DIRECT PRODUCTION OF WHITE SUGAR IN CANE MILLS: TECHNICAL AND ECONOMIC ASPECTS

V. Kochergin[1], M. Kearney[1], J.F.Alvarez[2]
[1]Amalgamated Research Inc., Twin Falls, Idaho, USA
[2] Sugar Cane Growers Cooperative of Florida, Belle Glade, Florida, USA

Abstract
A process developed for white sugar production directly in cane mills is discussed. The process also allows producing high quality raw sugar. The contribution of various unit operations in overall process cost is evaluated. Several routes intended to improve the process economics are outlined.

Keywords: membranes, chromatography, softening, sugar recovery

Introduction
Several technologies for production of white refined sugar have been proposed by various researchers over the last decade. Most processes address the important issue of sugar color often neglecting other specifications for refined sugar, such as ash and invert content. The issue of overall sugar recovery in a mill is usually not addressed. Although relatively low color sugar can be produced, e.g., by double sulphitation and/or recrystallization, these methods have their shortcomings. Obviously, some methods that can remove melassigenic components earlier in the process are required to reduce the overall quantity and purity of final molasses and, hence, increase sugar recovery. High molecular weight components adversely affecting sugar quality can be effectively removed by ultrafiltration. However, this process is not capable of removing the inorganic salts, which account for the lion's share of the non-sugars present in the cane mill juice and syrups. In this case processes such as chromatography or demineralization may be required. We have analyzed potential applications of large-scale chromatography in the cane industry. Chromatographic desugarization of cane molasses at the present time appears to be impractical mainly due to the difficulties associated with filtration. The generally lower sugar content in cane molasses contributes to the problem making it more difficult to justify the capital investment. Obviously, the main impetus behind molasses desugarization is an increase in sugar recovery. This additional sugar also is a major factor for justification of the capital investment in a new technology. Experience with molasses desugarization in the beet sugar industry demonstrates that the chromatographic process, although being capital intensive, provides fast payback. Earlier we reported (Kochergin, et al. (2000)) the process developed for additional recovery of sugar in cane mills. In terms of sugar recovery the process is equivalent or exceeds molasses desugarization and also provides a benefit of direct production of sugar satisfying all requirements of white sugar. This process has proven to be technically feasible, but requires analysis of economic feasibility.

The goal of the present paper is to discuss the main features of the proposed process and provide some thoughts on economical feasibility of the process and possible technical improvements that will allow achieving an overall cost reduction.

Process description
According to the proposed process cane clarified juice is subjected to micro- or ultrafiltration

using any suitable membranes. Depending on the type of membrane, additional screening may be required to protect feed channels from plugging. The orifice size of the screens is, therefore, determined by the size of the membrane feed channel. For example, spiral membranes with relatively narrow feed channels may require 100-150 micron prescreening, whereas the feed to tubular membranes may not need screening at all. However, a 500-micron screen in front of tubular membranes may provide additional protection from large particles that can potentially erode the membrane surface.

Membrane permeate is passed through ion exchange softening resin where calcium and magnesium are almost completely removed. This step is important for the following chromatographic purification, where divalent ions are detrimental to process performance. Softened permeate is then concentrated in the conventional mill evaporators. It is an important benefit of the process that evaporator scaling will be essentially eliminated. In the beet industry where thin juice softening is routinely applied, evaporator scaling does not present a problem anymore. Since permeate lacks suspended solids, more efficient falling film evaporators can be used.

Another interesting feature of membrane permeate is its complete sterility, therefore, very low bacterial count in the evaporated product should be expected. As a result concentrated juice can be stored successfully similar to thick juice storage in the beet industry.

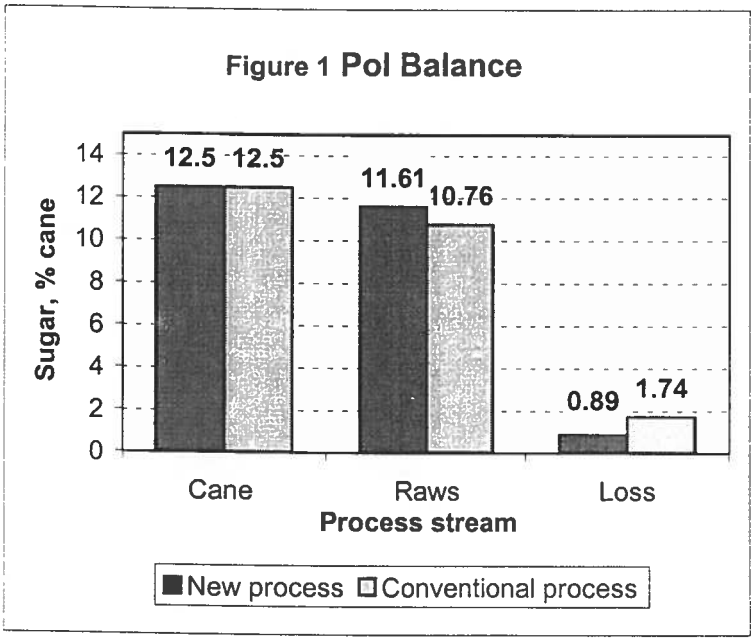
The evaporated and softened permeate is fed into the first stage of a chromatographic process, where most of the invert sugars and other small molecular weight components are removed. The upgraded sugar fraction is separated from mostly inorganic non-sugars in the second stage of the process. The sugar-rich extract is then concentrated from about 40% to 70% DS and sent to white sugar boiling. Raffinate is concentrated and can be sold as animal feed.

The pilot crystallization results shown in Table 1 indicate that unwashed raw sugar of very high quality can be produced. Simple washing allows the production of sugar with color below 25 ICUMSA, ash content below 0.006% and invert level below 0.01%.

Table 1. Comparison of Quality of Raw Sugar obtained from Chromatographic Extract and Conventional Raws

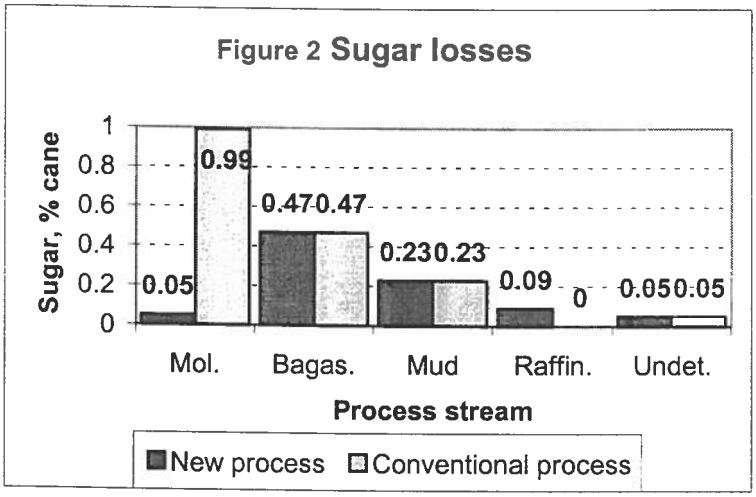
		Extract Pans*				Conventional Raw**		
Pan #		X-1	X-2	X-3	X-4	Day 7	Day 17	Day 37
Color (RBU)	Syrup	2322	2491	1875	2448	1802	1226	1056
	Unwashed sugar	641	501	642	623			
Invert (g/100 DS)	Syrup	0.27	0.25	0.23	0.27	0.71	0.47	0.51
	Unwashed sugar	B	0.028	0.03	0.03			
Conductivity Ash, %	Unwashed sugar	0.165	0.108	0.144	0.136	0.40	0.27	0.24
Turbidity (at 720 nm)	Unwashed sugar	37	10	18	15	1030	289	281

* No wash water applied, ** Small amount of wash water is used in conventional centrifuges



A pilot test program was carried out for several seasons at the Sugar Cane Growers Cooperative of Florida. Calculation of a material balance based on results of this pilot study shows an increase of 6.8 % in overall sugar mill recovery. The comparison of pol balance for conventional and the proposed process is presented by the graph in Figure 1. Breakdown of sugar losses throughout the mill shown in Figure 2, indicates that most sugar typically lost to molasses is recovered in the new process.

Depending on the process configuration, part of the sugar may be recovered as white refined sugar. In such case the sugar cane mill can be operated similar to a beet sugar plant, where the first strike produces refined sugar, the lower grade sugars are remelted and returned to the white pans. Another option would be to produce white sugar in the first and second boiling and return the mother liquor to the conventional mill, where high quality raws will be produced. The latter option allows more flexibility for gradual incorporation of the new process rather than conversion of the whole mill to white sugar production.



Because of several new unit operations that are currently not used by the cane sugar industry it is important to assess the confidence level when transferring the pilot data to industrial scale.

Scale-up of the unit operations

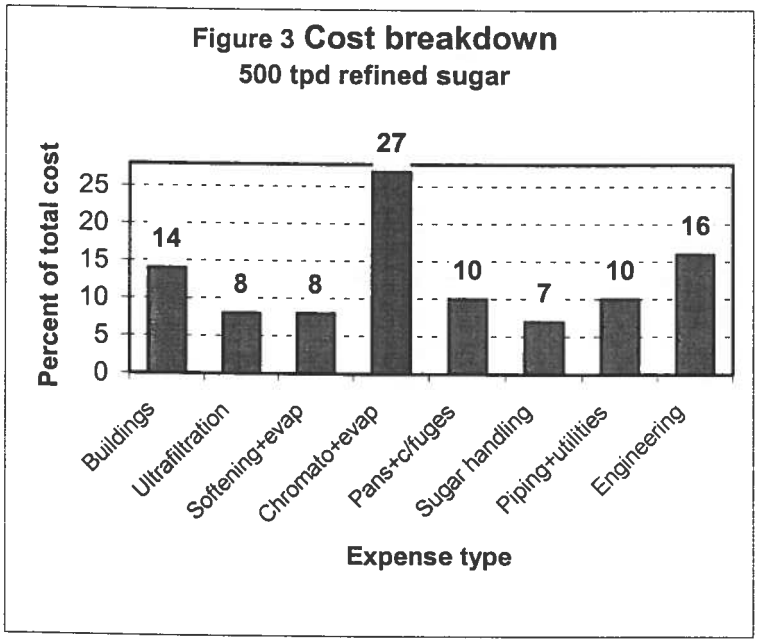
The pilot test program involved pilot equipment that was designed to provide sufficient data for industrial design. Industrial size membrane elements were used in the pilot study to assure reliable scale-up. Because of the modular nature of membrane filtration processes, the scale-up can be simply accomplished by designing a system containing multiple modules. Performance data for various concentration factors have been obtained as a part of the study. The issues of membrane durability and modes of potential failure have also been addressed in the program. Membranes considered as potential candidates for industrial use have been tested for a period of at least one season of continuous operation.

The reliable scale-up of softening and chromatographic equipment is assured by use of fractal fluid distributors (Kearney, 2000). Because of the self-similar nature of fractals, these distributors are proven to provide reliable scale-up of industrial equipment. Many industrial installations have been scaled up successfully based on the results of pilot tests in the chromatographic columns at Amalgamated Research Inc (ARi).

Crystallization tests have been carried our in the ARi pilot vacuum pan, which has been proven to produce reliable data. Finally, centrifugation in the pilot facility usually gives rather conservative estimates of sugar quality in comparison to industrial machines.

Cost saving opportunities

A study is currently under way evaluating the economic feasibility of the proposed process based on the results of thorough long-term pilot experiments. A process is considered where 500 tpd of refined sugar is produced directly in the mill, the rest of the mill is operated using the conventional process. Preliminary results have demonstrated that the concept of the new refinery is more economical compared to a conventional sugar refinery.



Understanding the cost structure of the process is of crucial importance for optimization. For our purpose we have factored the contribution of each unit operation into the overall capital cost of the new process (Figure 3). It is important to note that the calculations are based on initial rather conservative estimates.

Evidently, chromatography remains a major contributor to the capital cost, therefore, efforts should be directed to search for more efficient chromatographic operation. Several different options may be considered. The first option for equipment size reduction is to increase the

loading per unit of chromatographic resin. Another route is also considered, where more efficient chromatography allows using less elution water, therefore, reducing the requirements for the evaporation station. It is worth mentioning that a size reduction of chromatographic and/or evaporation equipment also affects the installation and construction costs.

Another important feature that affects the size of chromatographic equipment is the number of days in operation. Obviously, a chromatographic separator operating 300 days per year is only one half of the size of a system working 150 days (assuming equivalent annual production). For companies with a short processing season some juice storage may be required to take advantage of year-round operation.

Although juice softening contributes less into the overall cost, any improvements should be beneficial for the process economics. A new softener taking advantage of fractal distribution technology has been successfully tested in both beet and cane applications. The most important feature of the new softener design is extremely small size in comparison to conventional systems due to very high throughput. The peripheral equipment requirements are also minimized. The quality and concentration of suspended solids in the clarified juice determines performance of the membrane filtration. Any improvements made to the clarification process will result in higher flux and therefore, an overall reduction in both capital and operating cost. Several researchers have shown that a smaller membrane system is required if partially evaporated juice is exposed to membrane filtration. A concentration of 20-25% DS is considered to be optimal in terms of maximum solids throughput per unit of membrane area.

Some additional savings may be realized through use of steam saving configurations or better utilization of existing equipment. Lack of suspended solids in permeate allows to take advantage of highly efficient falling film evaporators. If white sugar is not needed the new process can be used to provide very high quality raw sugar with higher recovery. Because the new raws can be refined very easily the scheme can later be converted to white sugar production at minimal cost.

Conclusions

- The proposed process allows increasing overall mill recovery by 6-7% along with significant improvement of raw sugar quality.
- The concept of direct production of white sugar in cane mills appears to be more economical than building a conventional refinery.
- Several process improvement opportunities are currently being studied on the pilot scale.
- Long-term pilot studies are providing confidence in scale-up and design of the process.

References

1. Kochergin, V. et al. (2000). Chromatographic desugarisation of syrups in cane mills, *International Sugar Journal*, Vol. 102, No. 1223, November 2000, pp. 568-578.
2. Kearney, M. (2000). Engineered Fractals Enhance Process Applications, *Chemical Engineering Progress*, Vol. 96, No. 12, pp. 61-68.