OPERATIONAL PAPER

ESTIMATED RECOVERABLE CRYSTAL MEASUREMENT IN THE ZIMBABWE SUGAR INDUSTRY

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Abstract

The cane payment system in the Zimbabwe Sugar Industry (ZSI) is based on both the quantity and quality of cane delivered to the mill. The quality of the cane is measured as the Estimated Recoverable Crystal (ERC% Cane). This paper discusses the sampling and analysis of the growers' cane by using the Direct Analysis of Cane (DAC) method. The various factors that affect the ERC content of cane are discussed. Since sugar is created in the cane plant in the field and extracted at the mill, growers can maximise their revenue by applying the best management practices for growing and harvesting the sugarcane. The ZSI provides a field-testing service to growers to determine the maturity of the cane and its readiness for milling.

To avoid misunderstanding between the growers and millers, the ZSI has put a number of protocols in place to ensure that the mill's laboratory results are credible. These include audits by the ZSI Chief Chemist and external audits by accredited auditors, like the Sugar Milling Research Institute (SMRI) and the Scientific and Industrial Research Development Council (SIRDC). To ensure that the personnel and equipment at the two mill laboratories are equipped for their purpose, a weekly inter-laboratory proficiency testing scheme is conducted between the two mill laboratories and the ZSI laboratory, and this is administered by the ZSI Chief Chemist.

Keywords: ERC% cane, Zimbabwe cane payment system, interlaboratory proficiency testing.

Introduction

Commercial sugarcane farmers in the Zimbabwe Sugar Industry (ZSI) are paid for their produce, based on the quality and quantity of the cane that is delivered to the two mills in Zimbabwe, namely, at the Triangle (TR) and Hippo Valley Estates (HVE), which have a combined milling capacity of around 4 million tons of cane per annum. The farmers and millers can enter into two types of agreement, either a cane purchasing agreement or a cane milling agreement, of which the former is the preferred agreement. In both cases, the accurate measurement of the cane quality is of paramount importance. The quality of the cane is measured by the estimated Recoverable Crystal Index (ERC), which quantifies the percentage of sugar crystals that are extractable from a given quality of cane. The ERC% cane is given in the formula below (van Hengel, 1974):

$$\boldsymbol{ERC\ \%\ cane = aP - bN - cF}$$

Where: P = Pol % Cane

N = non-Pol % cane

F = Fibre % cane

a = Pol in sugar, bagasse and final molasses as a fraction of pol in cane

b = Loss of pol in molasses per unit of non-pol in cane

c = Loss of pol in bagasse per unit of fibre in cane

These factors are calculated as follows:

$$Factor\ 'a' = \frac{P\ in\ all\ sugars + bN\ in\ cane + cF\ in\ cane}{P\ in\ Cane}$$

$$Factor\ 'b' = \frac{(N\ in\ molasses + N\ in\ all\ sugar) * P\ in\ molasses}{N\ in\ Cane * N\ in\ molasses}$$

$$Factor\ 'c' = \frac{P\ in\ Bagasse}{F\ in\ Cane}$$

Each consignment of cane, or a percentage of the grower's cane, needs to be sampled and analysed for Pol, Brix and Moisture. The Fibre % cane and Non-Pol % cane are determined as follows.

Fibre % cane = 100 – Moisture % cane – Brix % cane

Non-Pol % cane = Brix % cane – Pol % cane

Both mills use the hatch method for cane sampling. The tracking of the consignment, as well as the sampling and analytical methods, are outlined in the Laboratory Manual for South African Sugar Factories, which includes the Official Methods (Anon, 1985). Factories that practise the clarifier mud recycle need to follow the official method of weighing and subtracting the Pol and Brix in the mud that is recycled to the clarifier. Both TR and HVE practise mud recycling. The Pol Factor adjustment for the clarifier mud recycle is shown below.

$$\mathbf{Pol\ Factor} = \frac{(\mathbf{tons\ Pol\ in\ Mixed\ Juice} + \mathbf{tons\ Pol\ in\ Bagasse} - \mathbf{tons\ pol\ in\ clarifier\ mud})}{\mathbf{tons\ Pol\ in\ DAC}} \times \mathbf{100}$$

The same methodology is used for the Brix Factor adjustment.

The a, b and c factors are constants that are applicable for the whole season. The values used for a particular season are the average of the two previous seasons, and they are considered to be provisional until the end of the season. The actuals for the current season are calculated after the 'sweep out', when all the sugar and molasses products have been reconciled.

The factors are approved by the ERC Committee, which is constituted by representatives from the Farmers Association, the Millers and the Zimbabwe Sugar Association Experiment Station (ZSAES). The actual factors for the season are then used to recalculate the ERC for the growers, and adjustments are made on the final payment to the farmers.

Good factory performance is indicated by high sugar recoveries and a high 'a' factor. In the ZSI, the 'a' factor has been above 0.96 since 2010, in response to the improved tooling of the mills and a stable workforce. The highest value of 0.975 was recorded in 2015. For the past five years, the 'a' factor has been above 0.97 and comparable with other mills in the region. The 'a', 'b' and 'c' factors are shown in Figure 1 for the period 2011 to 2021.

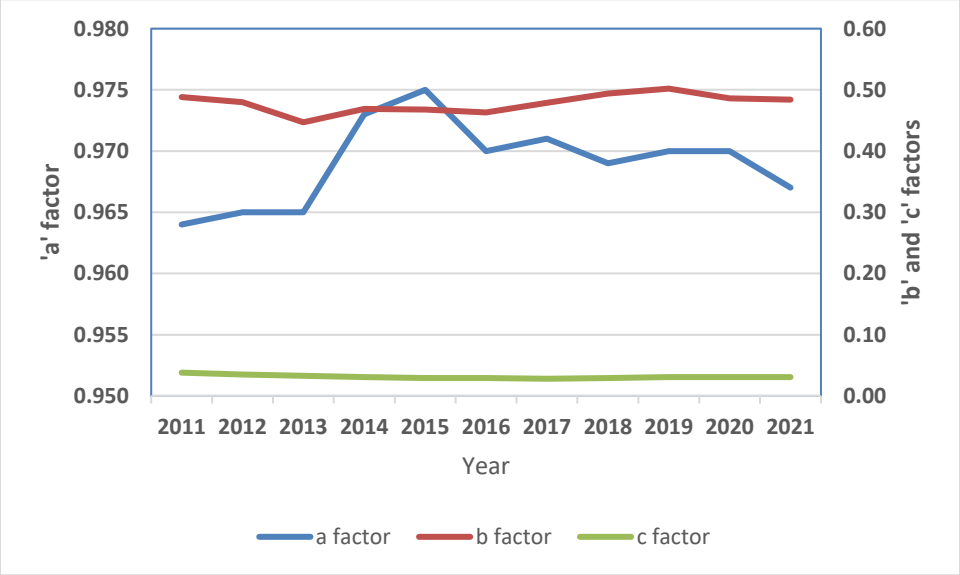

Figure 1. The trend of the a, b and c factors in the ZSI from 2011 to 2021

The payment due to the farmer is based on the Division of Proceeds (DoP) formula and the prevailing Mill Door Price (MDP). The DoP refers to the distribution of revenue between the farmer and the miller. Under the milling agreement, the farmer gets 77%, while the balance is retained by the miller to cover the cost of milling. The DoP is subject to review by mutual agreement. The MDP is the selling price per ton of sugar made from the farmer's cane.

Factors affecting ERC % cane

A number of factors affect the ERC content of the cane. Since sugar is created in the plant (fields) and extracted and recovered in the factory, the agricultural practices play an important role in the ERC content.

Cane variety

The cane variety (ZN10, N14 and others) plays a part in the ERC content. The best variety for the specific field conditions should be selected. Variety Z10 is known for its high potential ERC t/ha cane, which ranges from 21.4 to 24.2, while N14, an old variety that most farmers are accustomed to, ranges from 16.6 to 21.8 (A Guide to Varieties Released for Commercial Use and Bulking, 2005 (available at ZSAES)).

Cane age

The cane should be harvested at the optimum age. The recommended age for harvesting is ≥12.0 months. Young cane has a high level of Non-Pol, which lowers the ERC. The ZSI encourages growers to send cane samples, in order to test its maturity and suitability for harvesting. There is a defined procedure for the collection of samples. As a general practice, 24 stalks are taken as a sample from a single uniform field. Before the samples are collected, 10% of the field peripheries are discarded. The 24 stalks are collected systematically, in order to obtain stalks that are a representative sample of the whole field. This is done by counting the number of rows and their lengths and then collecting an equal number of stalks from each row in multiples of 24, depending on the size of the field, e.g. 12 × 2, 8 × 3, 6 × 4, and so forth. After 24 stalks are collected, the leaves are removed and topping is done at the natural breaking point by allowing the tops to break on their own. The clean stalks are then divided into three sub-samples of eight, where either the tops, or the middle or bottoms, are collected to constitute the representative sample of the field, with the other portions being discarded. The laboratory sample is then labelled with the farmer's details and taken to the laboratory for analysis and to calculate the ERC. Typically, good quality mature cane should have a Pol of 14-15%, a Brix of 17-18%, Fibre around 15% and Moisture between 68 and 70%.

Cane harvesting practices

The highest sucrose content is in the cane stalk, and therefore the base cutting and topping height are important harvesting practices. Cane that is delivered with roots, excessive trash and tops will increase the fibre content and decrease the ERC. Very dry (with moisture below 68%) and very hot burnt cane is not desirable for milling. Mills can reject cane that is below the 68% moisture level. Another important parameter is the Burn-To-Crush-Delay (BTCD). A long BTCD also decreases the ERC content of cane by increasing the fibre and Non-Pol, due to deterioration.

Seasonal variation

The ERC% cane varies within each season, and from season to season, depending on a number of agricultural and climatic factors.

The seasonal variations in the ERC content are shown in Figures 2 and 3. The ERC curve is at a peak between Weeks 25 and 37, or between August and October.

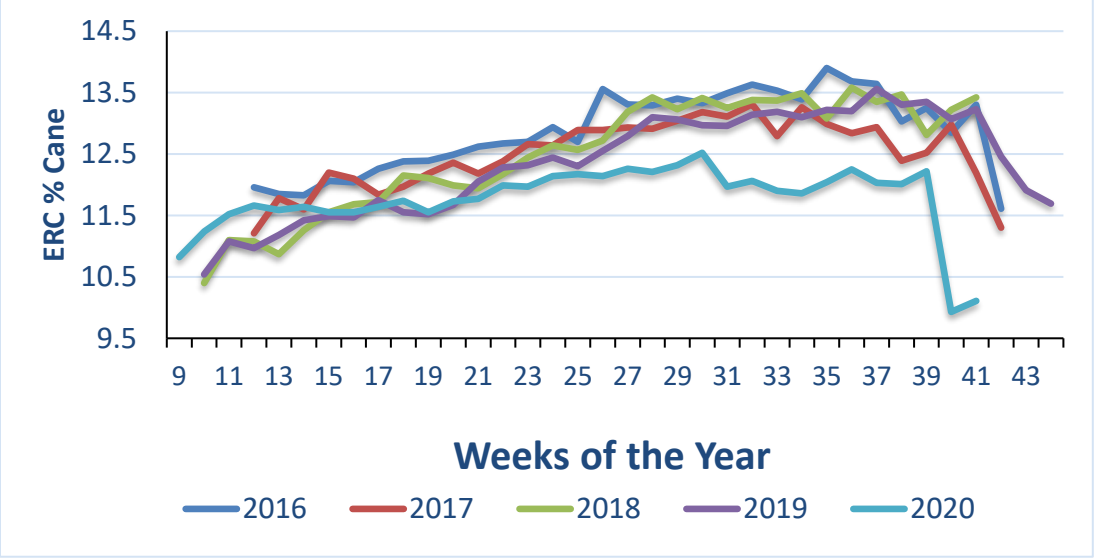

Figure 2. Seasonal variation of ERC% cane at the Triangle Mill from 2016 to 2020

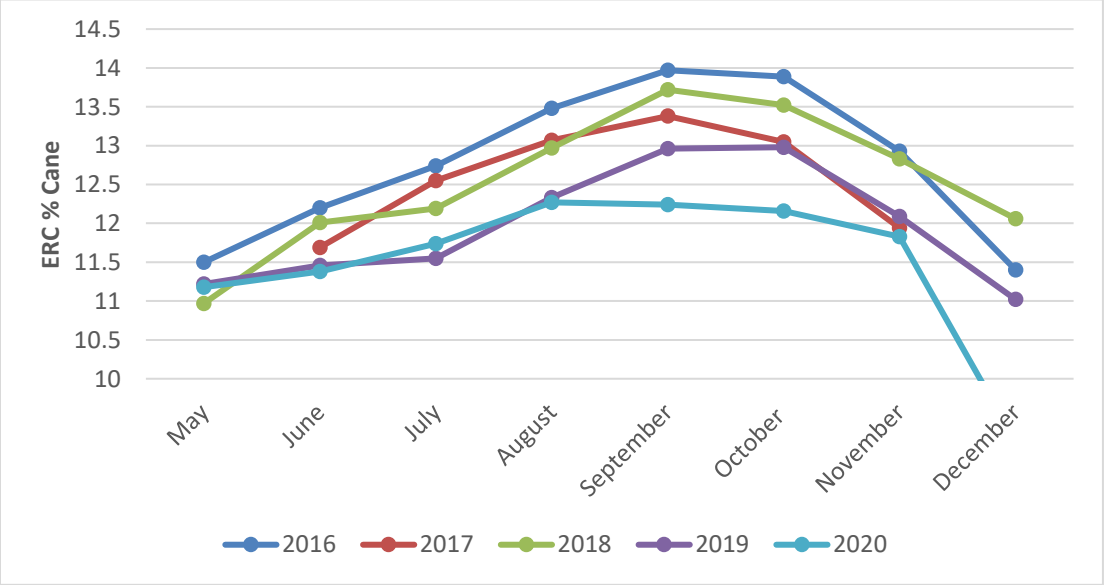

Figure 3. Seasonal variations of ERC% cane at the HVE Mill from 2016 to 2020

The season-to-season variations in the ERC content are shown in Figure 4. The ERC content was the lowest in 2010 and the highest was in 2016. Various reasons were given for the drop in ERC in 2010 and included the burn-to-crush delays, poor management practices, the economic recession (which affects the import of inputs), as well as the crushing of immature cane, among others. The highest ERC realised in 2016 was a result of good management practices, as well as availability of inputs due to economic recovery. Rainfall events during the milling seasons also affect the ERC, as the cane may be harvested with moisture, which may accelerate sucrose degradation.

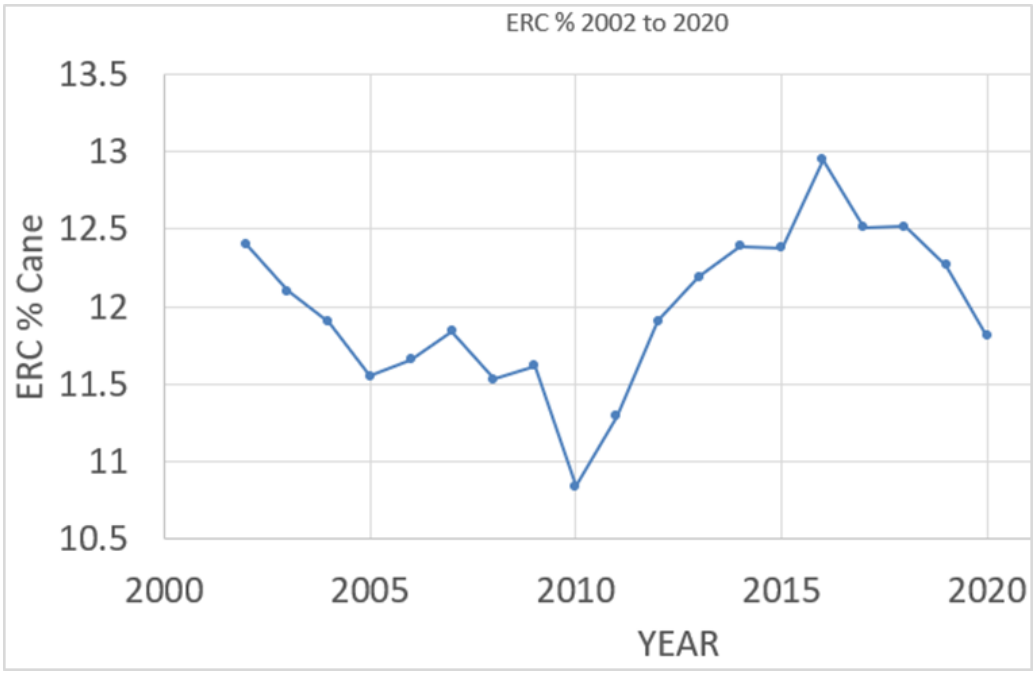

Figure 4. Average seasonal ERC% cane from 2011 to 2020

ERC adjustment by DAC factors

The to-date tons Pol and Brix for each grower are adjusted by the to-date Pol and Brix Factors based on the actual mill performance. The acceptable ranges for Pol and Brix Factors are shown in Table 1 below:

Table 1. Acceptable Pol and Brix Factor range

Factor	Acceptable range
Pol Factor	98.5 – 101.5
Brix Factor	99.0-103.5

Quality assurance and quality control to ensure credible ERC results

The Zimbabwe Sugar Industry has adopted measures to ensure that the results obtained at the two mill laboratories and the ZSAES laboratory are credible. The measures include ensuring that (i) all the equipment is calibrated on a yearly basis by independent service providers, (ii) the laboratories are manned by qualified personnel, (iii) modern equipment is used, (iv) standard protocols are followed, (v) the laboratory environment is clean, (vi) a weekly interlaboratory proficiency testing scheme is carried out, and (vi) external and internal laboratory auditors are engaged.

Interlaboratory proficiency testing scheme

The interlaboratory proficiency testing scheme seeks to standardise the analytical procedures among the three laboratories. The objective of the scheme is to check whether the standard operating procedures for the Direct Analysis of Cane (DAC) are being followed. This is assured by utilising the same level of analysts (trained and experienced), as well as similar equipment, a similar environment and similar protocols at the three laboratories. The proficiency testing scheme is conducted weekly (every Wednesday), starting with sample collection, distribution, analysis and sharing of the results, as described below.

Samples are collected from the hatch sampler. Four consecutive samples are collected within an hour. The samples are further shredded for five seconds and mixed thoroughly. Each sample is divided into three equal portions and packed into plastic bags. The samples are stored at 20°C, while awaiting transportation. The samples are transported in cooler-boxes and should be delivered within an hour to the other two laboratories. The HVE samples are to be delivered before 9:00 am and the TR samples before 11:00 am. The results should be submitted to ZSAES soon after completing the analysis. If the results are outside the tolerances, investigations are carried out by all the laboratories under the supervision of ZSAES. Table 2 shows the acceptable tolerances for the various parameters, including the Z score, which is a statistical measure of the difference between the given value and the calculated mean, divided by the standard deviation.

Table 2. Acceptable analytical tolerances for the various ERC parameters

Parameter	Moist % Cane	Brix % Extract	Pol % Extract	Brix % Cane	Pol % Cane	ERC % Cane	ERC Z score
Tolerance ±	0.50	0.15	0.15	0.30	0.30	0.60	2

Interpretation of Results

The differences between the two laboratories for each parameter are calculated. If the difference is greater than the tolerance shown in Table 2, that difference is noted as a variance or non-conformity. The differences between any two laboratories should not exceed five, otherwise an investigation has to be carried out to determine the origin of the differences.

Corrective Action

Corrective action shall focus on:

(a) Human capital – the competence of the analysts; assessing the need for training or refresher courses;
(b) Instruments – the state of the instruments; the need for calibration, services and repair;
(c) Procedures – checking if the procedure was followed; strict adherence; and
(d) Working environment – temperature, cleanliness, noise and relations.

Laboratory audits

The Agricultural and Industrial Research Chemist of the ZSI is mandated to carry out audits of the cane yard, weighbridges, tracking and sampling, as well as the mill laboratories. The mill audits are conducted at any time of the day during the milling season.

External audits

Further auditing of the laboratory processes, equipment and personnel is conducted by the Sugar Milling Research Institute (SMRI), which is based in South Africa, and the Scientific and Industrial Research and Development Council (SIRDC). The SMRI is also involved in the training of laboratory managers, engineers and analysts by means of the SMRI Ten-Week Course in Sugar Engineering, or the One-Week Sugar Technology Course.

Conclusions

The measurement and determination of the cane quality is a critical step in the evaluation of sugarcane for payment purposes. Standard operating procedures must be adhered to when analysing the cane samples, in order to produce credible and reliable results that are traceable. The four factors that affect the credibility of the results are manpower competence, the equipment and methods used and the environment, which must be continuously reviewed, in order to give confidence to the clients, who in this case are the sugarcane farmers.

References

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