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Impact of pulsed electric field and preheating on the lime purification of raw sugar beet expressed juices

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ABSTRACT

This work discusses the effects of pulsed electric field (PEF) and preheating on the lime purification of raw sugar beet expressed juices. The PEF pre-treatment was applied to sugar beet cossettes before their pressing at 20 °C with the PEF strength and duration of respectively $E = 600$ V/cm and $t_{PEF} = 10$ ms. Alternatively, cossettes were preheated at 80 °C for 10 min before pressing to produce the thermal juice.

A lime-carbonation process was applied for the purification of raw expressed juices. The influences of lime quantity (varied from 0 to 15 kg/m^3) on the filterability and the quality of juices were investigated. It was shown that the filtration kinetics of cold PEF juice is faster than that of thermal juice leading to lower values of filtration coefficient F_k and specific filter cake resistance α. Analysis showed that thin juices obtained after purification of PEF juices presents better qualitative characteristics than those obtained from thermal expressed juices. For instance, at the optimal lime quantity (10 kg/m^3), the purified PEF juice was less coloured (540 vs. 1360 IU), less turbid and had less proteins and colloids leading to a higher juice purity (0.961 vs. 0.945) comparatively to the purified thermal juice.

Keywords: Sugar beet; Pulsed electric field; Preheating; Pressing; Lime purification; Juice quality

1. Introduction

In conventional sugar beet processing, countercurrent aqueous extraction at 70–75 °C, for about of 1 h, is widely used. Aqueous extraction leads to the dilution of intracellular juice which should be then concentrated with high energy consumption. Prolonged heating results in the denaturation of cell tissue and facilitates the co-extraction of proteins, pectins and colourants, which are undesirable juice impurities (Asadi, 2007; Mathlouthi, 2000; Van Der Poel and Schwartz, 1998). Juice purification is an essential step to remove impurities, and minimize sucrose loss and colour formation (Decloux, 2002, 2003; Van Der Poel and Schwartz, 1998). Better juice purification leads to a higher crystallization yield and better sugar quality (Asadi, 2007; Mathlouthi, 2000; Van Der Poel and Schwartz, 1998). In sugar beet factories, a multistage liming-carbonation is used for juice purification (Asadi, 2007; Decloux, 2003). Hydrated lime is added to the juice to react with the impurities (proteins, colloids, colourants, etc.) forming insoluble calcium organic compounds that are removed by two stages filtration process. Excess lime is removed by two carbonation steps using CO_2. Industrially, the quantity of used lime depends on the quality of the raw juice and it varies from 12 to 15 kg/m^3 (Asadi, 2007). The efficiency of the purification operation is characterized by the filterability of the limed juice after the first carbonation and the quality (purity,

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Nomenclature

Abs	absorbance
Cs	weight fraction of cake-forming solids (kg/m^3)
E	electric field strength (V/cm)
F_k	filtration coefficient (s/cm^2)
J_{CO2}	CO_2 flow rate (L/h)
P	pressure (Pa)
R	purification yield
Rm	membrane resistance (m^{-1})
S	filtration surface area (m^2)
s	cake compressibility coefficient
t	time (s)
t_{PEF}	PEF duration time (ms)
$t_{preheating}$	preheating time (min)
$t_{pressing}$	pressing time (min)
T	temperature (°C)
V	filtrate volume (m^3)
v	filtrate volume per filter surface area (m)
[CaO]	total lime quantity used for purification (kg/m^3)

Greek symbol

α	specific cake resistance (m/kg)
β	optical rotation of filtrate (°)
μ	juice viscosity (Pa s)

Abbreviations

ICUMSA	International Commission for Uniform Methods of Sugar Analysis
PEF	pulsed electric field

turbidity, colouration, non-sugars compounds concentration) of the thin juice obtained after purification (Asadi, 2007; Decloux, 2003; Huberlant, 1984).

Recently, Loginova et al. (2011, 2012) studied aqueous diffusion (30 °C) of pulsed electric field (PEF) pre-treated sugar beet cossettes. It was shown that cold diffusion permits obtaining a juice with higher purity and less colouration than the conventional industrial method of sugar beet juice extraction (e.g., aqueous diffusion of untreated tissue at 70 °C). Moreover, Loginova et al. (2012) showed that the quantity of CaO required for efficient juice purification may be decreased from 15 kg/m^3 (for the juice extracted at 70 °C without PEF treatment) to about 8 kg/m^3 (for the juice obtained by PEF-assisted diffusion at 30 °C).

Alternatively, pressing was proposed as a promising method to produce the juice from sugar beet cossettes with no water addition and to obtain a pulp with higher dry matter allowing substantial energy savings for sugar processing (Van Der Poel and Schwartz, 1998).

To induce cell rupture and enhance the expression yield, pressing of sugar beet cossettes should be combined with a pretreatment. Different pretreatments have been tested in sugar beet industry for better pressing of cossettes including mechanical (high pressure), thermal (heating), chemical (liming), and electrical (pulsed electric field, ohmic heating) (Alain et al., 2001; Arnold et al., 2010; Bliesener et al., 1991; Bouzrara and Vorobiev, 2000; Eshtiaghi and Knorr, 1999, 2002; Jemai and Vorobiev, 2006; Lemaire and Petry, 1983; Mhemdi et al., 2012; Praporscic et al., 2005; Van Der Poel and Schwartz, 1998).

For the thermal pre-treatment, sugar beet cossettes are first preheated at high temperature (70–80 °C) and then subjected to pressing (Lemaire and Petry, 1983; Tierny, 2009). The rapid preheating of cossettes induces cells damage and facilitates the release of cellular juice from the interior of cells but it is energy costly (Mhemdi et al., 2013). Alternatively, a short electrical (PEF) pre-treatment can be applied to induce cell membrane permeabilization and enhance the juice extraction from sugar beet cossettes (El Belghiti and Vorobiev, 2004; Maskooki and Eshtiaghi, 2012; Vidal and Vorobiev, 2011; Vorobiev and Lebovka, 2010). PEF-treatment requires a rather low power consumption, typically lying within 1–15 kJ/kg and it defines the industrial attractiveness of this technology. For sugar beet, many studies showed the efficiency of this technology and the experiments pass now on the industrial scale (Vorobiev and Lebovka, 2010; Vidal, 2014). Industrial tests showed that the implementation of PEF technology in sugar beet industry enables important energy savings which are greater than the implementation costs (Vidal, 2014).

Recently, Mhemdi et al. (2014) compared the impacts of thermal and (or) electrical pre-treatments of sugar beet cossettes on the pressing yield, the energy consumption and the qualitative characteristics of juice. Sugar beet cossettes were first pretreated by PEF and (or) short preheating to different temperatures (20–80 °C). It was shown that the pressing yield obtained from PEF pretreated cossettes ($E = 600$ V/cm, $t_{PEF} = 10$ ms, $T = 20$ °C) was equivalent to that obtained from cossettes preheated to 80 °C and untreated electrically. The energy consumption of cold PEF treatment (≈2–3 Wh/kg) was very attractive as compared to preheating (≈138–194 Wh/kg). Moreover, the raw juice expressed from PEF treated cossettes at 20 °C had higher purity and less colouration than juice expressed at 80 °C. It was concluded that PEF treatment may be very useful for implementing the alternative sugar beet transformation by pressing. However, the impacts of this new extraction process on the subsequent purification and crystallization steps is still unknown and should be now explored to facilitate the implementing of the PEF technology in sugar beet factories.

The aim of this work is to compare, on the laboratory scale, the impact of cold electrical (pulsed electric field), and thermal (preheating of cossettes) pre-treatments on the lime purification process of raw expressed juices. The qualitative characteristics of raw and purified juices are determined. The effects of the lime quantity and the filtration pressure on the filterability and the quality of filtrates are investigated. The optimal operating conditions for the purification of expressed juices are determined.

2. Materials and methods

2.1. *Raw material*

Freshly harvested sugar beets (*Beta vulgaris* L.) regularly taken from a local sugar factory (TEREOS, Chevrières, France) were used in all experiments. The moisture content measured by drying 20 g of fresh tissue at 105 °C to constant weight was about 76–78%. The sugar content in beet (wt sugar/wt fresh beets) measured by means of a polarimeter POLAX 2L (ATAGO Co., LTD, Japan) was 17–18%.

2.2. *Juices preparation*

Fig. 1 presents the two processes which were used in this work to produce cold PEF and thermal expressed juices. Sugar beet roots were first sliced into grated particles termed