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# Quality and filtration characteristics of sugar beet juice obtained by "cold" extraction assisted by pulsed electric field

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ABSTRACT

Detailed comparison of various properties (concentration of soluble solids, purity, nature of impurities, coloration and filterability) of sugar beet juices obtained by pulsed electric field (PEF) assisted "cold" extraction ($T$ = 30 and 50 °C) and classical "hot" extraction ($T$ = 70 °C) was done. It was shown that application of PEF-assisted "cold" extraction results in lower concentration of colloidal impurities (especially, pectins), lower coloration and better filterability of juice. Concentration of various colorants and their intermediates decreased significantly with decreasing of the extraction temperature from 70 °C to 30 °C. Filtrate obtained by dynamic filtration of juice extracted with PEF treatment had a high purity (95.3 ± 0.4%) and low coloration ($1.2\times10^3$ IU). Obtained data suggest that PEF-assisted "cold" extraction is a promising method for preparation of sugar beet juices with high purity.



## 1. Introduction

Conventional technology of sugar production from sugar beet roots consists of the next subsequent stages: thermal denaturation of the sliced beet roots followed by diffusion in hot water at 70–75 °C, purification of extracted juice by lime, concentration of purified juice and crystallization (Asadi, 2007; McGinnis, 1982; Silin, 1967; van der Poel et al., 1998). The thermal treatment of sugar beet tissue leads to breakage of cell membranes and improves transport of sucrose through the tissue into the extracting liquid. However, thermal extraction at 70–75 °C results in a number of undesirable processes. Not only cell membranes get destroyed, but cell walls also change their inner chemical structure through reactions of hydrolytic degradation (molecular chain breakages, detachment of polysaccharide fragments) (van der Poel et al., 1998). Besides sucrose, other cell components (for instance, pectins, amino compounds, saponins, etc.) also penetrate the cell wall and pass freely into the extracted juice. Such pectins and other impurities deteriorate the quality of juice and complicate tremendously the subsequent process of juice purification (van der Poel et al., 1998).

Moreover, high temperature promotes further chemical reactions between extracted components. Thermal treatment promotes formation of colorants (like melanoidins), which results in a brownish yellow near black color of the extracted juice (van der Poel et al., 1998; Coca et al., 2004; Mersad et al., 2003).

Thermally induced degradation of beet tissue, extraction of non-sucrose cell components and formation of colorants decrease the juice purity and require its further purification. Purification of the juice by classical method of carbonation requires addition of a substantial quantity of lime (van der Poel et al., 1998). Consequently, it requires a number of additional unit operations (preliming, liming, 1st and 2nd carbonation, several filtrations, and sulfitation). The cross-flow microfiltration of juice extracted by hot water was proposed in order to avoid or to decrease the use of lime and multiple purification steps (Kishihara et al., 1989; Vern et al., 1995; Cartier et al., 1997; Decloux et al., 2000; Hinkova et al., 2002; Ghosh and Balakrishnan, 2003; Hakimzadeh et al., 2006; Jegatheesan et al., 2009). However, low purity of the thermally extracted juice decreases filtrate quality and results in quick membrane fouling (Hatziantoniou and Howell, 2002; Saha et al., 2006).

During the last decade, appreciable results were obtained in the development of non-thermal methods of cell damage based on the pulsed electric field (PEF) treatment. Under the effect of PEF (applied from several microseconds to several milliseconds), the membrane becomes permeable for small molecules or even some macromolecules (Weaver and Chizmadzhev, 1996).

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**Nomenclature**

| | |
|---|---|
| $A$ | absorbance (dimensionless) |
| $c_c$ | concentration of solids in filter cake (dimensionless) |
| $c_s$ | concentration of colloidal solids in juice (dimensionless) |
| $J$ | filtrate flux ($l\ m^{-2}\ h^{-1}$) |
| $J_s$ | quasi-stationary filtrate flux ($l\ m^{-2}\ h^{-1}$) |
| $P$ | purity (%) |
| $\Delta p$ | filtration pressure (bar) |
| $R_m$ | membrane resistance ($m^{-1}$) |
| $S$ | membrnae surface area ($m^2$) |
| $T$ | temperature of extraction (°C) |
| $t$ | filtration time (s) |
| $V$ | volume of filtrate (ml) |
| $V_o$ | initial volume of juice used for filtration (ml) |

*Greek letters*

| | |
|---|---|
| $\alpha$ | specific filtration resistance (m/kg) |
| $\lambda$ | wavelength (nm) |
| $\mu$ | viscosity (Pa s) |
| $\rho_l$ | density ($kg/m^3$) |

*Abbreviations*

| | |
|---|---|
| AR | absorbance ratio |
| MWCO | molecular weight cut-off |
| PEF | pulsed electric field |
| VRR | volume reduction ratio |

Moderate electric fields (0.5–5 kV/cm) are generally not destructive to the cell walls of plant materials (Fincan and Dejmek, 2002; Ammar et al., 2010; Grimi et al., 2010). Plant tissue with damaged cell membranes, but with a conserved cell wall network, can be selectively permeable and capable of better retaining some of cell compounds.

Recently, the PEF-assisted pressing and aqueous extraction from sugar beets were intensively studied (Bouzrara and Vorobiev, 2000, 2001, 2003; El-Belghiti and Vorobiev, 2004, 2005a; El-Belghiti et al., 2005b; Eshtiaghi and Knorr, 2002; Jemai and Vorobiev, 2003, 2006; Lebovka et al., 2007a,b; López et al., 2009; Praporscic et al., 2005; Sack et al., 2010; Vorobiev et al., 2005). The principal possibility of sugar extraction by cold or moderately heated water was shown (Jemai and Vorobiev, 2003). Lebovka et al. (2007a) compared the diffusion kinetics and diffusion coefficients $D_{eff}$ for untreated and PEF-treated sugar beet tissues at different temperatures. The values of $D_{eff}$ were nearly the same for sugar extraction from untreated tissue at 70 °C ("hot" extraction) and from PEF-pretreated tissue at 40 °C ("cold" extraction). Also, it was reported that purity of juice prepared in a lab scale by "cold" extraction of PEF-treated tissue was higher than the purity of juice prepared by "hot" extraction (Lebovka et al., 2007a).

Most of the published results on kinetics of sugar diffusion from PEF-treated sugar beets are limited by the small scale laboratory studies using a single tissue sample or a small quantity of sliced material in a batch extraction chamber. Recently, the study of PEF-assisted extraction from sugar beets was carried out in a pilot semi-continuous countercurrent extractor (with capacity 6 kg of cossettes per hour) (Loginova et al., 2011). Cossettes were prepared from sugar beets using industrial knives. PEF treatment of the cossettes was done with electric field strength $E$ varied between 100 and 600 V/cm, and the total time of PEF treatment was 50 ms. The effect of the extraction temperature ($T$ = 30–70 °C) on the extraction kinetics was investigated. The principal possibility of "cold" (at 30 °C) and moderate thermal (50 °C) extraction of sucrose from sugar beet cossettes treated by PEF was confirmed (Loginova et al., 2011).

It was reported that the purity of the juice obtained by "cold" and moderate thermal extraction was not lower than the purity of the juice obtained by conventional "hot" extraction at 70 °C (Loginova et al., 2011). Obviously, more detailed comparison of the quality of sugar beet juices prepared by means of PEF-assisted "cold" extraction and classical "hot" extraction is required.

The aim of this work is a more detailed characterization of the sugar beet juices obtained by PEF assisted "cold" (30 °C), mild thermal (50 °C) and classical "hot" (70 °C) extraction (concentration of soluble solids, purity, nature of some impurities, coloration and filterability).

## 2. Materials and methods

### 2.1. Raw materials

The field-grown sugar beet roots (*Beta vulgaris*) were provided by sugar plant TEREOS (Chevrières, France). All the extraction experiments were done in December 2009. Quality of the sugar beet roots was controlled during all this period by measuring sucrose content. Sugar beets were delivered two times per week and were used immediately or after 1–3 days of storing in a cold room at 4 °C.

### 2.2. Preparation of extracted juice

#### 2.2.1. Slicing of sugar beet roots

The sugar beet roots were cut into cossettes using a pilot slicing machine (British Sugar, England). The industrial knife blocks were provided by MAGUIN (France). The cossettes were 4–9 cm long and nearly 3 mm width. The total mass of cossettes used for PEF treatment was 500 g.

#### 2.2.2. Extraction experiments

Extraction was carried out in a specially developed pilot countercurrent extractor with a double envelope to maintain the desired temperature of extraction. It consists of 14 rectangular communicating sections separated by a double wall allowing the water flow from section to section. The flow rate of extracting water was 7.2 L/h. The perforated plastic baskets filled with 500 g of cossettes were moved manually between the neighboring sections each 5 min in the direction opposite to water flow. Construction and detailed principle of this extractor were reported elsewhere (Loginova et al., 2011).

Extraction experiments were carried out at the temperatures of 30 and 50 °C (with PEF-pretreated cossettes) and at 70 °C (with untreated cossettes). The temperatures of $T$ = 30 °C and $T$ = 50 °C corresponded to the PEF assisted "cold" and mild thermal extraction, respectively. The temperature of $T$ = 70 °C corresponded to the classical "hot" extraction. Note that optimum temperatures for the diffusion operation are about 70–73 °C (Asadi, 2007; van der Poel et al., 1998) and extraction above 75 °C is undesirable because of the inherently labile nature of beet and possible pectin degradations at elevated temperatures (van der Poel et al., 1998).

The total time of extraction was 70 min (=14 sections × 5 min). The draft (juice to cossettes ratio) was equal to 120%, which is typical for industrial process of sucrose extraction.

The portions of extracted juice were regularly sampled for measuring the content of soluble solids (Brix) and sucrose. After the extraction, juices were pre-filtered through the plastic mesh,