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Impacts of sugarcane deterioration and its implications in the manufacturing in Brazil

Impacto da deterioração da cana-de-açúcar e suas implicações na fabricação no Brasil

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Abstract
Food safety is a current challenge, as it aims to offer food free of agents that can endanger the health of consumers, for so it should be traceable in manufacturing and in the food chain, quality control of sugary products. The bacterium *Leuconostoc mesenteroides* produces dextran, and has been responsible for considerable losses, affecting the quality of the final product, this research was prepared on industrial scale to quantify the reduction of theatrically recovered sugars Theoretical Recoverable Sugar (TRS) in the process with different dextran concentrations in the raw material, which affects the different phases of production of sugar and ethanol. Because of the complexity of the factors affecting the formation of dextran, it must be analyzed from the point of view of the entire food chain and enable its rapid traceability from production of raw materials to the production of sugar, through industrialization to final distribution to the consumer. The main objective of this paper was to show the need of care indicators and microbiological control in analytical laboratory, which is reduce losses during the process until the final product. It was adapted and tested a rapid method of analysts called S.P.R.I (rapid test for determination of dextran), a test for turbidity in broth from sugarcane. The processing of the deteriorated sugarcane caused losses that reach 37% in industrial output. The losses of TRS are divided between the farmer and mill owner, since the sugarcane entering the mill is assessed and paid by TRS, and the contamination reduces production, making the process slower than the normal.
Keyword: dextran, TRS (Theoretical Recoverable Sugar), total recoverable sugar in the industry, microbiological deterioration, sugarcane juice, SPRI (rapid dextran screening test) and turbidity dextran.

Resumo
A segurança alimentar é um desafio atual e visa oferecer alimento livres de agentes contaminantes que possam pôr em perigo à saúde dos consumidores, os quais devem ser rastreáveis na fabricação e na cadeia alimentar, por meio de sistema de controle de qualidade de produtos açucarados. A bactéria *Leuconostoc mesenteroides* produz dextrana, e tem sido responsável por perdas consideráveis, afetando a qualidade do produto final. Esta pesquisa foi preparada em escala industrial para quantificar a redução dos açúcares recuperados no processo com diferentes concentrações de dextrana na matéria-prima, o que afeta diretamente nas diferentes fases de produção de açúcar e etanol. Devido à complexidade dos fatores que afeta a formação de dextrana, essa deve ser analisado ao longo e monitorada ao longo da cadeia alimentar e possibilitar sua rastreabilidade rápida desde a produção de matérias-primas até a produção de açúcar, passando pela industrialização, até a distribuição final ao consumidor. O principal objetivo do trabalho foi demonstrar a necessidade de indicadores analíticos e de controle microbiológico em laboratório, os quais ajudam a reduzir as perdas durante o processamento até obtenção do produto final. Foi adaptado e testado um método rápido de análise chamado S.P.R. I (teste rápido para determinação de dextrana), um teste de turbidez em caldo de cana-de-açúcar, entre outros. O processamento da cana deteriorada pode causou perdas até 37% na recuperação industrial do açúcar (ATR). Tais perdas indústrias são divididas entre o agricultor e o proprietário da usina, uma vez que a cana que entra na usina é avaliada e paga pelo açúcar teoricamente recuperável (ATR), e a contaminação reduz a produção, tornando o processo mais lento que o normal.
Palavra chave: dextrana, ATR (Açúcar teórico recuperável), açúcares totais recuperáveis na indústria, deterioração microbiológica.

INTRODUCTION

The main responsibility for losses in the value of commercialized sugarcane are the deterioration occurring after the cutting until processing (Clarke et al., 1980; Silva et al., 1994), which contaminant value in raw sugar should not exceed 100 mg/kg in the international refineries market (Eggleston & Monge, 2005). Sugar presenting amount of the contaminant above that, according Silva et al. (2013) when used by the food industry, cause many problems such as filter plugging and tubing, syrup viscosity changes, candies deformation, formation of turbidity alcohol deposits.

The microbiological spoilage of raw materials is the main factor for the formation of organic acids and dextrans by the action of the dextransucrase enzyme (Cuddihy & Day, 1999), degrades sucrose into a fructose molecule and a glucose molecule, which is polymerized in dextran (Clarke & Godshall, 1988).

Spencer & Meade (1945) says that dextran is considered the most common and problematic effect of microorganism contamination in the production of sugar, identified as coming from *Leuconostoc mesenteroides* (Oliveira et al., 2002), which in high concentrations reduces the recovery capacity and quality of sugar (Eggleston et al., 2008).

It was found that the deterioration not only reduce the weight of cane after harvest and cause further loss of sucrose in the industry, the dextran reduces the sucrose yield at the mill by avoiding the sucrose crystallization (Irvine, 2004).

Dextran formation may occur before or even during the cutting of the cane, as well as in industrial processing (Alvarez & Cardentey, 1988). Among the factors that influence the dextran formation in sugarcane, may be mentioned the harvesting system in the field - manual and mechanical, climatic conditions after harvest, quality and intensity of burning, storage, integrity and storage, length of the stem or oarlock (mechanical harvesting), time between burning, cutting, transporting and processing (Clarke et al., 1980; Wang et al., 1986).

From the industrial point of view, the processing of deteriorated sugarcane can cause damages that reach, according to the literature, up to 37% in real yield (Wang et al., 1986). There are several phases of the industry that can favor the development of dextran, such as storage, cane washing and fermentation of the broth (Clarke et al., 1980; Wang et al., 1986; Legendre et al., 1999; Eggleston et al., 2008). The influence of dextran is apparent in the production of sugars from the dissolved solids and polysaccharides. Due to their nature and high solubility, they are difficult to remove from processing (Godshall et al., 1996).

Alvarez & Cardentey (1988) reported that the formation of dextran can occur before or even during the sugarcane harvest, but also in commercial processing. Critical parameters that contribute to the deterioration of the cane and the formation of dextran were defined for the control of contamination by microorganisms producing dextran, such as the variety of sugarcane, the type and quality of cut, temperature, humidity, climate, quality and time of loading of storage (Clarke et al., 1980, Wang et al., 1986; Silva et al., 1994; Godshall et al., 1996).

The effects of dextran can make the filtration slower than normal, increasing the viscosity and total solids content (Simpson & Davis, 1998) and decrease or inhibit crystallization (Godshall et al., 1996) and centrifugation, becoming occluded in the sucrose crystal, increasing molasses production, reducing the filterability of raw sugar and prevent the refiner bleaching process (Zhou et al., 2008).

In South Africa dextran and gums have a negative correlation with filterability by a factor of 0.50 and 0.60 respectively, and was observed a turbidity increase (Simpson, 1999). Delgado &Cesar (1977) say that there is negative correlation between the levels of waxes and gums, which appear grouped as polysaccharides. According to De La Rosa (1998) is recommended to include polysaccharides analysis in sugarcane processing units routine analysis, the quantification of dextran is essential for a better quality control. This result enables the rapid traceability of sugar contamination, which requires fast and secure information from laboratory tests, that is, ensure food security to final consumers inserted in the production chain. However, the losses of TRS in manufacturing are harder to quantify, influenced by the concentration of dextran in broths and products.

The objective of this study was to show the need of care indicators and microbiological control in analytical laboratory, which is reduce losses during the process until the final product. It was adapted and tested a rapid method of analysis called S.P.R.I (rapid test for determination of dextran), a test for turbidity in broth from sugarcane.

MATERIAL AND METHODS

This study was conducted at a plant in Piracicaba, State of Sao Paulo - Brazil, and the points analyzed were: the cane pre-harvested the cane 72 hours after the cutting, in the sugar cane industry input, the input and output of the mill, treated juice and must.

The adopted method was the rapid dextran screening test (SPRI). This method is a test for determining turbidity in sugarcane juice produced by dextran (the test have duration of 2 minutes). This method is sensible to interferences and cannot be used in dark solutions. The rapid test indicates if the level of dextran in the juice is high or low, so it can be used to determine the quality of the cane, but is not an accurate and precise way to work in large scale. However, this method have the advantage to save time to a quickly analysis, showing in this research, similar results in the preliminary test if compared to the official method of AOAC (Association of Official Analytical Chemists, 1990) and Roberts & Clark, (1990), similar to that reported by Clarke et al. (1987).

Linear regression from the equation of known quantities of absorbance:
Dextran (ppm) x L ^{3} = 4405.1 - 4727.6 2669.2 + x L x L ^{2} - 5.1037 (R^2= 0,989**)
ppm =(Z + 118)/ 0.659. L =absorbance reading. Z = the result of linear regression

Laboratory analysis of dextran

Establishment of standard curve for dextran

Was dissolved 1.00 g of dextran PA with distilled water in a volumetric flask of 1000 ml (this solution needs to have 1000 ppm). This 1000 ppm solution was diluted in flasks of 200ml, so that the solution had concentrations of 25, 50, 100, 200, 500, 750 and 1000 ppm. The standard curve corresponds to the graphical relationship between the absorbance values (A) and the concentration of dextran (Fig. 1). Based on the graphical analysis it was possible to verify the relationship between this variables and calculate a conversion factor of absorbance for this values in concentration.

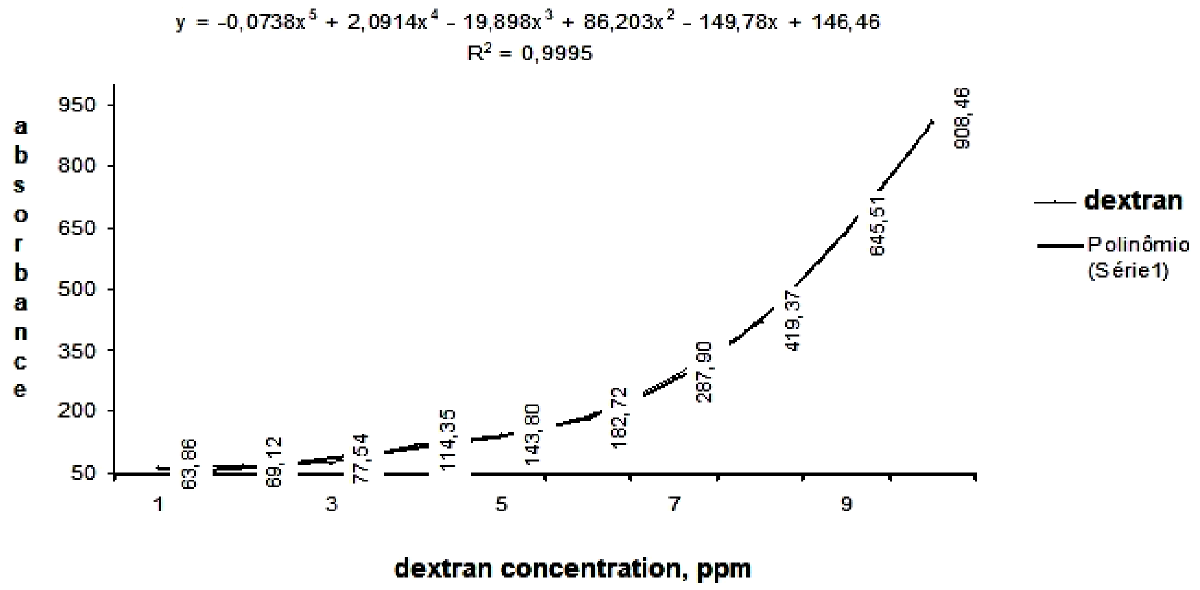

Figure 1. Standard curve between the absorbance values (A - Y-axis) and dextran concentration, ppm (X axis).
Figura 1. Curva de calibração padrão para concentração de dextrana (eixo X, em ppm) e os valores de absorbância (eixo Y).

The collected samples were filtered through cotton, and afterwards in a quantitative paper filter, then, the value of the TSS (brix) was read. With a serynge,10 mL of extract, 2 ml of the solution of TCA (trichloroacetic) 10 % and 0.2 g of Celite, was extracted an coupled in a filtration membrane, directing the extract to 5ml test tubes and after adding 5 ml of absolute ethyl alcohol and after 2 minutes taken with a spectrophotometer at 720 nm abs. The concentrations of dextran in industrial broth, showed the loss in production of sugar manufacturing recovery per unit of raw material processed in triplicate samples, measuring and making the process slower in 9 hours (4 hours until the syrup, 3 hours in the crystallization of sugar, and 2 hours in the vat of alcohol), and less efficient in the recovery industry.

RESULTS AND DISCUSSION

In the juice analyzed the production of dextran (1000 ppm), was above the reference value of contamination of *Leuconostoc mesenteroides* (377ppm), which already promotes a drop in real yield (Wang et al., 1986). Moderate and severe dextran >1000 ppm/°Brix in mixed juice in the manufacturing has long been acknowledged as an interrupter of normal processing operations (Edye et al., 1995).

Some Important information for quality control purposes in the sugar process is the measuring of the total soluble solids content. The percentage by weight of the total solids (sugars, polysaccharides, proteins, minerals) dissolved in juice (Hamerski, 2009), and that the sugar industry is a unit of purification and concentration of sucrose that should not increase the participation of polysaccharides in soluble solids total (TSS) in the process, the ratio dextran ppm/°Brix in mixed juice – TSS.

The bacterium *Leuconostoc mesenteroides* has caused great losses in the sugar industry during the process. This study observed inversion of 2 % between the analysis of pre-harvest and post-harvest cane after 72 hours, attributed to contamination of this bacterium associated with higher levels of dextran, and causing damage, reaching until 20,000 mg / liter dextran / TSS (brix) (Table 2).

With the proliferation of the bacterium *Leuconostoc mesenteroides*, the effects of dextran in the process are considerable (Clarke et al., 1980; Wang et al., 1986; Legendre et al., 1999; Eggleston et al., 2008).

In some Louisiana factories dextran concentrations > 800 ppm/ °Brix (TSS) in mixed juice cause the staff to add dextranase, whilst other factories just add it when manufacturing processes are obviously suffering (Eggleston &Monge, 2005).

It was found that as early as the beginning of decomposition, when analyzed, can be observed a 20% of reduction in TRS: TRS 150.00 / t cane fell to 120.00 TRS / t of cane (Table 1). The Dextran formation develops from deteriorated sugarcane, but there are other deterioration indicators that help in manufacturing control which are: increasing levels of invert sugar, levels of contamination by yeasts and reduction of pH due to increasing levels of organic acids. The international literature highlights the occurrence of dextran concentration above 1000 ppm /TSS in mixed juice relates to the interruptions of normal sugar processing operations in manufacturing (Clarke et al., 1980; Wang et al. 1986; Legendre et al., 1999; Eggleston et al., 2008).

Table 1. Results of technology broth sugarcane processing of agribusiness in Brazil
Tabela 1. Resultados tecnológicos do processamento do açúcar em agroindústria, no Brasil.

	Reading .Abs	*Dextran in PPM*	*TSS (brix)*	*Dextran/ TSS (brix) in mg/l*	*TRS*	*ethanol/ ton*	*Sugar/ Ton*
Pre-harvest	0,003	70,17	20,1	349,13	150,00	88,69	143,50
Sugarcane 72 hours after cutting	3,765	4027,05	20,1	20035,05	120,00	70,95	114,80
Input mill	4,526	4827,47	19,8	24381,14	-	-	-
Output mill	1,215	1344,96	5,2	25864,54	-	-	-
Decantedjuice	4,442	4739,12	17,6	26926,80	114,00	67,40	109,00
Grape sugar cane	4,605	4910,56	16,9	29056,56	105,60	62,08	100,45

When this cane entered the industry and continued proliferation based on industrial losses (cane washing, milling, undetermined loss, filter cake) which was around 12.00 of 70.95 l ethanol / ton of cane, production fell to 62.08 l ethanol / ton of cane in the process, where the pol down and became very viscous and difficult to clarify in the laboratory (Table 2). TRS loss was 44.40 l ethanol/ ton of cane, divided between the farmer and mill owner, since entering the plant is assessed and paid by TRS cane that have been around for 30.00 TRS and the mill owner in the industry had a loss of 14.40 TRS contamination in the process(Table 3).

Table 2. Results of analysis of technology broth in sugarcane pre-harvest, post-harvest with 72 hours in decanted juice and wort (wine) and the processing of raw materials.
Tabela 2. Resultados da análise tecnológica dos caldos em pré-colheita de cana-de-açúcar, pós-colheita com 72 horas após queima/corte, no caldo decantado e no processamento das matérias-primas.

	Pré-harvest	**Sugar cane 72 hours after cutting**	**Decanted juice**	**Grape sugar cane**
RBW (residual bagasse weight)	149,87	239,70		
Fiber	12,87	20,05		
TSS (brix)	20,1	20,1	17,6	16,9
Read saccharimeter	74,72	68,10	64,04	59,15
In	17,98	16,39	15,57	14,42
Purity	89,47	81,54	88,45	85,33
RS (reducing sugar)	0,48	0,62	0,80	1,04
TRS (total reducing sugar)	19,41	17,87	17,19	16,22
TRS (Total recoverable sugar)	150,01	120,03	114,01	105,60

The loss of TRS is divided between the farmer and mill owner, since when entering the mill the sugar cane is analyzed (Table 2 and 3) and paid per TRS (Table 4) and during manufacturing the mill owner has the process contamination which reduces production and makes the process long and slow. The total loss was around 32% compared to the final product.

Table 3. Results of loss of TRS and products from sugar cane juice in the pre-harvest CPSC (Cane Payment by Sucrose Content) after decanting wine and processing of raw materials 72 hours after cutting in agribusiness unit of Piracicaba Region, São Paulo State (Brazil).

Tabela 3. Resultados das perdas de ATR e de produtos a partir de caldos de cana na pré-colheita, SPCTS, após decantação e no mosto em processamento de matéria prima após 72hs de corte em unidade agroindustrial da região de Piracicaba – SP (Brasil).

	TRS	L alchol hydrated/ TC	Kg sugar VHP / TC
Pre-harvest	150	88,69	143,5
Cana 72 hours after cutting	120	70,95	114,8
Decantedjuice	114	67,4	109
Grape sugar cane	106	62,08	100,45

The Council of Producers of Sugarcane, Sugar and Alcohol of the Estado de S. Paulo, Brazil (CONSECANA-SP) is an association made up of industry representatives and alcohol and sugar planters of cane sugar, responsible for system payment of the raw material for the content of sucrose, with technical criteria for assessing the quality of cane delivered by growers to industries and to determine the price to be paid to the farmer, is based on the known total recoverable sugar (TRS).Applying the values of TRS of treatments in pay system (Concelho dos Produtores de Cana-de-Açúcar, Açúcar e Álcool do Estado de São Paulo, 2006), we use the factor x TRS (0.2792), the producer (supplier of cane) lost 8.38 U.S. dollars / ton of cane (20.0%) and lost U$ 12.4 ofmill / ton of cane (29.6%) slower process because it was more viscous broth made the process slow (Table 4).

Table 4. Results of loss of TRS and the agribusiness unit revenue from sugarcane juice in the pre-harvest, harvest, after decanting wine (wort) and processing of raw materials 72hours after cutting in Piracicaba Region – São Paulo States (Brazil).

Tabela 4. Resultados de perdas de ATR e de receita da unidade agroindustrial a partir de caldos de cana na pré-colheita, colheita, após decantado e no mosto em processamento de matéria prima após 72hs de corte, na região de Piracicaba – SP (Brasil).

	TRS	FACTOR* (US$/kg TRS)	PRICE/ TON
Pre-harvest	150,00	0,2792	$ 41.88
Sugar cane after 72h contaminated cutting	120,00	0,2792	$ 33.50
Decanted juice	114,00	0,2792	$ 31.83
Grape sugar cane	105,60	0,2792	$ 29,48

*R$ 0,5026/ kg TRS (Conselho dos Produtores de Cana-de-açúcar, Açúcar e Álcool do Estado de São Paulo, jan/2012), conversion rate: U$$ 1.00 = R$ 1.80, converter of dollar = US$ 0,2792 / kg TRS.

Especially in agribusiness unit in San Paulo State of Brazil, as is noted in Table 2 shows a comparison of the production of dextran in sugar cane juice obtained harvest of 2005 / 6 in the tests. It was found highest in the study of dextran in the juice (4910.56 and 29056.56 ppm% TSS (brix)) and, consequently, lower industrial efficiency (90%) –compared to other harvests. Studies conducted by Solomon et al. (2007; 2008) have also reported higher levels of reducing sugars in juice on storage of the harvested cane.

There were high levels of dextran in industrial broth, showing the significant losses in recovery of sugar production in the plant per unit of raw material processed, making the process slower 9 hours (4 hours until the syrup, 3 hours in the crystallization of sugar, and 2 hours in the vat of alcohol), and less efficient in the industry.

With the growing concern to produce and offer the consumer safe food, which is an obligation of the producer of sugar products, the removal of agents that can endanger the health of consumers requires the adequacy of its processes and agribusiness systems aiming at no chemical, physical and biological contamination throughout the food chain, from the production of sugarcane, through manufacturing, to final distribution to the consumer (Marmentini, 2010; Silva et al., 2013). The food safety assurance is the key to maintaining the competitiveness and survival of companies in the domestic and international markets. In the sugar cane plants we have invested in quality control systems, especially programs focusing on quality and food safety, by international certification, such as Good Manufacturing Practices (GMP) or Good Practices Manufacturing (GPM) and Food Safety System Certification 22000 (FSSC22000) is a complete certification based on ISO 22000, the international food safety system, combined with the technical specifications and additional requirements for Global Food Safety Initiative (GFSI) which attest to the quality and food safety in the production of sugar (Silva et al., 2013.). The procedures should be detailed for each certification process, be it the Good Manufacturing Practices or FSSC 22000, there should be systems to provide documentary evidence with laboratory results that show the correct procedures are being followed consistently in each step of the process of manufacturing, whereas the rapid and safe laboratory analysis results dextran along the process is required.

CONCLUSION

The determination of dextran by SPRI method (rapid method of analysis of dextran) adapted and tested in the quality control system of agribusiness unit obtained reliable and replicable results for process monitoring. The current payment system for the quality of cane adopted by CONSECANA - SP has no sensitivity to detect the deterioration of sugar cane and underestimates the losses in industrial sugars, which can be corrected by including the parameter "dextran" to improve the accuracy of the system.

Since the planting of the raw material to finished product is necessary to monitored and control the microbiological influence. Such contamination control must be: in the field during cutting, transportation, and processing is fundamental to reduce the impact on the industrial process. There is direct correlation between time of burning; infection rate and production of dextran and inverse correlation with industry efficiency.

The solution to minimize the damage of dextran in the sugarcane industry is going through a more integrated agriculture and industry (quality system control). It is important in trying to evaluate these problems the industry, making aseptic with specific products such as sodium hypochlorite 2 to 15% or calcium hypochlorite (13.8 g/100g) and hot water, so that the drop in industry yield and efficiency are minimized.

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