Journal of Academia and Industrial Research (JAIR)
Volume 6, Issue 6, November 2017

ISSN: 2278-5213

Research article

Influence of Poor Filterable Raw Sugars on the Refining Process Operations

Kamal Suleiman[1], Kanada T Korea[2] and Abubakr Musa[1,3*]
[1]Sugar Institute, University of Gezira, Wad Madani, Algezira, Sudan; [2] Alkhaleej Sugar Co Dubai, UAE; [3]School of Food and Biological Engineering, Jiangsu University, Zhenjiang, Jiangsu, China
abmuah@hotmail.com*

Abstract
The filtration process in a raw sugar refinery is influenced by two major factors namely; raw sugar quality and the operational parameters at the purification station. This paper discusses the influence of poor filterable raw sugars on the refining process operations. Raw sugar quality parameters namely polarization, color value, ash content, invert sugar content, starch content, dextran content, phosphate content, insoluble matter and turbidity were evaluated. The sugar sample A showed the highest level of turbidity followed by sugar sample D, whereas sugar sample E showed the lowest turbidity level. The correlation coefficient (r = - 0.92, n =6) indicates that turbidity has the most strong correlation and influence on the filterability of the raw melt liquor. Raw sugar polarization, color, RS, ash and dextran showed lesser influence on the filterability of raw melt liquor. The correlation data appears to suggest that it would be preferable to consider a combination of parameters affecting the filterability rather than taking a single quality parameter in particular as being the cause of filtration impedance.

Keywords: Raw sugar quality, filtration process, turbidity, raw melt liquor, quality parameter.

Introduction
Raw sugar is defined as the yellowish–brown, coarsely crystalline product obtained after a series of processes in the cane sugar factory (Baikow, 1982). The name is generally applied to a wide range of raw sugar qualities including low polarization raw sugar, very high-polarization (VHP) raw sugar and special qualities such as very low color (VLC) and very very high polarization (VVHP) raw sugars. Raw sugar quality is determined by its quality factors. According to Watson and Nicol (1975) there are eleven key parameters of raw sugar which directly impact the refining process operations. These parameters include polarization, moisture, color value, ash content, reducing sugar, starch content, dextran content, insoluble solids, turbidity and filterability. Polarization is defined as the measurement of sucrose content in sugar manufacturing. The term is customarily used in sugar analysis for the optical rotation of a sugar industry product. King (2005) mentioned that the optical rotation provides a robust and reliable quality criterion for pure sugars. Buyers and sellers of raw sugars often disagree over the premium or penalty for color more than any other quality factor (Godshall, 1997). Paton (1992) stated that low molecular weight colorants are colorants which are originated from sugarcane plant and they compose around 30% of all raw sugar color compounds. In the sugar industry talking of ash is understood as the conductivity ash rather than the inorganic component remaining after complete incineration of organic substances. It is the term used for inorganic salts, mainly potassium, calcium, and magnesium which are present in raw sugar, as defined by King (2005). Reducing sugar or invert sugar is defined by Poel *et al.* (1998) as the mixture of the two components of sucrose, the reducing monosaccharides D-glucose and D- fructose that results from the hydrolysis of sucrose. Fawcett (1986) reported that some customers are extremely sensitive to invert in many of the products they make due to its hygroscopic nature. Further, Webster (1988) reported that invert is a crystallization inhibitor; it increases viscosity, and causes loss in sucrose in molasses. Starch is a natural polysaccharide which occurs in many plants. In sugar cane it is found in the stalk and the green leaves (King, 2005). Sugar cane starch is largely present in the form of spherical granules of about 5 micron in diameter as reported by (Chou, 2000). Riffer (1980) defined dextrans as glucans, i .e. glucose–containing polysaccharides in which the main chain residues are at least 50% α-1,6 linked with α-1,4 and α-1,3 linkages at the branch points. The bacteria link up the glucose portions of sucrose molecules into long chains leaving the fructose as a by-product. The role of soluble phosphate (P_2O_5) in raw sugar factory clarification has been generally recognized in order to bring the percentage to the minimum of 0.03% (300 ppm) as reported by Chen and Chou (1993). In a carbonation refinery this would tend to reduce filterability as a result of the formation of fine calcium phosphate crystallites which block the interstices in the matrix formed by calcium carbonate aggregates, as reported by Hidi and McCowage (1984).

*Corresponding author

Insoluble solids in raw sugar are defined as the insoluble material that is caught on a standard filter. The other term is total suspended solids abbreviated as TSS, the portion of total solids retained by the filter medium. They do not settle out (Hidi and McCowage, 1984). Turbidity is defined as a measure of the degree of light scattering caused by the presence of suspended particles in solution (Godshall, 1997). Roberts *et al.* (1994) analyzed the turbidity causing fractions in the clarified juice which contributes to particulate fraction in raw sugar. Insoluble calcium salts, and small particles of field soil, polysaccharides, gums, waxes and lipids as reported by Khalid *et al.* (2000). Vianna (2000) stated that no single factor would impact on raw sugar filterability, but rather a combination of several factors. Chou (2000) summarized the impurities which are generally considered responsible of causing difficulties in filtration in sugar industry to include suspended particles with average size of less than 0.5 micron, phosphate particles which are often ultra-fine and fragile, starch which is a viscosity enhancing high molecular weight polymer and dextran is another polymer which is soluble in water. Factors affecting the filterability of raw melt liquor in the carbonatation refinery are starch, dextran, phosphates, insoluble solids, and turbidity as reported by Hidi (1984), Clarke (1996) and Khalid et al (2000) and Rein (2007). Other filtration impeding substances such as wax, gum, silica, aluminum, and magnesium have also been reported by different researchers (Chen and Chou, 1993). Clarke *et al.* (1984) and then Cuddihy *et al.* (2001) reported that total polysaccharide level in raw sugar is important because they decrease filtration rates. Devereux and Clarke (1984) then (Chou, 2000) added viscosity, brix, lime ratio and temperature as operational factors. So considering the above factors, this study discusses the influence of poor filterable raw sugars on the refining process operations.

Materials and methods

Materials: The raw sugar samples (each 500 g) were collected from the traceability store samples at Al Khaleej Sugar Refinery. Those samples were the raw sugar produced in Brazil, South-Africa, India and Thailand. They were collected from raw sugar ships being delivered to the refinery during the refining years from 1997 to 2008, AKS Lab. Reports (1998–2008). One more sample was received from Kenana Sugar factory in Sudan. Those samples were selected such that they comprise three raw sugar quality groups namely; low pol (LP), very high pol (VHP) and very very high pol (VVHP). They also include the highest values of quality parameters which are claimed to affect the filterability of raw melt liquor. During the experiments those samples were labeled by the letters: A, B, C, D, E and F.

Sugar-A: It was collected from the raw sugar ship received from Thailand and was unloaded in July 1997. The sugar was considered as the poorest raw sugar quality (low pol) received at Al Khaleej sugar refinery since the start up.

Sugar-B: It was collected from the raw sugar ship received from Brazil and was unloaded in Oct 2006. The sugar was considered as the typical Brazilian (VHP) raw sugar received at Al Khaleej sugar refinery.

Sugar-C: It was collected from the ship received from South-Africa and was unloaded in June 2004. The sugar was the typical South-african (VHP) sugar received at Al Khaleej sugar refinery.

Sugar-D: It was collected from the raw sugar ship received from India and was unloaded in Apr 2008. The sugar was considered to be the typical Indian (VHP) raw sugar received at Al Khaleej sugar refinery.

Sugar-E: It was collected from the raw sugar ship received from Brazil and was unloaded in Apr 2002. The sugar was considered to be of the best quality (VVHP) received at Al Khaleej sugar refinery.

Sugar-F: It was collected from Kenana sugar factory, in Sudan. It was the raw sugar produced during the crop of year 2005.

Those raw sugar samples were physically inspected for the shape of their crystals, appearance and odor. All the samples were found to be very sound and there were no objectionable impurities included.

Actual refinery carbonated liquor samples: For the experiment with actual refinery liquors, the carbonated liquor samples were collected at two different occasions during the refining year 2006/2007. About 100 mL liquor samples were collected two-hourly from the treated liquor after the carbonatation process, then those samples were composited every 24 h and tested for filterability.

Chemical reagents: The chemical reagents used in the experiments were prepared according to the international commission of uniform methods of sugar analysis (ICUMSA) methods book # 4 published in (1994) and supplemented in (1998). Distilled water with a conductivity ash less than 2 µS/cm was used as the solvent for preparation of sugar solutions and for preparing chemical reagents.

Physicochemical analysis for quality parameters of raw sugar samples in the laboratory: Each of the six raw sugar samples was chemically analyzed for the most important quality parameters using standard methods used in the sugar industry. Polarization (%), moisture (%), color value (I.U), reducing sugars (%), ash (%), dextran content (ppm) and insoluble solids (ppm) all were determined according to the international commission of uniform methods of sugar analysis (ICUMSA) methods (GS2/3-1), (GS2/1/3-15), (GS2/3-9), (GS2/3-5), (GS2/3 -17), (GS1-15) and (GS2/3 -19) respectively, ICUMSA Methods Book (1994). The pH indicator value (I.V) and alcohol precipitation test were performed according to

*Corresponding author

sugar processing research institute (SPRI) Methods (1984). Starch content (ppm) was done according to laboratory manual for Australian sugar mills (1984). Phosphate content (ppm) was performed according to laboratory manual for South African sugar factory materials analysis, Anon (1985) and the turbidity was analyzed using Nephlometric turbidity determination method by Hach2100N (1983). The parameters were analyzed and their results were presented in table and the correlation of these parameters with the filterability in actual refining process operations was reported.

Determination of the filterability of raw sugar samples using laboratory filtration equipment: This method is the modified Australian Nicholson Horsely filtration determination method (Lab Manual for Australian Sugar Mills, 1984). It is based on the comparison between the volume of filtrate of the test solutions of various raw sugars with the volume of filtrate of a pure white sugar solution under standard and identical conditions. The calibration test performed using pure refined sugar was done first and the volume of the filtrate was collected after 5 min and used as the reference to calculate the filterability of different test samples.

Procedure: A sample solution for each raw sugar was prepared and adjusted to 65.0 brix in a plastic bottle. The pH of the solution was adjusted to pH 8.2 using buffer solution 9. The filter aid Celite Hyflosupercel was added (0.5% on solids). The mixture was stoppered and heated in a water bath till 80°C with gentle shaking. The filtration apparatus was assembled and mounted in a water jacket. Water was circulated in the jacket and maintained at 80°C. The sample was transferred to the filter funnel having 8 micron filter paper and the stop watch was simultaneously started. The filtrate volume for each sample was collected after 5 min in a measuring cylinder for the calculation of filterability. The accumulated filtrate volumes against filtration time were recorded for 10 min. Finally a graph was plotted using the accumulated filtrate volume versus the filtration time. For standardization, a pure refined sugar solution was prepared and adjusted to 65 brix and the same procedure for filtering raw sugar samples was followed. The volume of filtrate collected after 5 min was recorded. The filterability of each raw sugar sample was calculated against the refined sugar volume using the formula:

$$\text{\% Filterability} = \frac{\text{Vol. of filtrate of the test solution}}{\text{Vol. of filtrate of the pure refined sugar solution}} \times 100$$

Determination of filterability of actual refinery carbonated liquor samples from VHP and VVHP raw sugars: For the determination of the filterability of actual refinery liquor, 50 mL of the carbonated liquor samples were collected from the carbonated liquor tank just before the filtration process on 2 h basis. Those samples were composited every 24 h, then heated to 80°C. The brix and pH were measured. Finally the sample was analyzed for the filterability determination using similar procedure as for the raw sugar samples (Laboratory Manual for Australian Sugar Mills, 1984). This procedure was followed with two different raw sugars namely, VHP and VVHP. Those analyses for the filterability were tripled for each type of raw sugar and the test results were averaged.

Statistical analysis: To specify the correlation between raw sugar quality parameters and the filterability of raw melt liquor, the values of each quality parameter were plotted versus the values of filterability of raw melt liquor. The correlation coefficient of each quality parameter was calculated using www.easycalculation.com/statistics/learn Correlation). The graphical representation for each of those quality parameters were conducted in excel 2007 (MS office 2007).

Results and discussion

Physicochemical analyses of raw sugar samples: Six raw sugar samples namely sugar-A from Thailand, sugars-B and E from Brazil, sugar-C from South Africa, sugar-D from India and sugar-F from Sudan, were chemically analyzed using the standard ICUMSA methods for the following quality parameters namely polarization, moisture content, color value, pH indicator value, alcohol precipitation, invert or reducing sugars, ash content (conductivity), starch content, dextran content, phosphate content, insoluble solids, and turbidity (Table 1). Results of filterability test (mL/10 min) for the six raw sugar samples under investigation are shown in Table 2. The physicochemical analysis of the composited samples of carbonated liquor from VHP and VVHP are presented in Table 3. The results of the filterability determination for those refinery liquor samples are presented in Table 4.

Raw sugar polarization: In Table 1, sugar sample A had the polarization of 97.64%. This is the lowest % polarization among the sugar samples. Further, it contains the highest values of non-sugar impurities such as color, starch, insoluble matter and turbidity. On the other hand, sugar sample E represents the highest pol%, among the raw sugar samples. This means the lesser the non-sugars available, the better the refining quality of raw sugar (Table 5).

*Corresponding author

Table 1. Results of physicochemical analysis for the raw sugars.

Parameter/Sample	Unit	A	B	C	D	E	F
Polarization	%	97.64	99.42	99.27	99.24	99.65	99.21
Moisture content	%	0.39	0.07	0.10	0.07	0.04	0.08
Color value	I.U	6617	730	2180	1390	429	827
pH ind. value (I.V)		3.30	2.72	1.81	2.50	1.33	2.31
Alcohol ppt.		Dark brown	Light green	Brown	Brown	Light green	Brown
Reducing sugar	%	0.68	0.10	0.12	0.14	0.06	0.12
Ash (conductivity)	%	0.33	0.15	0.14	0.13	0.06	0.14
Starch content	Ppm	313	211	188	240	145	160
Dextran content	Ppm	48	16	22	14	8	18
Phosphates	Ppm	29	18	32	38	14	22
Insol. solids (8 µ)	Ppm	354	221	218	243	162	210
Turbidity (25 Bx)	NTU	88	69	71	82	35	65
Filterability	%	20	65	48	27	80	52

*Values in the above table are average of three tests.

Table 2. Results of filterability test (mL/10 min) for the six raw sugar samples under investigation.

Time (min)	A	B	C	D	E	F
1	10	28	24	12	40	16
2	13	47	34	17	56	30
3	16	54	41	21	66	38
4	18	60	45	25	74	45
5	20	65	48	28	80	52
6	22	68	50	30	85	57
7	23	71	52	32	88	60
8	24	73	54	33	91	63
9	25	75	55	33	95	65
10	25	76	56	34	98	67

Table 3. Results of the physicochemical analysis for actual refinery carbonated liquor from VHP and VVHP sugars.

Parameter	Carbonated liquor from VHP sugar	Carbonated liquor From VVHP Sugar
Brix (%)	63.5	64.2
pH	8.2	8.1
Color (I.U)	352	260
R.S (%)	0.10	0.06
Ash (%)	0.15	0.07
Starch (ppm)	80	24
Insol. Solids (ppm)	22	15
Turbidity (NTU)	60	40

Table 4. Results of filterability determination for the actual refinery carbonated liquor from VHP and VVHP sugars.

Parameter	VHP	VVHP
1	22	32
2	32	47
3	41	59
4	48	68
5	54	76
6	60	80
7	64	87
8	66	93
9	69	98
10	70	102

*Corresponding author

Fig. 1. Polarization versus filterability.

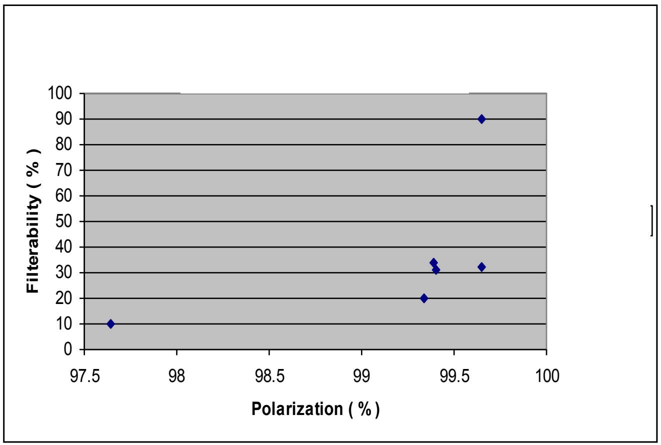


Fig. 2. Color versus filterability.

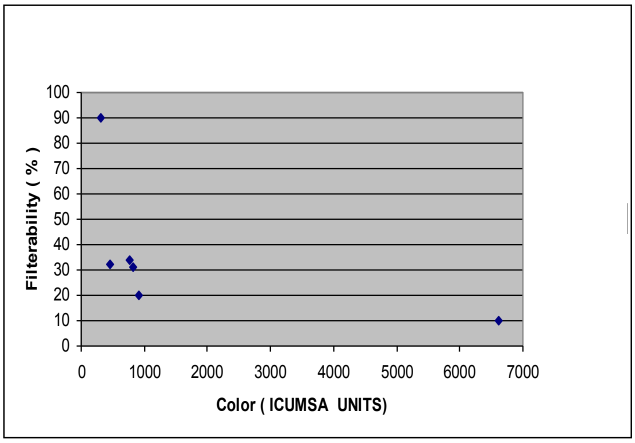


Figure 1 shows the graph of polarization versus filterability. The coefficient of Correlation (r=0.77, n=6) which indicates that polarization has less influence on the filterability. However, raw sugar polarization is very important for the energy requirement during processing, Low pol sugars increase the energy consumption in the refinery as reported by Humm (1979). The main reason is the non-sugar impurities which end up in the recovery house demanding for more re-boilings. This statement coincides with the practical experience gained at AKS refinery when raw sugar quality was changed from low pol (LP) sugar to very high pol (VHP) sugar which resulted in the reduction of refinery steam consumption from 0.65 ton per ton of refined sugar to 0.44 ton per ton of refined sugar and the electrical energy from 60 KWH per ton of refined sugar to 50 KWH per ton of refined sugar (Al Ghurair and Singh, 1999).

Raw sugar Color: The result of the physicochemical analysis for the six sugar samples showed that sugar A has the highest color value (6617 I.U), whereas sugar E revealed the lowest color value (429 I.U). The remaining sugar samples fall in between these two values. Figure 2, demonstrates the graphical representation of color versus filterability. However, the correlation coefficient value (r=-0.75, n=6) indicates that color also has less influence on the filterability of raw melt liquor. This value is slightly lower than the value (r=0.78) reported by Simpson and Davis (2001). The effect of color on filterability is indirectly reflected by the viscous nature of some coloring matters causing a decrease in the filtration rate (Vianna, 2000). Clarke *et al.* (1998) reported two tests which are purposely used to identify the origin, type and chemical nature of the colorants in raw sugar. These tests are pH indicator value and alcohol precipitation. They provide knowledge about the different types of color, their interactions and behaviors during the refining process.

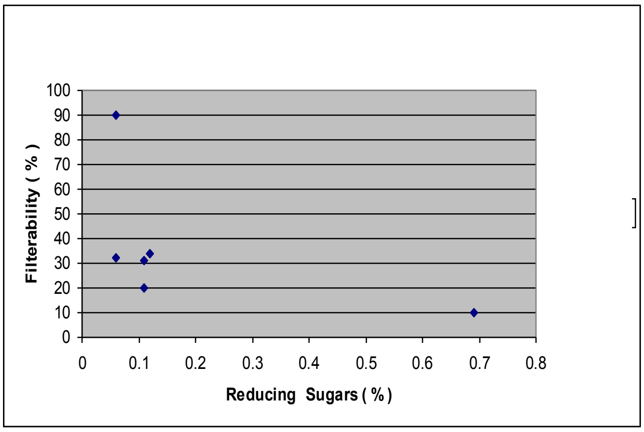
pH Indicator value and alcohol precipitation test: Although not used for purchasing or in contracts, several tests are available that can provide additional information about the type of colorant in raw sugar. Among these are indicator value (I.V) and alcohol precipitation tests. They were performed for each sugar sample in order to identify their color types and origins. As depicted in Table 1, sugar A had the highest pH indicator value followed by sugar B, with values being above 2.5, whereas sugar E gave the lowest pH indicator value. With reference to the statement of Clarke *et al.* (1984), sugars A, B will decolorize satisfactorily at the refinery purification station, whereas sugars E and C will not. According to Clarke *et al.* (1998) raw sugars with higher pH indicator values have got the greater degree of phenolic materials and will decolorize satisfactorily during the purification process, whereas those with low pH indicator value have got higher levels of amine color or caramel color and both are more difficult to be removed by most refinery processes. Sugar A in Figure 3 displayed a heavy precipitate of reddish color indicating the presence of phenolic colorants. On the other hand, sugars B, C, D, E, and F produced a light precipitates of grey–brown colors indicating the presence of melanoidin or melanin colorants. Again Clarke *et al.* (1998) stated that the grayish color precipitate is associated with high dextran levels, whereas the yellow or reddish brown colors tend to indicate high molecular weight colorants, and the grey-brown or duller colors are associated with uncharged high molecular weight melanoidin or melanin colorant.

Reducing sugars (RS): The results of the physicochemical analysis for reducing sugars (RS) in Table 1 indicated that sugar A contains the highest RS with the value (0.68%), while sugars B and E got the lowest RS values. Figure 4 shows the graphical representation of reducing sugars versus filterability.

*Corresponding author

Fig. 3. Alcohol precipitation test for raw sugar samples A-F.

Fig. 4. Reducing sugar versus filterability.



The correlation coefficient (r=-0.71, n=6) indicates that RS has less influence on the filterability of raw melt liquor. Webster (1988) then Godshall *et al.* (1996) reported that high reducing sugars content will inhibit crystallization, leads to the increase in the viscosities, lengthen boiling time and creates problems in molasses.

The practical experience from Al Khaleej sugar refinery showed that reducing sugars content of more than (0.30%) will result in color build-up in the process liquor streams drastically, in particular, when the pH is slightly higher than normal. The consequences were very noticeable operational problems at various refinery stages, including carbonatation, centrifugation, sugardrying, conditioning, and conveying system, AKS laboratory reports (1998-2008). These remarks are in total agreed with the statement of Clarke and Benjamin (1996) that high reducing sugars create poor purging and makes the sugar difficult to dry. Chou (2000) also supported this statement.

Ash content%: The result of the physicochemical analysis in Table 1 showed that sugar A had the highest ash content (0.33%), whereas sugar E followed the quality logic by having the lowest ash value of (0.05%). Figure 5 gave the coefficient of correlation of (-0.75). This value indicates that ash has no influence on filterability of raw melt. Ash is a quality parameter which has a negative effect on the sugar refining process. It is understood that more ash brings down more sucrose to final molasses. By its nature turns out to be a complex mixture reported by Tuson (1979). Ash will influence the refinery processes and operations in various ways, some affecting the equipment, some affecting the yield and some affecting the product quality. The major effect being on the cost to produce a consistent, within specification; final product (Tuson, 1979). Lopez–Ona (1979) reported that when ash exceeds (0.12%), the refinery will experience difficulty in the refining process. The practical experience at Al Khaleej sugar refinery showed that processing raw sugars with higher ash content was difficult to separate at the affination section. Hence more affination syrup was sent to the recovery house, which means that more steam will be needed for the re-boiling of remelt sugars. This observation coincides with the statement by Chou (2000) that high ash content needs more steam, increases sugar loss in molasses and deteriorates the final product quality. This is in addition to its definite impact on the conditioning capacity at sugar silos.

Starch content: Table 5 showed that sugar A had the highest starch content, followed by sugars B and C respectively, while sugar E got the lowest starch content. In Figure 6, the starch content of different raw sugars showed correlation coefficient of (r=-0.84, n=6), which proves that it has a strong influence on the filterability of raw melt liquor. This value is higher than the values found by Simpson and Davis (1998) and Vianna (2000). In a carbonatation sugar refinery, starch has been recognized by most research workers as the main quality factor which severely impedes the filtration performance.

*Corresponding author

Fig. 5. Ash versus filterability.

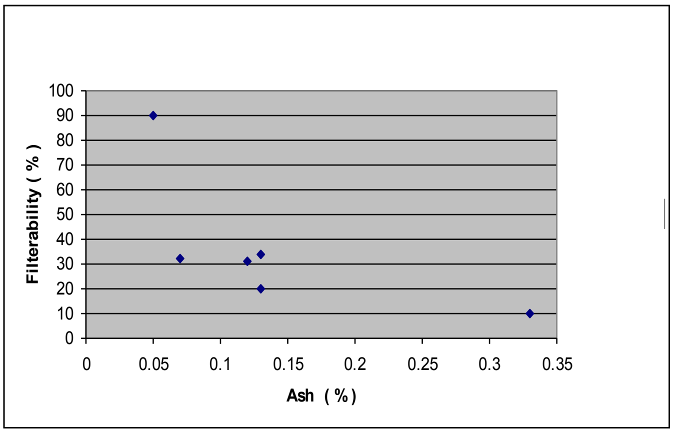
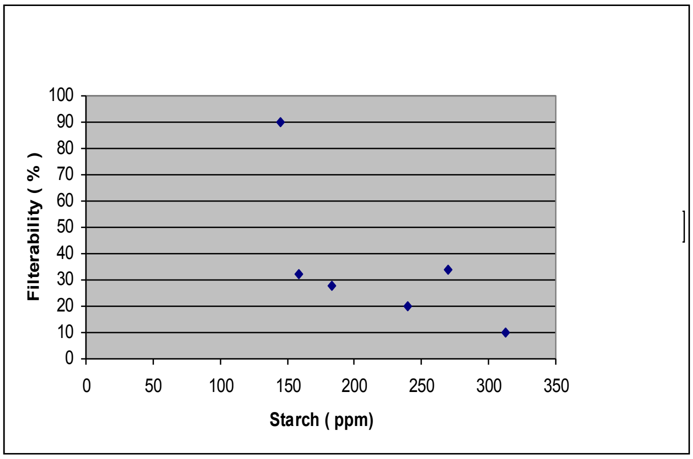


Fig. 6. Starch versus filterability.



Therefore, it is expected to show a very good correlation to the raw melt liquor filterability. Bennett and Gardiner (1967) then Murray and Runggas (1974) explained how the starch affects filterability in the carbonatation refinery. They reported that amylose component of the starch will interfere with the growth of calcium carbonate crystals causing the reduction of the filterability of the resulting cake. Further, the practical experience at Al Khaleej sugar refinery showed that processing raw sugars with starch content above 100 ppm will create processing problems at the filtration stage causing a direct reduction of the refinery melting rate. This practical remark contradicts the statement of Ramsey and Watts (1974) who reported that raw sugars with starch level below 150 ppm will not cause filtration difficulties.

Dextran content: As depicted in Table 5, almost all sugar samples showed dextran levels less than 50 ppm, which indicates that dextran levels in raw sugar production is always controlled. However, even at those low levels it can affect the filterability.

Figure 7, gave the correlation coefficient (r=- 0.72, n=6) which means that dextran has lesser influence on the filterability of raw melt liquor. This value falls in between the values (-0.50 and -0.78) obtained by Simpson and Davis (1998) and Vianna (2000) respectively. Raw sugars containing dextrans of smaller molecular weight less than 2 $x10^6$ had no significant effect. On the other hand, dextrans with molecular weight between 5-40 x 10^6 had very serious effects reported by Riffer (2000). Simpson and Davis (1998) reported a benchmark for dextran content of VHP sugar as 300 ppm. Above this level, it will create problems in the refinery. This benchmark is far higher than the values normally obtained in VHP raw sugars purchased by sugar refineries during last few decades as raw sugar producers are taking more care. Chou and Wnukowaski (1980) observed that high dextran increases the viscosity of raw melt liquor, hence affects the rate of flocculation, floatation, filtration and the rate of scum compression. Bose and Singh (1981) evaluated the dextran level in raw sugars with respective sucrose losses incurred to it. Table 6 shows the sucrose loss due to dextran effect in a refinery.

Phosphate content: The result of the determination of soluble phosphate content of the raw sugar samples were presented in Table 5. It is clear that sugar sample D got the highest phosphate content followed by sugar samples C, A, F, and B respectively, whereas sugar E showed the lowest phosphate value. Surprisingly, sugar sample A which is belonging to the quality group of LP sugars, came third in the descending order indicating that high quality raw sugars such as VHP can also possess some of the quality factors higher than that of low quality raw sugar. In Figure 8, the correlation coefficient (r=-0.84, n=6) indicates that phosphate content has a strong influence on the filterability of raw melt liquor. However, this value is 10% higher than the value (-0.76) obtained by Simpson and Davis (1998). In a carbonatation refinery phosphate content would tend to reduce filterability of raw melt liquor as a result of the formation of fine calcium phosphate crystallites which block the interstices in the matrix formed by calcium carbonate aggregates as stated by Chou (2000). Simpson and Davis (1998) reported a benchmark of 20 ppm for good quality raw sugar. This finding agreed with that of Hidi and McCowage (1984) found after adding phosphates to the sugar solution. They noticed a rise in the filtration impedance of the raw sugar melt indicating a linear relationship between phosphate content and the filterability of raw melt liquor.

Insoluble solids: It is clearly shown in Table 6 that the insoluble solids content for sugar sample A is the highest. On the other hand, sugar sample E showed the lowest content. The remaining sugar samples fall in between these two values.

*Corresponding author

Table 5. Levels of starch, dextran and phosphates for raw sugar samples.

Sugar	Starch (ppm)	Dextran (ppm)	Phosphates (ppm)
A	313	48	29
B	211	16	18
C	188	22	32
D	240	14	38
E	145	8	14
F	160	18	22

Table 6. Levels of insoluble solids and turbidity for raw sugar samples.

Sugar	Insoluble solids (ppm)	Turbidity (NTU)
A	354	88
B	221	69
C	218	71
D	243	82
E	162	35
F	210	65

Fig. 7. Phosphate versus filterability.

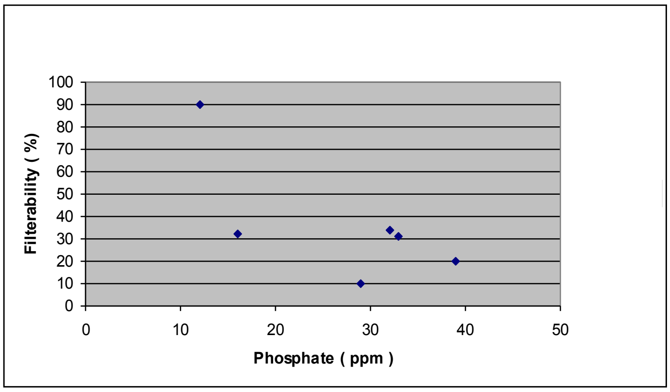
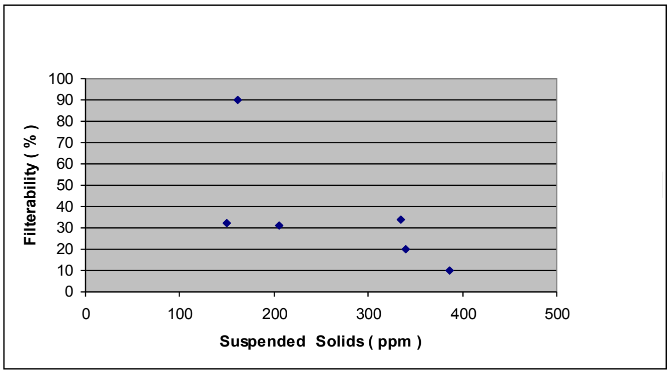


Fig. 8. Phosphate versus filterability.



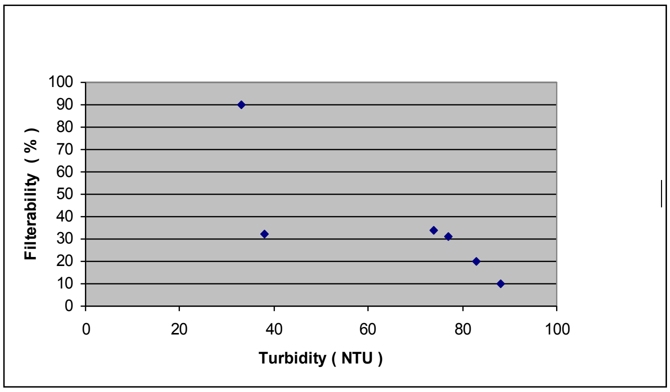
In Figure 8, the correlation coefficient (r=- 0.86, n=6) means that the insoluble solids have a strong influence on the filterability of raw melt liquor. This value was even higher than the values of starch and dextran. Normally the insoluble solids are widely considered as the greatest contributor to filtration impedance especially those having particle sizes below 4 micron as reported by Devereux and Clarke (1984).

Simpson and Davis (1998) also reported a value (-0.83) which is a reasonable indication as being most strongly correlating factor. In practical terms, the impurities in raw sugar known to cause filtration difficulties fall into three main categories. They include insoluble, partly miscible and soluble. The insoluble normally include debris, machinery parts, metals, rubbish, stones and sand. Devereux and Clarke (1984) reported that high insoluble solids content affects mostly the clarification, filtration and centrifugation processes.

Turbidity: In Table 6, the sugar sample A showed the highest level of turbidity followed by sugar sample D, whereas sugar sample E showed the lowest turbidity level. In Figure 9, the correlation coefficient (r=-0.92, n=6) indicates that turbidity has the most strong correlation and influence on the filterability of the raw melt liquor. This value is quite higher than the value (-0.76) obtained by Simpson and Davis (1998) but approximately matching values (0.93) obtained by Vianna (2000). Turbidity is a very important quality problem in raw sugar because it affects the carbonatation process, blocks the filters in the refinery process and gives final product not suitable for the refreshment industry. In fact, there are many parameters contributing to the turbidity of raw melt liquor including insoluble solids and others and since those factors got a strong influence on the filterability of raw melt liquor. Thus turbidity is eventually expected also to have a strong correlation and influence on the filterability of raw melt liquor. The practical experience from Al Khaleej sugar refinery showed that carbonatation process followed by filtration removes (95%) of the raw melt turbidity, AKS laboratory reports (1998-2008).

*Corresponding author

Fig. 9. Turbidity versus filterability.



Conclusion

Raw sugar turbidity showed the strongest influence on the filterability of raw melt liquor. The insoluble solids, phosphate and starch came in the second order. Raw sugar polarization, color, RS, ash and dextran showed lesser influence on the filterability of raw melt liquor. The correlation data appears to suggest that it would be preferable to consider a combination of parameters affecting the filterability rather than taking a single quality parameter in particular as being the cause of filtration impedance. Following the proposed methods of handling poor filterable raw sugars will give remedies which reduce the economic impacts.

Acknowledgements

Authors are grateful to the staff members of Sugar Institute, University of Gezira-Sudan and Alkhaleej Sugar Refinery Company, Dubai, United Arab Emirates.

References

1. Al Khaleej Sugar Refinery (AKS), Laboratory Reports (1998–2005).
2. AlGhurair, J. and Singh, C. 1999. Al Khaleej Sugar the Energy Efficient Refinery. Sugar International Technologists Conference (SIT). Baltimore, USA.
3. Baikow, V.E. 1982. Manufacture & Refining of Raw Cane Sugar, 2nd edit., pp. 285-350.
4. Bennet, M.C. and Gardiner, S.D. 1967. Raw Liquor Carbonatation. *Int. Sugar J*. (69): 198-202.
5. Bose, S. and Singh, L. 1981. Problems associated with dextran and the major microbiological cause of sucrose loss and their remedies in raw sugars. *Ind. Sugar.* 12: 603-608.
6. Carpenter, F.G., Roberts, E.J. and Clarke, M.A. 1975. Constituents in raw sugar that influence refining. *ISJ*. 77: 9-12.
7. Chen, J.C. and Chou, C.C. 1993. Cane sugar handbook: A manual for cane sugar manufacturers and their chemists. John Wiley & Sons.
8. Chou, C.C. 2000. Handbook of Sugar Refining. *New York*, pp.565-597.
9. Clarke, M.A., Blanco, R.S., and Godshall, M.A. 1998. Proc. (SPRI).
10. Cuddihy, J.A., Porro, M.E. and Rauh, J.S. 2001. The presence of total polysaccharides in sugar production and methods for reducing their negative effects. *J. Amer. Soc. Sugarcane Technol. Bundaberg.* (21): 73-91.
11. Davis, S.B. 1959. ISJ, pp.300-392.
12. Devereaux, J.A. and Clarke, M.A. 1984. Non-sucrose components of cane sugar and efficiency of pressure filtration. *Proc. Sug. Ind. Technol.* 43(36): 59.
13. Fawcett, G. 1986. Ash and invert in raw sugar from a refiner's viewpoint.
14. Godshall, M.A. 1997. Symposium on sugar color. Part 2. Color analysis. S.I.T. paper: 211-23.
15. Godshall, M.A., Clarke, M.A. and Dooley, C.D. 1996. Proc. Sugar Process.
16. Hidi, P. and McCowage, R.J. 1984. Quantification of the effects of different raw sugar impurities on filtration rates in carbonatation refineries. *Proc. sugar process research.* pp. 186-208.
17. Humm, D.M. 1979. Raw Sugar Polarization, (SIT), pp.127-133.
18. ICUMSA, International Commission for Uniform Methods of Sugar Analysis, book 1994 with 1st supplement 1998. Colney, Norwich, England.
19. Kennedy, A.M. and Smith, P. 1976. Color in refineries. In *Proc. Sugar Ind. Technol.* (35): 156-160.
20. Khalid, I., Linda, S. and Godshall, M.A 2000. Sugar Processing Research Institute (SPRI), pp.261-273.
21. King, S. 2005. Raw cane sugar quality from the Producer Perspective, Sugar International Technologists Conference, Dubai.
22. Laboratory Manual for Australian sugar Mills 1984, (1).
23. Lopez, O. and Bumert, J. 1979. The Effect of Raw Sugar Quality on Sugar Cane Syrups. *Int. Sugar J.* 97: 339-343.
24. Murray, J.P. and Runggas, F.M. 1974. Proc. of ISSC, pp.1296-1306.
25. Paton, N.H. 1992. The Origin of Color in Raw Sugar, Proc. Australian Society of Sugar Cane Technologists (ASSCT).
26. Ramsey, A.C. and Watts, R.S. 1974. Queensland Society of Sugar Cane Technologists (QSSCT), pp.223.
27. Riffer, R. 2000. Phosphatation for Turbidity and Color Removal. Handbook of sugar refining by Chou, pp.55-71.
28. Simpson, R. and Davis, S.B. 1998. Investigation into the filtering quality of raw sugar. *Proc SA@ Sug Technol Ass*, pp.72.
29. Tuson, W.R. 1979. SIT, Ash in Refining Process.
30. Vander Poel, P.W. 1998. Sugar Technology Beet and Cane Sugar Manufacture PW van der Poel, H. Schiweck, T. Schwartz. Berlin: Verlag Dr. Albert Vartens KG.
31. Vianna, E. 2000. Filterability study of raw sugar. In Proceedings of the Sugar Processing Research Conference, Porto, Portugal.
32. Watson, J.A. and Nicol, W. M. 1975. *Sugar Technol. Rev.* pp.69-126.
33. Webster, G. 1988. Chemoreception, (SIT) (Doctoral dissertation, Univ. of Manchester Inst of Sc. & Tech., Elsevier, London, UK).

*Corresponding author