Insoluble and Soluble Starch: Changes Across Sugarcane Factories and How They Are Controlled by Amylase Applications

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The new knowledge that much more insoluble starch is present across the sugarcane factory and refinery than previously considered has processing implications. Processing parameters such as viscosity and filtration are implicated, as well as the application of amylases to control not only soluble but insoluble starch. Samples from crusher juice to C raw sugar and in between were collected across two Louisiana factories, and analyzed for insoluble, soluble, and total starch using the new USDA research method. Crusher juices contained >99% insoluble starch. Starch was only solubilized in the factory when heat was applied. Differences in soluble and insoluble starch were found between the two factories. A two year study was conducted at the laboratory, pilot plant and factory scales to optimize the application of amylase for control of both starch forms. Amylase preferentially hydrolyzes soluble starch>swollen starch>insoluble starch. Different combinations and doses (0 to 10 ppm) of an intermediate temperature stable amylase were added to the clarification tank, next-to-the-last evaporator, and last evaporator at a factory. The syrup inside the evaporator where the amylase was directly applied, had small but meaningful reductions in viscosity. As expected, soluble starch was easier to control than insoluble starch. A full picture of how starch is transformed and removed during clarification and evaporation is described, using chemical and microscopy techniques.

Further Advances in Solving Starch and Associated Problems at Louisiana Factories and Refineries

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Raw sugar quality is very important to both the sugarcane factory and refinery and is usually evaluated according to the following eight major criteria: 1) Pol, 2) moisture content, 3) invert content, 4) color, 5) grain size and shape, 6) per cent crystallinity, 7) filterability, and 8) starch content. Most raw sugars easily meet these criteria as they are parameters related to the quality of the sugarcane as well as factory processing conditions. However, starch concentration and type, i.e., soluble and insoluble, are natural components of sugarcane and cannot always be easily controlled. In this presentation, starch content and type, its persistence into raw sugars,
and its effects on filterability as determined with the newly developed USDA Insoluble/Soluble Starch Research Method are highlighted. Possible solutions to controlling both insoluble and soluble starch are also briefly discussed.

**Are Biocides Effective in Louisiana Mills?**

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Post-harvest sugar loss due to microbial contamination is a concern during raw sugar mill processing. Microbial contamination mostly originates from deteriorated or damaged cane in the field or mill, and stored in sleeper loads or in factory storage piles. Microbial contamination in cane juice degrades sucrose and can lead to the formation of the compounds dextran and mannitol. Dextran may cause factory processing problems, false pol values, including poor clarification, increased viscosity of massecuits, crystal elongation, formation of false grain, centrifugation difficulties and high purity of final molasses. Biocides are currently used in Louisiana sugarcane mills to reduce microbial contamination and growth, thereby reducing dextran levels and related processing problems. This biocide study was undertaken at two Louisiana sugarcane mills across the 2014 processing season, and evaluated the effectiveness of three biocides (Sodium Hypochlorite, (Chlorine), Carbamate (Busan™) and Humulone (Hops). Study results indicated that tested biocides did not work under Louisiana factory conditions. Chlorine reduced microbial growth in juice by only (8%), Busan™, and Hops, and/or combinations of biocides showed no microbial growth reduction. However, microbial growth was reduced significantly in flash heated limed cane juice samples (99%) and during the process of juice clarification (100%). Heating and clarification of cane juice are effective in reducing microbial growth and sugar loss during sugarcane factory milling. The biocides were not effective in the sugar mill where microbes are exposed to biocides for short time periods of much less than the required 90 minutes.

**Size Matters - Seed Crystal Size in Louisiana**

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Good grain and proper vacuum pan operation is required to produce sugar which purges well in the centrifuge and allows for high recovery and low losses to molasses. The grain is grown on very small seed sugar crystals which are added as sugar-alcohol slurry. These slurries are either directly prepared from powdered sugar and isopropyl alcohol or are ball-milled from granulated or powdered sugar and the alcohol.
In this work we surveyed all powdered sugars used in Louisiana sugar factories and analyzed for their particle size. The comparison showed some subtle, though significant differences between the different sugars. As such the choice of sugar for the slurry can be of relevance and affect the boiling house performance. Prior to the 2014 grinding season every ball mill used in Louisiana factories was tested and the factory specific recipe was evaluated, monitoring the crystal size change while milling. The tests showed quite some variation indicating the individuality of each ball mill and recipe. For the typical milling time of 4 hours, the use of powdered sugar produced the smallest seed crystals. Granulated sugar has the potential to reach identical sizes, though it required on average 1-2 hours more milling time to overcome a “lag time”. After the lag time the number of crystals per gram of sugar increases linearly with time. As such control of the ball milling time is essential for reproducible results. While the ball mill performance can vary from recipe to recipe, the variability of each recipe is negligible and ball-milling sugar is good practice to obtain small, uniform seed crystals.

The Potential Use of LLT Clarifiers in Distillery Applications

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The clarification of filtrate juice is an operation that offers multiple benefits to sugar factories. In this paper we investigate the possibility of the application of filtrate clarified juice for its use in distilleries. The process parameters, juice quality requirements are discussed. Finally, the results obtained during the 2014 harvest season for the alcoholic fermentation of clear filtrate juice obtained from an LLT clarifier are presented as well.

The Benefits of the Horizontal Heavy Duty Drum Fed Cane Shredder to the Louisiana/Florida Cane Industry

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The 11 remaining factories in Louisiana over the past 5 years have averaged 13,121,043 short tons of cane ground per season. Sugar production in the same period averaged 1,523,425 short tons, which is 232 pounds of sugar per ton of cane. At a price of $ 0.23/lb this equates to an industry average total of $ 700,775,408. If we can achieve a conservative increase in sugar yield of 1.5% at the mill in a factory with a Boiling House Recovery of 90% then we can expect to increase industry income by $9,460,468 per season. Almost all cane received in the factories is chopped and billeted in the fields thanks to mechanized harvesting. Most Louisiana factories use old fashioned cane knives driven by steam turbines or electric motors to prepare the cane for milling. These devices are inefficient and maintenance intensive. When processing whole-stick
or billeted cane, burnt or green, a modern horizontal drum fed inline cane shredder will improve the cane preparation to a minimum of 90PI. Front end operations will become smoother and a potential increase in mill extraction of 1.5% is possible when compared to the industry average of 75PI in Louisiana. This paper covers the design, operation, maintenance, savings in power and financial gains to be realized by replacing existing cane knife sets by one single modern electrically driven drum fed horizontal cane shredder.

**Equipment Selection for NIR Scanning of Sugarcane Juice Samples**

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United States Sugar Corporation operates 5 Foss NIR System 5000’s, four of which are equipped with beverage units with probes. The Foss 5000 probe system allows the scanning of juice samples without washing between samples, so it is suitable for processing large quantities of samples on a daily basis. In 2011, Foss announced that the 5000 front beverage module was to be discontinued and then in 2014 announced that the front beverage module parts would no longer be available after 2014. In 2011, USSC undertook a review of suitable replacement equipment and selected 4 units from different manufacturers for extensive testing before selecting the Bruker MPA, along with a customized probe system, as a suitable replacement for the Foss unit. The research work to develop a new calibration model considered three approaches: a) Utilization of the Foss data base spectrums (>7000 first expressed and mixed juice samples) by transferring the database into Bruker format, plus an additional 1500 new samples scanned on the Bruker MPA. Foss data was transformed using a Piecewise Direct Standardization (PDS) algorithm to match the Bruker spectral structure, b) Removal of redundant samples from the Foss database, reducing the transferred data to around 4000 samples, along with the new 1500 samples, c) Development of a new calibration model, solely using the 1500 Bruker new samples. The best predictive model for the MPA instrument was achieved utilizing only new data for the first expressed and mixed juice samples (R² of 0.96 and 0.83, respectively). With the data collected to date, the Foss NIR System 5000 (>7,000 samples) provides slightly better accuracy than the Bruker MPA (1500 samples). For the first expressed juice, the Bruker brix SEP is 0.153 (Foss = 0.131) and the Bruker sucrose SEP is 0.188 (Foss = 0.179). However, the Bruker MPA instrument is more stable and consistent, does not need bias correction, and offers reduced maintenance costs. To manage the Bruker MPA data, the Bruker OPUS software has been linked to a SQL server for direct integration of the data to the USSC data management system. US Sugar intends to migrate to the use of the Bruker MPA unit during the 2015-2016 crop.

**Capital Cost Estimation and Return of Investment for a Filtrate Clarifier for a Louisiana Sugar Mill**

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An economic analysis for the implementation of a Filtrate Clarification plant was performed for a Louisiana Sugar Mill with an approximate grinding capacity of 13,000 tons of cane per day. Filtrate can account for almost 15-20% of the limed juice and its recirculation can be detrimental to the process. An initial capital cost estimation for a full size filtrate clarifier for this sugar mill was performed and later on a Net Present Value analysis was conducted suggesting that a the potential Internal Rate of Return that could be obtained from the implementation of the technology would be of up to 32%. The financial possibilities and limitations on the implementation of this technology are discussed in the present work.

**Challenges by Transferring Proven Efficient Design from Beet to Cane Based on Practical Experience**

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In the past, development in beet and cane sugar factories took place separately. Both industries used to rely on their local sugar institutes and technologists, who were best aware of the local economic conditions. One major difference between the cane and beet sugar industries is the energy supply issue: The cane sugar factories are self-sufficient in energy by burning bagasse, whereas the beet sugar factories need to buy their primary energy. Since the beginning, the beet sugar industry was driven by improving energy efficiency. Nowadays cane sugar factories are keen on improving their energy efficiency, too. Additional revenue shall be generated by selling power to the grid. Recently, efficient designs proven in the beet sugar industry have been successfully transferred to cane sugar factories. The challenges in designing efficient sugar mills are explained especially for the sections Evaporation and Sugar Boiling.

**Production of Seed Magma by Cooling Crystallization in the Cane Sugar Industry**

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Since the cane sugar process has to look for better heat efficiency due to the interest to produce also electricity to the grid, more attention has to be paid to better energy usage during the process. CAHSA installed in their factory STA. MATILDA, Honduras cooling seed preparation equipment which allows an increase to the capacity of the refinery by 30% with a minimum of extra energy. The paper will demonstrate how the goals were achieved by using equipment which was copied from the beet sugar industry. CAHSA is planning to include the same system
to the raw sugar and direct white sugar production. During the current crop season, CAHSA is experimenting to use this system for the white sugar production with very promising results.

**Decentralized Drive Technology for Sugar Mill Drives**

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The trend in refurbishing sugar cane grinding mills is beginning to shift from replacing and/or repairing the extremely large parallel shaft unit with like for like, to replacing them with more modern planetary gear reducers. These new reducers are sometimes utilized between the smaller steam turbine driven parallel shaft units and the mill shafts, sometimes replacing the entire system with a large planetary and an electric motor drive, or a planetary gear motor on each rotor shaft. All three options and their advantages will be discussed in the presentation.

**Evaporators Descaled with EDTA – a Season’s Experience**

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U.S. Sugar has four sets of evaporators of which three are usually online and the fourth is being chemically cleaned. These evaporators were commissioned in December of 2006 and have been since been chemically cleaned during the crop using Caustic Soda followed by Sulfamic Acid. The chemical cleaning regime did not clean the tubes back to metal and a little ground was lost after each cleaning cycle. The evaporators were water blasted with high pressure water jets during every off season to clean the accumulated scale off the tubes to return them back to metal for the start of the next season. As the crops have become larger and longer, the need for a more effective chemical cleaning regime (which did not damage the evaporators) became greater. U.S. Sugar, in an effort to find a more effective cleaning solution, embarked on trials using EDTA as an alternative to Sulfamic Acid. The trials were conducted in partnership with AkzoNobel during the latter part of the 2013-14 crop. The results of the trials were promising enough that U.S. Sugar embarked upon the 2014-15 crop with the intent of replacing the Sulfamic Acid which can be corrosive and result in damage to the carbon steel bodies. EDTA is well known for its ability to dissolve Ca based scales – but its use requires optimization based on scale type and amount present and of course to fit into plant operations. At U.S. Sugar, the type of scale present through the evaporator set (train) varies with effects #1 – 2 being composed principally of Ca phosphate based scale, while effects # 3 - 5 is composed of Ca sulfate, oxalate and carbonate scales. These later scales are readily dissolved with a standard solution of EDTA at ~ pH 13, however effects #1 – 2 are optimally dissolved with EDTA at a pH 6.5. The amount of scale present in each evaporator – thus the amount of EDTA needed - was also found to be highly variable and changed significantly thru the season. Scale amounts in effects #3 - 4 were
consistently low requiring less EDTA. Effects #1 – 2 had significant scale and required a consistently higher amount of EDTA be used for scale removal. Interestingly, effect #5 was found to have a highly variable amount of scale thru the 2014 season – peaking in late Dec, dropping Jan – Feb, but again rising in March.

**New Approach to Measure and Control the Quality of Raw Sugar**

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The two main criteria for raw sugar quality are the colour and the sucrose content (polarization) of the sugar. Based on the experience from many years of reliable online colour measurement Neltec has now developed a method to give the Pol of the raw sugar in real-time as well. During the last campaign the new method was tested on two different production lines at the Belle Glade Factory of Sugar Cane Growers Cooperative of Florida. With this new information it is possible to monitor the performance of the centrifugals and the pans as soon as the crystals leave the centrifugals, allowing timely corrections to the filling level and spray water time of the centrifugals, and giving feedback to the pan operators about the quality of the massecuite pan by pan. The paper shows results obtained, and gives an outlook for possibilities to optimize the sugar house operation.

**2015 Manufacturing Abstracts - Posters**

**Preliminary Study and Simulation of C-strike in Louisiana**

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The low grade boiling or C-strike is a very important operation for maximum molasses exhaustion. A number of variables can be measured or calculated to keep track of the performance of the C-strike and detect possible equipment or processing issues. Examples of such measurements include the purities of mother liquor (Nutsch molasses) after pans, crystallizers and reheaters; the crystal content, temperature and crystal size of massecuites; the crystal size of C-sugar and the purity of final molasses. A preliminary survey of the purity drop/rise along the C-strike has been performed for three of the Louisiana sugar factories. Purity drop from pan to crystallizer averaged 8.4 points while purity rise across centrifugals averaged 2.58 points. Measurements for some of these variables can be estimated through simulation of the C-strike when data are not available. A simulation model of the C-strike was developed for one of the factories in the software SUGARS™ to obtain the crystal content and the centrifugals’ performance parameters. The model was in good agreement with the factory, with a maximum deviation of 6.24% between the simulation results and the factory data. Crystal content of massecuites from the pan was found to be 35.75% and 41.80% after crystallizers. The data showed that 23.28% of the crystals were lost during centrifugation.
Deashing of Sugar Syrups Using Electrodialysis

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Sweet sorghum and energy cane are considered to be feasible biomass feedstock for the southeastern US. Particular the possibility to be harvested with existing sugar cane equipment and their potential processing in raw sugar factories gives them an edge over other feedstock. Crystallization to raw sugar is not desirable and in case of sweet sorghum near impossible. As such the main product for fermentation and thermal conversion to bio-based chemicals are syrups produced from these row crops. The current “gold” standard for syrup for bio-based chemical production is corn derived glucose syrup, which features storability, ease of handling, low ash level and low color levels. Clearly, syrups produced by a raw sugar factory do not exhibit low ash levels or low color. High ash levels are particular an issue for thermochemical conversion and have to be reduced to glucose syrup levels (0.05%/Bx) before being able to compete. Ion exchange is commonly used for deashing, though the high level of ash (up to 10%/Bx with potassium chloride being the dominant component) would require substantial amounts of chemicals for the regeneration of resins. Electrodialysis is thought to serve as a chemical-free alternative to ion exchange and the preliminary testing of electrodialysis for the deashing of energy cane and sweet sorghum syrups is reported in this work. Electrodialysis requires the use of anion and cation exchange membranes which should exhibit high capacity, low electric resistivity and low permeability to fermentable sugars. Three commercially available membrane pairs were tested under standard conditions (electrodialysis of 10% potassium chloride solutions with and without sucrose) for their potential to reduce ash level. The NeoSepta® AMX/CMX membrane from Astom/Ameridia exhibited good deashing capability, while permitting only a 0.12% sugar loss. The application of this membrane pair was capable of reducing the ash level of energy can syrup by more than two-thirds to 3.7%/Brix with significantly less operational cost than ion exchange.

Evaluation of Fermentable Sugar Loss During Syrup Storage

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Energy crops are currently being investigated as alternative resources for the production of biofuels and bio-based chemicals. Both energy cane and sweet sorghum are of interest in the southeastern United States because of their similarity to sugar cane which may be utilized for biofuel production. These crops can be harvested like sugar cane and processed in current facilities of the raw sugar industry. In Louisiana, the harvesting season for sweet sorghum ranges from late July until October and for energy cane from November until early January. In order to couple seasonal syrup production with a year-round biorefinery, a viable storage method with the
minimum amount of fermentable sugar loss must be achieved for a minimum of 6 months. This work evaluates fermentable sugar deterioration in sugar cane syrup stored in a column, which simulates tank storage conditions, during an 8 week period. Biological activity occurred at the surface of the column. Conductivity ash, pH, dry mass, sucrose, glucose, and fructose concentrations at different depths of the column were measured in an attempt to evaluate if degradation is limited to the surface. Results show a fermentable sugar loss of 28% throughout the entire column depth.