Impact of Clarification on Raw Sugar Quality in Cane Sugar Factories

Case Study: Kenana and El-Guneid Sugar Factories, Sudan

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Date of Examination: 16 / 11 / 2017
Dedication

To

My family

Mother, father's soul

Brothers and sister

To my colleagues, teachers and friends
Acknowledgement

First of all, my full praise to Allah who gave me health and patience to accomplish this work. And thanks to my family for their support.

I avail this opportunity to express my deepest thanks, appreciation and gratitude to my supervisor Prof. Elnur Kamal Eldin Abu Sbah for his guidance, understanding encouragement, confidence and supervision of this work.

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Impact of Clarification on Raw Sugar Quality in Cane Sugar Factories

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Abstract

Sugar cane is the main source of sugar in all tropical and subtropical countries of the world. It is an important food commercial crop in Sudan, and the main source of sugar produced for both export and domestic consumptions. The clarification process in sugar manufacturing is required to remove suspended matters, provide a clear juice with a minimum turbidity, and color in addition to saving of sucrose from inversion sugar. The objective of this research is to study and compare the impact of clarification on raw sugar quality, in Kenana and El-Guneid sugar factories. The data were collected during the last weeks of season (2016-2017) to test quality for clarified juice and raw sugar, include polarization (%), color value (IU), brix (%), turbidity (NTU), dextran content (ppm) and ash conductivity for clarified juice (%) and raw sugar (µS). Reducing sugar (%), purity (%), phosphate content (ppm) and pH value for clarified juice. Filterability test (%) for raw sugar. Official methods in accordance with the International Commission of Uniform Methods of Sugar Analysis (ICUMSA). Samples from Kenana and El-Guneid sugar factories were collected during six successive days. The samples of clarified juice were taken first, and the samples of A- raw sugar were taken after 4 hours. The average of readings was taken for each parameter of the analyzed samples. The results showed that both sugar factories had high clarified juice color, turbidity, reducing sugar and high raw sugar dextran content. When comparing results of Kenana and El-Guneid sugar factories, Kenana sugar factory was better than El-Guneid sugar factory in brix (12.43%), purity (84.09%), turbidity (1480.25 NTU), reducing sugar (0.745%) and dextran content (75.3) for clarified juice, and was better in turbidity (132.3NTU), dextran content (371.25ppm) and filterability (15.04%) for raw sugar. El-Guneid sugar factory clarified juice and raw sugar was better than Kenana sugar factory in color (7044.56, 511.33 IU) and ash conductivity (2618.33µS, 0.0285%) respectively. The study recommends to improve clarification process in both factories, particularly El-Guneid sugar factory as it's raw sugar is a final product. Also it is recommended further study of membrane technology in clarification process in Sudanese sugar factories.
تأثير عملية التنقية على جودة السكر الخام في مصانع سكر القصب

دراسة حالة: مصنع سكر كنانة و الجنيد، السودان

هند دفع الله محمد دفع الله

ملخص الدراسة

يعتبر قصب السكر المصدر الرئيسي للسكر في المناطق الاستوائية وشبه الاستوائية. وهو محصول غذائي وتجاري هام في السودان، والمصدر الأساسي لإنتاج السكر للتصدير والإستهلاك المحلي. عملية التنقية في إنتاج السكر تتطلب إزالة المواد العالقة وإنتاج عصير نقي قليل العكارة و اللون بالإضافة إلى حفظ السكريات

من التحول. الهدف من هذا البحث هو دراسة و مقارنة تأثير عملية تنقية العصير على جودة السكر الخام لمصنعي كنانة و الجنيد. لإجراء الدراسة أخذت عينات من مصنع سكر كنانة و سكر الجنيد خلال الأسابيع الأخيرة لموسم (2017-2016) لإختبار جودة العصير النقي و السكر الخام، و تشتمل القطبية (%)، اللون (I.U)، نسبة المواد الصلبة الذئبة بالكتلة (%)، العكارة (NTU)، الدكستران (ppm)، ومحتوى الرماد (μS) للسكر الخام (%). تم إجراء الاختبارات تبعا لوحدة اللجان الدولية للمواد

الموهرة لتحليل السكر. تم جمع العينات خلال ستة أيام متتالية، حيث تم جمع عينات العصير، و بعد أربع ساعات تم جمع عينات السكر الخام. تم أخذ متوسط القراءات لكل العينات. أوضح النتائج أن كلا المصنعين يحتويان على نسبة عالية من اللون، العكارة و السكر المختزل في العصير النقي، ومحتوى الدكستران في السكر الخام.

المقارنة بين مصنعي كنانة و الجنيد أوضحت أن العصير النقي في مصنع سكر كنانة أفضل من مصنع سكر الجنيد في نسبة المواد الصلبة الذئبة بالكتلة (%12.43)، العكارة (NTU84.09)، السكر المختزل (%75.3ppm)، ومحتوى الدكستران (1480.25 NTU) و أنه السكر الخام أفضل في العكارة (132.25 NTU) ومحتوى الدكستران (%15.04) والفطرة (%15.04) العصير النقي و السكر الخام في مصنع سكر الجنيد أفضل من مصنع سكر كنانة في اللون (7044.56 IU) و موصلية الرماد (511.33 μS) و على التوالي أوصت الدراسة بتحسين عملية تنقية السكر في كلا المصنعين.

إذن النتائج أظهرت أن العصير النقي من مصنع سكر الجنيد أفضل من العصير النقي من مصنع سكر كنانة، حيث كانت نسبة المواد الصلبة الذئبة بالكتلة (%12.43) و الحكارة (NTU84.09) أعلى في العصير النقي من مصنع سكر الجنيد، بينما كانت نسبة السكر المختزل (%75.3ppm) و السكر الخام (%84.09) أعلى في السكر الخام من مصنع سكر الجنيد. كما أوصت الدراسة أيضاً بدراسة تقنية الأغشية في عملية التنقية في مصانع السكر السودانية.
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<td>IU</td>
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Chapter One

1.0 Introduction

1.1 The Cane Sugar Industry

The sugar requirements of the world are supplied from two main sources the sugar cane and the sugar beet. The sugar cane has been known for at least 2,000 years, and crystal sugar has been manufactured from it for a similar period, as indicated by the Sanskrit word "sharkara", which denotes material in a granular form, and is the origin of the term "sugar" in modern languages. The manufacture of sugar from the beet sugar plant is of more recent origin, having developed since the beginning of the 19th century (Jenkins, 1966).

1.2 Sugar production

Sugar production from sugar cane syrup has a great economical and technical importance. The process simply involves purification, decolorization and crystallization of sugar cane juice. Purification and decolorization are classically achieved by defecation, sulphitation, phosphitation, carbonation, etc. of sugar juice. Most existing technologies utilize many chemicals, which are not only polluting, but also affect the quality of the sugar product. (Abdul Aziz et al, 2004).

The production of raw sugar from sugarcane consists of a series of units of operation, which begins with the extraction of the cane juice from the cane stalks and subsequent removal of the non-sugars. (Broadhurst, 2002).

1.3 Processing in Cane Sugar Industry

The first step in the production of raw sugar is the preparation of the cane stalk. This involves the washing of the cane, knifing and shredding to produce a cane fiber bed. (Rein, 2007). Fig. 1.1 shows the production steps of raw sugar.

According to (Rein, 1995) and (Kelly and Robert, 1978) There are two processes for extracting juice from cane, milling and diffusion.

The fiber bed is fed into either a diffuser or milling tandem. The aim of the diffuser or mill is to extract sucrose from the fiber bed with the least amount of impurities. The diffuser uses hot water to wash the sucrose from the fiber bed, while the milling tandems use pressure as well as a relatively small amount of water to remove the sucrose (Rein, 2007).
The juice extracted from the diffuser or milling tandem, most commonly termed raw juice, is passed through a clarifier. The clarifier removes the impurities, colloidal and fine suspended matter, and soluble constituents. The fine suspensions coagulated to give particles which will settle at a reasonable rate, and the juice is then pumped to settling vessels to allow the coagulated matter to settle (Jenkins, 1966). The solution that results from the clarifier is termed clear juice. Mud is a waste product and is passed through a mud filter where excessive water is removed and where the remaining solids are usually returned to the fields as fertilizer (Engelbrecht et al., 2009).

Evaporation follows the clarification process. In the evaporation process the water content of the clear juice is reduced in order to form syrup. The syrup is then processed through three evaporation/crystallization pans, A, B and C, as each pan evaporates a lower quality material than the previous. i.e. A pans evaporates syrup, B pans evaporates A molasses etc. With the addition of seed crystals to these pans, crystallization occurs growing the seed crystals (Rein, 2007). After evaporation in the pans the resultant sugar crystals and mother liquor, now termed massecuite, is mixed to obtain an even consistency then passed through a centrifuge. The centrifuge removes the sugar crystals from the remaining mother liquor. The crystals are then sent on to drying and storage or packaging. The remaining mother liquor is passed to the next evaporation pan or passed out of the C pan as molasses (Engelbrecht et al., 2009). The newly created sugar crystals are dried to ensure suitable properties for handling and to prevent conglomeration during storage (Rein, 2007).

Problems in raw sugar quality are attributed to the problems in clarification process if it is good or bad. Clarification process in general consists of removing all kind of particles, sediment, natural organic matter and color. Juice clarification reduces the amount of insoluble particles in the raw juice resulting in a clear juice ready for crystallization. This step in the sugar factory involves the removal of bagacillo from the raw juice, heating of the juice and lastly the removal of suspended particles from the raw juice. Clarification produces a clear juice and a waste product, viz. mud. (Boote, 2010).

High quality of raw sugar means high pol, low color and low ash. Small reductions of pol may correspond to increase in the impurity loading on the recovery house.
The amount of ash removed in affination is depending on a number of factors; one of the most important being the quantity and composition of the impurities in the adhering molasses film (Terry, 2009).

Dextran problems lead to allowing fine suspended matter to carry over into clarified juice. Dextran is formed from the breakdown of sucrose as a result of bacterial action and heat. The presence of fine insoluble matter has an adverse effect on filterability in the refinery. Likewise it's impact on sugar processing by increasing viscosity in syrup streams resulting in reduced heat transfer coefficients of pans with reductions in boiling rates, and viscosity that causes reduction in crystallization rate. (Terry, 2009).

Mud, bagacillo, turbidity, Phosphorous, silica and other inorganic impurities, dextran, starch, gums, proteins and other high molecular weight polysaccharides can also reduce filterability. This is costly in terms of increased energy costs and reduced production. (Terry M Jansen, 2009).

This discussion explains the importance of clarification step.

The clarification stage among the other process operations in the sugar factory, is the stages that affect all the following stages. For that, this study is concentrating on clarification and it’s impact on raw sugar quality.
Simplified flow diagram from clear juice to raw sugar production (from cane sugar factories)

Parameters to be tested

- Polarization, Color value, pH value, Brix,
- Purity, Turbidity, Reducing sugar,
- Conductivity ash, Dextran content,
- Phosphate content.

Fig (1.1) Flow diagram
1.4 Objectives

The general and specific objectives of the research are:

1.4.1 General objective

The impact of clarification on raw sugar quality.

1.4.2 Specific Objectives

The specific objectives are:

- Effecting of clarification in both factories.
- Determination of raw sugar quality that corresponding to the clear juice quality in both factories.
- Comparison between clear juice and raw sugar for both factories.
Chapter Two

2. 0 Literature Review

2. 1 Importance of clarification

A good quality raw sugar product is impossible without good clarification of sugar cane juice. The purpose of clarification is the precipitation and removal of all possible nonsugars, organic and inorganic compounds, and the preservation of the maximum sucrose and reducing sugars possible in the clarified juice. Poor clarification of cane juices complicates the entire process of sugar manufacture. In many cases where juices remain dirty after prolonged settling, it is necessary to stop grinding and allow additional time for settling the mud. This quite often occurs in raw sugar factories which receive mechanically-harvested or mechanically-loaded sugar cane. Generally, when difficulties in clarification and settling of mud arise, it is recommended to increase the capacity of the clarification station by installation of additional continuous clarifiers. However, excessive capacity in clarifiers may result in loss of sugar. Therefore, increase in settling capacity must be carefully planned and the different factors taken into consideration. The greatest part of sugar cane juice is water and organic compounds, mostly sucrose, glucose and fructose. Glucose and fructose are in equal amounts. There are other less important reducing substances present, and approximately 0.5% of the cane juice consists of soluble inorganic compounds or ashes. A certain amount of fiber, mainly cellulose, also remains in sugar cane juice after crushing, as it passes through the cushion cushion screen in the form of so-called 'bagacillo'. The raw cane juice is generally limed to pH 8.0 in order to obtain clarified juice of about pH 6.8—7.2. (Baikow, 1982).

The most common method of clarification in sugar factories is defecation. This involves the addition of lime to the raw juice which forms flocks that trap suspended matter. As the particles gain mass they settle to the bottom of the tank where, after forming mud, can be drained out (Rein, 2007). The mud formed is filtered or passed back to the diffuser in order to extract more sucrose. In Sudan particularly in Kenana and Al-Guneid sugar factories where no diffuser, the mud is filtered and the filtrate is pumped pack to limed juice tank.
Sugar quality is measured according to a number of parameters namely, pol, color, ash, insoluble solids, dextran content, starch, reducing sugars and grain size/distribution, and filterability (Rein, 2007). All of the above affect the cost and ease of refining.

The filterability of raw melt in the sugar refinery after the production of a raw sugar may be affected by the impurities remaining in the sugar after clarification. This is mainly due to the high loads of suspended solids and turbidity (Mkhize, 2003).

Problems in the clarification process can also be attributed to operational errors. (Mkhize, 2003) reported that one of the causes of poor clarification could be over liming of the raw juice as a result of poor pH control. Poor pH control could be attributed to pH controller failure, poor lime quality, lime preparation problems and lime dosing pump problems. In the case of poor liming and he reported that high juice turbidity could last at least 20 minutes and in most cases it lasted for almost three hours. Mkhize added that the frequent start up and shut down of the factory can also cause high turbidity problems. This becomes more of a problem towards the end of the season when the supply of cane to the factory is unsteady (Mkhize, 2003). The effects of inconsistent operation of the factory on the clear juice could last a couple of hours.

Phosphates in the raw juice prior to the addition of lime are required to achieve good clarification. The phosphates react with the lime to form a precipitate that constitutes an important part of the floc precipitated in the juice. A phosphate level of 200 – 300 mg/kg juice has been suggested as minimum for effective precipitation. Phosphates occur naturally in the cane, however, when the concentration drops below the minimum, the addition of inorganic phosphates is required (Rein, 2007). The low phosphate level in the sugar factory is a problem which often leads to poor clarification (Mkhize, 2003).

During clarification there is a possibility of mud carryover. In the case of mud carryover there is an increase in color of the clear juice. The affinated sugar that has been contaminated by the mud carryover also experiences a significant increase in calcium and phosphate levels. The ash levels in both the syrup and molasses also increase. (Sahadeo et al, 2002).
Carryover can also contain fine suspended matter from the clarifier. Dextran content in the raw juice has been identified as the cause of the fine suspended matter. Dextran is formed from the breakdown of sucrose as a result of bacterial action and heat, thus important factors that control its formation are temperature, moisture and residence time. The formation of dextran is also increased when mechanical chopper harvesting is undertaken due the increased surface area and exposure of the cane ends to contamination (Ravno and Purchase, 2005)

According to (Ravno and Purchase, 2005) the dextran acts a protective colloid and inhibits coagulation, therefore preventing the entrapment of fine matter in the mud. The fine matter has an effect on the quality of the sugar, increasing the ash content and increasing its color. The subsequent processing of the low quality sugar in the sugar refinery is impeded. More specifically the suspended matter causes poor filtration of melts and hence a reduction in throughput. And they added if, the reduction in through put is substantial refiners may seek alternative sources of raw sugar.

2.2 Reactions of Clarification

Juice treated with lime separates into three distinct layers. Substances less dense than the liquid float to the top in the form of scum, while substances more dense than the juice settle to the bottom as a flocculent precipitate, leaving the central portion of the juice more or less clear. The efficiency of the treatment depends upon sharpness of the separation, rate of settling, volume of the settlings, and quantity and nature of the substances removed by settling and floating. (Honig, 1953). With juice constituents, lime brings about reactions of three types:

(1) Formation of insoluble substances.
(2) Formation of substances which remain in solution.
(3) Coagulation of coarsely dispersed and colloidal suspensions.

2.2.1 Lime Chemical Reaction

Lime slurry consists mainly of a coarse suspension and colloidal solution of calcium hydroxide Ca (OH)₂. The solubility in water is only 0.12% at 25 °C. Solubility is greatly increased in a sucrose solution, so that a 10 per cent solution of sucrose dissolves 1.5% CaO. The solubility is likewise increased by some non-sucrose substances in the juice.
Calcium hydroxide solubility decreases with increase in temperature. Thus a solution saturated at room temperature will precipitate out on heating (Honig, 1953). The solubility likewise is apparently affected by the physical properties of the lime particles, the quantity present, and the temperature at which the lime is added. Calcium hydroxide is a relatively strong base, since it is a hydroxide of a divalent metal; ionization takes place in two steps (Honig, 1953).

\[
\text{Ca(OH)}_2 \leftrightarrow \text{CaOH}^+ \text{OH}^-
\]

\[
\text{CaOH} \leftrightarrow \text{Ca}^{2+} + \text{OH}^-
\]

### 2.2.2 Reactions of Calcium Hydroxide

In a complex system as represented by cane juice, where a large number of ionic, molecular, colloidal, and dispersed substances are capable of reacting with an added substance, the first reactions are those of rapid rates which are essentially non-reversible. These are characterized by the formation of an insoluble, slightly ionized or volatile product. Fundamentally, that reaction will take place preferentially which will result in a system of lower free energy content. However, the speed of attaining equilibrium is a factor of prime concern when time is a limiting condition. It is probable that in liming cane juice, equilibrium conditions are seldom attained. This is certainly the case with what is considered the most important reaction of the clarification, the precipitation of calcium phosphate (Honig, 1953).

### 2.2.3 Calcium Phosphate Precipitation

The complexity of the reaction between lime and phosphate in juice is due to the complexity of the phosphoric acid-calcium hydroxide reaction, as well as the complexity factors caused by the presence of other inorganic and organic substances. The reaction rate is very slow. (Holt et al., 1925) found that equilibrium was not reached until 10 days in titration of phosphoric acid with lime water. The slowness of the reaction in reaching equilibrium has been attributed to two factors; the intermediate precipitation of CaHPO$_4$ which later dissolves with great slowness, and the slow rate at which Ca$_3$(PO$_4$)$_2$ precipitates. The two following reactions take place simultaneously:
\[
\begin{align*}
(1) \quad & \text{Ca}^{+2} + \text{HPO}_4^{-2} \quad \leftrightarrow \quad \text{CaHPO}_4 \\
(2) \quad & 3 \text{Ca}^{+2} + 2 \text{PO}_4^{-3} \quad \leftrightarrow \quad \text{Ca}_3(\text{PO}_4)_2
\end{align*}
\]

However the reaction between the active parts, CaO and P\textsubscript{2}O\textsubscript{5} is accelerated by heating and shown by the fundamental equation

\[
3\text{CaO} + \text{P}_2\text{O}_5 \quad \rightarrow \quad \text{Ca}_3(\text{PO}_4)_2
\]

High molecular weight polymer like Separan is added to juice entering clarifier to assist forming heavy precipitant.

### 2.3 Mechanism of Clarification

Though often neglected, the liming station is one of the most important stations in a raw-cane sugar factory for, without correct liming, good clarification cannot be expected. The importance of proper treatment of raw cane juices with milk of lime must be kept in mind when a sugar factory is designed or modified, and the requisite capacity of liming tanks should be provided. The addition of milk of lime to the raw cane juice is a chemical treatment, and as in all chemical treatments, the correct procedure must be accurately followed. (Baikow, 1982).

Raw sugar cane juice is composed of a great number of organic and inorganic compounds, acids, salts etc., in varying amounts. When it comes from the mill tandem, the juice is an opaque liquid varying in color from greenish-gray to dark green, and it carries suspended matter such as fine bagasse (bagacillo), gums, albumin, wax, coloring matter, particles of soil, sand, clay and mud. The normal raw cane juice has pH 5.2—5.4 (Baikow 1982).

#### 2.3.1 Treatment with Lime

The gums, wax and albumin make the raw sugar cane juice rather viscous and it cannot, therefore, be readily filtered when cold. Liming and heating cause many impurities in the juice to become coagulated and precipitated out. At the same time, the acids are neutralized and any phosphates present are flocculated, adsorbing a large amount of coloring matter, colloids and other impurities. Usually, the lime is added to the raw sugar cane juice in the form of milk of lime, for better dispersion and quicker reaction. (Baikow, 1982)
In preparing the milk of lime it is more advantageous to use already prepared hydrated lime, rather than to burn limestone and slake it at the factory. The lime must be carefully selected. It should contain over 95% of Ca(OH)2 and not more than 1% MgO, and should be almost free of iron, aluminum oxides and sand. (Baikow 1982)

2.3.2 The Liming Process

Several methods of liming are practiced. In general, the chemistry involved in all the processes is almost similar, although there is a variations in procedure. (Honig, 1953). There are four main methods of liming

2.3.2.1 Cold Liming

Milk of lime (usually 2.5-7.5 % CaO) is added to raw juice, bringing it to a pH of 7.2-8.6. The juice is then heated to 100-102 °C and allowed to settle. Normally, an approximately neutral clarified juice is desired. (Honig, 1953). In Sudan (Kenana and El-Guneid factories) where cold liming is practiced, the concentration of milk of lime is 5 Pume (one Pume equals 1.8 Brix).

2.3.2.2 Hot Liming

Raw juice is heated to 100-102 °C. Milk of lime is added to a pH 7.6-8.0 and the juice allowed to settle. (Honig, 1953).

2.3.2.3 Fractional Liming with Double Heating

This method is intended especially for treatment of refractory juices, and generally gives a very substantial improvement when the ordinary liming becomes insufficient (E-Hugot 1960). It consists of five steps:

1- Liming the cold juice to a pH of 6.2-6.4.
2- Heating to boiling.
3- Re-liming to a pH of 7.6-8.2.
4- Heating again to boiling.
5- Leaving to settle.

2.3.2.4 Java Method

In this method: Pre-liming of the juice to between pH 6.0 and 6.6. Then separation the prelimed juice into two portions. The first portion 40%, limed cold to pH 9.5, and the second portion 60%, heated.

Mixing of the two portions, giving a pH 7.6-7.8 and a temperature of 1 50°F (E-Hugot 1960).

2.3.3 Insufficient Liming
If the juice is insufficiently limed, the pH controller will increase the flow of milk of lime into the tank to adjust it to the desired pH. If the juice is overlimed, the pH controller will not add any additional milk of lime, and the excess of pH will be shown on the recording chart, in such a case manual pre-liming can be slightly modified. If the pH meter is in good operating condition and properly adjusted, it should not be difficult to maintain a constantly uniform pH of limed juice. (Baikow 1982).

2.3.4 Excess of Lime

However, there are some factories using less amount as in Kenana where one kg hydrated lime is used per ton of cane according to process. (Obeid et al, 2017) at the time of sample collection.

An excess of lime should be avoided. All the lime used in excess of the amount required to neutralize the acids and precipitate impurities has a destructive action upon reducing sugars, which are transformed into soluble lime salts which increase the color and viscosity of cane juices. In other chemical reactions, excess lime upon heating attacks reducing substances to produce acids which may further invert sucrose. (Baikow 1982).

2.4 Effect of pH

If the pH of the limed juice is too low, the precipitation of phosphate, sesquioxides and silicic acid is incomplete. The lower pH will not affect the redissolution of suspended matter, originally present in the mill juice. It has the advantage that there is no destruction of reducing sugars, no abnormal increase in the lime content in the clarified juice, as caused by decomposition of reducing sugars.

A high alkalinity has the advantage of a complete precipitation of removable inorganic nonsugars (inorganic phosphates, sesquioxides and silicic acid).

To a certain extent it may affect the redissolution of the proteinic nonsugars and increase the nitrogen content of the clarified juice. The greatest disadvantages of too high alkalinity (pH) are the decomposition of reducing sugars and the increase of the lime content (Honig, 1953).

2.5 Impact of Clarification on Raw Sugar Quality

Raw sugar quality is a critical factor as it determines raw sugar value and affects the performance of refineries. Refiners are increasingly demanding high quality raw sugar to optimize their own operations. Raw sugar producers need to understand the impact
of quality issues on their customer’s (refiners) production. The raw sugar quality criteria such as pol, color, ash, dextran, filterability, grist and starch are very important to a refiner as they all have an effect on the efficiency and performance of the refinery (Terry, 2009).

The following section represents the effect of clarification on the evaporation, crystallization, centrifugation, processes and color.

2.5.1 Impact on Evaporation Process

Scale in evaporators affects the heat transfer and hence the efficiency of the evaporator (Rein, 2007). A major component of scale is silica which is deposited as the brix increases across the evaporators and pans (Walthew et al., 1998). The amount of silica present in the clear juice is determined by the quality of cane entering the factory and the pH of the imbibition water used in the diffuser (Walthew et al., 1998). First and second evaporators oftenly affected by precipitation of calcium salts as lime, solubility decreased by heat and low concentration of sucrose on solution. All precipitation in tubes, or in other words scaling reduced the heat transfer coefficient, retard boiling and decrease the flow rate and capacity. (Honig, 1953).

2.5.2 Impact on Crystallization and Centrifugation Processes

During crystallization in the A pan there is a possibility of contamination by airborne bagacillo (Simpson and Davis, 1998). If the raw sugar contains a high quantity of bagacillo, problems will occur further down the line in the sugar refinery, more specifically during refinery filtration. Bagacillo in the raw sugar is also caused by poor flashing of the raw juice during clarification (Simpson and Davis, 1998). The conditions in a crystallizer are suited to the buildup of sugar or encrustation on the walls of the crystallizer. The vacuum pans are streamed out or cleaned on a routine basis to prevent excessive encrustation. When encrustation becomes sevre it can break off the walls and block tubes and outlets. Encrustation is found more in the higher grade pans, i.e. the A-pan. The rate of encrustation is therefore affected by the purity of the massecuite being boiled. For example the C-pan only needs to be cleaned out approximately every 38 weeks, while the A-pan need to be cleaned out after a few weeks (Rein, 1990).

Other factors that affect the rate of encrustation are the crystal surface area to unit volume, the super saturation in the mother liquor, the rate of evaporation, and the viscosity of the massecuite. The rate of evaporation influences the amount of splashes
that hit the walls of the crystallizer tank and the viscosity affects the period of time the massecuite takes to run down the wall. Increasing the time the massecuite remains on the wall increases the possibility for crystallization. In addition to these factors the number of crystals and the size of the crystals also effects encrustation. The higher the concentration of crystals the higher the possibility that they will stick to the wall of the crystallizer and the smaller are easier for them to attach (Rein, 1990).

The shape of the crystal formed during the crystallization process affects the efficiency of centrifuging. Low raw juice quality results in the distortion of sugar crystals, for example the elongation of crystals and needle grains. The deformed sugar grain impedes molasses exhaustion in the centrifugal (Smits and Blunt, 1976). The fragile shape of the crystals causes them to break easily in the centrifuge therefore resulting in the loss of sugar through the screen (Ravno and Purchase, 2005). The poor quality raw juice also causes an increase in massecuite viscosity and therefore rapid blinding of centrifugal screens (Smits and Blunt, 1976). In order to counteract the poor molasses removal in the centrifuge additional wash water is required (Ravno and Purchase, 2005). An increase in the wash water results in an increase in loss of sucrose to the molasses and increase in the amount of steam required for evaporation of the water in subsequent pans (Ravno and Purchase, 2005; Ried, 2006). Impurities in the raw juice also block the crystal faces causing incomplete crystallization in the time available (Ravno and Purchase, 2005).

The crystals should be large and uniform in size to aid centrifuging. The larger the crystals are the smaller the surface area to volume ratio becomes, hence allowing easier molasses removal. The crystals should also be of similar size. This ensures a lower packing density in the centrifugal and hence maintains pathways through which the mother liquor can flow (Ravno and Purchase, 2005).

Scale build up in the crystallizer causes a reduction in the heat transfer between the thick juice and heating surfaces. This is particularly a problem in the later evaporators, i.e. B and C evapocrystallizers. As the inorganic ions in the later evaporators become supersaturated they precipitate out and are deposited on the heating surfaces. Scaling in the crystallizers also causes an increase in the loss of sucrose (Eggleston and Monge, 2005). Eggleston and Monge (2005) reported that the reduced heat transfer results in an increased retention times and decreased flow rates.

In order to compensate for this the heat juice temperature is increased. An increase in
the juice temperature however increases the conversation of sucrose to glucose and fructose (Eggleston and Monge, 2005; Eggleston and Monge, 2007).

2.5.3 Impact on Color

Most refiners regard color as the most important raw sugar quality parameter. The removal of color is the key function of a refinery and is a high cost procedure, regardless of the methods employed. In effective processing, having knowledge of the total color and the nature of the colorants in the raw sugar is very important, as well as the distribution of colorants between the syrup film and the crystal (Terry, 2009).

2.6 Filterability of Raw Sugar

Filterability of raw sugar is one of the foremost sugar quality parameters. The filterability of the dissolved raw sugar is important as this directly influences refinery throughput to the refiner.

When a raw melt is difficult to filter, the refiner has to reduce the filtration brix, and/or reduce the melt rate. Reducing the brix gives a considerable reduction in viscosity and hence is quite effective solving filtration problems, but this can be expensive in terms of the extra steam required to evaporate the excess water. If the evaporator cannot cope with the lower brix, then the pan feed will have a lower brix, slowing down the pans and causing a loss in production (Lee and Donovan, 1995).

Filterability is an indication of the filtering characteristics of raw sugar when it is processed through the clarification stage of a carbonation refinery. Anything that impedes the normal rate of filtration is a concern as it greatly increases operating costs by reducing throughput and hence refining capacity. The typical operational response to poor filterability is to reduce liquor brix (Donovan, 1993). This is costly in terms of increased energy costs and reduced production. Poor filterability can result from one or a combination of the following impurities:

- Mud, bagacillo and turbidity. Particulate impurities of 5 μm or less have the greatest adverse effect.
- Phosphorous, silica and other inorganic impurities. Phosphorus is not generally a problem with modern high standards of clarification. However, colloidal and soluble silica appear to be one of the most critical impurities. Salts of Mg$^{2+}$, Fe$^{3+}$ and Al$^{3+}$ have been shown to impede filtration (Watson and Nicol, 1975).
- Dextran, starch, gums, proteins and other high molecular weight. Polysaccharides can also reduce filterability. Although starch can cause serious filtration problems in
carbonation refineries, it may not affect the filterability test and so is analyzed separately. High molecular weight (HMW) polysaccharides reduce filterability through a viscosity effect. Protein levels are normally low in raw sugar.

Starch is a naturally occurring polysaccharide found in the stalk, leaves and tops of sugar cane. Starch molecules have a high partition co-efficient to sugar crystals and consequently attach themselves to the growing crystals more easily than other impurities. In carbonation refining it interferes with the precipitation and coagulation of calcium carbonate crystals. This results in poor filterability characteristics (Donovan, 1993).

Fig 2.1 represents the steps of production sugar from sugar cane for Kenana sugar factory. The same steps are in El-Guneid sugar factory, but the difference is El-Guneid sugar factory has one heater for mixed juice.
Fig (2.1): Flow sheet for Kenana Sugar Factory
2.7 Clarifiers

Clarifier or subsider is the name given to a continuous settler. A continuous subsider is a vessel into which the juice to be settled is fed uniformly and continuously, and which is large enough to reduce the velocity of flow and of circulation of the juice to such a low value that it does not prevent settling from taking place. The clear juice obtained is similarly withdrawn from the upper part of the subsider in an equally uniform and continuous manner, as also are the muds from the lower portion. (Hugot, 1960).

The desirable characteristics in the subsidation process are rapid settling, giving a clear juice overflow and a minimum volume of settlings. The extent to which these requirements are realized will depend primarily on the efficiency of flocculation in the clarification process proper, but are also influenced considerably by the design of the subsider (Jenkins, 1966).

Clarifiers are generally divided into several compartments, so as to increase the area for settling. Clarifiers are similar in principle, and vary in their details only (Hugot, 1960).

2.8 Types of Continuous Clarifier

Stationary batch clarifiers for juice have been replaced almost everywhere by continuous clarifiers. The better known of these on the market are RapiDorr 444, the Graver clarifier and "Prima Sep" (both manufactured by Graver), Bach clarifier, and BMA clarifier.(Baikow, 1982).

SRI clarifier is recently introduced in Kenana sugar factory.

2.8.1 RapiDorr 444

RapiDorr 444, manufactured by the Dorr-Oliver Company, is a four compartment machine with a small-diameter feed chamber at the top as shown on Fig. (2.1). It also has a foam removal apparatus. The feed is distributed to the various compartments through a hollow rotating central tube, which is divided vertically. The raw juice is introduced evenly into all four compartments. At each point of introduction, there is a large-diameter feed well for uniform feeding and flocculation. The RapiDorr 444 is actually four single compartment clarifier's superimposed one above the other. There are one or two separate pumps for mud withdrawal. Clarified juice is withdrawn from all four compartments. The limed juice is introduced at the center and flows outward
at a decreasing velocity. Settled muds are moved inward for better concentration by blades attached to the arms, which are flexibly connected to the central feed tube (Baikow, 1982).

Normal range of capacities will be in the range of $6.5 \times 10^{-2}$ to $7.43 \times 10^{-2}$ m$^2$ of thickening area per ton of cane per day, or $80.8—106$ L capacity by volume per ton of cane ground. The variation in volume depends on cleanness of sugar cane. The minimum retention time recommended is 2 h, and the maximum is 3h. The connecting valves between all compartments must be opened to start operation of the RapiDorr 444 clarifier. Consequently, at the start it is operated like a conventional machine. After the overflow rate is established, the valves are closed and the RapiDorr 444 is operated as four separate clarifiers, with the concomitant benefits of mud concentration and ease of removal (Baikow, 1982).

2.8.2 Graver Clarifier

The Graver clarifier presented in Fig (2.2) has trays slanting toward the periphery. The theory is that settling mud acts as a filtering medium on its way downward. Instead of being concentrated on each tray, the mud is dispersed, and thickening occurs at the bottom compartment (Baikow, 1982).

2.8.3 Prima-Sep Clarifier

The Prima-Sep clarifier shown on Fig (2.3) has retained the principles of the Graver clarifier, but with modifications. The upper tray slants downwards toward the center where primary mud thickens and is removed through a separate mud sump into the main sump which is located at the bottom. The other trays are slanted toward the periphery, and are progressively smaller in diameter from top to bottom (Anon., 1960).

2.8.4 BMA Clarifier

The BMA continuous clarifier for sugar cane juice as shown on Fig. (2.4) comprises a cylindrical container of sheet steel with a conical bottom inclined at a $10^\circ$ angle. The cover supports both drive and center shaft. The clarifier is divided into several compartments with conically inclined trays. For a larger grinding rate, the clarifier is bigger. It has one inlet compartment and five clarifying compartments, with the bottom one higher for mud concentration. Each tray is employed for settling of mud. The mud is discharged from the trays into the mud cone by arms at each
compartment. The arms are driven by a central shaft, the driving assembly of which is mounted on the top of the clarifier (Baikow, 1982).

2.9 Batch Clarifiers
Batch clarifiers have been replaced by continuous clarifiers as was mentioned in section (2.8).

Fig. (2.5) presented batch clarifier.
Fig. (2.2) The RapiDorr 444 clarifier

Source (Baikow, 1982)
Fig. (2.3) Graver Clarifier

Source (Hugot, 1960)
Fig. (2.4) Prima-Sep Clarifiers

Source (graver.com)
Fig. (2.5) The BMA continuous cane-juice clarifier

Sourse (Baikow,1982)
Fig. (2.6) Bach clarifier
Source (Hugot, 1960).
2.10 Advantages of Continuous Clarification

Hugot (1960) reported that Continuous clarification has rapidly become general, and has replaced the classical procedure of discontinuous decantation, it offers the following advantages:

1. Simplicity: one vessel instead of 12 or 15.
2. Saving in space: one large vessel occupies less space than 12 or 15 small ones.
3. Economy in man-power consequent on continuous operation: no valves to operate, little supervision required.
4. Uniformity in quality of juice, for the same reason: no time lag in operation of 2-way valves.
5. Better conservation of the heat of the juice: the loss of heat between heaters and effects is negligible.
6. Muds are thicker, since they come from the extreme bottom of the subsider.
   In the neighborhood of the boundary between clear juice and mud, the muds are always somewhat lighter.
7. Clarified juice is clearer, for a similar reason: it is always taken off at the most favorable zone.

2.10 Disadvantages of Continuous Clarification

On the other hand, there are two minor disadvantages:

1. Necessity of abandoning defecation in the strict sense. Thanks to the "cap" or scum, the purification obtained in a defecator is slightly superior to that obtained in a subsider.
2. Liquidation is more difficult: the clarifier is generally left full over Sunday, and on Monday morning a fall of purity, sometimes very appreciable, is observed in juice which has been held for 36 hours at high temperature. To reduce this drawback, it is necessary:
   (a) To modify the liming during the last 3 hours of operation, so as to maintain the clear juice at a pH of 7.0 or 7.2, if it is not already at that value (about 8.8 in the limed juice).
   (b) Draw off all the muds before shutting down.
   (c) Liquidate whenever the plant is to be shut down for more than 40 hours.
(d) Avoid interruptions to operation, that is, work for 24 hours in 24 throughout the week.
Chapter Three

3.0 Materials and Methods

3.1 Materials

Materials used in the experimental were clarified juice and raw sugar.

Twelve clarified juice and twelve raw sugar samples were collected from Kenana and El-Guneid factories (six samples of clarified juice and six samples of raw sugar from Kenana sugar factory and the other samples were from El-Guneid sugar factory).

Samples from Kenana sugar factory were collected during six successive days. The samples of clarified juice were taken first. Then after four hours the sample of raw sugar was taken. That was to take the raw sugar approximately corresponds to the relevant clarified juice. Samples were taken between 18th to 24th of April, 2017.

Likewise, the samples from Al-Guneid sugar factory were taken in the same manner, between 11th to 18th of May, 2017.

3.2 Chemical Reagents

The chemical reagents used in the experiments were:

1- Buffer solution.
2- Fehling's solutions A and B (Copper sulphate and sodium potassium tartarate + sodium hydroxide) respectively.
3- Herles reagent (lead nitrate and sodium hydroxide solutions).
4- Lead acetate.
5- Methylene Blue Indicator.
6- TCA solution (Trichloroacetic acid)

3.3 Apparatus

The apparatus and devices used for the laboratory experiments included:

1. Volumetric glassware: various volumetric glassware with special 100ml flasks.
2. Water Bath.
3. Thermometer.
4. pH Meter model 3310.
5. Conductivity Meter model 4310.
7. Sucroscan.
8. Brixometer (Refractometer).
12. Filter papers (0.45 microns for normal filtration, and 18 cm for filterability test).
13. Stop watch.

The following figures represent laboratory apparatuses which were used in determination of the parameters.
Fig (3.1) Conductivity Meter
Fig (3.2) pH Meter
Fig (3.3) Brixo Meter
Fig (3.4) Sucroscan
Fig (3.5) Spectrophptpmeter
Fig (3.6) Saccharimeter
3.4 Methods for Determination of Quality Parameters

Each of the twelve raw sugar samples was analyzed for the most important quality parameters using standard methods used in the sugar industry. Polarization (%), color value (I.U), reducing sugar (%), dextran content (ppm), phosphate content (ppm), ash conductivity, turbidity, pH, purity and filterability test, were determined according to laboratory manual for South African sugar factory materials analysis, and the standard laboratory method for Australian sugar mills. All methods coincide with ICUMSA.

3.4.1 Determination of polarization of Raw Sugar Samples

26 gm. of raw sugar was dissolved in 100 ml volumetric flask and clarified with lead acetate. The volume completed to the mark with distilled water, then mixed, and filtered through filter paper. The polarization reading was taken by Saccharimeter devise in 200mm tube after adjustment with distilled water and rinsed with the sample twice.

3.4.2 Determination of Color of Raw Sugar Samples

30gm of raw sugar was dissolved in 70 ml of distilled water. Small portion of solution was taken for brix determination. The pH was adjusted at 7 and filtered through filter paper. Then the absorption was read in spectrophotometer at wave length 720 nm.

\[
\text{Color} = \frac{\text{Absorption}}{C} \times 1000
\]

Where C is solution concentration in gm/cm³ at x Brix.

3.4.3 Determination of turbidity of Raw Sugar Samples

Turbidity was determined by the same procedure of color determination. For turbidity the color was determined twice, before and after filtration.

\[
\text{Turbidity} = \text{color value of unfiltered solution} - \text{color value of filtered solution}.
\]

3.4.4 Determination of Filterability for Raw Sugar Samples

This method has been adopted officially within The Australian Sugar Industry. A financial incentive scheme is based on this method in relation to payment for raw sugar delivered.

The filterability test of raw sugar reflects the efficiency of the mill clarification process and is broadly indicative of refinery carbonation, filtration performance (The standard laboratory method for Australian sugar mills, 1991-04).
This method is based on the comparison between the mass of filtrate of the test solutions of various raw sugars with the mass of filtrate of a pure white sugar solution under standard and identical condition.

The calibration test performed using pure refined sugar was done and the weight of the filtrate was collected after 5 minutes and used as the reference to calculate the filterability of different test samples.

Procedure: a sample solution for each raw sugar was prepared by dissolving 60gm, and adjusted to 60 brix. The pH of solution was adjusted to pH 9. The mixture was stoppered and heated in water bath till 70°C with gentle shaking. The sample was transferred to Buchner funnel having filter paper and the stop watch was simultaneously started. The filtrate weight for each sample was collected after 5 minutes for the calculation of the filterability.

For standardization, a pure refined sugar solution was prepared and adjusted to 60 brix, and the same procedure for filtering raw sugar was followed.

Calculations

The filterability of each raw sugar sample was calculated using the formula:

\[
\% \text{filterability} = \frac{\text{Wt. of filtrate of test solution}}{\text{Wt. of refined sugar filtrate}} \times 100
\]

3.4.5 Determination of Dextran Content in Raw Sugar Samples

According to Bose and Singh (1981), after sample was filtered, a small portion was taken for Brix% determination. In two 100 ml volumetric flasks, 50 ml of juice was transferred in each. One of the flasks was clarified with lead acetate, completed to 100 ml with distilled water, mixed, filtered through filter paper and polarized. In the second sample 2 ml of solution A and 2 ml of solution B were added. The mixture completed to the mark with distilled water, then mixed and filtered, and then the polarization reading was taken.

Solution A is sodium hydroxide where solution B is lead nitrate, they were prepared by dissolving 25gm from each with distilled water then the volume was completed to 50ml.

Calculation

If \(P = \) polarization of sample clarified with lead acetate
Pl = polarization of sample clarified with modified Herles Reagent (lead nitrate and sodium hydroxide solutions).

Y = P – Pl = elevation of reading due to dextran.

According to method of dextran determination in cane juice, 

\[ Y = 0.001x - 0.1597 \]

where \( x \) is dextran concentration in ppm.

\[ x = \frac{Y + 0.1597}{0.001} \]

### 3.4.6 Determination of Ash Conductivity for Raw Sugar Samples

5 g of sugar was dissolved and completed to 100 ml in volumetric flask. The solution was heated in water bath at 60°C for 30 min, then cooled to 20°C.

**Calculation**

If \( A = C_{\text{water}} \), (water conductivity) corrected for temperature multiplying by cell constant, and by the water correction coefficient.

\( B = C_{\text{soln}} \), (solution conductivity) corrected for temperature multiplying by cell constant.

Ash Conductivity = \( (B-A) \times 0.0006 \), where 0.0006 is a constant.

### 3.4.7 Determination of pol in Clarified Juice Samples

Small amount of clarified juice was clarified with lead acetate and then polarized in 200mm tube. Pol percentage was determined from the table of pol reading versus brix.

### 3.4.8 Determination of Color and Turbidity in Clarified Juice Samples

The same procedure of color and turbidity determination of raw sugar was followed to determine color and turbidity for clarified juice at 5 Bx. The volume required to make the solution equals to 5 Bx was taken according to the bellow equation.

\[ V = \frac{100}{Bx} \times 5 \]

Then the volume was completed to 100 ml.
3.4.9 Determination of Dextran in Clarified Juice Samples

25 ml of juice was taken. 5 ml of TCA solution (Trichloroacetic acid) and 5g of super cell were added. The solution was filtered, in two flasks; 5ml of filtered juice was transferred in each. For one of flasks 5 ml of distilled water was added and used as a blank. In the second flask 5 ml of ethanol was added (sample). Then the absorbance reading was taken by Sacroscan apparatus after 20 min. The dextran concentration in ppm was found from the dextran chart against absorbance.

3.4.10 Determination of Phosphate in Clarified Juice Samples

100 ml of juice was taken, 1 g of sodium chloride, 5 drops of ammonia solution and 1 ml of glacial acetic acid were added. The solution was titrated with 1ml of uranylacetate – dihydrate. Small amount of the titrated solution was added to potassium hexacyanoferrate (ii). Then the solution was heated to the boiling point, the titration was completed with 0.5 ml and small amount of it was added to potassium hexacyanoferrate (ii). The titration continued in this manner by adding 0.5 ml till the precipitate was formed with potassium hexacyanoferrate (ii).

Calculation

If BR = The volume which was taken from the burette.

\[ D_0 = \text{Density at } xBX. \]

\[ P_2O_5(\text{ppm}) = \frac{BR \times 0.005}{D_0} \times 10000 \]

3.4.11 Determination of Reducing Sugar in Clarified Juice Samples

50 ml of juice was taken in 200 ml volumetric flask and completed with distilled water to the mark. Equal amount of Fehling’s solutions A and B were kept in conical flask, and then titrated with 10 ml of the sugar solution. The solution in the flask was heated to the boiling, and without removal of heat, 3 drops of methylene blue indicator were added and the titration was completed as the color change to reddish.

Calculation

If V = the volume which was taken from the burette.

19.2 = constant.
\[ RS = \frac{19.2}{V} \]

3.4.12 Determination of pH for Clarified Juice Samples

The pH for clarified juice was read directly by pH meter after calibration with buffer solution.

3.4.13 Determination of Ash Conductivity for Clarified Juice Samples

The ash conductivity for clarified juice was read directly by conductivity meter after calibration with buffer solution.

3.4.14 Determination of Brix for Clarified Juice and Raw Sugar Samples

The brix reading for clarified juice was read directly using Brixometer apparatus, and for raw sugar was read after dissolving in distilled water (30gm raw sugar in 70 ml distilled water).
Chapter Four

4.0 Results and Discussion

4.1 Physicochemical Analysis of Clarified Juice and Raw Sugar Samples

The samples of raw sugar and clarified juice were analyzed using the laboratory manual for South African Sugar Factory Materials Analysis and the Standard Laboratory Method, and Australian Sugar Mills Methods for the following quality parameters:

1- Polarization.
2- Color value.
3- pH value.
4- Brix.
5- Purity.
6- Turbidity for clarified juice and raw sugar.
7- Reducing sugar for clarified juice.
8- Ash conductivity for clarified juice and raw sugar.
9- Dextran content for clarified juice and raw sugar.
10- Phosphate content for clarified juice.
11- Filterability test for raw sugar.

The results were presented in tables 4.1, 4.2, 4.3 and 4.4. Those analyses were conducted for the purpose of finding out the influence of different quality parameters of the clarified juice from Kenana and El-Guneid factories on the raw sugar quality.
Table (4.1): Physicochemical Analysis of Clarified Juice Samples
Kenana sugar factory

<table>
<thead>
<tr>
<th>Parameters/Sample</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color value.</td>
<td>I.U</td>
<td>10650</td>
<td>8842.6</td>
<td>15543</td>
<td>16211.43</td>
<td>9943</td>
<td>5423.5</td>
<td>11102.25</td>
</tr>
<tr>
<td>Brix.</td>
<td>%</td>
<td>14.03</td>
<td>12.96</td>
<td>10.78</td>
<td>11.17</td>
<td>12.02</td>
<td>13.65</td>
<td>12.43</td>
</tr>
<tr>
<td>Purity.</td>
<td>%</td>
<td>86.5</td>
<td>83.02</td>
<td>85</td>
<td>82.8</td>
<td>82.86</td>
<td>84.35</td>
<td>84.09</td>
</tr>
<tr>
<td>Turbidity.</td>
<td>NTU</td>
<td>1434.9</td>
<td>2417</td>
<td>1551.7</td>
<td>687.56</td>
<td>530.55</td>
<td>2259.8</td>
<td>1480.25</td>
</tr>
<tr>
<td>Reducing sugar.</td>
<td>%</td>
<td>0.741</td>
<td>0.7</td>
<td>0.817</td>
<td>0.747</td>
<td>0.678</td>
<td>0.784</td>
<td>0.745</td>
</tr>
<tr>
<td>Ash conductivity.</td>
<td>µS</td>
<td>3770</td>
<td>3320</td>
<td>2820</td>
<td>2590</td>
<td>3090</td>
<td>3120</td>
<td>3118.33</td>
</tr>
<tr>
<td>Dextran content.</td>
<td>ppm</td>
<td>67</td>
<td>75</td>
<td>70</td>
<td>85</td>
<td>83</td>
<td>72</td>
<td>75.3</td>
</tr>
<tr>
<td>Phosphate content.</td>
<td>ppm</td>
<td>118</td>
<td>71.2</td>
<td>71.8</td>
<td>71.84</td>
<td>95</td>
<td>94.87</td>
<td>87.11</td>
</tr>
</tbody>
</table>
Table (4.2): Physicochemical Analysis of Raw Sugar Samples Kenana sugar factory

<table>
<thead>
<tr>
<th>Parameters/Sample</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization.</td>
<td>%</td>
<td>97.85</td>
<td>97.59</td>
<td>97.56</td>
<td>98.27</td>
<td>97.94</td>
<td>98.57</td>
<td>97.96</td>
</tr>
<tr>
<td>Color value.</td>
<td>I.U</td>
<td>452</td>
<td>1113.2</td>
<td>1062</td>
<td>448.68</td>
<td>386.2</td>
<td>329.22</td>
<td>631.88</td>
</tr>
<tr>
<td>Turbidity.</td>
<td>NTU</td>
<td>52.83</td>
<td>298.15</td>
<td>249.87</td>
<td>31.22</td>
<td>122.11</td>
<td>39.2</td>
<td>132.23</td>
</tr>
<tr>
<td>Ash conductivity.</td>
<td>%</td>
<td>0.08</td>
<td>0.08</td>
<td>0.072</td>
<td>0.039</td>
<td>0.029</td>
<td>0.027</td>
<td>0.054</td>
</tr>
<tr>
<td>Dextran content.</td>
<td>ppm</td>
<td>209</td>
<td>509.7</td>
<td>249.7</td>
<td>239.7</td>
<td>729.7</td>
<td>289.7</td>
<td>371.25</td>
</tr>
<tr>
<td>Filterability</td>
<td>%</td>
<td>8.68</td>
<td>10.7</td>
<td>23</td>
<td>9</td>
<td>28.7</td>
<td>10.2</td>
<td>15.04</td>
</tr>
</tbody>
</table>
### Table (4.3): Physicochemical Analysis of Clarified Juice Samples El-Guneid sugar factory

<table>
<thead>
<tr>
<th>Parameters/Sample</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization.</td>
<td>%</td>
<td>13.72</td>
<td>15.04</td>
<td>13.57</td>
<td>13.49</td>
<td>14.07</td>
<td>13.82</td>
<td>13.95</td>
</tr>
<tr>
<td>Color value.</td>
<td>I.U</td>
<td>6504</td>
<td>6818.6</td>
<td>7034.8</td>
<td>7093.7</td>
<td>7663.6</td>
<td>7152.7</td>
<td>7044.56</td>
</tr>
<tr>
<td>pH value.</td>
<td>$-\log_{10}\text{H}^+$</td>
<td>7.45</td>
<td>7.05</td>
<td>6.55</td>
<td>7.55</td>
<td>6.59</td>
<td>6.57</td>
<td>6.96</td>
</tr>
<tr>
<td>Brix.</td>
<td>%</td>
<td>16.17</td>
<td>17.75</td>
<td>17.35</td>
<td>16.21</td>
<td>16.63</td>
<td>16.24</td>
<td>16.73</td>
</tr>
<tr>
<td>Purity.</td>
<td>%</td>
<td>84.8</td>
<td>84.73</td>
<td>78.2</td>
<td>83.22</td>
<td>84.6</td>
<td>85.09</td>
<td>83.44</td>
</tr>
<tr>
<td>Turbidity.</td>
<td>NTU</td>
<td>4933</td>
<td>432.27</td>
<td>1513</td>
<td>452</td>
<td>1296.9</td>
<td>432.3</td>
<td>1509.9</td>
</tr>
<tr>
<td>Reducing sugar.</td>
<td>%</td>
<td>1.01</td>
<td>1.005</td>
<td>1.116</td>
<td>1.129</td>
<td>1.129</td>
<td>1.1</td>
<td>1.08</td>
</tr>
<tr>
<td>Ash conductivity.</td>
<td>$\mu$S</td>
<td>2550</td>
<td>2610</td>
<td>2760</td>
<td>2500</td>
<td>2640</td>
<td>2650</td>
<td>2618.33</td>
</tr>
<tr>
<td>Dextran content.</td>
<td>ppm</td>
<td>72</td>
<td>74</td>
<td>100</td>
<td>85</td>
<td>71</td>
<td>87</td>
<td>81.5</td>
</tr>
<tr>
<td>Phosphate content.</td>
<td>ppm</td>
<td>94</td>
<td>74</td>
<td>70</td>
<td>60</td>
<td>70.2</td>
<td>84.7</td>
<td>75.48</td>
</tr>
</tbody>
</table>
Table (4.4): Physicochemical Analysis of Raw Sugar Samples El-Guneid sugar factory

<table>
<thead>
<tr>
<th>Parameters/Sample</th>
<th>Unit</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization.</td>
<td>%</td>
<td>98.46</td>
<td>98.25</td>
<td>98.75</td>
<td>98.54</td>
<td>97.47</td>
<td>98.19</td>
<td>98.27</td>
</tr>
<tr>
<td>Color value.</td>
<td>I.U</td>
<td>539</td>
<td>648</td>
<td>363.7</td>
<td>435</td>
<td>296.3</td>
<td>486</td>
<td>511.33</td>
</tr>
<tr>
<td>Turbidity.</td>
<td>NTU</td>
<td>220.2</td>
<td>428.5</td>
<td>222.7</td>
<td>147.8</td>
<td>202.11</td>
<td>331.5</td>
<td>258.8</td>
</tr>
<tr>
<td>Ash conductivity.</td>
<td>%</td>
<td>0.012</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.019</td>
<td>0.0285</td>
</tr>
<tr>
<td>Dextran content.</td>
<td>ppm</td>
<td>459.7</td>
<td>469.7</td>
<td>719.7</td>
<td>719.7</td>
<td>959.7</td>
<td>229.7</td>
<td>593.03</td>
</tr>
<tr>
<td>Filterability</td>
<td>%</td>
<td>12.6</td>
<td>14</td>
<td>9.6</td>
<td>10.8</td>
<td>9.9</td>
<td>7.5</td>
<td>10.73</td>
</tr>
</tbody>
</table>
4.2 Discussion

The experiments were conducted at late season (2016-2017) i.e. in the last fifteen days. The results were affected by discontinuously of process due to problems in field, no cane and too much trash at the end of season. This is clear in both cases of Kenana and El-Guneid sugar factories. Particularly in color, turbidity and dextran content. The clarification in both cases is affected by the mechanical harvest that brings more soil, tops, roots and trash.

The following sections represent the discussion of raw sugar samples and clear juice.

4.2.1 Raw Sugar Polarization

Polarization is defined as the measurement of sucrose content in sugar manufacturing (Kanada, 2008).

The polarization is a rough indicator for sucrose content of the sugar, it is the key commercial measure of sugar quality, and forms the basis of payment for the international sugar sales (King, 2005).

In table 4.2, the polarization of sugar sample No (6) is 98.57%. This is the highest polarization% among Kenana sugar factory raw sugars samples. Further, it contains the lowest values of color value and the second lowest values of turbidity.

On the other hand sugar sample No (3) represent the lowest % polarization (97.56%). It showed the highest values of color value and turbidity among the samples except sample No (2) which showed the highest color value and turbidity.

In table 4.4 the highest polarization% (98.75%) is sample No (3) from El-Guneid sugar factory. The corresponding color value relatively low except No (5) for color and turbidity. While sample (5) has got the lowest polarization% (97.47%), color value and turbidity except sample No (4) that showed, the lowest turbidity. The unsteady process might affected the sample of raw sugar which is supposed to be approx. corresponds to the clear juice.

Dextran in sample No (2) table 4.2 and samples (3, and 5) on table 4.4 is more than 500ppm, and that might causes false polarization reading. According to (Kaur et al,
2008) and Aquino, et al 2009), a falsely high polarization caused by dextran in the juice, syrups and sugars i.e., 1000mg/kg dextran can enhance pol reading by 0.30.

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).

4.2.2 Raw Sugar Color and Turbidity

Color is the primary control parameter for raw commercial and refined sugar, it is used for sugar quality evaluation, and it is most significant parameter than any other quality indicator. Buyers and sellers of raw sugar concentrate on the premium or penalty of color more than any other quality factor (Godsall, 1997).

Turbidity is defined by (Godsall, 1997) as the measure of the degree of light scattering caused by the presence of suspended particles in solution.

The result of analysis for the six raw sugar samples in table 4.2 from Kenana sugar factory showed that sample (2) was the highest color value (1113.2 I.U) and turbidity (298.15 NTU) Sample No (6) was the lowest color value (329.2 I.U) and turbidity (39.2 NTU) except sample No (4) that showed the lowest turbidity value (31.22 NTU).

In table 4.4 for El-Guneid sugar factory, sample (2) represented the higher color value (638 I.U), and turbidity (428.5 NTU), while sample No (5) showed the lowest color value (296.3 I.U) and turbidity (202.11 NTU) except sample No (4) that showed the lowest turbidity value (147.8 NTU).

Cane juice and the resultant sugar contain coloring materials. These colorants are organic and are a complex mix of compounds (Don et al, 2000).

Strong correlation was observed between turbidity and color since as color increases, the non-sugar contents that contribute to the turbidity also increases. Turbidity is one main parameter used to assess the clarification process performance because it is related to the presence of non-sugar, flocks and suspended formation contributing materials such as starch, dextran and other indigenous sugar cane polysaccharides, gums and proteins in the juice (Hamerski et al. 2012). Low turbidity value indicates the considerable removal of these components.
4.2.3 Raw Sugar Ash Conductivity

The result of analysis for the raw sugar samples in table 4.2 showed that samples (1 and 2) were the highest ash conductivity (0.08%), whereas sample (6) showed the lowest value of ash conductivity (0.027%).

In table 4.4 for El-Guneid sugar factory, sample No (1) represented the lowest value, samples (2 and 4) represented the highest value (0.04%).

Ash increases the solubility of sucrose in water and as a consequence, reduces the amount of pure sugar that can be produced from cane in a mill or from raw sugar in a refinery (Don et al, 2000). Tuson (1997) stated that ash will impact the refining process in variety of ways, some affecting the equipment, some affecting the yield and some affecting the product quality.

4.2.4 Raw Sugar Dextran Content

Dextran is defined by (Imrie and Tilbury, 1972) as being a natural polysaccharide produced due to biological degradation of sucrose in sugar cane, or juice by Leuconostoc Mesentroides bacteria which produces dextranucrase to cause polymerization of dextrose into dextran.

In table 4.2 which presented Kenana sugar factory samples, four of sugar samples showed dextran levels less than 500 ppm, while samples (2, 5) showed dextran levels more than 500 ppm.

The samples El-Guneid sugar factory in table 4.4 showed that three samples (3, 4, 5) have a high dextran level, that exceed than 700 ppm.

Dextran concentrations greater than 500 mg/kg in raw sugar juice can cause processing problems, such as increased viscosity, slowed filtration, crystal distortion and sucrose losses (Kaur et al 2008) and Aquino, et al 2009). Also it can be responsible for problems in sugar processing which reduce both the recovery of sucrose during sugar production and the final quality of the sugar. (Bukhari et al, 2015). Also it Increased viscosity and retards crystal growth. Formed dextran in juice and sugar leads to poor mill and refinery throughput, and almost certainly leads to higher sugar content in final molasses (Don et al, 2000).
4.2.5 Raw Sugar Filterability

Sugar sample No (5) which belongs Kenana sugar factory in table 4.2 gave the highest filterability% (28.7%) followed by sample No (3) with filterability (23%), and sample (1) gave the lowest filterability (8.68%).

Sample (2) in table 4.4 for Al-Guneid sugar factory, gave % filterability (14%) as a highest reading, while sample (6) gave the lowest value (7.5%).

A solution of poor filterability reduces the rate of throughput of a refinery. This forces the refiner to adopt lower process sugar concentrations, leading to a loss in thermal efficiency of the refinery, as greater evaporation is required prior to the pan boiling stage than where the process solution contains less water. The end result of low filterability is increased cost for the refiner. (Don et al, 2000).

4.3 Comparison between Kenana and El-Guneid Sugar Factories

The comparison between Kenana and El-Guneid Sugar factories included clarified juice and raw sugar parameters.

The following discussions show the comparison between the clarified juice.

4.3.1 Polarization, Brix and Purity

The range of polarization% of Kenana sugar factory is 13.12% as a higher value to 9.16% as a lower value.

El-Guneid sugar factory polarization is from 15.05% to 13.49%, this shows that the polarization% of El-Guneid sugar factory is higher than Kenana sugar factory.

On the other hand El-Guneid sugar factory clarified juice has higher brix than Kenana sugar factory; this is because of El-Guneid sugar factory raw juice is not sufficiently diluted.

The brix % of raw juice is also one of the factors for increasing the mud settling rate. For better mud settling rate the raw juice brix % should be below 16. The laboratory trials as well as application at number of sugar mills indicate that the lower the brix of raw juice is the better in the mud settling rate. Therefore, so as to achieve good settling, one rate has to maintain the juice brix below 16. This can be achieved by increasing imbibition water at the mill station (E-Hugot, 1960).
The range of purity of Kenana sugar factory is from 86.5% to 82.8%, and El-Guneid sugar factory from 85.09% to 78.2%. That means Kenana sugar factory clarified juice is higher purity than El-Guneid sugar factory.

The relationship between these parameters is:

Purity of clarified juice is proportional to the pol% and inversely proportional to Bx.

**4.3.2 Color value and turbidity**

From table 4.1 and 4.3 the color values of Kenana sugar factory (16211.43 to 5423.5 I.U) are higher than El-Guneid sugar factory (7663.7 to 6504 I.U). However the range of turbidity is from 530.555 to 2259.8 NTU for Kenana sugar factory, and 432.27 to 4933 NTU for Al-Guneid sugar factory.

For Louisiana, Eggleston reported measurements of ICUMSA color in mixed juice and clear juice, treated by hot liming, which ranged between 8512 I.U and 7107 I.U, respectively; leading to an average color reduction of approximately 16.5%. Additionally, Saska et al, 2010 reported measurements of color in the same streams that ranged between 14367 and 9766 I.U, achieve an average color reduction of approximately 32%.

A clear juice with turbidities below 180 NTU can be considered to have good quality. (Santiago, 2013).

**4.3.3 pH Value**

The range of pH of clarified juice must be between 6.8—7.2.(Baikow,1982).

Just one sample from each factory is in this range, sample 5 from Kenana and 2 from El-Guneid sugar factories the rest samples are out of range. However the average values for both factories were in the acceptable range.

**4.3.4 Reducing Sugars**

Reducing sugars is defined by (Van der Poel et al, 1998) as the mixture of the two components of sucrose, the reducing monosaccharide D- glucose and D- fructose that results from the hydrolysis of sucrose.
From the tables it's clear that El-Guneid sugar factory appears to show highest values of reducing sugar, but if we look to Bx and compare by R.S/Bx. Ration that difference will disappear.

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.

4.3.5 Ash Conductivity

Kenana sugar factory is higher ash conductivity than El-Guneid sugar factory; this may be due to White Nile river water which is rich with potassium (Faisal at el, 2013).

More ash brings down more sucrose to molasses, and also causes more scale formation in pans, it has melassigenic affect in the recovery house as reported by (Chen and Chou, 1993).

4.3.6 Dextran Content

The range of dextran is between 85ppm as a higher value and 67 as a lower value for Kenana sugar factory, and from 100 ppm to 71.2 ppm for Al-Guneid sugar factory. That indicated Kenana sugar factory has less amount of dextran content than El-Guneid sugar factory which, has the highest amount, and this indicate the cane is fresher in Kenana sugar factory or sanitary condition in mill is better.

4.3.7 Phosphate Content

Kenana sugar factory represented that phosphate content is from 118 ppm as a higher value to 71.2 ppm as a lower value, and 94 to 60 ppm as a higher and lower values respectively for Al-Guneid sugar factory. That means Kenana sugar factory has a higher amount of phosphate content than Al-Guneid sugar factory, this may be due to shorter retention time in clarifier because of high crushing in Kenana sugar factory.

The Optimum requirement of phosphate content 100-200 ppm in clear juice (Sowndra, at el, 2014). Phosphate content in Kenana and Al-Guneid sugar factories is out of this range except sample No (1) from Kenana sugar factory.
4.4 Comparison between the Performances of Two Factories
The average of the results of clarified juice and raw sugar samples were tabulated in table 4.5 and 4.6.

4.4.1 Clarified Juice Samples
From table 4.5, the results showing that:

Kenana sugar factory clarified juice is better in purity, turbidity, reducing sugar, and dextran content.

El-Guneid sugar factory clarified juice is better in color, and phosphate content. The pH values approximately are equals.
Table (4.5): Result's average of clarified juice

<table>
<thead>
<tr>
<th>Factory/parameter</th>
<th>Unit</th>
<th>Kenana</th>
<th>Al-Guneid</th>
<th>Standard</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization</td>
<td>%</td>
<td>10.61</td>
<td>13.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color value</td>
<td>I.U</td>
<td>11102.25</td>
<td>7044.56</td>
<td>1350</td>
<td>Process for the manufacture of sugar and other food products</td>
</tr>
<tr>
<td>Brix</td>
<td>%</td>
<td>12.43</td>
<td>16.73</td>
<td>_</td>
<td></td>
</tr>
<tr>
<td>Purity</td>
<td>%</td>
<td>84.09</td>
<td>83.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbidity</td>
<td>NTU</td>
<td>1480.25</td>
<td>1509.9</td>
<td>180</td>
<td>Design and Implementation of A very Short Retention Time Filtrate Clarifier</td>
</tr>
<tr>
<td>Reducing sugar</td>
<td>%</td>
<td>0.745</td>
<td>1.08</td>
<td>0.3</td>
<td>Process for the manufacture of sugar and other food products</td>
</tr>
<tr>
<td>Ash conductivity</td>
<td>µS</td>
<td>3118.33</td>
<td>2618.33</td>
<td>_</td>
<td></td>
</tr>
<tr>
<td>Dextran content</td>
<td>ppm</td>
<td>75.3</td>
<td>81.5</td>
<td>_</td>
<td></td>
</tr>
<tr>
<td>Phosphate content</td>
<td>ppm</td>
<td>87.11</td>
<td>75.48</td>
<td>_</td>
<td></td>
</tr>
</tbody>
</table>
Table (4.6): Result's average of raw sugar samples

<table>
<thead>
<tr>
<th>Factory/parameter</th>
<th>Unit</th>
<th>Kenana</th>
<th>Al-Guneid</th>
<th>Standard</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization.</td>
<td>%</td>
<td>97.96</td>
<td>98.27</td>
<td>99.30</td>
<td>Proc Aust Soc Sugar Cane Technol Vol 31 2009</td>
</tr>
<tr>
<td>Turbidity.</td>
<td>NTU</td>
<td>132.23</td>
<td>258.8</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Ash conductivity.</td>
<td>%</td>
<td>0.054</td>
<td>0.0285</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Dextran content.</td>
<td>ppm</td>
<td>371.25</td>
<td>593.03</td>
<td>90</td>
<td>Proc Aust Soc Sugar Cane Technol Vol 31 2009</td>
</tr>
<tr>
<td>Filterability</td>
<td>%</td>
<td>15.04</td>
<td>10.73</td>
<td>_</td>
<td>_</td>
</tr>
</tbody>
</table>
These results showed that, Kenana sugar factory is better quality of clarified juice than Al-Guneid sugar factory.

### 4.4.2 Raw Sugar Samples

Table 4.6 represents the average of the samples parameters of raw sugar for each factory, to see which factory achieved the best quality.

From the results of two sugar factories raw sugar, it is so clear that Kenana raw sugar looks better in turbidity, dextran, and filterability, as in table 4.6.

Dextran content average in the two factories is more than 250 ppm. Raw sugar with dextran concentrations above 250 ppm is subject to payment penalties of the magnitude of 0.007% of the price multiplied by the amount of tons sold (Cuddihy et al, 1998).

Filterability average for raw sugar in both canes is low except sample No (5) for Kenana. In previous study by (Kanada, 2008), the range of filterability test of six raw sugar samples from different sources around the world for first 5 minutes found to be between 20% as lowest and 80% as highest.

Low filterability range according to (Winn, 1979) related to concentration of soluble, insoluble and partly miscible impurities.

Soluble impurities include: phosphate, silicates and any precipitated materials by processing reagent.

The group of insoluble impurities include: debris, metal, machinery parts, vegetable matter (particularly bagacillo), stones and sands.

Partly miscible impurities are: starch, dextran, gum, waxes, colloids, high molecular weight compounds, and bacteria.

Although Kenana sugar factory raw sugar is an intermediate product and still under further process where El-Guneid sugar factory raw sugar is a final product, according to this study Kenana sugar factory raw sugar looks better than El-Guneid raw sugar.
4.5 Raw Sugar Charts

![Color (IU) vs Ash Conductivity (%)](image)

Fig (4.1) Color (IU) vs Ash Conductivity (%)
Fig (4.2) Filterability (%) vs Turbidity (NTU)
Fig (4.3) Filterability vs Dextran
Fig (4.4) Raw Sugar Polarization (%)

Kenana (97.96)
El-Guneid (98.27)
Standard (99.3)
Fig (4.5) Raw Sugar Color (IU)
Fig (4.6) Raw Sugar Ash Conductivity (%)
Fig (4.7) Raw Sugar Dextran (ppm)
4.6 Clarified Juice Charts

![Bx (%) vs Turbidity (NTU)](chart.png)

Fig (4.8) Bx (%) vs Turbidity (NTU)
Fig (4.9) Clarified Juice pH

Clarified Juice pH

- **Kenana**: pH 6.91
- **El-Guneid**: pH 6.96
- **Standard**: pH 7.2

The chart shows the pH levels of clarified juice for Kenana, El-Guneid, and the standard, with the standard having the highest pH of 7.2.
Fig (4.10) Clarified Juice Turbidity (NTU)
Fig (4.11) Clarified Juice Color (IU)
Fig (4.12) Clarified Juice RS (%)
Chapter Five

5.0 Conclusion and Recommendations

5.1 Conclusion

In this research the impact of clarification on raw sugar quality in cane sugar factories was studied. A comparative status was carried out on analytical data collected from Kenana and El-Guneid Sugar Factories season (2016 – 2017), by testing the quality parameters of raw sugar and clarified juice.

The results in tables (4.2 and 4.4) showed that both factories have a high raw sugar dextran content, low filterability of raw sugar, high color and turbidity.

High purity, low brix, and low reducing sugars were obtained in Kenana clarified juice in table (4.1). However Kenana sugar factory raw sugar is in far better situation as it is an intermediate product exposed to following process steps of at least melting and recrystallization.

5.2 Recommendations

It is recommended that:

1- El-Guneid sugar factory needs to pay more attention to imbibition water in mill for more than one reason. Particularly they need to have lower Bx, i.e. less dens Bx in order to facilitate precipitation of non-sugar. On the other hand mill extraction needs more water, if there is a problem in evaporators, more effort should be done in evaporators to evaporate more water from juice.

2- Both factories need to reduce dextran content, i.e. more effort should be done in harvest process and sanitary conditions.

3- The two factories should have to reduce the color by removal colorants materials in clarification process.

4- Clarification process in sugar factories should be more effective to avoid the problems which appear in evaporation, crystallization processes and raw sugar quality. Raw sugar quality problems include high viscosity that leads to poor filterability, high color and turbidity. The final result will be on less chance of completion and visible price.
5- All quality parameters tested must be applied for clear juice and raw sugar to avoid problems and penalties in the final product, especially El-Guneid sugar factory if there is any idea to export in the future because El-Guneid sugar factory raw sugar is final product.

6- For more tide research in future it is better to take the sample in range of 4-6 hours as composite for clear juice and raw sugar as well as keeping sampling of raw sugar to start 4 hours later for more corresponding sample of sugar to clear juice.

7- Such study is better to be carried out in mid-season. However that opportunity was not available for this study.
References


Kanada Toto Korea,(2008). Investigation into Correlation between Raw Sugar Quality Parameters and Filterability in the Sugar Refinery.


Sowndra et al (2014). Estimation of Calcium Oxide and Phosphate Content Present in the Cane Juice

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