Simplified "Green" Sugar refining process for the 21st century

By

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(I) Introduction

As we entered the 21st century, the sugar industry found itself at a cross road facing many challenges and opportunities: limited energy supply, diminishing other resources (food, water, etc.), environmental pressure, health and safety issues, regulatory compliance, nutritional values of refined sugar under attack, global competition (WTO); and a global economy in which the only **Constant** is "**change**". We sugar technologists must be more innovative and creative in our approach to reduce the sugar production cost to a minimum possible.

The best way, economically, technically, and environmentally, to produce refined sugar in the 21st century's economy is to (a) attach a simplified refinery to a sugar mill with matching capacity and (b) for an autonomous refinery, use VHP raw sugar with maximum color of 1000 ICU as the refinery input to simplified the refining process.

This paper describes the development of ***an environmentally friendly simplified refining process*** employing only phospatation with addition of purifying aids when the input VHP raw color is 1000 ICU max. **When the input VHP raw sugar is less than 600 ICU color, ONLY** press filtration with addition of purifying aids is needed. No Ion exchange process (therefore no dark brine regenerant waste disposal problems) and No UF- and nano-membrane systems are used in the process. Also No sulfitation (air pollutant and health hazard) and No conventional sugar silo for sugar conditioning are needed.

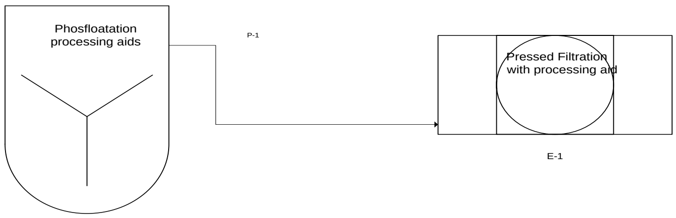
In an attached simplified refinery, bagasse is the only fuel needed to produce refined sugar. No other source of energy, such as coal, gas, or oil is needed.

(II) Autonomous Simplified refinery

In USA sugar refineries, the average liquor color going to the pan floor for boiling refined white sugar ranges from 175 to 275 ICU. The average combined sugar color of the 1st strike (R1), 2nd strike (R2), and 3rd strike (R3) is around 35 ICU meeting all industrial and grocery product requirements.

Any process selected for a simplified refinery should be able to produce pan feed liquor color of less then 275 ICU. It has been demonstrated that when the VHP raw sugar color is less than 1000 ICU, all a simplified refinery needs is Phosphatation plus press filtration as shown in figure 1:

Figure 1 depicts the simplified refining process selected:



(II a) Color of input raw sugar exceeds 600 ICU. In this case, phosphatation process is definitely needed to decolorize the liquor to be less than 275 ICU using various FDA approved purifying aids as shown below. It should be noted that all processing aids used meet US government regulatory requirements.

Decolorization test I

All PuriAids products comply with US FDA requirements

		Color (ICUMSA)
Melt liquor		1070
PuriAids	CP 25 (300 ppm)	
PuriAids	HP 35 (300 ppm)	
PuriAids	DC 22 (200 ppm)	
Phosphatation	(500 ppm)	140

Decolorization test II

		Color (ICUMSA)
Melt liquor		1092
PuriAids	CP 25 (500 ppm)	
PuriAids	HP 35 (300 ppm)	
PuriAids	DC 22 (200 ppm)	
Phosphatation	(500 ppm)	155

Decolorization test III

		Color (ICUMSA)
Melt liquor		1093
PuriAids	CP 25 (500 ppm)	
PuriAids	HP 35 (300 ppm)	
PuriAids	DC 22 (200 ppm)	
Phosphatation	(500 ppm)	135

From above decolorization tests, it is obvious that phosphation process, together with addition of various purification aids, can produce pan feed liquor color of less than 155 for boiling of refined sugar even when the input raw sugar liquor color were as high as 1100 ICU.

The refinery, which consists only phosphatation and press filtration and is designed for production of 35 ICU liquid sugar, normally has an input raw/melt liquor color of less then 1000 ICU. However, when the VHP raw sugar exceeded 1000 ICU, the dose of PuriAids CP 25 can be increased to improve decolorization as shown in the decolorization test IV data.

The phosphataion process was able to reduce color from as high as 1582 ICU to 226 ICU level for boiling of refined sugar. It appears that PuriAids CP 25 is a very effective decolorizing agent.

Decolorization test IV

		Color (ICUMSA)
Melt liquor		1582
PuriAids	CP 25 (800 ppm)	
PuriAids	HP 35 (300 ppm)	356
Phosphatation	(500 ppm)	226

When the PuriAids CP 25 was reduced from 800 ppm to 500 ppm, the rate of color removal was considerably decreased as shown in decolorization test V. Further reduction in the dosage to 300 ppm greatly effect the color removal efficiency as shown in declorization test VI.

Decolorization test V

		Color (ICUMSA)
Melt liquor		1317
PuriAids	CP 25 (500 ppm)	
PuriAids	HP 35 (400 ppm)	
Phosphatation	(500 ppm)	402

Decolorization test VI

		Color (ICUMSA)
Melt liquor		1317
PuriAids	CP 25 (300 ppm)	
PuriAids	HP 35 (300 ppm)	
Phosphatation	(500 ppm)	618

Although the color of 402 ICU in the decolorization test V and 618 ICU in test VI are not sufficiently good enough to boil refined sugar, other purifying aids can be added in the following filtration step to reduce the color to less then 275 ICU for boiling as shown in the next section.

(II b) the color of raw sugar is less than 600 ICU. In this case, ONLY press filtration with addition of various Puriaids, is need to reduce pan feed color to less then 275 ICU for boiling of refined sugar.

Decolorization test VII (By press filtration ONLY)

			Color (ICUMSA)
Melt liquor			600
(a) PuriAids	DN 22 (1%)		44
(b) PuriAids	DN 22 (0.6%)		66
(c) PuriAids	DC 22 (0.55%)	+ DR 22 (0.075%)	100
(d) PuriAids	DC 22 (0.55%)	+ DN 22 (0.1%)	80
(e) PuriAids	DC 22 (0.55%)	+ DN 22 (0.2%)	50

With 1% of PuriAids as shown in (a), the liquor color was reduced from 600 to 44 ICU. The high dose of 1% was used because the refinery wanted to produce liquid sugar of less then 80 ICU. To reduce cost, when PuriAids was reduced to 0.6% (b), the resulting liquor was still 66 ICU. Various tests were performed, from (c) to (e), to optimize the cost of production. For this particular customer there was no need to remove ash.

From the above tests it appears that for production of refined sugar, which only need a pan feed liquor color of less than 275 ICU, no phosphatation will be needed if the melt/raw liquor color is less than 600 ICU. Only press filtration with addition of some PuriAids is sufficient to reduce color to less than 275 ICU for pan boiling.

(III) Attached a simplified refinery to a sugar mill

Based on the presentation/discussion of the above section (II), the raw sugar produced in the mill and to be fed to the attached simplified refinery must have a color of less then 1000 ICU.

A sugar mill with conventional lime clarification can easily produce the targeted color of less than1000 ICU VHP raw sugar by (A) improved/modified sugar boiling scheme in the pan floor or (B) by installation of phosphatation process to clarify evaporated syrup as described in section 5.77 of the 12th edition of “Cane sugar handbook”.

(III a) a standard process flow of a lime juice clarification sugar mill, with a raw /evaporated syrup clarifier added, is shown below:

Mixed cane juice (from mill) => Adjust PH to 6.2 to minimize inversion => Juice Heaters (heating to 103-105 ℃) => Flash Tank (to 100 ℃) => Liming tank (adding lime milk to hot cane juice) and mixing to reach pH 7.5 – 7.7 => Continuous Clarifier (e.g. Dorr Oliver Co.) => Clear juice with PH of around 7.1 (20^{o}C) => to 150 mesh strainer to remove suspended matter and/or microbes => to Multi-effect Evaporators (to 63-68 Bx) => Raw/evaporated Syrup clarifier => 24 mesh strainer to remove scale => to Boiling House (Use Step-up Three Boiling System).

A sugar mill with sulfitation can be converted to lime juice clarification practically with no change in equipment. Use of sulfur will be eliminated.

The most important factor to produce VHP raw sugar with high refining quality is to have stability and clarity in the juice continuous clarifier, including but not limited to:

(1) Lime recirculation loop to avoid blockage of milk of lime.
(2) Good automated PH control.
(3) Good automatic temperature control.
(4) Sufficient addition of P_2O_5

(III b) Improved phosphatation process is achieved by:

(1) a highly efficient micro air diffusion system to minimize phosphatation carry-over and after floc (improved clarity of effluent), and to reduce scum volume for better sweet water and sucrose loss control

(2) a simplified PH control system to improve operational process stability,

(3) a plant water discharge line sugar detector to minimize sucrose loss.

(4) press filtration after clarifier to remove:

(a) microbes for food grade products requirements,

(b) micro particulates to reduce sediment in sugar products, and

(c) heavy metals, such as lead and arsenic, when needed

The following data is collected from a liquid sugar production refinery on turbidity removed by phosphatation followed by that removed by press filtration. The data show that the turbidity of clarifier effluent are excellent, i.e. all below 6 NTU. No deep bed filters are needed as generally required in a conventional phosphatation system.
The turbidity of press filtrate are all less than 2 NTU which is as good as LCMT (low color, mineral, turbidity) value added special syrup for both pharmaceutical and cordial industries.

Turbidity removal by phosphatation and by press filtration

Turbidity (NTU)—Refinery Data

Time of Sampling	Clarifier feed liquor	Clarifier effluent liquor	Press filtrate
14:00	151 (NTU)	4.31	1.34
18:15	33.9	2.33	1.57
22:15	47.8	5.78	1.37
2:00	130	3.08	0.87
6:00	28.3	2.7	0.88

The following table shows the refinery color profile with VHP raw sugar input over a month period. As expected, the color removal across the clarifier is about 25 %. A typical color removal averaged 30 to 35 % if the input melt color is around 1000 to 1200 ICU. With the addition of color precipitant into the clarifier the color removal should be about 50 to 60%.

Refinery Color Profile							
Date	Raw	Raw Melter	Clarifier	Column Feed	Anion	Cation	BV
1/4/2009	589	445	291	287	25	37	12
1/5/2009	547	368	254	263	15	24	15
1/7/2009	528	327	267	277	12	24	10
1/9/2009	575	365	304	290	14		12
1/12/2009	555	419	319	311	20	33	10
1/14/2009	564	376	309	298			11
1/16/2009	572	395	322	170*	9	25	10
1/23/2009	561	445	287	333	14	17	16
1/27/2009	564	442	302	291	27	36	12
1/29/2009	556	482	359	255	13	19	15
Average	**561.1**	**406.4**	**301.4**	**289.4**	**17.50**	**26.9**	**12.3**
	* Part of feed was pan material						

The averaged clarified liquor color of 301.4 ICU can easily be decolorized to less than 200 ICU for sugar boiling by addition of 0.05% of PuriAids during press filtration. The press filtration is needed to remove microbes and precipitated heavy metals (present in raw sugar), and to reduce sediment in refined sugar products) in order to meet US food grade standards.

(IV) Pan capacity in the attached simplified refineries

When a simplified refinery is attached to a sugar mill, it is obvious that additional pan capacity will be needed to boil refined sugar. The problem can be alleviated by the following undertakings:

(1) Install stirrer in A & B pans.

Stirrers will reduce the boiling time by 30%.

(2) Increase the brix of evaporated syrup to 67 Brix minimum to free up vacuum pan for refined sugar boiling.

(3) Conversion of sulfitation plants to lime clarification will also increase pan capacity by reducing the evaporator and pan scale.

(V) Energy saving of the attached Simplified refineries.

The energy saving can be assessed by the following calculation:
Typically for bagasse, the percentage of bagasse to cane range between 25-35% depending on the fiber content of the cane. 30% will be a good average number which means 30 tons of bagasse/100 tons of cane. Steam generated per ton of bagasse again depends on the efficiency and pressure of the boiler and moisture content of bagasse . Typically 2.2 lb steam/lb of bagasse burned.
Therefore, 100 tons of bagasse will produce 220 tons of steam (High pressure out of boiler). Therefore, 100 tons of cane will produce 66 tons of steam (220/100x30=66). Assuming the sugar yield is 11% of cane, each ton of raw sugar would have 6 tons of steam available (66/11=6). The energy usage and availability is shown below:

Energy usage and availability

Energy consumption for a VHP refinery ---------------- 0.8 ton of steam /raw sugar
Energy consumption for a Cane mill --------------------- 3.2 tons of steam /raw sugar
Energy needed for a cane mill with attached refinery -- 4.0 tons of steam /raw sugar
Energy available in a mill with attached refinery-------- 6.0 tons of steam /raw sugar
Excess energy in cane mill if process is optimized------- 2.0 tons of steam /raw sugar

It appears that there is an excess of 2 tons of steam /raw sugar in cane mill even with a simplified refinery attached to it if operation is optimized. Bagasse is the only fuel needed for the mill. No other source of energy, such as coal, gas, or oil is needed. **This has been confirmed by two sugar mills with attached refineries.**

The energy saving of refined sugar produced in an attached refinery is equivalent to 0.8 tons of steam per ton of sugar refined compared to that produced from an autonomous VHP sugar refinery.

(VI) What are the expected performance of the “green” refining process

A) Refining cost (not including labor and energy)

1) For VHP raw sugar at 600 ICU-- refining cost: US$11.5 to $13 per ton raw sugar processed
2) For VHP raw sugar at 1000 ICU-- refining cost: US$18.5 to $20 per ton raw sugar processed

B) Percent sugar yield

1) % yield on VHP raw sugar processed: **98.09**
Estimated as follows:
VHP raw sugar: Pol. 99.4, non sucrose solid 0.5%, molasses purity 53.

Sucrose carried to molasses: 53/47 x 0.5 = 0.56%
Total sucrose loss (including unknown) 0.75% (over 15 years average of a large sugar refiner in USA)
% yield = 99.4 - 0.56 - 0.75 **= 98.09%**

2) % Sucrose recovery = 98.09/99.4 = **98.68%**

C) Product quality:
Combination of R1 (first strike), R2 and R3 sugar:
less than 40 ICU.

E) Ability to produce value added products meeting US food grade quality standard.

(VII) Capital cost of an attached simplified refinery is much less than that of an autonomous simplified refinery.

(VIII) Summary

(1) A simplified "green" sugar refinery consists of phosfloatation and press filtration only
(2) The color of VHP raw sugar entering the refinery should not exceed 1000 ICU.
(3) If color is less than 600 ICU, It is optional to use phosphatation process. Only press filtration with decolorizing processing aids is needed.
(4) If color exceeds 600 ICU, selective decolorization aids will be needed at the phosfloatation clarifier depending the VHP raw sugar color level.
(5) Baggasse is the only fuel needed for a mill with an attached refinery to produce refined sugar.
(6) There is an estimated saving of 0.8 ton steam per ton of refined sugar produced in a refinery attached to a sugar mill as compared an autonomous refinery.
(7) No sulfitation, ion exchange decolorization process, carbonation, and Granular carbon system are needed in a simplified refinery resulting in considerable savings in capital investment, and both operating environmental cost
(8) An attached simplified refinery is ideal for countries where the crop (cane grinding) season is over eight month a year.
(9) Capital cost of an attached simplified refinery is much less than that of an autonomous simplified refinery.
(10) The refining cost ranges from US$11.5 to $20 per ton of raw sugar processed depending on raw sugar color input.
(11) % sugar yield and % sucrose recovery are estimated to be 98.09% and 98.68% respectively.
(12) Sugar product color (combined R1, R2 and R3 sugar) of less than 40 ICU
(13) Ability to produce value added sugar based products meeting US food grade quality standard.

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