Determination of Sucrose Recovery Maximization in Nzoia Sugar Factory, Kenya

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Abstract

Sucrose recovery is one of the main goals of a sugar factory. The factory aims at maximizing sucrose recovery at every step including; juice extraction, flocculation, liming, clarification, juice filtration crystallization and centrifugation. Despite the efforts to minimize sugar losses during processing, these losses still occur resulting in financial losses to the sugar milling factory. Currently, the factory has an overall recovery of 81% and an actual recovery of 68.05% with a sugar production of 250 tonnes. This is below the 300 tonnes target per day. Boiling house recovery (BHR) is 77.46% which is below the target of 90%. The main objective of the study was to determine sucrose recovery maximization. Bagasse and filter cake polarity and the final molasses purity were determined. The results were compared to set specifications to establish the extent to which sucrose is recovered from sugar processing. In mud filtration, the average filter cake pol percentage was 3.6 % while in the c-sugar centrifugation stage the mean final molasses purity was 37.5. Mud filtration and c-massecuite curing were the two main stages in which major sugar losses occurred exceeding pol% and purity of 3.0 and 36, respectively due to inefficient process. Nzoia sugar factory did not maximize sucrose recovery therefore, it is recommended that critical stages of sugar loss be investigated. In addition, regular repair and replacement ofthe rotary vacuum screen should be done to minimize loss of sugar through scum. Efforts should be made to minimize sugar loss in the final molasses by employing skilled operators to man c-sugar centrifugation hence maximizing recovery.

Key Words: Sucrose Recovery, Sucrose Loss Stages, Bagasse Polarity, Filter Cake Polarity, Final Molasses Purity

INTRODUCTION

Sugar cane *(sacccharum officinarum*) is a member of the grass family which is mainly valued for the juices extracted from its stems (Salassi, 2008).. The plant is thick, tall and perennial flourishing in the tropical or sub-tropical regions. Sugar synthesized in the leaves is used as a source of energy for growth or is sent to the stalks for storage. The reed accumulates sugar to about 15% of its weight. White sugar is obtained when raw sugar produced from juices squeezed from the reed/stalk is later refined. Sugar is a basic food consumed in all countries in the world, making it one of the world‘s largest cash crops, produced by more than 90 countries (Pippo and Luengo, 2013). Hence, the world's sugarcane production has experienced dramatic growth in the last decade with more than 1,685 × 106 tons processed in 2010. In addition to it‘s use as a food in households, refined sugar is an essential raw material in food processing, confectioneries, beverage manufacture, soft drinks and pharmaceutical industries among others (Mulwa et al, 2012).

In Kenya, the development of the sugar industry started with private investments at Miwani in 1922, followed by others that include Ramisi, Muhoroni, Chemelil, Mumias, Nzoia, South Nyanza, West Kenya, Soin, and Kibos (Waswa and Netondo, 2014). Other firms have continued to be constructed. According to the Kenya Sugar Industry Strategic plan 2009-2014, the sugar sector is a major employer and contributor to the national economy. Approximately 300,000 small scale farmers who constitute the out growers schemes of the sugar companies supply 90% of the sugar milled (Wamalwa et al, 2014). This shows that most farmers in the producing areas rely on sugar cane as their main source of income. However, the performance of the Sugar industry has continued to experience difficulties that affect optimum returns from sugarcane production and processing. Among these is the high cost of production as a result of poor operational efficiencies with average sugar recoveries of 85%, a value less than the world average of 92%. Consequently, the estimated cost of local sugar production is 74,000 Kenya Shillings per metric ton which is almost double the amount of 24,000 Kenya Shillings registered by Swaziland (KESREF 2013)

Nzoia Sugar Company established in 1978 is in western Kenya. A recent investigation by Mwanaongoro and Imbambi (2014) of Nzoia, and other sugar companies in western Kenya addressed the relationship between plant and equipment maintenance strategies and factory performance. It was established that robust plant and equipment maintenance strategies play a key role in factory performance and sugar companies should invest in maintenance. An earlier survey in 2005 established that except for Mumias Sugar Company with an average cost of 314 US$ per ton of sugar produced compared to a world average of 263 US$, all public sugar companies in Kenya produced sugar at a cost higher than 150% of the world average (LMC, 2005). Nzoia sugar had a 455 US$ production cost per ton. Currently, the Nzoia sugar factory has an overall recovery of 81% and an actual recovery of 68.05% with a sugar production of 250 tones. This is below the 300 tones target per day. Boiling house recovery (BHR) is 77.46% which is below the target of 90%. This shows that there are losses of sucrose during the sugarcane production process.

Raw sugar production from sugarcane uses several unit processes that generally begin with extraction of the juice, followed by heating and clarification (flocculation and settling of suspended solids) then evaporation (concentration of dissolved solids) and finally crystallization and centrifugation (Rein, 2007). The main goals of a raw sugarcane factory are to have an efficient profitable operation with the required sugar quality and maximum sucrose recovery. The loss of sugar to final molasses accounts for 45-47% of the total sugar loss (Salassi, 2008). This follows a sucrose mass balance equation of:

100 tonnes sugarcane = 86 T sugar +10 T molasses + 2 T bagasse + 1 T filtercake + 1 T undetermined losses.

Sucrose recovery is the major concern of every sugar factory and Nzoia sugar factory is not an exception. Consequently, there have been many efforts to minimize sucrose loss. Unfortunately, at the end of each financial year, sugar production does not correlate with the quantity of the sugar cane delivered, indicating that sucrose recovery from cane is not maximized. Sucrose losses are experienced right from the milling section to packaging. Post-harvest losses have been reported and are linked to low sugar recovery and other problems during sugar processing. Therefore, the objectives of the study were to identify the critical stages of sugar loss in the production process and determine the sucrose content at these stages with reference to bagasse pol. filter cake, final molasses and undetermined losses. This could enable the factory to take remedial measures to minimize sugar losses and increase their financial gain hence reducing the cost of sugar to consumers and improving returns for the small holder farmers.

MATERIALS AND METHODS

Materials

Samples for the study were collected from the process line. Bagasse samples from mill no.5 after juice extraction, filter cake from rotary drum vacuum filter and final molasses from low grade station of Nzoia sugar factory were utilized in this study.

Sugar Production Process Stages of Samples and Analyses

The general procedures covered routine analytic procedures employed in the laboratory. Specific procedures covered operations relating to determination of bagasse polarity, filter cake polarity and final molasses purity. Figure 1 shows the processing stages at which samples were collected.

JUICE EXTRACTION - Bagasse pol%
(Bagasse sampling, preparation and analysis)

↓

MUD FILTRATION - Filter cake pol%
(Sample collection from the filter and analysis for m.c and pol %)

↓

C-SUGAR CURING - Final molasses purity
(Sampling and analysis for polarity, brix and purity) Figure 1. Flow chart of processing stages of sample collection and analyses

Physical Analysis

Physical analysis involved assessing other factors contributing to undetermined sugar losses; including leaking pumps, overflowing vessels and spillages along the wet sugar conveyor.

Moisture Content Analysis for Bagasse and Filter Cake

Bagasse from mill No. 5 was sampled and its moisture content determined to ensure that the bagasse taken to the boiler had moisture content of (51-52) for effectively burning. Moisture content of Filter cake was also determined. The same procedure for moisture content determination was used for both bagasse and filter cake pol. An initial quantity of 100 g of bagasse/filter cake was weighed into a crucible. The sample was then placed in an oven and heated for 3 hours at 105^0C. The sample was then weighed again and the recorded as final weight. Moisture content was obtained using the following formula

Moisture content of sample = (final weight – initial weight) g/100 g of sample.

Determination of Bagasse Polarity

To determine bagasse polarity, 150 g of bagasse was weighed into a digester container and 2000 ml of distilled water added. Digestion was carried out for five minutes by use of an electric motor. After digestion, about 400 ml of the resulting juice was analysed. Lastly, 2 spatulas full of lead acetate was added to the juice contained in a beaker. The juice was filtered using a filter paper to obtain a filtrate whose polarity was determined by the polarimeter.

Determination of Filter Cake Pol

The filter cake pol was determined by weighing 150 grams of filter cake into a beaker and adding 2000 ml of distilled water and thoroughly mixing, About 400 ml of the resulting juice was taken for analysis. Lastly, 2 spatulas full of lead acetate were added to the juice contained in a beaker. Filtration was done by use of a filter paper to obtain a filtrate whose polarity was determined by the polarimeter.

Determination of Final Molasses Purity

Some 50 g of molasses was weighed and 250 ml of distilled water was added and stirred thoroughly to obtain a perfect solution, before 150grams of the resulting solution was weighed into a 250 ml volumetric flask,and topped up to the mark with distilled water. The solution was transferred into a beaker and 3 spatulas full of lead acetate added and the solution filtered. To the filtrate, 3 drops of acetic acid were added to obtain the pol% of the filtrate at the polarimeter. The brix obtained was multiplied by 6 (the dilution factor) while the polarity obtained was multiplied by 2.6.

Purity = pol/brix * 100%

Data Analysis and Presentation of Findings

Data from analysis of various samples which were collected three times per day and mean figure obtained. This exercise was done for two weeks. Data collected was analyzed using statistical for scientific analysis (SAS) programme.

RESULTS AND DISCUSSION

Final Bagasse, Filter Cake and Molasses Purity

Analyses of the bagass showed that, There was moderate interaction between mc and pol% (0.0324^{**}) of samples collected during the two week study (Table 1), showing that the rise in moisture content resulted in slight increase in pol%. However, there was no significant difference in moisture content of these samples which were also within the required range (0.54) possibly due to consistent operations and analytical procedures. Also, there was no significant difference in bagasse polarity (0.05) showing that the values obtained were the same and within the accepted range possibly because they were collected from the same batch.

Table 1. Analysis of variance for samples collected at different stages in Nzoia sugar factory

Source of Variance	Degree of Freedom	Mean Squares
Filter cake mc	2	0.91**
Filter cake mc*pol[1]	1	0.84*
Filter cake pol	2	0.01**
Filter cake pol*mc	1	0.56***
Bagasse mc	2	0.54
Bagasse mc*pol	1	14.12**
Bagasse pol	2	0.05
Bagasse pol*mc	1	0.03**
Final mol Brix	2	18.06**
Final mol pol	1	0.06
Final mol purity	2	8.18**

Level of significance; * less significant, ** moderate significant and *** highly significant at 5% degree of freedom

[1]Pol is a specific unit for sucrose content of sugarcane juice. A pol (polarization) is a measure of the sucrose content of sugar. Sugar with 98 pol (or 98° pol) contains about 98% sucrose.

Table 1 also shows that there was significant differences for the filter cake moisture content content (0.91**) of the samples collected during the two weeks possibly because they were from the same batch of materials and consistency in mud filtration operations. There was a moderately significant difference in filter cake pol% (0.01**) which may be explained by variation in analytical procedures and samples collected for analysis. The significance difference between mc, and the pol% was high (0.56***) also showing the results obtained varied as samples came from different sources.

Determination of brix for final molasses purity showed that there was significant difference in total dissolved solids (18.06**) which may be attributed to differences in operation by different operators. There was significant difference in final molasses purity (8.18**), though the samples were obtained from the same batch during sampling and analysis period. Table 2 further clarifies Table 1, showing details of the values for bagass moisture and polarity, filter cake polarity and molasses purity that were collected for 11 days during the two week sampling.

Table 2. Moisture and sugar content of samples collected from juice extraction, mud filtration and c-curing in sugar production at Nzoia Sugar Company

Day	Bagasse moisture	Bagasse polarity	Filter cake polarity	Final molasses purity
1	50.20±0.10***	2.99±0.25***	3.88±0.08**	38.54±0.80**
2	50.20±0.10***	2.99±0.25***	3.88±0.08**	38.54±0.80**
3	50.23±0.15***	2.70±0.07*	3.65±0.08*	38.08±0.18***
4	50.30±0.20***	2.71±0.06	3.59±0.09***	37.43±0.42*
5	50.27±0.06*	3.01±0.47*	3.87±0.15***	36.28±0.64
6	50.47±0.21***	2.73±0.43	3.80±0.10***	36.79±0.02**
7	50.50±0.10**	28.5±0.07*	3.77±0.24***	36.31±0.75***
8	50.23±0.21***	2.73±0.43	3.71±0.09***	36.79±0.51
9	50.17±0.21***	2.74±0.06*	3.77±0.07	36.20±0.53
10	50.37±0.15***	2.73±0.02***	3.80±0.1***	36.60±.0.33*
11	50.10±0.10**	2.80±0.11***	3.86±0.09***	36.47±0.59*

Values are mean ± standard deviations.

Level of significance; * less significant, ** moderate significantant and *** highly significant at 5% degree of freedom

[1]Pol is a specific unit for sucrose content of sugarcane juice. A pol (polarization) is a measure of the sucrose content of sugar. Sugar with 98 pol (or 98° pol) contains about 98% sucrose.

Juice Extraction Process Sugar Content

Figure 2 shows the bagasse polarity for the whole sampling period was below the specification of (3.5%).The first two days, bagasse pol was 3.3%, on day 3 and 6, 3% a value that was maintained through the remaining days.

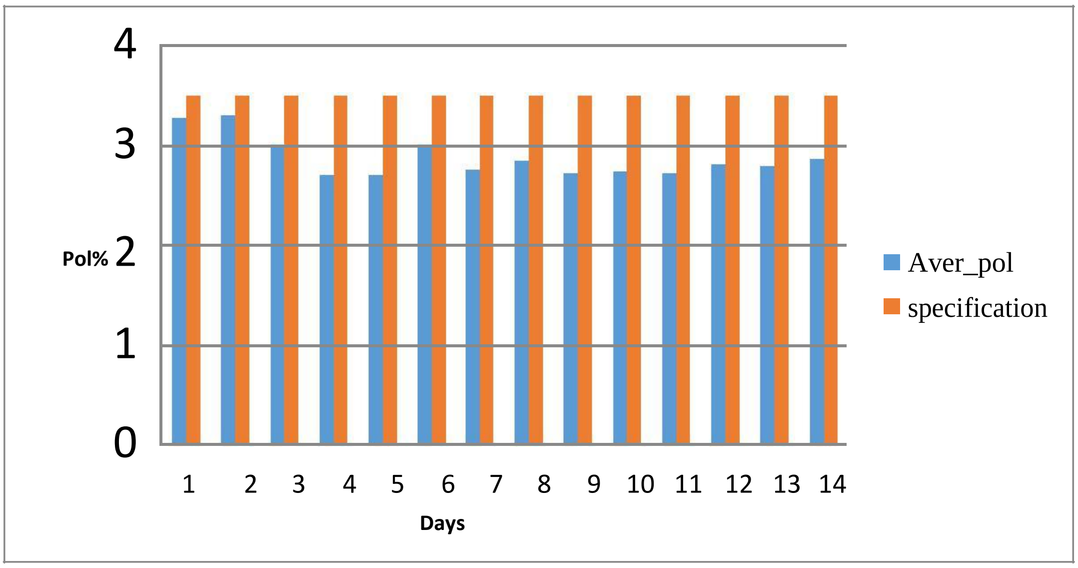

Figure 2. Bagasse polarity at 3.5 specifications

The pol% of the bagasse was within the required specification, attributed to proper mill settings at the juice extraction stage. The rollers force feed, delivery and discharge rollers were set by the mills engineer to maximize juice extraction. Imbibition is the process of adding water in to the bagasse to maximize cane juice extraction. The juice preferably compounds at 200%, was added after the 4th mill, obtained in the 5th mill, pumped to the 3rd mill, collected in the 4th and the process continues up to 2nd mill. This process was adequate, hence the bagasse pol% was within the specifications. This attained a mill balance equation of:

tonnes canes+ imbition water= Mixed juice+ bagasse.

The target preparation index in premilling is >75, mainly is to rupture and expose sugar cane cells for effective juice extraction. According to the results, bagasse pol% was <3.5 indicating PI was within the specifications.

Mud Filtration Process Sugar Content

Figure 3 shows that the filter cake polarity was above the specification of (3.0% polarity) throughout the sampling period. Mud filtration is carried out to recover juice from mud that has been discharged from the clarifier using a rotary drum filter that employs the principle of vacuum filtration (Sandeep et al, 2014). Over 90% of the mud is actually clear juice that has to be recovered. The purpose of the filter station is to separate as efficiently as possible, the mud solids from the clear juice in clarifier mud. The mud from the clarifier is conditioned before filtration. The coarse material is screened out of bagasse to leave fine bagacillo which is mixed with the mud. Some lime and flocculant may be added, especially when mud proves to be difficult to filter. The clear juice fraction is recycled to the limed juice tank. The solid mud together with any added filter aid is called filter cake (70% moisture, 29% solids and 1% brix).

The reason for the filter cake pol % being above the specification of 3.0% may be explained by poor mud conditioning due to insufficient bagacillo added to the mud to act as the filtering aid, or insufficient water spray to the rotary vacuum filter resulting in poor filtration, hence causing loss of juice to the scum. It is also possible that low vacuum during the filtration operation results in loss of juice in the scum, since low vacuum leads to reduced sucking of the juice from the mud. This occurs during operations in cases when the vacuum pumps develop mechanical problem, creating low vacuum, which may also be caused by low water volume supplied to the vacuum pumps. Another cause may be physical damage of the rotary vacuum filter screen resulting in loss of juice to the scum when the filter operation is inefficient.

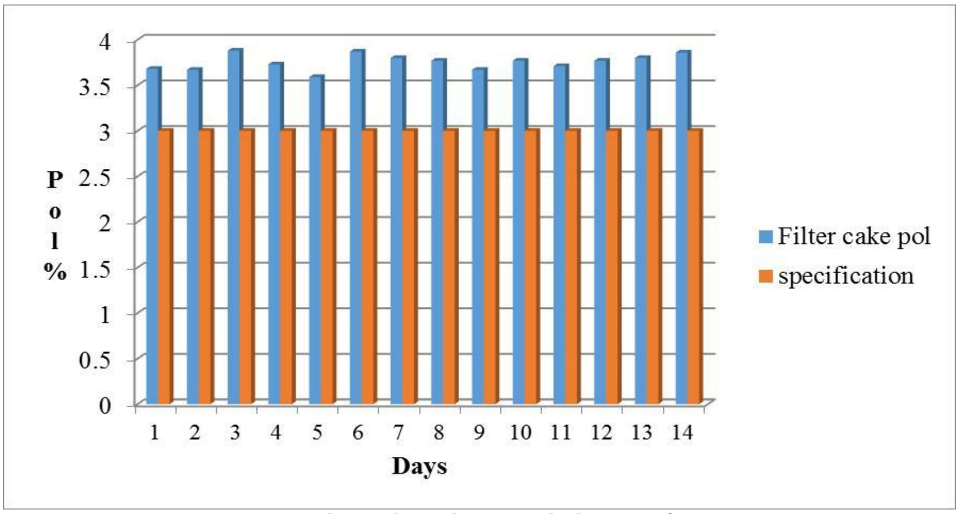

Figure 3. Filter cake polarity with the specifications

Final Molasses Purity

The target purity of 36% at the c-sugar centrifugation stage was exceeded throughout the sampling and analysis period (Figure 4). Massecuite leaving the crystallisers has to be separated into crystals and molasses.The more efficient this seperation,the the more sucrose will be recovered as sugar and the less sucrose will be lost in molasses. Centrifugal seperation is never 100% efficient as a film of molasses will always remain in the molasses.Centrifugal performance is measured by the quality of sugar produced and by aiming for a molasses purity not more than 1 or 2 units higher than nutch purity.The final molasses purity was above the specification, particularly on the second, third and fourth days when it was above 38% which was well above the specification(purity of 36%).This showed that the c-station was the major sugar loss stage as compared to the other stages i.e. juice extraction stage and filtration stage

This may be attributed to poor c-granulation, where the boiling system adopted during c-sugar boiling never recovered available sucrose in the mother liquor exhaustively. This results when the purities of materials used for boiling c-sugar are very high or the boiling time is not long enough to exhaust sucrose in the mother liquor. Crystallization process involves boiling of the syrup to obtain sugar crystals .This process ensures that the available sucrose in the mother liquor is recovered maximally to obtain the final molasses with a target purity of 35-37% (Mullin,2001). Also, after c-sugar boiling, the massecuite is stuck in the crystallizers, where they are given enough retention time for exhaustion (crystallization) to take place. A short retention time results in high molasses purities, hence sugar loss in the final molasses. According to Salassi (2008), when a lot of washing water is used during curing operations, it dissolvs most of the sugar crystals in the massecuite, resulting in sugar loss in the final molasses. The loss of sugar to final molasses accounts for 45-47% of the total sugar loss.. In addition, if the screen of the centrifugal machine is torn, there is high final molasses purity, hence sugar loss. Further losses may also be caused by steam leakage along the pipe lines to the c-station leading to dissolution of the sugar in the final molasses, hense sugar loss.

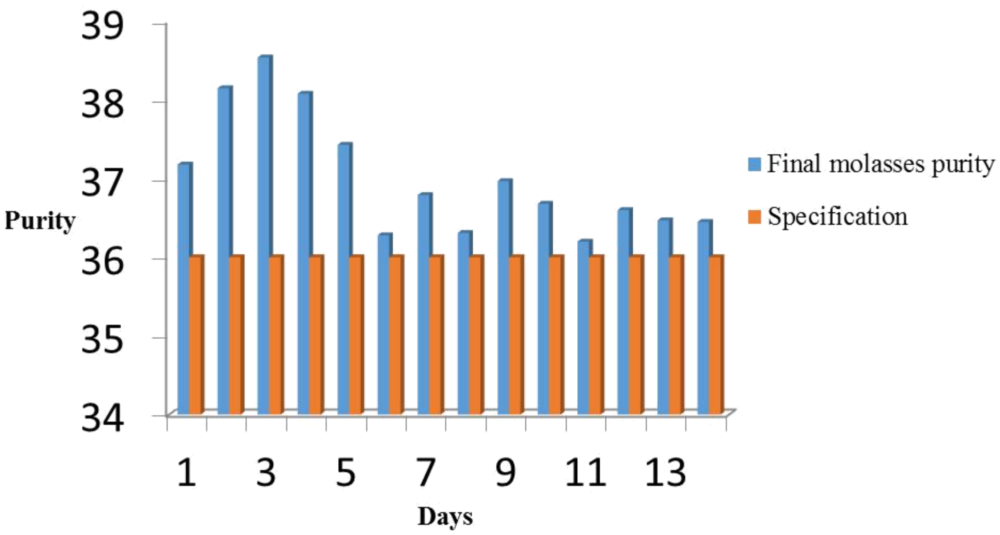

Figure 4. Final molasses purity with the specifications

CONCLUSION

Nzoia sugar factory did not maximize sucrose recovery due to inefficient process, particularly in mud filtration and c-sugar centrifugation stage and mud filtration and c-massecuite curing stage are the major sugar loss stages.

RECOMMENDATIONS

To minimize loss of sugar through scum, the company should ensure regular repair and replacement of rotary vacuum screen. Since the c-station (c-sugar centrifugation) is the final stage of sugar recovery, a lot of effort should be made to minimize sugar loss in the final molasses. Skilled operators to man c-sugar centrifugation to ensure efficient operations to maximize sugar recovery. Further research needs to be done in the field sugar process to identify critical stages of sugar loss since sugar processing is wide and diverse field.

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BIO-DATA

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