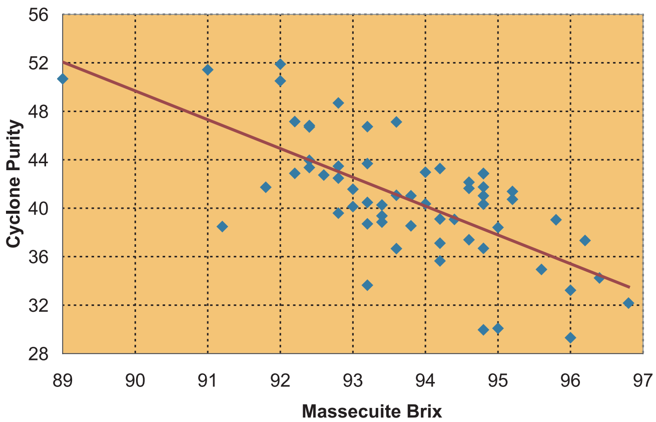



Figure 12: Effect of massecuite Brix on hot C cyclone

Figure 13 shows the effect of massecuite Brix on the cooled C cyclone (Nutsch) of the cooled C massecuite leaving the crystallizers. Each Brix unit increase lowers the cooled cyclone purity by about 1.3 purity points, or about half the effect noted above for the hot cyclone.

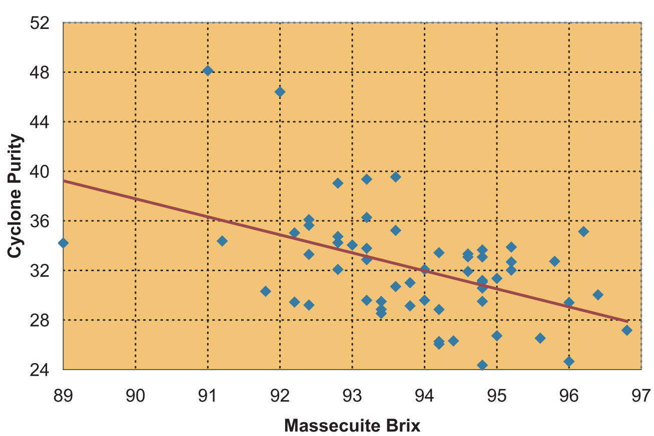



Figure 13: Effect of massecuite Brix on cooled C cyclone

## Effect of Massecuite Purity on Cyclone (Nutsch) Purity

The effect of C massecuite purity on the hot massecuite cyclone leaving the pan is shown in Figure 14. Each purity point rise in the C massecuite purity increases the cyclone purity by about one purity point.

The effect of the C massecuite purity on the cooled C massecuite cyclone is depicted in Figure 15. Each purity point rise in the C massecuite purity increases the cooled C cyclone purity by about 0.75 purity points.

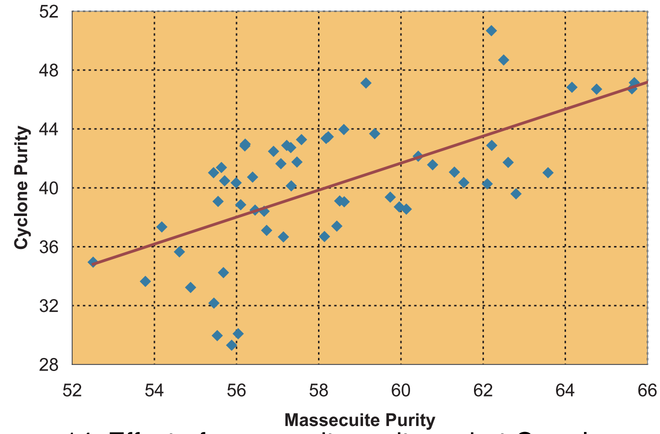



Figure 14: Effect of massecuite purity on hot C cyclone.

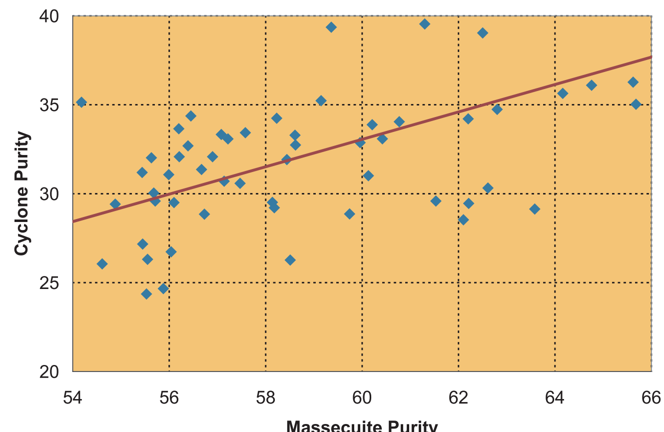



Figure 15: Effect of massecuite purity on cooled C cyclone

## Reheaters

Operating parameters, purity rises and heat transfer coefficients were determined for Honiron (Bosch), Fletcher Smith and Stevens coil reheaters.

Operating data gathered on the various reheater types tested is summarized in Table 5 (see next page). The high purity rise across the reheater (1.7 purity points) for Run 2 at Factory B was atypical of normal operations and was caused by a very high level of dextran on the day of the test. The heat transfer coefficient achieved by the moving element reheater (Stevens) was about three times higher than for the stationary reheater types (Honiron-Bosch and Fletcher Smith). Also of note is that even relatively high reheating water temperatures resulted in relatively small purity rises.

The purity rise across the reheater for all of the reheaters tested is shown in Figure 16. The average purity rise is double that measured for the larger reheaters shown in Table 5. This indicates that those factories with undersized massecuite reheaters would benefit from larger reheaters.

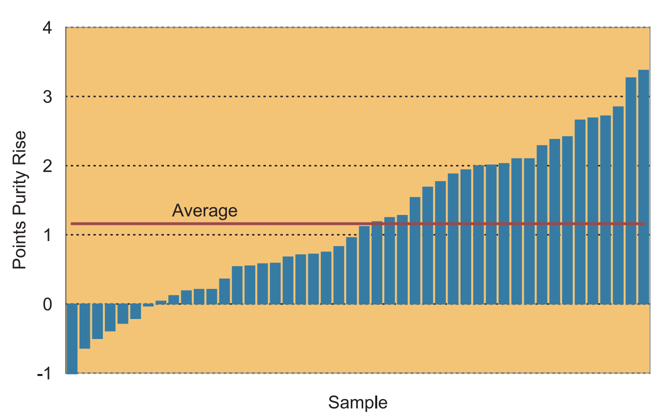



Figure 16: Purity rise across reheaters

Table 5: Operating data and heat transfer coefficients for various types of C massecuite reheaters.

| Factory | Type | Heating Surface ft² | Flow ft³./ day | Massecuite Temp. In, deg. F | Mass. Temp. Out, deg. F | Mass. Temp. Rise, deg. F | Mass Temp. In, deg. F | Water H.T.C., BTU/ (hr.ft².F) | Purity Rise |
|---|---|---|---|---|---|---|---|---|---|
| B | Hon-B | 7,534 | 15,785 | 113 | 138 | 25 | 155 | 3.9 | 0.7 |
| B | Hon-B | 7,534 | 12,914 | 106 | 135 | 29 | 154 | 3.3 | 1.7 |
| K | FS | 5,436 | 10,500 | 104 | 134 | 30 | 150 | 4.9 | 0.8 |
| K | FS | 5,436 | 10,179 | 110 | 128 | 18 | 159 | 1.9 | 0.2 |
| H | FS | 7,350 | 9,859 | 132 | 140 | 8 | 146 | 2.7 | 0.4 |
| C | Stevens | 695 | 9,179 | 117 | 130 | 13 | 167 | 7.8 | 0.5 |
| C | Stevens | 695 | 8,375 | 101 | 124 | 23 | 160 | 11.8 | 0.5 |

### Purity Rise Across Low Grade Centrifugals

Purity rise across the low grade centrifugals is shown in Figure 17. The average purity rise was three purity points and exceeded eight purity points in a few cases.

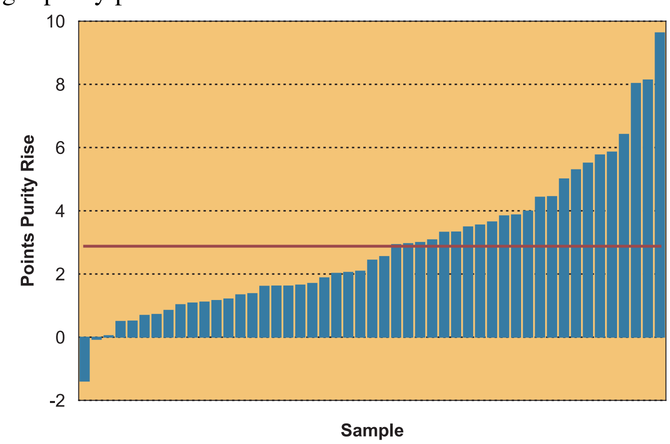



Figure 17: Purity rise across centrifugals

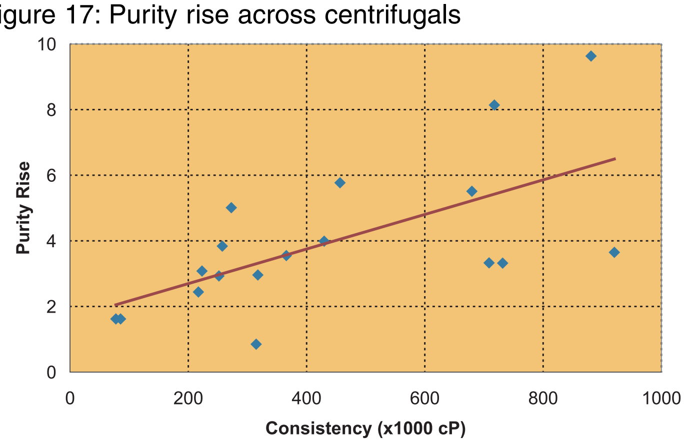



Figure 18: The correlation of purity rise across centrifugals with reheated massecuite consistency.

The purity rise across the centrifugals as a function of the reheated massecuite consistency is plotted in Figure 18. The data suggest that high massecuite consistencies result in a higher purity rise at the centrifugals.

Most Louisiana factories lack adequate massecuite reheating equipment. The existing equipment at most factories is too small to achieve the required degree of massecuite reheating without excessively high reheating water temperatures. There is great hope for improving C centrifugal operation, where the purity rise was often excessive.

The manner in which equipment is operated was found to be much more important than the type of equipment installed.

## C-Massecuite Studies Using Infrared Imaging and Microwave Technology

Low grade crystallization is an important step in the sugar industry. Sucrose loss in molasses must be minimized to improve recovery. Crystallization of C massecuite is carried out in the vacuum pans first and then in the cooling crystallizers. In the latter operation, massecuite temperature is lowered, allowing crystals to grow by further crystallization. Then the temperature is raised to facilitate centrifugal operation. This temperature must be high enough to lower the molasses viscosity to promote its purging through screens; however, this temperature must not be too high to avoid melting the sucrose crystal. This operation must be quick and well controlled to avoid dissolution. In a normal operation, this heating is done in large heat exchangers using hot water.

During the last season, different aspects of C massecuite processing were studied. An inspection of the C massecuite crystallizers was made on one of the Louisiana sugar mils using an Infrared (IR) camera. Massecuite from the C vacuum pan was fed to four crystallizers at a rate of 250 ft³/h, which corresponded to a total residence time of 16 hours. The massecuite temperature decreases along the first three crystallizers where cooling water flows cocurrently and countercurrently (Figure 19) at a rate of 40 gpm.

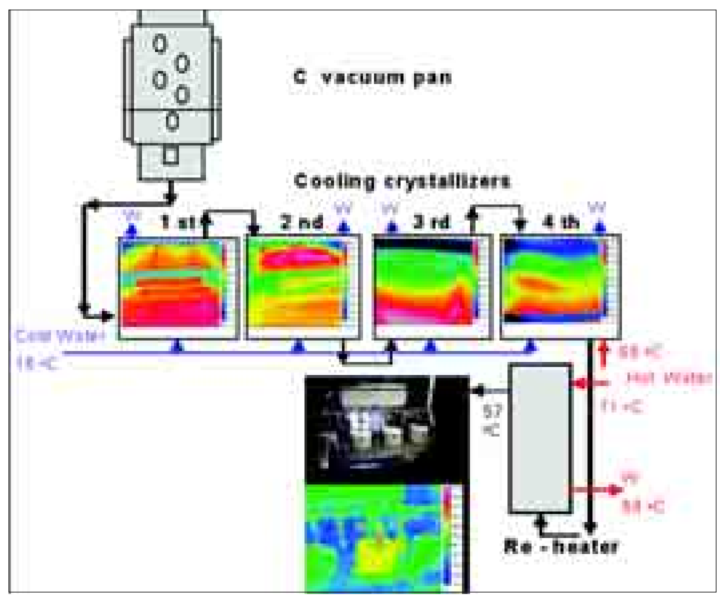



Figure 19: IR images of cooling crystallizers and centrifugal station.

In the fourth crystallizer, massecuite can be cooled or heated depending on the operating conditions. During the inspection, hot water was used to heat massecuite before being pumped to the reheater. Temperature variations in the massecuite can easily be seen by inspection using a high sensitivity IR camera and can potentially be controlled to avoid massecuite channeling in cooling crystallizers and local overheating in reheaters, factors that increase sugar losses to molasses. Improved temperature control of the massecuite cooling system could be achieved with an IR camera used on a continuous display basis.

Microwave heating of C massecuite has been studied as a means of increasing the efficiency of this operation. The advantage of applying microwave technology is the ability to heat massecuite within a fraction of a minute using a small piece of equipment that does not require any heating fluids. Also, the elimination of heating surfaces and localized hot spots reduces sugar dissolution and massecuite channeling. Studies using a 5kW continuous microwave system at North Carolina State University show that microwave heating is uniform throughout the liquid phase. Figure 20 shows results of these tests in which the temperature was measured at the inlet and several cross-sectional points of the outlet (I1 through III3).

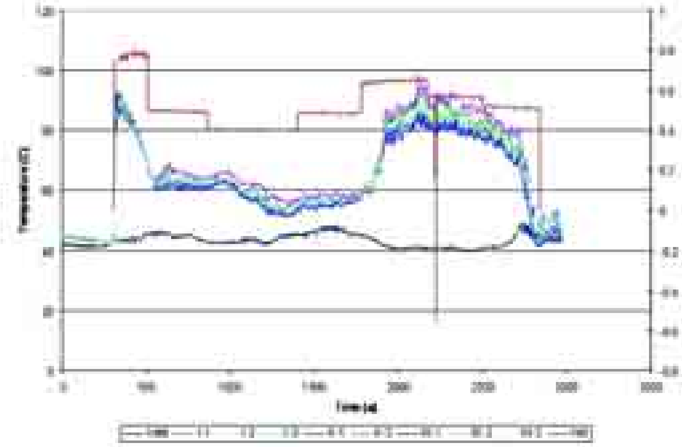


Figure 20: Massecuite heating with microwaves.

## The Use of a Coriolis Mass Flow Meter to Measure Molasses Production

As part of the program to measure sucrose losses at Raceland mill, two Coriolis meters were installed in series on the molasses line from the C centrifugals to the storage tanks. Coriolis meters were selected for the duty for the following reasons:

- They have an accuracy of around 0.1%.
- They measure mass flow and do not require any estimates of molasses density.
- They are simple, robust, have no flow restrictions and are easy to install, without requirements of lengths of straight pipe before and after the meter.
- They give a simultaneous output of fluid density.
- They are not sensitive to vibration.
- They have a good turn-down.

Coriolis meters manufactured by Endress + Hauser and Foxboro have been evaluated over two seasons. During the last season, a set of molasses batch scales was installed at Raceland, so that the meters could be compared against an accurate mass flow measurement.

Both meters were affected by an unforeseen problem, mainly the fact that the molasses pumps turn on and off regularly, as the feed tank level changes. The meters were not always able to follow the step changes in flow that occurred, and were affected by air ingress if the level in the molasses feed tank dropped too low. It was also necessary to ensure that the vertical line stayed full without draining.

Figure 21 shows how the Foxboro meter output (red) fluctuated as it adjusted to density (green) changes, and the much slower response of the Endress + Hauser instrument (blue) to flow step changes. The Endress + Hauser instrument was more affected by entrained air, shown by the fact that it did not return to zero when the pump stopped and the molasses was badly aerated. The Foxboro meter claims to be able to handle badly aerated liquids, and this seems to be true.

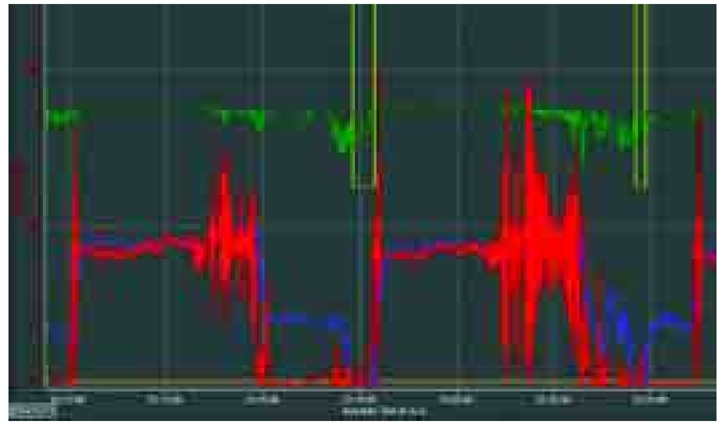


Figure 21: Coriolis meter recordings showing mass flow (red Foxboro, blue Endress + Hauser) and density (green) over a period of 15 minutes.

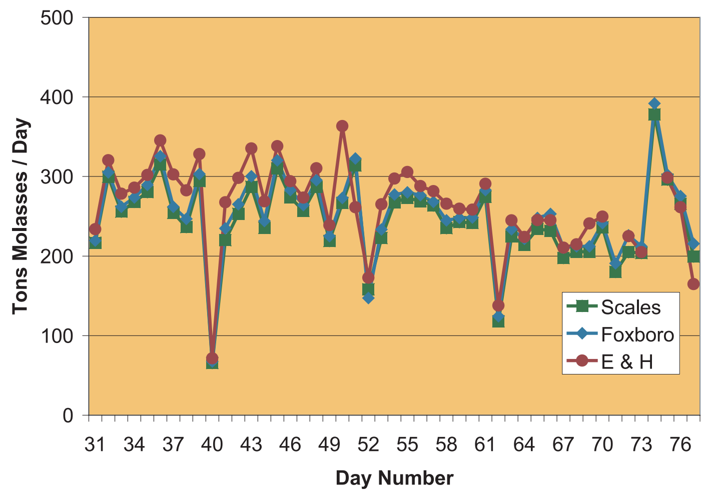



Figure 22: Daily molasses production measured by molasses scales and two Coriolis meters.

Figure 22 shows the daily average molasses qualities, for the two meters compared to the molasses scales. Both meters recorded higher molasses quantities than the scales. On average, the Foxboro meter gave readings that were 3% higher and the Endress + Hauser meter 9% higher.

It is considered that the Coriolis meter should be able to achieve its stated accuracy in an application where a continuous molasses flow is measured, and it could be a good cost-effective option for accurate molasses production measurement.

## Color Removal Studies

The characterization of colorants present in sugar solutions was conducted with the objective of separating colorants in sugar products for further analytical work to identify the chemical nature of colored compounds, especially those with a higher affinity for sugar crystals.

The approach used is the following:

1. Fix the colorants compounds in an absorbent.
2. Remove the colorants with solutions of different hydrophobicity and alkalinity.
3. Separate and wash the absorbent.

Five solvent solutions were used at different concentrations and/or alkalinity. These solutions were labeled as:A1, A2 … E1,

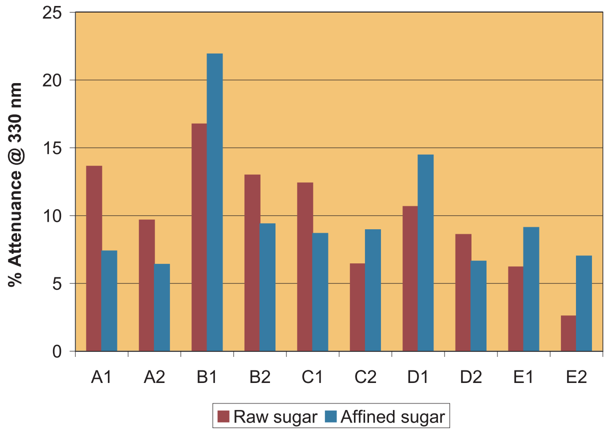



Figure 23: Colorant distribution in raw and affined sugar.

E2. The relative composition of colorants (measured by absorbance at 330 nm) in raw sugar and affined sugar is presented in Figure 23. According to these results, colorants from extracts B1, C2, D1, E1 and E2, are present at a higher percentage in affined sugar than in its precursor, the raw sugar. These colorants, labeled as HC for harmful colorants, will have a higher affinity for sugar crystals. The quantity of HC in this raw sugar sample represents 42.7% of total colorant (at 330 nm). Colorants present in other extracts will remain preferentially in the raw sugar syrup layer.

Figure 24 shows the percentage of colorants at 330 nm in cane white sugar. Based on these results, extracts B1 and D1 (considered as HC in the previous results), are mostly present in white sugar, with a percentage of 19.4 and 13.0%, respectively. The lower percentage of other HC in white sugar indicates that these colorants were probably partially removed during refining process.

Further studies will be performed on extracts B and D (Figure 25).

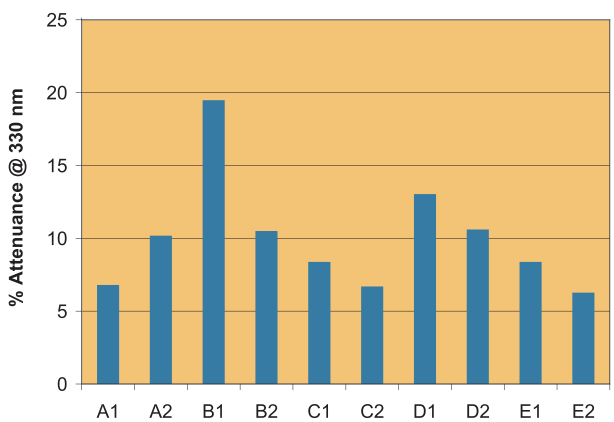



Figure 24: Colorant distribution in white sugar.

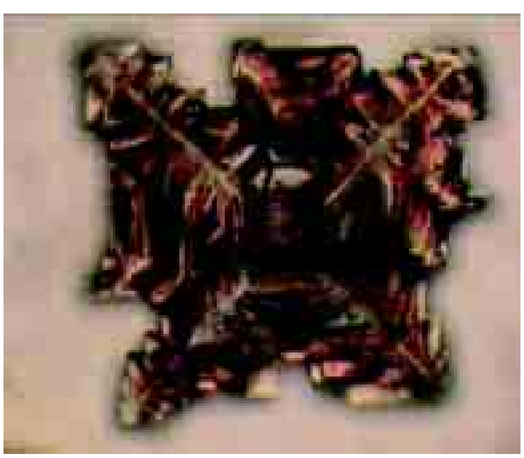


Figure 25: Colorant from D extract in NaCl.

# Inhibition of a-Carbonyl Condensation in Maillard Reactions and Related Chemistries

Of the many colorant-forming mechanisms working against the production of low-color sugar (including flavonoid/phenolics, caramels, HADP and melanins), the production of melanoid or Maillard colorant groups is perhaps of greatest importance and complexity.

The "Maillard Reaction," as it is called, is actually a series of concomitant reactions involving reducing sugars and amino acids; reactions include the Schiff base reaction, the Amadori Rearrangement, the Strecker Degradation, aldol-type condensations and dehydration reactions. The chemistries are very complex, yielding a wide range of products. An example of colorant condensation is given in Figure 26.

From here, it can be seen that condensation of these reactive intermediates is a cornerstone of colorant formation. These com-

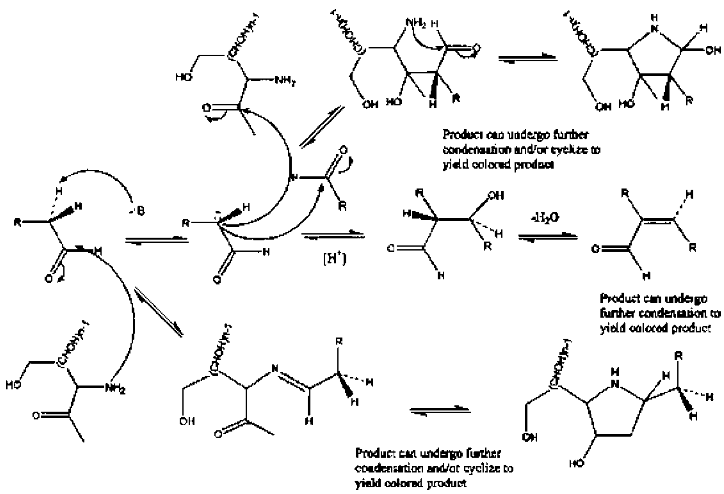



Figure 26: Reactions leading to colorant precursors and initial steps of subsequent condensation into colorant.

Figure 27: Colorant formation is clearly seen following in a clockwise fashion from time= 0 hr to 11.5 hr; appearance of visible color is apparent at less than 1 hour.

pounds are colorless (at visible wavelengths) but readily condense at high Brix to yield highly conjugated and, hence, colored compounds. Furthermore, many of these intermediates are documented in the formation mechanisms described for caramel and phenolic (melanin) colorants. Inhibiting condensation of these compounds will reduce the amount of resultant color under process conditions.

Figure 27, an uninhibited glucose:L-phenylalanine (amino acid added in proportions normally found in juice for total amino acid, for example, 0.5%) Maillard Reaction is given.

Color increase begins promptly and accelerates with both increasing Brix and time; this is not surprising, because colorant results from condensation-type chemistries. Ideally, it seems that preventing the evolution of color would prove more efficient than removing it once it is present. A selected inhibiting adjuvant was evaluated, and a parallel experiment is shown in Figure 28.

In pure Maillard systems, inhibiting intermediate condensation can reduce colorant formation by an order of magnitude or more. Inhibition may also render colorants more amenable to removal using ion-exchange techniques.

Figure 28: Clockwise, the formation of color over time in a glucose: phenylalanine model Maillard reaction. This reaction was inhibited with a selected additive where phenylalanine was present in slight stoicheometric excess over the inhibitor; apparent color formation begins at 5 hours.

## Fluorophore Content of Model Systems and Product Sugars

It has been found that development of highly fluorescent materials will occur throughout the process of synthesizing color under both caramel and Maillard regimes. The Maillard reaction series in synthetic syrup:phenylalanine are illustrated in Figure 29, where the sequence is seen under normal "white" light and in Figure 30 under long wave ultraviolet light (350-400 nm).

Spectral examination of caramel and Maillard model systems reveals formation of strongly fluorescent material (UV absorbance maxima 280-330nm) even when no color can be observed (that is, absorbance at 420nm is negligible). Figure 31 are spectral plots for a caramel made from synthetic syrup at 75g/dL maintained at 98-

Figure 29: Synthetic syrup:phenylalanine Maillard reaction series under "white" light; time increases left to right, final time is 10 hours.

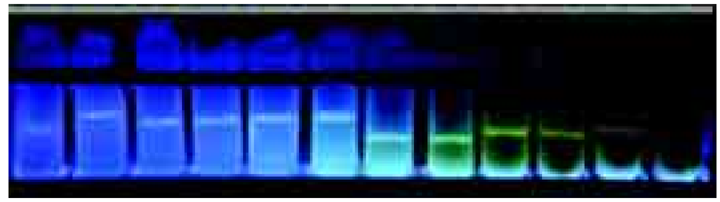


Figure 30: Synthetic syrup:phenylalanine Maillard reaction series under LWUV light; time increases left to right, final time is 10 hours. Note quenching of fluorescence in later samples with greater color content.

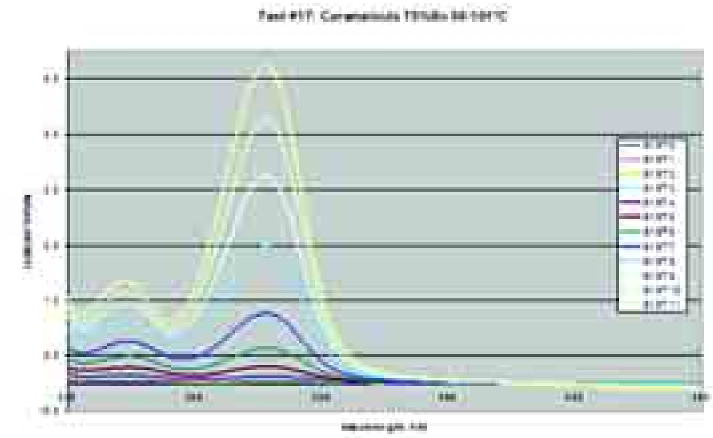


Figure 31: UV-VIS spectra of caramel made from synthetic syrup; absorbance increases with time.

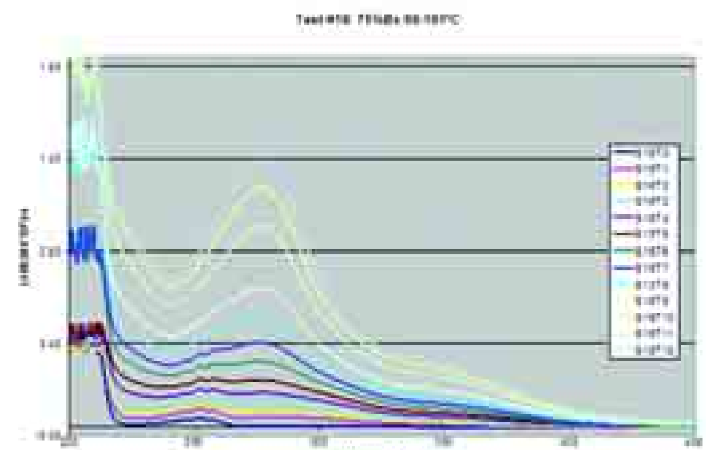


Figure 32: UV-Vis spectra of a Maillard reaction of synthetic syrup and phenylalanine; note the shift in absorbance maxima toward red with time.

101°C via reflux under vacuum. Note strong absorbance at 230 and 285nm and negligible absorbance in the visible range (starting at 400nm).

Maillard systems demonstrate fluorophore formation before colorant formation. Figure 32 shows a synthetic syrup:phenylalanine Maillard reaction, that the total material is more-or-less equal to

the analogous caramel, but that the product distributions are quite different. In the Maillard system, the absorbance maxima shifts toward longer wavelengths (toward red) with time, for example, from ~255 at t = 0 to 285, and then with appearance of maxima at ~400 nm at t= 3 (2.5 hours). This indicates with high probability that the fluorophores condense to form more conjugated structures, and hence, absorb light at longer wavelengths. This helps to explain what is happening in Figure 31, where at ~t=5 the fluorescence begins to quench (in this case, the incident or emitted light is absorbed by the nearby colored molecules).

Some of these fluorescent materials survive processing, making their way into refined sugar. When observed with 300nm ultraviolet light, as in Figure 33, this effect is clearly seen in refined and raw sugars.

It must be noted that the quenching effect is also seen in raw sugars (where colorant is still found). This suggests that fluorescent components in raw sugar are ending up in refined products. Isolation and characterization of these components will likely reveal some insight into mechanisms involving occlusion of colorant (and evidently, fluorophores) into sugar crystals.


Figure 33: From left to right: analytical grade sucrose, refined white, and raw sugar; all backlit with UV light at 300 nm.

## Online Analysis of Color in Sugar

Photography of the samples can yield a significant amount of data. Using a software package such as Adobe Photoshop version 7.0 (APS), samples can be analyzed for color using the hue-saturation method. With this method, the three constituent colors red, green and blue (RGB) are given as values between 0 and 255 as shown in Figure 34. All zeroes equal "black," all 255's equal "white." Figure 34 shows the difference between a synthetic syrup:phenylalanine Maillard reaction control and an inhibited analogue. Synthetic syrup is formulated to contain sucrose, glucose and fructose, and it is chromatographically analogous to cane syrup. The curves can be equated to transmittance for each color band. Assuming that 255 equals 100% transmission of red, green or blue, we can assign a value 100% red, green or blue for virtually any sample at some particular time. Following this, a 765 summative value of the three would equal 100% white; a sum of zero equals 100% black.

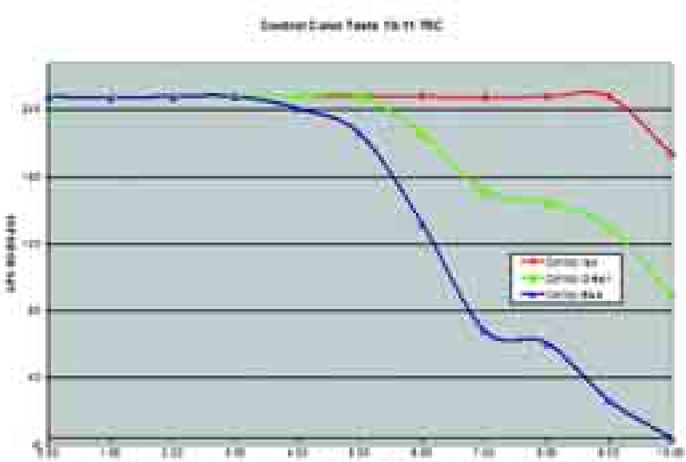


Figure 34: A control synthetic syrup:phenylalanine Maillard reaction at 75 °C. Note the rapid drop in the transmittance of blue bandwidths (increasing absorbance).

APS-RGB must first be correlated to both color and Brix (to adjust for sample concentration) before it can prove useful for juices, syrups or molasses. As it is, a simple correlation to ICUMSA color may prove useful for quick characterization of color in raw and refined sugars, perhaps as an online method.

## Direct Production of White Sugar: Results of 2004 Work

### Introduction

Raw sugar produced in Louisiana mills is of good quality with a low color. Thus suitable treatment of clarified juice can lead to the production of sugars for direct human consumption. These sugars can include the following special products:

1. White sugars (semi-white and white; white soft sugar)
2. Liquid sugars (invert liquid sugar; brown liquid sugar)
3. Yellow soft sugars (yellow soft sugar; demerara/muscovado sugar).

Depending on the sugar produced and on commercial opportunities, the production of these sugars could be between 25% and 100% of mill production. The advantages of such production in the mill are the ability to use the utilities available in the mills (hot water, steam, vapor, energy) and facilities such as the control laboratory and maintenance services. The proposed production scheme will include various adsorbents to purify the juice before evaporation, syrup clarification, crystallization, centrifugation, drying and screening. The sugar product to be used (juice, syrup, raw sugar) and the complete production scheme will depend on the product to be obtained. In the first part of this study done last year, a pilot column run at St. James mill gave encouraging results, suggesting that direct production of white sugar is feasible for Louisiana.

The production of edible sugars directly in sugar mills is an opportunity to diversify mill production with high added-value products. The results of this study will show the value to the industry or individual mills of production of direct consumption sugars. For a mill processing 1 million tons of cane a year, the potential benefit in terms of increased revenue is considered to be $6 million a year.

### Pilot Plant Description

The pilot plant project involved installing a dosing tank, a packed column and a small evaporator at the St. James sugar mill. After the dosing tank, the juice passed through the packed bed. The juice to be concentrated was then collected in a holding tank and later concentrated in a small evaporator. Because of the operation being run continuously, when the treated juice was not collected, it was returned to the mud tank. This is illustrated in Figure 35.

### Objectives

The specific research objectives are:

- Investigate various adsorbent treatments.
- Test the effects of oxidation reactions on juice in conjunction with different adsorbents.
- Perform crystallization tests on the resulting product.
- Study various regeneration schemes.

### Results

The color results comparing the feed color to the final product color are shown in Figure 36. Although more samples are still to be analyzed, the results are very promising even with minor experimental setbacks. The main problem encountered was the failure of

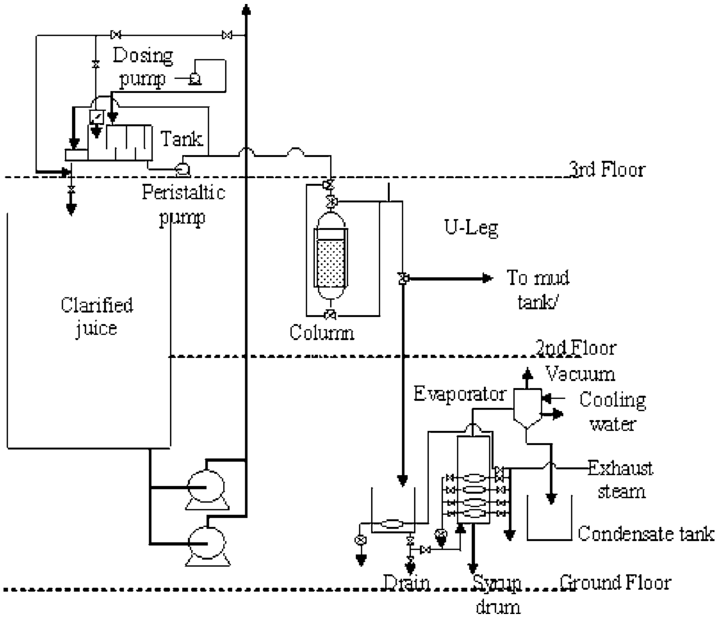


Figure 35: Flow diagram of St. James pilot plant.

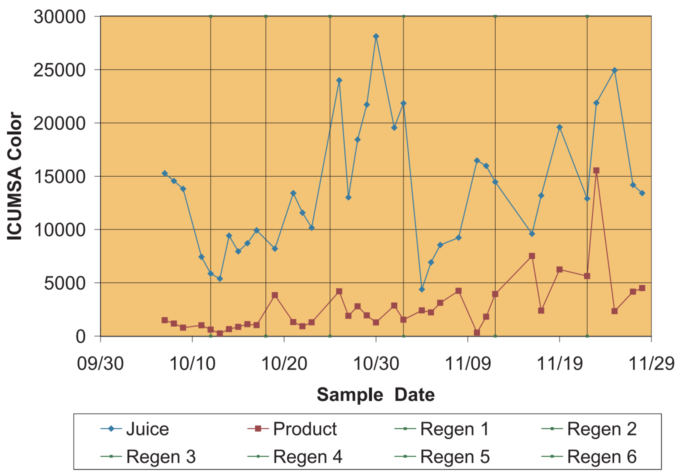


Figure 36: Comparison of ICUMSA colors of juice before and after column.

the peristaltic pump tubing with prolonged use. This problem improved by changing the pump head and the peristaltic tubing, but the tubing still required frequent changing. Other problems encountered were associated with the blocking of various thin tubes. Also, when an increased throughput was passed through the column, a larger pressure drop was witnessed across the bed. This could be attributed to increased mud deposition experienced at low flow-rates when large amounts of mud were present in the feed cane.

Crystallization tests are to be performed on syrup that was concentrated and collected using the evaporator. Approximately 20 gallons of syrup were collected, which will enable ion exchange work and other treatments to be performed on the product at a later stage.

Low temperature regenerations were used to regenerate the column. The regenerations were performed every seven to 10 days. The cleaning stages included a high up-flow water wash and various chemical washes. Various concentrations and flow-rates were tried during the regenerations as well as different regenerant temperatures.

## NIR Spectroscopy for Factory Control

Near Infrared (NIR) spectroscopy is an analytical technique that has been expanding into many industries for both analytical and control purposes. NIR is used widely in the food processing and grain industries throughout the world. Sugar industries in Australia and South America use NIR for factory control. NIR can provide analytical results faster than conventional analyses and can be used as a laboratory instrument or online. The main benefits of NIR are lower labor and chemical costs and more consistent analytical results.

Audubon has been building calibrations for juice and molasses for several seasons. Molasses, syrup and juice samples have been scanned on Audubon's Foss 5000 NIR and analyzed by ASI to obtain reference data for the past four seasons. Reference data include Brix, pol, sucrose, glucose, fructose and conductivity ash. The final molasses survey will be conducted using NIR for the 2005 season. All samples will be analyzed with the NIR, with only a portion being validated by conventional laboratory analyses.

Several NIR instruments from other vendors have been evaluated over the past years; none were able to provide reproducible scans for all products. Two vendors have shown promise and will be evaluated further. A lab test of one of these is in the planning stages and will be completed by the end of the 2004-2005 fiscal year.

The Enterprise Factory and Audubon Sugar Institute worked together to perform a proper evaluation in a factory laboratory to demonstrate the feasibility of a Foss NIR 5000 beverage analyzer for factory control in Louisiana. NIR proved to be at least as accurate as the factory laboratory and capable of providing multiple constituent analyses with one scan. Scanned samples were retained for HPLC analyses. The instrument will be calibrated against HPLC sucrose results. This will provide Enterprise Factory with the capability to acquire more accurate sucrose analyses in the factory control laboratory.

Audubon will continue to work with the Enterprise Factory in monitoring and updating the calibrations through the upcoming season.

## Juice Survey Results for the 2004 Grinding Season

Through the 2004 season, Audubon Sugar Institute analyzed weekly composite juice samples from Cora Texas, Raceland, Enterprise and St. James. For Enterprise, the samples were analyzed from two streams, juice from the mill tandem (dil. juice) and juice from the diffuser (draft juice), to compare the differences between these extraction techniques.

Figure 37 demonstrates related trends of the weekly averages of True Purity and (F+G)/Ash for the same years. Figures 38 and39 show the behavior of the above parameters plus the Target Purity for juice for from each mill. The strongest influence of the (F+G)/

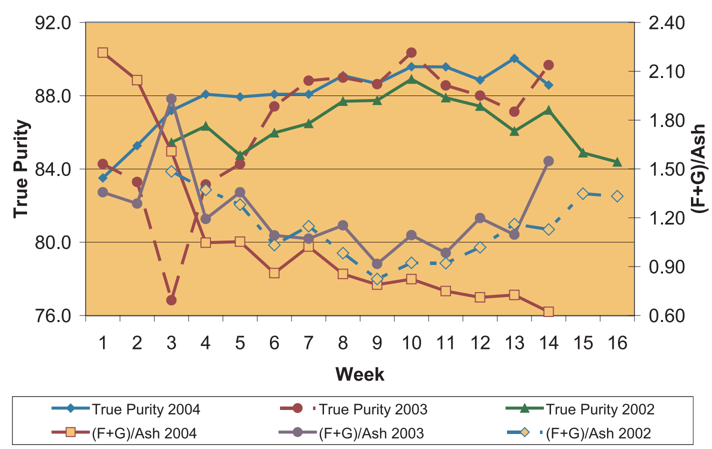


Figure 37: 2004 Weekly Averages of True Purity and (F+G)/Ash in Juice

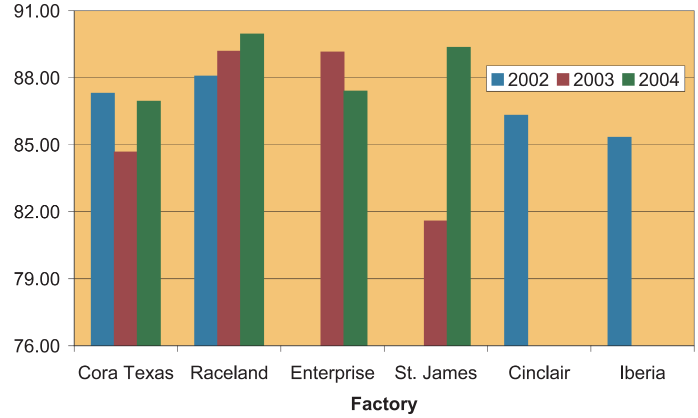



Figure 38: Juice True Purity of Participating Mills.

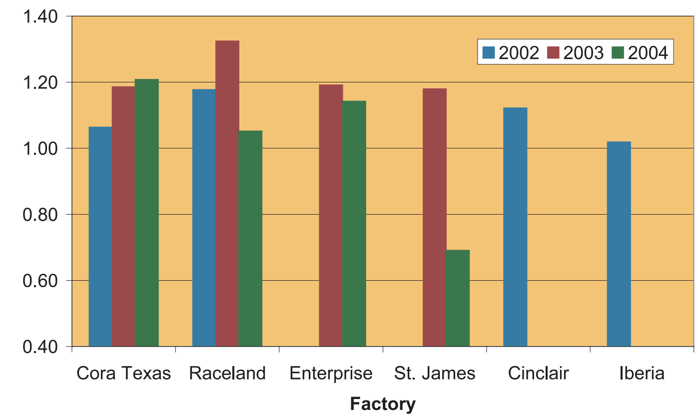



Figure 39: Fructose and Glucose to Ash Ratio in Juice of Participating Mills.

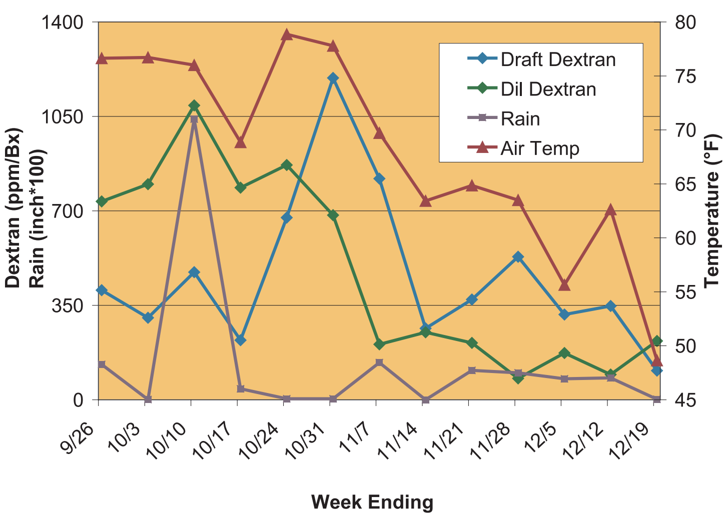



Figure 40: Dextran content of mill and diffuser juice plotted together with daily ambient temperature and rainfall.

Ash parameter in the Target Purity (desired exhaustion of final molasses) is clearly observed in the samples from St. James.

Figure 40 shows the difference in the concentration of dextran. At the beginning of the season, it was higher for the mill juice and then this relationship shifted about half-way through the season; it is not surprising to find some correlation between polysaccharide and the air temperature for the season. A comparison of the diffuser and mill juice at Enterprise shows that juice purities in both streams are almost identical but that starch is lower and color higher in diffuser juice.

## Final Molasses Survey Results for the 2000 to 2004 Grinding Seasons

Audubon reintroduced the final molasses survey for the 2000 season using HPLC sugars analyses to assess actual losses in final molasses more accurately. The normal measurements used in a sugar mill laboratory are not accurate enough at the low purities associated with final molasses to determine losses acceptably. Also, the measurement of reducing sugar levels is essential to determine achievable exhaustion.

Over the past five 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. Part of this evaluation has been the continued practice of running all analyses blindly with weekly check samples. Table 6 contains standard deviation data on select analyses and calculated results on the check samples that show progress made.

Table 6: Standard Deviations of Key Componenets of Molasses Check Samples.

| Year | Ref. Brix | App. Purity | True Sucrose | True Purity | Target Purity | T. P. Diff. |
|---|---|---|---|---|---|---|
| 2000 | 1.01 | 0.89 | 1.14 | 1.19 | 0.37 | 1.36 |
| 2001 | 0.44 | 0.66 | 0.49 | 0.69 | 0.14 | 0.68 |
| 2002 | 0.27 | 0.77 | 0.32 | 0.40 | 0.11 | 0.44 |
| 2003 | 0.15 | 0.68 | 0.42 | 0.54 | 0.14 | 0.56 |
| 2004 | 0.13 | 0.85 | 0.30 | 0.36 | 0.18 | 0.40 |

The average weekly Target Purity Differences (TPD) values for 2004 are graphed with the yearly averages from the past seasons in Figure 41. Expected trends due to startup and liquidation and cane maturity continued. Table 7 contains the average target purity, TPD, F/G ratio, F+G, (F+G)/ash ratio, and ash for the past five seasons. The TPD was higher for 2004 and total reducing sugars dropped a little, resulting in a slightly higher target purity. In Table 7 one can see that the F/G ratio has dropped from 1.68 to 1.35 from 2000 to 2004.

Table 7: Final Molasses Survey Data Summary for 2000-2004

| | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|
| TP | 35.5 | 33.3 | 34.0 | 33.6 | 34.3 |
| TPD | 10.2 | 10.5 | 10.4 | 8.9 | 9.9 |
| Ash | 18.9 | 16.8 | 17.1 | 17.3 | 17.1 |
| F+G | 15.7 | 18.8 | 16.9 | 18.2 | 16.2 |
| F/G | 1.68 | 1.41 | 1.44 | 1.33 | 1.35 |
| (F+G)/Ash | .78 | 1.14 | 1.00 | 1.07 | .97 |

A significant increase in the TPD for 2004 was observed. The 2004 season was wetter and warmer than the 2003 season. 2003 was a dry season compared to the last five. Higher ambient temperatures and more rain made 2004 more demanding on the processors, resulting in higher TPDs. Plotted in Figure 42 are the average fructose plus glucose to ash ratios for the past five seasons. The average weekly Pol/sucrose ratios are shown in Figure 43. Lower F/G ratios indicate that Maillard reaction has been decreased, improving exhaustion conditions. A comparison of juice, syrup and final molasses data from three mills is illustrated in Table 8.

Analysis of the data in Table 8 reveals little difference between the juice and syrup of the three submitting mills. One mill sends nothing back between juice and syrup sample points (some mills recycle magma to clarified juice), which allowed for a calculation of sucrose loss to inversion through evaporation. The loss was 0.28%, a reasonable value.

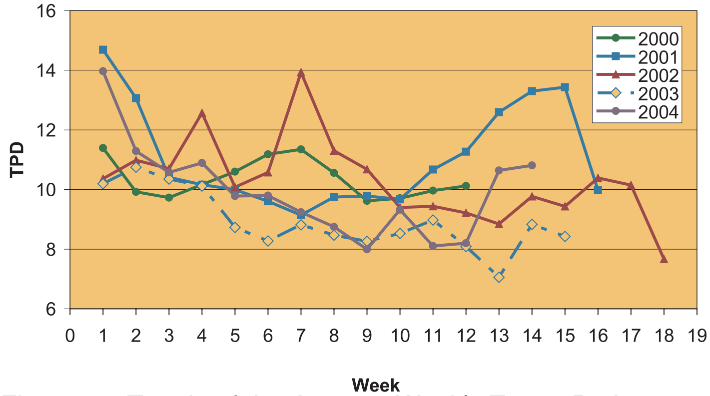



Figure 41: Trends of the Average Weekly Target Purity Differences over the Last 5 years.

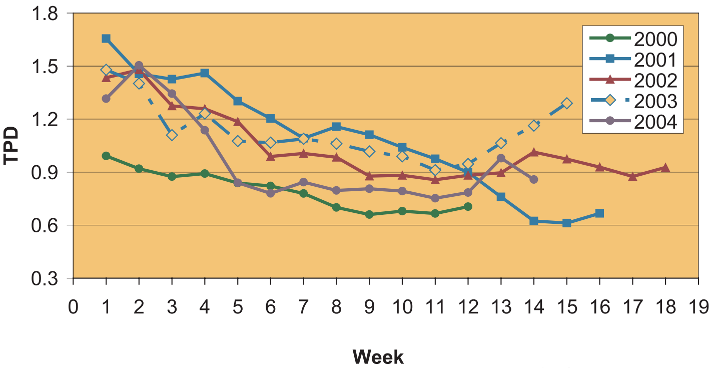



Figure 42: Trends of the Average Weekly (F+G)/Ash Ratios over the Last 5 Years.

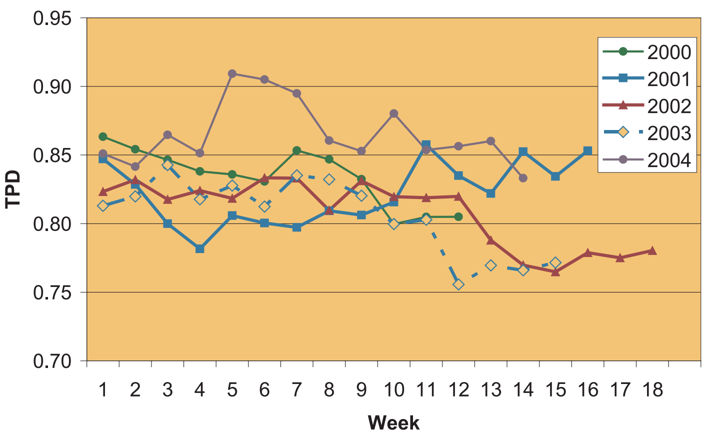



Figure 43: Trends of the Average Pol/Sucrose Ratios over the Last 5 Years.

Table 8: Comparison of Juice, Syrup and Final Molasses 2004 Season

| | Pol/Sucrose Ratio | F/G Ratio | Ash % Brix | (F+G)/Ash Ratio |
|---|---|---|---|---|
| Juice | 0.96 | 1.12 | 4.0 | 1.02 |
| Syrup | 0.97 | 1.06 | 3.6 | .99 |
| Final Molasses | 0.86 | 1.40 | 16.8 | 1.02 |

## Feasibility Study on the Production of Fuel Alcohol from Louisiana Molasses

The use of ethanol in a blend of 10% ethanol in gasoline does not require any modifications to be made to automobiles, helps reduce the country's dependence on imported fuels and provides a cleaner burning fuel. A study was undertaken to look at the feasibility of using molasses to produce fuel alcohol.

When the price of molasses is low, the opportunity exists to add more value by fermenting the sugars in molasses to ethanol. The quantity of molasses produced averages 450,000 each year. Most ethanol plants are more economically viable at a large size. It would pay to have a single plant to process all the Louisiana molasses.

Ethanol production from molasses is a well-developed technology and is essentially a risk-free investment technically. The level of technology is similar to that involved in sugar production and integrates well into a sugar factory operation. The ethanol concentration in the fermented liquor is normally about 9% by volume and is recovered by distillation. It is general practice to produce ethanol in anhydrous form for use as a fuel extender.

Rectification produces ethanol as a constant boiling ethanol-water azeotropic mixture containing about 96% ethanol by volume. Traditionally the remaining water has been removed by azeotropic distillation involving the addition of cyclohexane. A better option now available involves dehydration using molecular sieves. The ethanol leaves rectification as a vapor, and water is adsorbed in zeolite-packed beds. Periodically these adsorbents need to be regenerated by flooding them with ethanol vapor, which strips off the water and is returned to distillation. The ethanol is produced at a quality of 99.8% ethanol and is denatured before being pumped to rail tank cars for transport. Steam requirement is estimated to be 2.8 kg/l or 45 t/h.

By contrast to ethanol from corn, the effluent product in the ethanol from a sugarcane plant is generally the source of a severe problem. Of the options available, the use of a high-rate anaerobic reactor is considered to be the best. The biogas produced has value as a fuel for use in the boilers and helps offset the cost of treatment. The liquid from the anaerobic reactor does not meet standards for re-use or disposal and must be put into ponds, or an activated sludge plant is required.

In Louisiana, the average molasses analysis of 35.4% sucrose and 14.6% invert, if converted to an equivalent sucrose basis, is 49.2% sucrose. Assuming a yield (fairly conservative) of 141.6 gallons per ton sucrose (590l ethanol/metric ton), one ton of molasses will yield 69.7 gallons of ethanol. Based on 450,000 tons of molasses per year, annual ethanol production will be 31.4 million gallons a year. Assuming the plant operates 330 days a year, this implies a production rate of 95,000 gallons a day.

Ethanol production is not a capital-intensive process. The capital cost of a plant to produce 32 million gallons a year was an estimated $41 million. This includes the cost of a biogas stillage treatment facility and an allowance for infrastructure and integration into a sugar mill. The major element in the cost of production is the cost of the raw material, molasses. The price of cane molasses varies over time, generally in the range of $40 to $60 per ton. It has been well established that the cost of production depends on the cost of the feedstock, which generally represents two-thirds of the total cost. In this case, a cost of production of $1.08 per gallon is expected. Ethanol prices are historically quite variable, but they have been consistently around $1.40 for the past two years.

Gasoline blended with 10% ethanol is exempt from 5.3 cents of the 18.3 cents per gallon federal excise tax on gasoline. This provides an effective subsidy of 53 cents per gallon of ethanol produced when used in gasoline at 10%, generally making it cost competitive with MTBE as an additive for improving the octane rating.

Assuming that ethanol can be made for $1.08 a gallon and sold for $1.40 a gallon, the annual net earnings on 31.4 thousand gallons per year are $10.4 million. Based on an initial capital outlay of $41 million, a simple payback period of 3.9 years is indicated. Based on initial approximate estimates, it appears that the production of ethanol from final molasses may be a commercially

viable proposition in Louisiana. The viability is sensitive to the price that can otherwise be obtained from molasses and the long-term sustainable price for fuel alcohol.

In view of restrictions on sugar production with quotas, special circumstances may make ethanol production from B molasses a viable option.

## A Nutraceutical from Sugar

Last year we highlighted research that led to a new functional food additive produced from sugar. This research is being pursued, with the support of the American Sugar Cane League, toward the production of this material in final molasses. The goal is to upgrade the value of the molasses that is used in animal feed. The presence of the nutraceutical could potentially add value to feed products made from molasses while increasing the selling value of the molasses at the mill. This year we hope to validate the production process in blackstrap molasses and plan a pilot scale system for a Louisiana mill for 2006.

Non-therapeutic antibiotic growth promotants (AGPs) are used to promote feed efficiency for food-producing animals and poultry; however, the use of antibiotics, particularly as growth promotants, has been recognized as a factor in the international emergence of antibiotic-resistant bacteria in human health and agriculture. Competitive exclusion (CE) is a promising approach to the control of Salmonella in poultry, and it has been confirmed by a number of studies. The CE agents are considered to exert their effect by one or more of four general principal actions, namely the creation of a restrictive physiological environment, competition for bacterial receptor sites, elaboration of antibiotic-like substances (for example bacteriocins) or depletion of essential substrates. The precise mechanism of the protective effect is unknown and may never be determined because of the complexity of the gut as a habitat for microorganisms and the variety of host-microbe and microbe-microbe interactions that can occur.

Many oligosaccharides, when fed to animals or humans, can reach the colon unchanged, providing a carbohydrate substrate particularly suited to the growth of probiotic microorganisms such as the bifidobacteria and some lactic acid bacteria. Bifidobacteria and lactic acid bacteria are beneficial microorganisms, thought to create conditions unfavorable to the growth of pathogens, such as Salmonella. Consequently, an increase in growth of Bifidobacterium and lactic acid bacteria with a decrease of Salmonella would benefit the host animal. The use of oligosaccharides as prebiotics should lead to the production of intestinal lactic acid, an increase in short-chain fatty acid production and lowering of pH in the large intestine, thereby being a potential feed additive that can help prevent colonization by pathogenic bacteria.

Table 9: Test Results of isomaltooligosaccharide on poultry

| | Control | 1% Nc diet |
|---|---|---|
| Feed efficiency kg weight gain/kg feed | 0.58 | 0.67 |
| Cecal pH | 5.81 | 6.63 |
| Salmonella Loading cfu/bird x107 | 3600 | 3.0 |

Isomaltooligosaccharides have been produced from sucrose. In vitro study by Chung and Day (2002) showed that isomaltooligosaccharide (IMO) was used preferentially by strains of Bifidobacterium bifidum, B. longum and Lactobacillus johnsonii. Ultimately, it was hoped that adding isomaltooligosaccharide (IMO) to poultry feed would lead to microbiological control and improve bird performances, allowing for more consistent production responses in the absence of prophylactic antibiotics.

Rat toxicity testing showed that IMO is a safe dietary additive. Testing on poultry at the USDA showed significant positive changes in broilers feed a standard diet with 1% Nutraceutical as an additive. Changes included a drop in Salmonella loading in the birds and a 16% gain in feed efficiency. More extensive testing is needed to prove commercial viability.

## Sugarcane Biorefinery Program – Conversion of Cellulose to Fuel and By-products

Significant research effort at ASI has gone into a joint program with Michigan Biotechnology Institute (MBI) toward the development of an alcohol and by-product process using sugarcane biomass as a feedstock. We are working to produce a small-scale process that will produce sufficient feedstock for fermentation testing. Hydrolysis of cellulose in bagasse to fermentable sugar requires a method of removing or reducing the amount of lignin and hemicellulose in the feedstock, thus increasing cellulose availability to hydrolytic agents. MBI has an ammonia explosion process (AFEX) that works on corn stover and is being tried on bagasse.

Pretreatment of biomass with ammonia (AFEX) is a promising technology for biomass-to-ethanol conversion. Additional enhancements to the basic process that is licensed from the inventors by MBI are being investigated at Audubon. It is expected that partial removal of lignin and hemicellulose from AFEX-treated biomass before enzymatic saccharification will lead to increased activity of the cellulose enzymes and improved economics of the overall process.

A series of tests performed with samples of CLM (cane leaf matter) solids that were processed before the extraction by the AFEX process at the laboratories at MBI in Lansing, Michigan, is illustrated in Figure 44. Some 15% to 25% of the mass of AFEX-treated samples (dry weight basis) can be extracted with water at 100 °C, and more so with 1% solutions of sulfuric acid (acid extraction) and sodium hydroxide (alkali extraction).

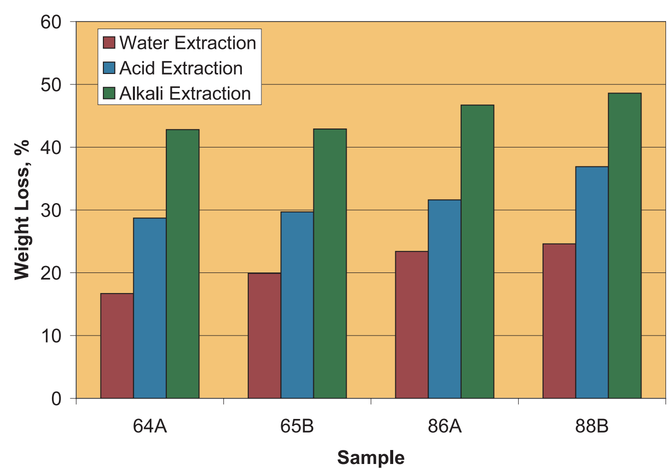



Figure 44: Extractability of AFEX-treated cane leaf matter (CLM).

For higher temperature tests, the 2-gallon Parr reactor at ASI was modified by welding a fine screen to its bottom to prevent plugging of the bottom discharge valve, and coupled with a smaller ½-gallon Parr reactor to allow separation of the extract from the fiber at the pressure and temperature during extraction. Extraction tests at 120 and 140 °C were performed; the results of four tests at 120 °C are reported in Table 10.

Table 10: Aqueous Extraction: 1 or 2 L of water - 120 °C - 1 hour

| Sample | Feed Mass (g) | Feed DS (%) | Product Fiber (g) | Product DS (%) | Product Extract (g) | Product DS (%) | Weight Loss (%) | Recovery (%) |
|---|---|---|---|---|---|---|---|---|
| CLM (as is) | 100.9 | 91.6 | 413.0 | 21.0 | 1641.0 | 0.7 | 6.2 | 106.3 |
| AFEX CLM 64A, 65B, 66A, 66C | 99.6 | 56.5 | 160.7 | 22.0 | 820.0 | 1.6 | 37.2 | 86.1 |
| AFEX CLM 83B, 85B, 86A, 86B | 101.5 | 69.1 | 215.3 | 22.8 | 730.0 | 2.9 | 30.0 | 100.2 |
| AFEX Bagasse 91A, 91B, 94B, 98B | 100.9 | 82.8 | 294.0 | 22.1 | 710.0 | 1.9 | 22.2 | 93.9 |

Table 11: EtOH Extraction: 1 L 100% ethanol - 120 °C - 1 hour

| Sample | Feed Mass (g) | Feed DS (%) | Product Fiber (g) | Product DS (%) | Product Extract (g) | Weight Loss (%) |
|---|---|---|---|---|---|---|
| CLM (as is) | 45.0 | 90.9 | 61.1 | 70.0 | 512.0 | -4.6 |
| AFEX CLM 64A, 65B, 66A, 66C | 104.0 | 49.0 | 84.3 | 55.3 | 656.0 | 8.5 |
| AFEX Bagasse 99A, 99B, 100A, 100B | 134.0 | 75.1 | 95.1 | 92.4 | 574.0 | 12.7 |

Table 12: EtOH Extraction: 1 L of 100% ethanol – 140 °C - 1 hour

| Sample | Feed Mass (g) | Feed DS (%) | Product Fiber (g) | Product DS (%) | Product Extract (g) | Weight Loss (%) |
|---|---|---|---|---|---|---|
| AFEX CLM 64A, 65B, 66A, 66C | 94.9 | 53.9 | 67.9 | 69.4 | 677.0 | 7.9 |
| AFEX CLM 83B, 86B, 87A, 88A | 104.4 | 56.5 | 67.7 | 78.5 | 634.0 | 9.9 |
| AFEX CLM 83B, 85B, 86A, 86B | 94.0 | 70.1 | 59.3 | 94.8 | 717.0 | 14.7 |
| AFEX Bagasse 91A, 91B, 94B, 98B | 100.0 | 57.9 | 57.8 | 89.5 | 712.0 | 10.7 |

Ethanol is a good solvent for lignin and used in the Alcell wood pulping process. Tests with ethanol pulping of bagasse were reported recently by researchers in Brazil. A series of extractions of AFEX-treated bagasse and CLM solids with anhydrous ethanol at 120 and 140 °C are reported in Tables 11 and 12, respectively. The weight loss (extractability) is in the range of 10% to 15% (dry weight basis), less than with water at comparable conditions.

Fine-powdered samples of lignin were prepared by spray-drying the concentrated water and ethanolic extracts, giving light brown products with 20% and 2% sugar content, respectively. The industrial applications of the sugarcane lignin are being explored.

Other methods of pretreatment are also being investigated. One such method is the use of oxidative compounds such as Audubon's newly patented "biocide."

A singlet oxygen-producing complex [biocide] (US Patent 6,866,870) was found to remove both lignin and hemicellulose from sugarcane bagasse. After treatment, the cellulosic residue is readily separated from the lignin and hemicellulose by sedimentation. The pulp produced contained up to 80% by weight cellulose. This pulp was 50% degradable by cellulases. The treatment of oxidation, followed by a caustic wash, produced a solid that could be 85% and 100% degraded to simple sugar by cellulases. The pulp from this process can be used to produce a non-acid paper.

Because the cost of conversion is vitally important to the success of a biorefinery, especially if the major product is fuel ethanol, pretreatments with lower concentrations of chemicals, followed by a 0.6% NaOH wash were tested (Figure 46). Success with a post-treatment has led us to try a series of sequential treatments. This test matrix will be expanded and combined with AFEX treatments. The nature of the lignin produced with each treatment must also be considered because it is a potential source of major byproducts from a biorefinery.

Figure 45: Bagasse paper produced after oxidative/caustic treatment from bagasse.

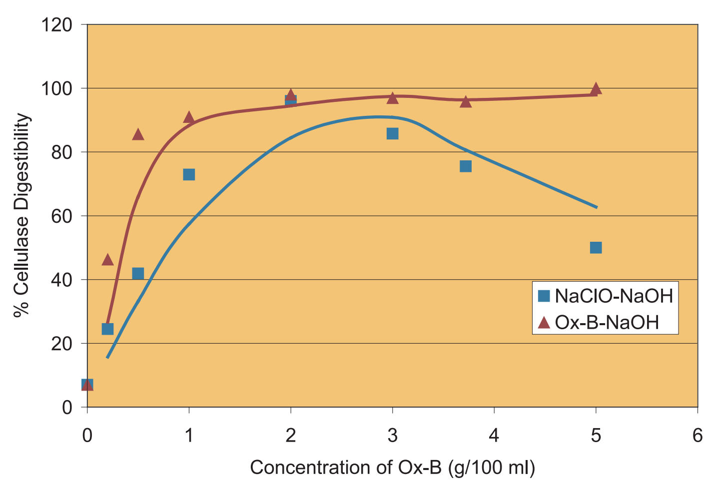



Figure 46: Cellulase digestibility of bagasse treated with NaClO or Biocide followed with a 0.6% NaOH wash.

## Fiber Products from Sugarcane Bagasse

Experimental work was initiated to demonstrate a process for continuous production of erosion mats for temporary protection from erosion of roadsides during and after construction. These materials were identified as potential new sugarcane by-products in discussion with the Louisiana Department of Transportation and Development and a local distributor of the current wood and straw-based products. Two "wet laid" arrangements to form the mats at Audubon's pilot plant were tested: a "suspension" design, and a simpler "nozzle" design. The nozzle design appears to be more suited for the production of mats with acceptable uniformity. These tests also pointed toward de-pithing (removal of short fibers) and softening of the fibers by pre-cooking with alkali (soda ash liquor) as a more promising approach that is now being pursued. On the other hand, the short pith fibers are considered a more promising material for enzymatic conversion to ethanol than whole bagasse.

Figure 47: Testing a process for continuous production of erosion tests from bagasse fibers.

### Thermo-chemical Conversion of Sugarcane Biomass

A series of sodium carbonate-catalyzed liquid pyrolysis tests of bagasse and CLM solids at 300 °C was performed in a 2-gallon pressurized reactor to investigate basic parameters of conversion of sugarcane biomass to fuels and chemicals.

Approximately 40% to 50% of the dry weight of feed biomass was converted to oils and tars in the form of an emulsion with the alkali liquor, 10% to 20 % was converted to a gas product, mostly carbon dioxide and carbon monoxide, and the rest formed the char solid residues.

Table 13: Mass balance on sugarcane biomass soda ash catalyzed pyrolysis tests.

| Run - Starting material | Feed (g) | Liquid Product (g) | Solid Product (g) | Gas Product (g) |
|---|---|---|---|---|
| 1 – Bagasse | 90.0 | NA | 10.4 | NA |
| 2 – Bagasse | 90.0 | 44.2 | 28.7 | 17.1 |
| 3 – CLM | 86.0 | 38.3 | 30.8 | 16.9 |
| 4 – CLM | 86.0 | 43.2 | 25.6 | 17.2 |
| 5 – CLM | 86.0 | 53.4 | 23.0 | 9.6 |
| 6 – CLM | 86.0 | 51.3 | 26.3 | 8.4 |
| 7 – Bagasse | 90.0 | 50.3 | 27.7 | 12.0 |
| 8 – Bagasse | 90.0 | 46.3 | 28.0 | 15.7 |

GC-MS characterization of the organic extracts of the aqueous fractions is under way.

Preliminary batch gasification tests of sugarcane bagasse and CLM solids were organized and performed (Figure 48) at the Technology Development Laboratory of Shaw Environmental and Infrastructure, Inc., in Knoxville, Tenn., a division of the Shaw Group Inc. of Baton Rouge. Shaw's patented gasification technology is designed to convert agricultural waste and other materials to useful by-products and energy. Effect of catalysts, such as $Na2CO3$, MgO and CaO were investigated at gasification temperatures of 600 to 850 C.

Figure 48: The rotary thermal apparatus (RTA) employed in the sugarcane biomass gasification tests.

## New Equipment: Agilent 1100 High Pressure Liquid Chromatograph (HPLC)

Funded in part by the Louisiana Board of Regents, the American Sugar Cane League and Cargill foods, the Color Removal project has begun to bear fruit by enhancing the arsenal of analytical tools that the Audubon Sugar Institute (ASI) may bring to bear when solving research and extension-related chemical problems where the separation of complex mixtures is required.

In this case, ASI has acquired an Agilent 1100 HPLC quaternary gradient HPLC shown in Figure 49.

The instrument was provided with a photodiode array detector (DAD), which simultaneously acquires UV-VIS spectra from 180-900nm. For example, Figure 50 displays a full spectral matrix.

When interfaced with Agilent 3D Chemstation, up to five chromatograms at different wavelengths may be extracted from the spectral matrix simultaneously. A sample of extracted chromatograms is given in Figure 51.

Provided with an autosampler capable of handling 100 samples, the new instrument is more than able to handle the rigorous throughput required of multidimensional experimental matrices and routine extension work. The autosampler (Figure 52) also can allow us to remove the column and use the DAD as a flow injection analysis system (FIA). FIA is useful because it is fast (less than 1 minute) and can return the full UV-VIS spectrum.

Affixed to this system is an ESA Chromachem ELSD. The ELSD is a non-selective mass-sensitive detector that is capable of

detecting non-colored materials (carbohydrates) with great sensitivity. In other words, the ELSD can "see" what the DAD cannot. In tandem, the two detectors can provide the whole picture of what is going on in a particular system. For example, we could simultaneously measure change in sugar concentrations relative to formation of colored materials. Further, relative mass can be derived from ELSD data. Coupled with extracted UV-VIS spectra provided by DAD, we can tentatively elucidate the identities of well-resolved components of unknown complex mixtures. This helps us greatly by increasing throughput and accuracy when attempting to acquire absolute structural identification using techniques such as mass, Fourier transform infrared or nuclear magnetic resonance spectroscopy.

Figure 49: Agilent 1100 HPLC, from top-to-bottom, vacuum eluent degasser, quaternary gradient pump, autosampler, column heater, photodiode array detector, and, to the left, an ESA Chromachem evaporative light scattering detector (ELSD).

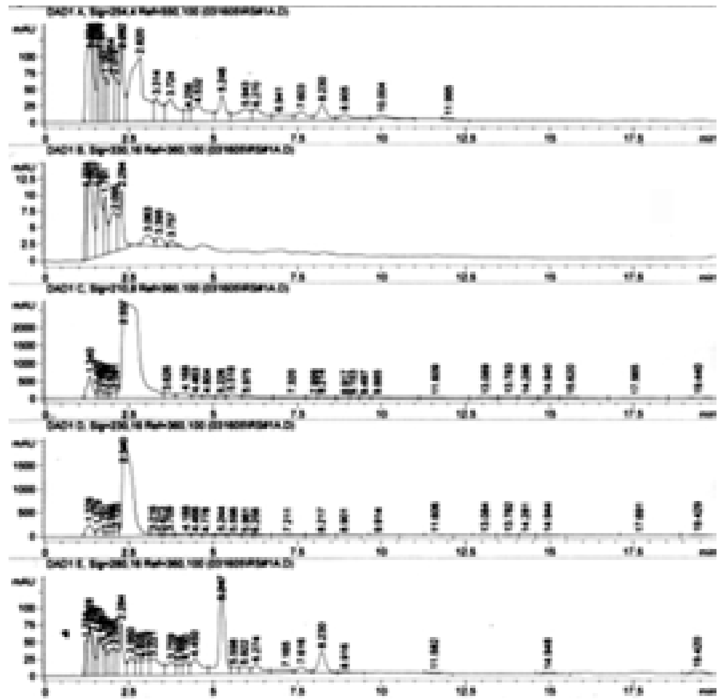


Figure 51: Simultaneously extracted chromatograms for colorant material isolated from raw sugar. From top to bottom, these chromatograms are extracted from the spectral matrix at 254, 330, 210, 230 and 280 nm.

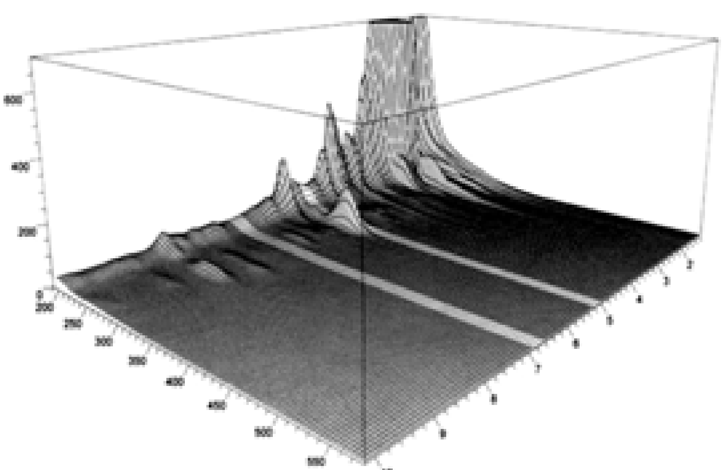


Figure 50: A full spectral matrix displaying x, reverse time, y, wavelength from 200-580nM, and z, absorbance in milli-absorbance units (MAU).

Figure 52: Agilent 1100 autosampler; note the 100 sample tray and robotic arm.

# Extension Work

## Ash % Bagasse

Ash % bagasse was determined for samples collected by the American Sugar Cane League as part of a harvester fan speed study. Ash % bagasse was also determined for several boiler efficiency tests.

## Boiler Tests

Boiler efficiency tests were performed at several factories where natural gas consumption was higher than normal and/or where there was simply a desire for higher efficiency. Two official boiler emissions tests were performed during the 2004 crop.

## Preparation Index and Milling Tests

The preparation index was measured at four factories. Mill pol extraction was determined for each mill in the tandem at two of these mills.

## Cane Analysis Core Lab

Two factories requested help in reviewing their core lab procedures. Direct cane analysis at one core lab verified the factory's core lab results, and suggestions were given to the other factory for improving its procedures.

## Undetermined Losses/Overall Chemical Control

A few factories requested a review of their chemical control and undetermined losses. Independent checks on key analyses were performed.

## Cold Tolerance Tests

Collaborative work with LSU AgCenter Extension and USDA personnel was undertaken to monitor the rate of deterioration of various cane varieties following the freeze in December.

## Harvester Pour Rate Tests

Samples were analyzed for theoretical recoverable sugar as part of a study on the effect of harvester pour rate tests conducted by USDA and American Sugar Cane League personnel.

## Juice Heating Using Vapor 2.

Advice was given to two mills on the incorporation of vapor 2 heating of mixed juice and the effect on evaporator capacity. Both steam economy and evaporator capacity are significantly improved.

## Design of Feed Systems for Evaporators

Advice was given to two mills on modifying the juice feed arrangements, with a peripheral feed replacing the center feed arrangement.

## Continuous A Pan Design Details

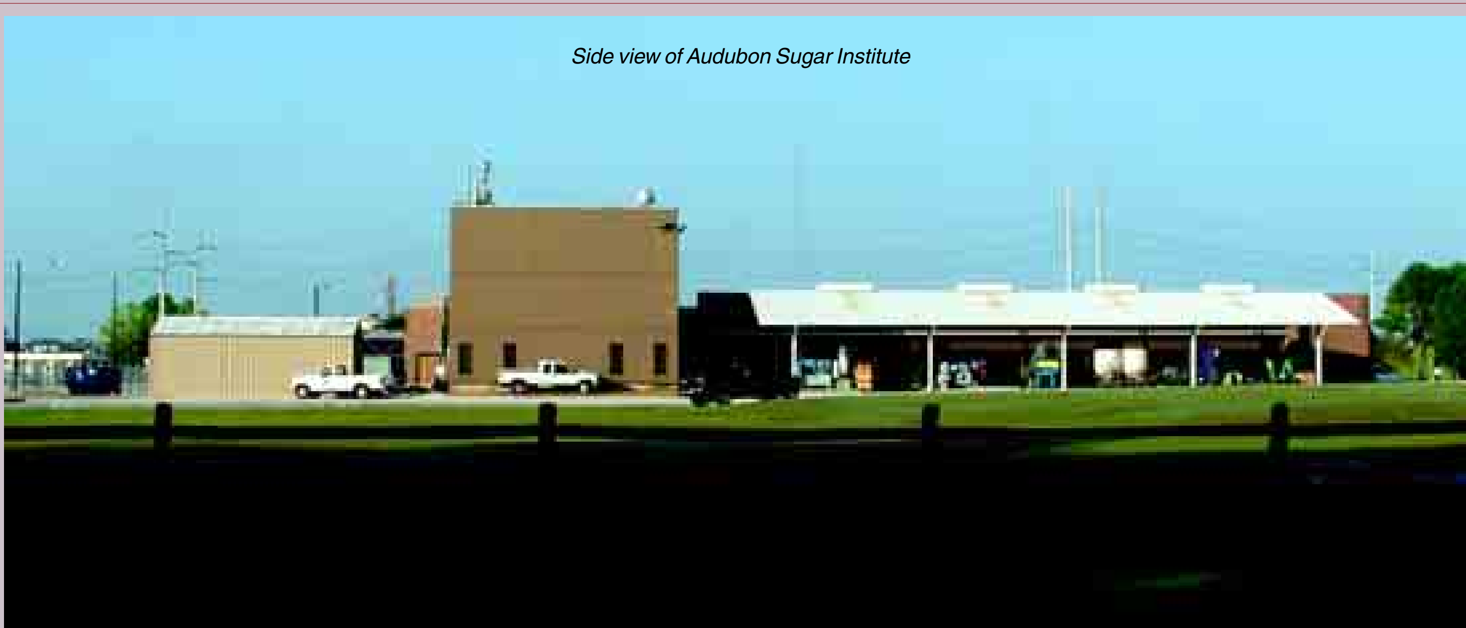
Assistance was given in the finalization of details of a new 160 $m^3$ continuous pan. The pan tube length was reduced to 55 inches (1.4 m) and steam was admitted from only one side of the calandria. Measurements on the calandria showed a pressure difference of only 7 inches WG (0.25 psi) from one end of the calandria to the other.

## Remelter Design

A three-compartment remelter was designed and installed at Enterprise mill. The design is free of glands that can leak, and elimination of surplus magma recycle reduces unnecessary exposure of the remelted sugar to high evaporator temperatures. Remelting with clarified juice also assists steam economy.

## Mill Technical Audit

A detailed evaluation of one of the Louisiana mills was undertaken and a report submitted on equipment and operation of the mill.



*Side view of Audubon Sugar Institute*

## Audubon Sugar Institute Analytical Capabilities

Audubon has eight operational HPLC systems. Three units are ion chromatography units, one set up for cation analyses and the other two for anion analyses including organic acids. An ion exchange chromatography unit is dedicated to alcohol, sugar and oligosaccharide analyses. Two HPLCs are used for routine sugar analyses on juice, syrup and molasses and other process samples as well as project samples. One other HPLC is set up for sugar analyses for special projects. Another HPLC system was purchased through a grant from the Louisiana Board of Regents. 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 to 950 nm. With the ESLD attached, the system is capable of determining components present in low levels because of its high sensitivity. The Agilent system will be used mostly for color studies and analysis of high molecular weight compounds.

An Agilent 6890 gas chromatograph (GC) has been purchased and used mainly in analyses of alcohols and biogas. Additionally, three other similar units were donated to Audubon. Two of the donated GCs have been installed, one of which has a thermal conductivity detector ideal for gas analyses. A license for the Agilent software was purchased to control the two GCs.

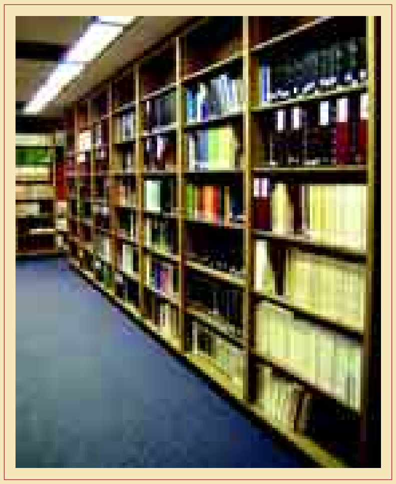
Analytical instrumentation acquired includes a Graphite Furnace Atomic Absorption Spectrophotometer, a refractometer, a polarimeter, two refractive index detectors, four autosamplers and a conductivity meter. The refractometer with 0.01 Brix resolution has temperature compensation capabilities; the polarimeter with 0.01°Z resolution has both 589 and 880 wavelength for sucrose by Pol. The conductivity meter is also equipped with temperature compensation for conductivity ash. Audubon also has a Near-Infrared (NIR) Transmittance Spectrophotometer that will be used for molasses survey samples for the 2005 season.

Audubon attributes its success in the upkeep of its analytical facility to the efforts of lab personnel to improve equipment reliability and quality control. The team is experienced and capable, not only to operate the instruments but also to install, upgrade and maintain them. With this team involvement, Audubon will continue to enhance its analytical capability even further.

*Research associates Stella Polanco and Chardrie Verret run calibration on the Near Infrared Spectrophotometer and correlate the data during the 2004 off-crop season before the equipment is used in the mill lab at Enterprise Factory.*

*Preliminary work investigating the correlation of starch content with viscosity has been ongoing since 2004. This starch analysis is now a project that is funded by the American Sugar Cane League for 2005.*

# LIBRARY & PUBLICATIONS



## Library

The Audubon Sugar Institute Library offers a good selection of the most up-to-date books on sugar processing and engineering fundamentals and a wide range of chemical engineering and chemical journals and abstracts. Also available are local and international sugar periodicals such as The Sugar Bulletin, ZuckerIndustrie, Louisiana Sugar Journal, and International Sugar Journal. The library currently consists of over 4,000 books and journals and has been a useful resource for researchers within the department and many others related to the sugar industry.

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# TRAINING & EDUCATION

## LSU AgCenter, Audubon Sugar Institute Short Courses

Audubon Sugar Institute continued its short course program in 2004, with three new classes added to the list. The short courses have traditionally been offered as spring and fall sessions that coincide with the off-crop season. These courses qualify for Continuing Professional Development for registered professional engineers but are designed to increase knowledge of people at all levels in the sugar industry. The participants in the short courses this year represented both Louisiana and the Florida sugar mills.

Audubon Sugar Institute courses can be viewed online at www.lsuagcenter.com/audubon/. Courses offered in 2004 included:

### An Introduction to the Technology of Sugar Production – Two days

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

### Cane Sampling and Cane Payment – One day

Offered for the first time this year, this one-day course provided an understanding of how value is assigned to cane in terms of its recoverable sugar, its effect on mill costs and the incentives implicit in the various cane payment systems used in Louisiana and around the world.

### Energy Efficiency in the Raw Sugar Mill – One day

This new course is designed to help individuals involved in the operation or design of sugar mills to understand the issues affecting efficient use of steam and energy in a sugar. The syllabus includes methods of determining steam requirements and the factors affecting these requirements, and options for reducing the overall usage.

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

This refresher course was 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.

### Bagasse Boiler Operation – Two days

The course objective was to provide boiler plant operations personnel with 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 incorporated. This year, a site visit was included to observe a boiler operation at the neighboring Syngenta Crop Protection, Inc.

### Chief Chemist – Four days

This course was designed for chemists, process engineers and managers who need 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.

### Bench Chemist – Four days

This course was developed to suit newly employed bench chemists in a raw sugar factory who are 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.

### An Introduction to 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 participants how to boil pans and allowed hands-on trials in making sugar on ASI's pilot plant.

*Post doctoral researcher Dr. Chung conducts fermentation studies using a 2-l fermentor acquired through a Louisiana Board of Regents grant.*

## Degree Courses for Sugar Engineers at LSU

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.

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 degrees in Chemical Engineering, Biological Engineering, 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 two years ago continue 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 are listed at www.lasuagcenter.com/audubon.

### 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 to 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, using this period as an internship yielding 3 credit hours (allowed for in BE 3249). This could substitute for one of the required courses but would probably require a slightly longer time in which to complete the degree.

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

Students are recruited to earn a master's in Chemical, Mechanical or Biological Engineering. This 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 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. He or she would be given maximum exposure to sugar processing at every opportunity.

### Options for presenting the Sugar Engineering Courses as Condensed, Intersession or Continuing Education Courses.

As an alternative or in addition to the normal course arrangement, consideration will be given to condensing the Sugar Engineering courses into full-time intensive courses held over a three-week period during the summer. This course could be opened to outsiders through a Continuing Education program.

*Graduate student Irina Dinu handles a pressurized reactor that is being used to run pyrolysis studies on bagasse and cane leaf matter.*

# FACULTY & STAFF


## Faculty and Staff

### Administrative Staff

**Dr. Peter Rein**, Professor and Head –BSc. and MSc. Chemical Engineering (University of Cape Town, South Africa), Ph.D. Chemical Engineering (University of Natal, South Africa)

**Jane Crawford,** University Administrative Specialist

**Lanelle Mabile,** Administrative Assistant

**Melati Tessier,** Research Associate Specialist – B.S. Chemical Engineering (Louisiana State University)

### Factory Staff

**Julie King**, Research Associate – Factory Manager – B.S. Mechanical Engineering (Louisiana State University)

**Ron Giroir**, Research Associate – Electronics/Instrumentation Engineer – B.S. Industrial Engineering (Louisiana State University)

**Lamar Aillet**, Maintenance Foreman

### Analytical Lab

**Brian White,** Research Associate –Analytical Chemist –B.S. Chemistry (Freed-Hardeman University)

**Stella Luz Polanco Duque,** Research Associate – B.S. Chemical Engineering (Universidad del Valle, Colombia)

**Lee Madsen,** Research Associate – B.S. Chemistry (Louisiana State University)

**Chardcie Verret,** Research Assistant – B.S. Chemistry (Southern University)

**John Daigle,** Student Worker – B.S. Biology (Nicholls State University)

**Morgan Stelly**, Student Worker

**Michael Robert**, Student Worker

**Jordan Aillet**, Student Worker

## Faculty and Staff

**Dr. Donal Day**, Professor – B.Sc. Biochemistry (University of New Hampshire), Ph.D. Microbiology (McGill University, Canada)

**Dr. Michael Saska**, Professor – B.S. Chemical Engineering (Prague Institute of Chemical Technology, Czechoslovakia), M.S. Chemical Engineering (Louisiana State University), Ph.D. Chemical Engineering (Georgia Institute of Technology)

**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)

**Dr. Harold Birkett**, Associate Professor – B.S. Chemical Engineering (Louisiana State University), M.S. Chemical Engineering (Louisiana State University), Ph.D. Chemical Engineering (Louisiana State University)

**Dr. Chang-Ho Chung**, Post-Doctoral Researcher – B.S. Food Science (Sejong University, Korea), M.S. Food Science (Sejong University, Korea), Ph.D. Food Science (Louisiana StateUniversity)

**Dr. Giovanna Dequeiroz**, Post-Doctoral Researcher – B.S. Food Science (Clemson University), M.S. Food Science (Clemson University), Ph.D. Food Science (Louisiana State University)

**Jeanie Stein**, Research Associate – B.S. Plant Science (Nicholls State University)

**Stuart 'Lenn' Goudeau**, Research Associate – B.S. Industrial Technology (Louisiana State University)

**Joy Yoshina**, Research Associate – B.A. Marine Affairs (University of Miami)

*Luis Bento's poster on 'Decolorization of Sugar Solutions with Oxidants and Ion Exchange Resins,' presented at the 2004 Annual Sugar Industry Technologists Meeting in Vancouver, Canada, was recognized by the Frank Chapman Memorial Award committee as the best poster presentation.*

**Bruce Ellis**, Research Associate – B.S. Chemical Engineering (University of Natal, South Africa), M.S. Chemical Engineering (Louisiana State University)

**David Solberg**, Research Associate – B.S. Chemical Engineering (University of Natal, South Africa), M.S. Chemical Engineering (Louisiana State University)

**Dr. Duwoon Kim**, Graduate Assistant – B.S. Food Science (Chonnam National University, Korea), M.S. Food Science (Louisiana State University), Ph.D. Food Science (Louisiana State University)

**Luis Echeverri**, Graduate Assistant – B.S. Mechanical Engineering (Universidad del Valle, Colombia)

**Nicolas Gil Zapata**, Graduate Assistant – B.S. Chemical Engineering (Universidad Industrial de Santander)

**Lee Yong-Jae**, Graduate Assistant – B.S. Food Science (Chonnam National University, Korea)

**Kim Mi-Sook**, Graduate Assistant – B.S. Food Science & Nutrition (Dankook University, Korea), M.S. Food Science & Nutrition (Dankook University, Korea)

**Irina Dinu**, Graduate Assistant – B.S. Biology (Al. I. Cuza University of Ia°i, Romania)

**John White**, Graduate Assistant – B.S. Chemical Engineering (University of Michigan); M.S. Science & Engineering (Johns Hopkins University)

## Adjunct Faculty

**Mary Godshall**, SPRI –B.S. Biological Science (Louisiana State University, New Orleans), M.S. Biochemistry (University of New Orleans)

**Dr. Terry Walker**, Department of Biological Engineering –B.S. Engineering Science & Mechanics (University of Tennessee), M.S. Agricultural Engineering (University of Tennessee), Ph.D. Agricultural Engineering (University of Tennessee)

## Staff Changes

**Maggie Matherne**, Secretary, transferred to LSU Psychology Department as of April 2004.

**Scott Barrow**, Research Associate, resigned September 2004.

**Bruce Ellis**, transferred as of January 2005.

**David Solberg**, transferred as of January 2005.

**Dr. Matt Gray**, Post-Doctoral Researcher – B.S. Chemistry (Simon Rock College, Massachusetts), Ph.D. Chemical Engineering (Dartmouth College, New Hampshire) as of April 2005.

## Foreign Visitors to the Institute

**April 2004**
Klaus Thielicke (Germany); Christian Idenbrink (Germany); Stephen Staunton (Australia); Michael OShea (Australia), Kevin Schaffler (S.Africa), T. Kirkpatrick (UK)

**July 2004**
Clive Grimwood (UK); H.E.Clevinger (Netherlands); A.V. & J.V. Campen (Netherlands); L.T. Waze (Netherlands); Richard Fitzgerald (Ireland); Peter Jordan (Ireland); J.P. Gechot (France); Graff Raymond (France); Michael Andre (France); Marion & Mike Blacker (UK); Joe & Jillian Russo (Australia); Otto Van Arnold (Sweden); I. Beyzer (France); Gabriel Goddy (Brazil)

**August 2004**
Edena Èechová (Czech Rep), Doman Kim (Korea)

**October 2004**
Mike Getaz (UK); Colin Sanders (UK); Mullapudi Narendranath (India); Niconor Reece (Jamaica)

**January 2005**
John Gillett (Belize)

**February 2005**
Jan Coetzee (S.Africa); Alan Williamson (S.Africa); Bruce Moor (S.Africa)

## Meetings, Conferences and Workshops Attended

**April 2004**
ASI Annual Conference (all staff and faculty)
SPRI, Atlanta, Ga. (L.Bento, P.Rein, D.Day, B.White)
ICUMSA, Atlanta, Ga. (L.Bento, B.White)

**May 2004**
SIT, Vancouver, Canada (P.Rein, L.Bento)
26th Symposium on Biotechnology for Fuels and Chemicals, Chattanooga, Tenn. (M.Saska)

**June 2004**
ASSCT, St. Petersburg, Fla. (P.Rein, D.Day, H.Birkett, M.Saska, J.King, B.White, L.Madsen, M.Tessier, D.Solberg)

**August 2004**
International Congress of Chemical and Process Engineering, Praha, Prague (M.Saska)

**January 2005**
ISSCT Congress, Guatemala City, Guatemala (P.Rein, L.Bento, D.Day, M.Saska, L.Echeverri)

**February 2005**
ASSCT (La. Division) Baton Rouge, La. (all staff and faculty)

## Representation on Technical Societies and Research Institutes

**ISSCT (International Society of Sugar Cane Technologists)**
Executive Committee and Immediate Past Chairman: P.W. Rein
Co-Products Section Committee: D.F. Day
Processing Section Committee: M. Saska
P.W. Rein was named Honorary Lifetime Member of ISSCT at the 25th silver jubilee congress held in Guatemala City, Guatemala, January 30 to February 4, 2005

**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

**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

**Society for Industrial Microbiology**
D.F. Day

**Southern Region Development Committee – USDA**
D.F. Day

*Drs. Dequeiroz, Day and Chung investigate the use of Aspergillus terreus as an alternative method to enzyme hychrolysis.*

*Peter Rein, head of LSU AgCenter's Audubon Sugar Institute, points out Institute highlights to U.S. Senator Mary Landrieu at ASI's Open House. Landrieu had secured nearly $500,000 in federal grant money for ethanol research, half of which goes to ASI.*

*Audubon Sugar Institute acknowledges Syngenta Crop Protection Inc. for the generous donation of the facility. At left is Syngenta's Plant Manager Bob Slaven receiving a plaque from Peter Rein.*

# OPEN HOUSE AUGUST 31, 2004

*This Open House tour group gets a preview of Harold Birkett's laboratory where short courses are conducted to train sugar mill chief and bench chemists.*

*Graduate student Bruce Ellis gives Open House guests from SPRI, USDA, LSU and LSU AgCenter some insight on his two-year research modeling cane sugar colorant removal.*

*Faculty member Don Day highlights his microbiological laboratory at this event with his cellulose hydrolysis studies and production of paper from bagasse.*

## 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 2005)



**Audubon Sugar Institute**
LSU AgCenter
3845 Highway 75
Saint Gabriel, LA 70776
USA