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Evolution of colorants in sugarbeet juices during decolorization using styrenic resins

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ABSTRACT

Molecular size distribution of coloring impurities in sugar beet juices was studied in order to get a better understanding of the evolution of colorants during ion exchange decolorization processes using styrenic resins as well as to provide useful information about the influence of operating decolorization conditions and regenerant consumptions on the removal of harmful colorants. A study of resin life was also performed. Size exclusion chromatography (SEC) of sugar beet thin juices confirmed the presence of colorants with molecular masses above 100 kDa, 20 kDa and 2 kDa. The global color reduction percentages achieved in the decolorization stage were about 75–80%. The colorants with a molecular mass of 20 kDa were completely removed whereas components above 100 kDa and 2 kDa presented lower removal efficiencies, showing lower affinity for the styrenic resin. Colored impurities are likely to be related to melanoidins, Maillard reaction products. Low regenerant consumptions, about 57 L of solution per m^3 of treated juice, removed adsorbed colorants from the styrenic resin without reducing its decolorization capacity considerably.

1. Introduction

Many factors affect the quality and quantity of beet sugar. These factors are related to the formation of non-sugars, mainly colored compounds. These components are formed through beet processing as a result of pH changes, thermal and autocatalytic effects. These impurities are of high molecular masses, polymeric and with tendency to occlude within the sugar crystal (Bento and Sá, 1998). The nature of beet coloring matter is quite different to cane colorants (Godshall et al., 2002). The mechanisms concerning color formation in beet sugar processing are very complicated because of the many parameters involved. The main mechanisms related to color formation during purification stage are Maillard reaction and alkaline degradation of invert sugars. Maillard reaction products, melanoidins, are formed by the reaction of monosaccharides and carbonyl compounds with amino acids. Melanoidins are recognized as being acidic and polymeric compounds, with a highly complicated structure (Cämmerer and Kroh, 1995; Cämmerer et al., 2002; Yaylayan and Kaminsky, 1998). The formation of melanoidins proceeds much faster at high temperature and basic pH conditions. In concentrated juices, the Maillard reaction also proceeds faster. Alkaline degradation products of hexoses (HADP) may be responsible for up to 80% of color in sugar beet juices (Heitz, 1995). The production of colored HADP takes place at the common pH of a beet sugar factory (8–11). The formation of degradation products takes place mainly in the purification step where temperature increases up to 85 °C and pH rises up to strong basic values (11–12). The nature and structure of colored HADP have not been elucidated but they are probably due to the extensive aldolisation of intermediate di-carbonyl compounds in alkaline solutions (De Bruijn, 1986).

To meet standards of whiteness, it is necessary to undertake efforts to reduce color levels in the end product. In addition to preventive industrial actions, a decolorization stage becomes necessary. Most of resin applications for decolorization have been made in cane sugar industry (Bento, 1992, 1997; Godshall, 1999). Ion exchange technology has also considerable potential to decolorize beet sugar juices, removing colorants by adsorption as well as by ion exchange (Broughton et al., 1991; García Agudo et al., 2002). At usually process pH conditions, most of these colorants exhibit an anionic nature thereby anion styrenic resins are efficient decolorizing materials (Bento and Sá, 1998; Guimaraes et al., 1996; Gula and Paillat, 2005). Styrenic matrices increase the affinity of colorants, showing higher decolorization efficiencies than acrylics but the regeneration stage is more complicated (Bento, 1997). The extent of decolorization depends on colorant properties: molecular size, ionic charge and hydrophobicity. However, colorants in sugar solutions are usually managed as a single substance. The global color measurement by spectrophotometric analysis at 420 nm wavelength does not make possible to distinguish the different characters of colorants. Therefore, it is necessary to advance in the knowledge of beet colorants through the decolorization processes for a sound factory scale design.

This paper is concerned with the removal of colored components from beet sugar solutions using a commercial polystyrenic

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resin. Analysis by size exclusion chromatography coupled with diode array detection was chosen to explore the characteristics of colorants through the decolorization process, providing a better understanding about the nature and molecular size distribution of these impurities in juices and regeneration effluents. The affinity of colorants in beet sugar streams towards a strong styrenic resin was analyzed together with the influence of the regenerant consumptions on resin life. This information is of great importance for the design of reliable decolorization processes.

2. Materials and methods

2.1. Adsorbent

Based on previous laboratory studies, a commercial strong anion styrenic resin Lewatit 6368 Sulphate (Bayer) was selected as adsorbent. Prior to being used, the resin was regenerated with sodium chloride and washed with distilled water.

2.2. Adsorbate

Sugar beet solutions were taken from a Northern Sugar factory in the campaign 2006/2007. Thin juice (15–18% dry matter) was prepared by dilution of thick juice containing 70% dry matter. Table 1 summarizes the average characteristics of thin juice solutions.

2.3. Experimental set up

Experiments were carried out in duplicate in jacketed columns operating in parallel. Each column held 100 mL of resin (1 Bed Volume). The experimental setup is shown in Fig. 1. First, a series of decolorization experiments feeding thin juice were performed at 70 °C in down flow direction varying the flow rate between 7 and 15 bed volumes per hour (BV/h). The cycle length was prolonged up to reduce about 80% of color. Decolorization was followed measuring absorbance at a wavelength of 420 nm, according to ICUMSA methods (ICUMSA, 1994). After decolorization, resins were washed with 13 BV/h of distilled water in up flow mode until the outlet stream had almost no sugar in solution (0% to 1% dry matter). Resin regeneration was achieved with a solution of sodium chloride (20%) and sodium hydroxide (0.7%). Regenerant was fed through the resin in down flow at 60 °C. Regenerant volume was varied between 2 and 3.5 BV. Finally, the resin was washed with distilled water at 13 BV/h in up flow mode until a value of dry matter content in the effluent lower than 5%. Washings were performed at room temperature. After washing, the regener-

Table 1
Characteristics of thin juice

Color (IU)	Dry matter (%)	pH	Purity (%)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	Citrate (mg/L)	Lactate (mg/L)	PCA (mg/L)
2910±100	16.7±1.0	9.1±0.4	92.9±2.0	425±15	617±25	71±4	60±3	2180±100	1130±50

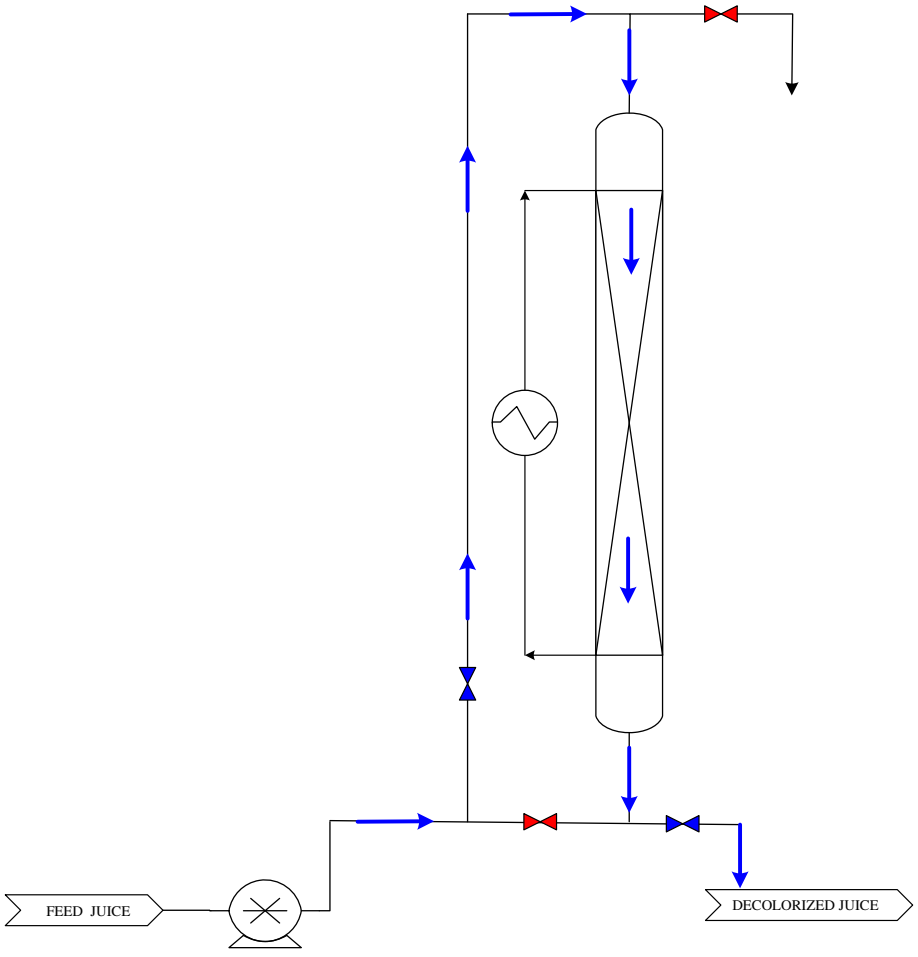

Fig. 1. Set up diagram.