POLARISATION BY FILTRATION FOR CANE PAYMENT AND FACTORY CONTROL

By

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Abstract

LABORATORY analyses are used worldwide to assess the quality of sugarcane and sugar processing products. Polarimetry is the basic sucrose analysis in the laboratory to assess sugarcane quality and factory performance. Pol measurement requires a clarification step that is usually carried out with lead subacetate. A non-lead method has been developed based on filtration. This filtration method has been assessed for its suitability for cane analysis for payment purposes and for factory products (mixed juice, bagasse, mud and molasses) for process control. Results for pol in cane are on average 0.08% lower with the filtration method than with the standard lead clarification method. Results for factory control show that apparent sucrose entering the mill decreases by 0.08, resulting in an equivalent decrease in undetermined losses. To conclude, polarisation by filtration is suitable for cane payment and factory control and is now used in Reunion Island for these purposes.

Introduction

For many years, the world sugar industry has used laboratory measurements to improve its efficiency, carrying out analyses on sugarcane and on sugar processing products. The analyses of sugarcane are needed to measure cane quality for agronomic and commercial purposes, whereas the analyses on sugar processing products are needed to measure factory balances and sugar losses in the mills and to improve sugar recovery. All the cane analysis methods use polarisation to estimate sucrose as it is an accurate, simple and economical method.

In the past, the polarisation method used lead subacetate but, with the increasing recognition of environmental and health factors, new methods have recently been developed employing other chemicals (Altenburg and Chou, 1991) or using filtration (Hoareau *et al.*, 2008). Lead clarification produces juice with low colour and a polarimeter with a visible wavelength (from 587 to 589.44 nm, pol_{589}) can be used. Filtration does not remove colour and an infrared wavelength (825 to 882.60 nm, pol_{882}) polarimeter therefore has to be used.

In many countries, the sugar content in cane is measured for payment purposes. In Reunion Island, the *Centre Technique Interprofessionnel de la Canne à Sucre* (CTICS) is responsible for cane analysis for cane payment. The analysis is based on core sampling of each load followed by cane analysis by the press method. Methodological differences should be taken in account to maintain the economic balance between growers and millers. The first trials on non-lead pol started at the end of the 1990s and methods were developed in collaboration with eRcane.

This paper compares results by lead clarification pol (pol_{589}) with filtration pol (pol_{882}) for cane payment systems and factory control.

Materials and methods

Polarisation method for cane payment

Pol measurement

Lead clarification pol (pol_{589}) was carried out on pressed juice using lead subacetate (1.5 g / 250 mL) followed by gravity filtration with Fioroni 1591 filter paper.

Filtration pol (pol_{882}) was carried out on pressed juice using a filter aid (8 g of Clarcel CBL) followed by pressure filtration (Schmidt and Haensch Autofilt) with Fioroni 1105A filter paper. The pol and brix were measured on the same filtrate sample.

An REI Polaser SRC64 polarimeter (825 nm wavelength) was used for cane analysis at CTICS.

Pol in pressed juice with lead or by filtration was used to calculate pol in cane, according to the CTICS protocol (2009).

Cane sampling

Cane analysis by the press method is used for payment purposes in Reunion Island. Experiments were carried out at CTICS during the 2007 and 2008 crushing seasons when 4537 and 6439 samples were collected respectively to compare pol_{589} and pol_{882}. The trials were performed in five delivery stations in different parts of the island (Figure 1).

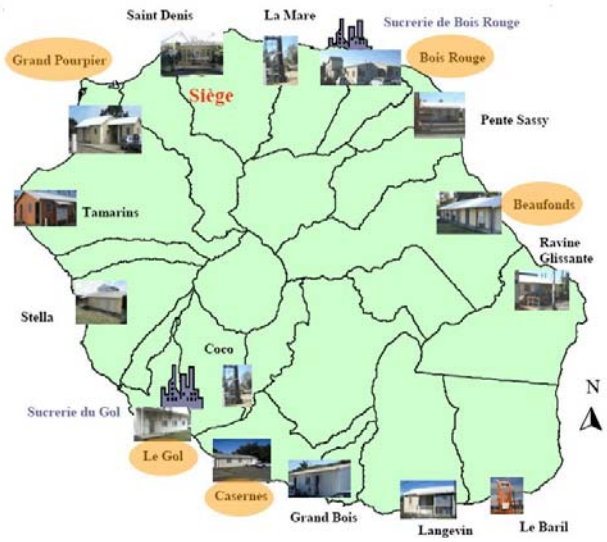

Fig. 1—Map of CTICS delivery stations in Reunion Island (trials in brown shaded sites).

Polarisation method for factory control

Pol measurement

Lead clarification pol (pol_{589}) was carried out on factory products using lead subacetate (Table 1) followed by gravity filtration with Fioroni 1591 filter paper.

Table 1—Lead clarification pol method for factory products (ARTAS, 1992; ICUMSA, 1994)

Product	Dilution	Lead weight (g/250 mL)	Polarimeter tube length (mm)
Cane	–	3.75	100
Mixed juice	–	2.5	200
Final molasses	1/6 (w/w) follow by 13/100 (w/V)	13	200
Mud	72 / 500 (w/V)	0.4	200
Bagasse	250 g + 2500 g	0.2	200

Filtration pol (pol_{882}) was carried out on pressed juice using a filter aid (Table 2) followed by pressure filtration (Schmidt and Haensch Autofilt) with Fioroni 1105A filter paper.

Table 2—Filtration pol method for factory products.

Product	Dilution	Clarcel CBL weight (g/200 mL)	Polarimeter tube length (mm)
Cane	–	8	100
Mixed Juice	–	15	100
Final molasses	1 / 20 (w/w)	20	100
Mud	72 g + 500 mL	5	100
Bagasse	250 g + 2500 g	5	100

A Schmidt & Haensch Polartronic NIR W2 dual wavelength (589.44 nm and 882.6 nm) polarimeter was used for all factory products.

Sucrose analysis by HPLC and HPAEC-PAD

Sucrose in juice and molasses was analysed by HPLC (ICUMSA, 2002) and by HPAEC-PAD for mud and bagasse (ICUMSA, 1998). Hoareau *et al*. (2010) present further details of these methods.

As the lead concentration in the filtrate was around 3.8 g/L, the juice was filtered through an OnGuard II H Cartridge (Dionex) to avoid column damage.

Factory product sampling

Experiments on mixed juice and molasses were conducted in the 2001, 2002, 2006 and 2008 crushing seasons with weekly composite samples from the Le Gol and Bois-Rouge factories. These samples were analysed for pol_{589}, pol_{882} and sucrose. Bagasse and mud were analysed during the 2008 crushing season.

Statistical analyses have been done with R Development Core Team software (R Development Core Team, 2009).

Filtration pol is suitable for cane payment

Pol by filtration is lower than pol with lead clarification

Results show that pol by filtration is suitable for measuring pol in cane. During the 2008 crop, 6439 analyses were compared for pol_{589} and pol_{882}. A strong correlation was found between the two methods (Figure 2). The regression coefficient is highly significantly different from zero (p value<$2.2\ 10^{-16}$).

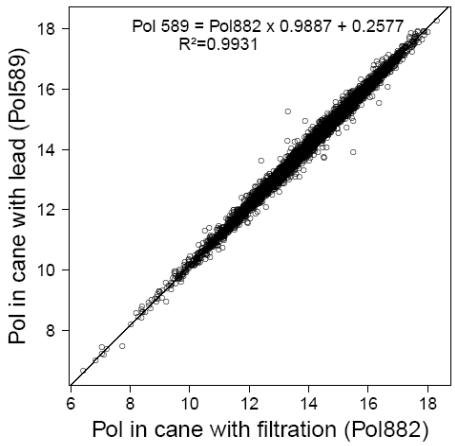

Fig. 2—Pol in cane measured with lead clarification and with filtration (2008 results).

The results of filtration pol are 0.08 lower on average than lead clarification pol (Table 3). The same trials conducted in 2007 showed a difference of 0.07. This average difference takes into account the results of the trials in the five delivery stations. In individual delivery stations, the average differences ranged from 0.06 to 0.13. The sugarcane tonnages delivered to the five delivery stations were used to calculate the 0.08 weighted average.

Table 3—Average differences between filtration pol (pol_{882}) and lead clarification pol (pol_{589}) for the 2007 and 2008 crushing seasons.

	Pol_{882} % cane – Pol_{589} % cane	
Delivery station	2007	2008
Beaufond	–0.07	–0.13
Bois-Rouge	–0.04	–0.08
Grand-Pourpier	–0.14	–0.13
Le Gol	–0.08	–0.06
Casernes	–0.11	–0.07
Weighted average	–0.07	–0.08

Filtration pol is now used in Reunion Island for cane payment. From the results in Table 3, there is a statistically significant difference between the two methods (p value=0.0004).

The payment system had to be modified to maintain the economic balance between growers and millers. It has therefore been adjusted with a correction factor of 0.075 that is the average difference between the two years of testing. The new payment system uses the following formula:

$$\text{Pol \% Cane} = Pol_{882} \text{ \% Cane} + 0.075$$

Explanation of differences between pol by filtration and by lead clarification

The differences measured between lead clarification and filtration pol can be explained by the removal of glucose and fructose by lead. Sucrose, glucose and fructose were analysed in 35 samples from lead clarified filtrates and filtration filtrates. According to the specific rotation of these sugars, derived pol was calculated (Schoonees, 2003) from the lead clarification pol and filtration pol results (Table 4). In these 35 samples, the pol%cane differences were 0.09 and the pol%cane derived differences were 0.07.

Fructose and glucose concentrations are lower in lead filtrates (0.50%) than in filtration filtrates (0.66%). This 0.16% decrease in reducing sugars content decreases the pol measurement by 0.05. The 0.08 differences observed between pol measurements are mainly explained by the removal of reducing sugars by lead.

Table 4—Pol in cane derived and sugar content of filtrates.

	Glucose	Fructose	Sucrose	Pol%cane	Pol%cane derived
	g/100 g Juice			*g/100 g Cane*	
Pol_{882} (filtration)	0.33 ±0.24	0.30 ±0.22	18.25	14.44	14.74
Pol_{589} (lead clarification)	0.28 ±0.23	0.22 ±0.18	18.28	14.53	14.81
Differences	0.05 ±0.06	0.07 ±0.08	–0.03	–0.09	–0.07

A possible limitation to the explanation of the differences observed is that the sample selections were not randomised. They were sampled using the maximum and minimum differences observed between lead and non-lead methods. This sampling methodology implies high standard

deviation for the different analyses. The results can be used to explain average differences but should be evaluated with care.

Filtration pol for factory control

Comparisons of pol_{589} and pol_{882} were carried out on mixed juice, bagasse, mud and molasses.

Pol by filtration is different from pol by lead clarification

Differences between pol by lead clarification and by filtration vary depending on the factory product in question (Table 5). For mixed juice, pol by filtration is lower than pol by lead clarification, meaning that pol by filtration underestimates sucrose by 0.13% cane on average. For bagasse, both pol values are close to the sucrose values. For mud, pol by filtration is closer to sucrose values than lead clarification. For molasses, pol by filtration is lower than pol by lead clarification, resulting in an important underestimation of sucrose.

Table 5—Differences of filtration pol and sucrose compared to lead clarification in factory products (Hoareau*, et al.*, 2008).

Differences compared to pol_{589}		
	Pol_{882}	Sucrose
Mixed juice	– 0.07	+0.13
Bagasse	+0.01	– 0.03
Mud	+0.06	+0.09
Molasses	– 3.82	+2.60

Filtration pol for sugar loss measurements

The results show that filtration pol is suitable for measuring sugar losses but modifies the standard values. The entire sugar mill uses laboratory measurements to make a mass balance for measuring sugar losses. Results based on lead clarification and filtration pol show that sugar losses will be affected (Table 6). As the changes will be the same each week, a relative comparison can be made on a weekly basis.

Mixed juice sugar content will appear to be lower with filtration pol. For sugar mills that use mass balance (Cane + Imbibition = Mixed juice + Bagasse) to calculate pol%cane, the measurement for sugar entering the factory will decrease, resulting in an apparent decrease in undetermined losses. For Reunion Island sugar mills, this implies a decrease of 0.08 in pol%cane.

Sugar losses in bagasse and in mud will not be affected by the change in method. Sugar losses in molasses will decrease by 0.25, resulting in an increase of 0.25 in undetermined losses with the change in method. In Reunion, molasses losses are calculated on a weekly composite sample analysed by HPAEC-PAD, meaning that the pol method will not affect sugar losses in molasses. These differences have been examined in more detail by Corcodel and Hoareau (2009).

Table 6—Sugar losses calculated with lead clarification pol, filtration pol and sucrose.

	Lead clarification pol pol_{589}	Filtration pol pol_{882} (except molasses)	Filtration pol pol_{882} (with molasses)	Sucrose
Pol%cane calculated from mass balance in the milling tandem*	12.50	12.42	12.42	12.63
Sugar losses in bagasse	0.30	0.30	0.30	0.29
Sugar losses in mud	0.11	0.11	0.11	0.11
Sugar losses in molasses	1.29	1.29	1.04	1.29
Total sugar losses	1.99	1.92	1.92	2.12
Undetermined losses	0.29	0.21	0.46	0.43

* Cane + Imbibitions = Mixed Juice + Bagasse

A possible limitation of this paper is the lack of clear explanation for the differences between lead clarification and filtration pol for factory products. Nevertheless, the polarisation of sugarcane compounds could be more fully investigated.

Pol by filtration has been used for factory control in Reunion Island since 2005. Mill staff are using laboratory results as previously. The main problematic point is the new system of reference used for results concerning molasses.

Conclusions

Polarisation by filtration is suitable for cane payment and factory control. Results for pol in cane by filtration are on average 0.08% lower than for lead clarification pol. Factory control figures are modified, with a decrease of apparent sucrose entering the mills, resulting in a decrease of undetermined losses.

Pol analysis without lead is an environmentally friendly, non hazardous method. As polarimetry is used to estimate sucrose levels, non-lead pol is sufficient for payment and factory balance purposes. As the lead standard is disappearing, this new standard can be adopted by sugar technologists.

In Reunion Island, sugar mills started to use filtration pol analysis methods in 2005 for factory control and in 2009 for cane payment.

Acknowledgment

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LA POLARISATION PAR FILTRATION PERMET LE PAIEMENT DE LA CANNE ET LE CONTROLE DE FABRICATION

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MOTS-CLÉS: Qualité Canne, Analyse, Pol, Plomb, Filtration.

Résumé

LES ANALYSES sucrières sont utilisées mondialement pour mesurer la qualité de la canne ainsi que des produits de la sucrerie. La polarimétrie est l'analyse fondamentale du saccharose pour mesurer la qualité de la canne et les performances industrielles. La méthode de pol nécessite une étape de clarification généralement réalisée avec de l'acétate de plomb. Une méthode sans plomb a été développée par filtration. Cette méthode par filtration permet l'analyse de la canne pour le paiement et les produits de fabrication pour les bilans de fabrication (jus mélangés, bagasse, écume et mélasse). Les résultats sur la détermination de la richesse indiquent que l'analyse par filtration est inférieure de 0.08 comparé à l'analyse par clarification au plomb. Le résultat sur les bilans de fabrication vont être une baisse (–0.08) de la mesure du sucre en entrée usine qui va conduire à une baisse (–0.08) des pertes indéterminées. Pour conclure, la méthode de polarisation par filtration permet le paiement de la canne et le contrôle de fabrication. Cette méthode est utilisée à La Réunion pour le paiement de la canne et le contrôle de fabrication.

POLARIZACIÓN POR FILTRACIÓN PARA PAGO DE CAÑA Y CONTROL DE FÁBRICA

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PALABRAS CLAVE: Calidad de Caña, Análisis, Pol, Plomo, Filtración.

Resumen

LOS ANÁLISIS de laboratorio se utilizan a nivel mundial para determinar la calidad de la caña y los productos de su procesamiento. La polarimetría es el análisis básico de sacarosa en el laboratorio para determinar calidad de caña y desempeño fabril. Las mediciones de pol requieren un paso de clarificación que es usualmente efectuado con subacetato de plomo. Se ha desarrollado un método basado en filtración y que no hace uso del subacetato. Este método ha sido caracterizado para determinar su adaptabilidad en análisis de caña con fines de pago y para productos de la fábrica (jugo diluido, bagazo, cachaza y mieles) para control de proceso. Los resultados de pol en caña son en promedio un 0.08% mas bajos con el método de filtración que con el método estándar de clarificación. Los resultados para control de fábrica muestran que la sacarosa aparente entrando al molino disminuye en 0.08 lo que resulta en un decrecimiento de las pérdidas indeterminadas. Para concluir, la polarización por filtración es adecuada para pago de caña y control fabril y es usada actualmente en la Isla Reunión para esos propósitos.