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# Combined pressing-diffusion technology for sugar beets pretreated by pulsed electric field

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ABSTRACT

This work presents a new efficient process for sugar beet sucrose extraction by tuning experimental conditions. Sliced beets were first treated by PEF at $E = 600\ \mathrm{V\ cm^{-1}}$ and $t_{PEF} = 10$ ms. Electroporated slices were then pressed and the obtained press cake was finally introduced in a pilot diffuser (10 kg/h) to extract the residual sucrose.

Results showed that cold PEF treatment followed by rapid pressing permitted expression 50% of undiluted juice (Brix ≈ 21.2%). Sucrose extraction from pressed slices with reduced draft (80–100%) allowed substantial water and energy savings for the extraction step. Experiments revealed that slices were better exhausted by the new extraction process which permitted to reduce the sucrose loss in pulp from 1.2% to 0.8%. Moreover, the obtained juice was more concentrated in sucrose, less colored (7000 vs. 10,000 IU) and purer (92.8% vs. 91.8%) than that conventionally extracted by diffusion.



## 1. Introduction

Sugar beet (*Beta vulgaris* L.) is a plant whose root contains a high concentration of sucrose. It is grown commercially for sugar production in many countries over the world. According to the UN Food and Agriculture Organization (http://faostat.fao.org/site/339/default.aspx), 271.6 million metric tonnes of sugar beets were harvested in 2011.

Sugar beet process is multistaged (slicing, extraction, purification, evaporation, crystallization). The extraction is a key step influencing all the transformation process. Conventionally, sugar beet slices are first rapidly (10 min) preheated at high temperature (85–90 °C) to denature cells membranes. Sucrose extraction is then carried by countercurrent diffusion in hot water (70–75 °C) for about of 60–90 min. The thermal aqueous extraction of sugar is very energy costly (Van-Der-Poel and Schwartz, 1998). Moreover, it promotes the co-extraction of undesirable compounds (such as proteins, pectins and colloids) and increases the juice coloration (Asadi, 2007; Loginova et al., 2011a; Mhemdi et al., 2014). The presence of juice impurities complicates enormously the subsequent purification, evaporation and crystallization steps and may adversely impact the sugar quality (Asadi, 2007; Mathlouthi, 2000; Van-Der-Poel and Schwartz, 1998).

In order to reduce the energy consumption and to improve the juice quality, many researchers have interested on the alternative sugar beet extraction technologies (Arnold et al., 2010; Bliesener et al., 1991; Lemaire and Petry, 1983; Van-Der-Poel and Schwartz, 1998). For instance, several recent studies have showed the potential of the application of pulsed electric field (PEF) to induce permeabilization of cell membranes and enhance the solid/liquid extraction from sugar beet tissue (El-Belghiti and Vorobiev, 2004; Eshtiaghi and Knorr, 2002; Knorr and Angersbach, 1998; Knorr et al., 2001; Loginova et al., 2011a; Lopez et al., 2009; Maskooki and Eshtiaghi, 2012). The low power consumption (≈2–3 kW h/kg) required for PEF-treatment is very attractive for its industrial implementing (Mhemdi et al., 2014).

The extraction of juice from electrically pre-treated tissues can be then carried by conventional diffusion process at moderate (50–60 °C) or even at low temperature (20–30 °C) (El-Belghiti et al., 2005; El-Belghiti and Vorobiev, 2004; Loginova et al., 2011a). Decreasing the extraction temperature reduces the energy input and limits the liberation of undesirable compounds in the juice (Loginova et al., 2011b). However, the industrial implementation of the cold diffusion may be limited by the higher sucrose loss in pulp and the risks of microbial contamination in the diffuser at low temperature and 60–70 min duration (Loginova et al., 2011a; Van-Der-Poel and Schwartz, 1998).

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Alternatively, Bouzrara and Vorobiev (2001, 2003), Eshtiaghi and Knorr (2002), Jemai and Vorobiev (2006) and Mhemdi et al. (2014) have revealed that cold PEF assisted pressing presents an economical alternative method to extract undiluted juice which can be concentrated with lower energy consumption. As it is expressed at the ambient temperature during short time, the obtained juice is more pure and less colored than thermal juice (Mhemdi et al., 2014). However, it was found that several pressing-washing steps may be required to attain the sucrose losses in the pulp equivalent to that of conventional process (Bouzrara and Vorobiev, 2003; Eshtiaghi and Knorr, 2002; Jemai and Vorobiev, 2006). Consequently, the industrial implementing of this process needs an important investment for restructuring the extraction plant.

In this work we investigate an original process for sugar beet transformation which combines cold PEF treatment, pressing and diffusion (Fig. 1a). Sugar beet slices were first pretreated by pulsed electric field at ambient temperature. Electroporated slices were then rapidly compressed (4 min) in order to extract 50% of intercellular juice. Pressed slices were finally introduced in a continuous pilot diffuser (10 kg/h) to extract the residual sucrose. The impacts of this new process on the diffusion parameters (draft, temperature, residence time), the qualitative characteristics of juices (sucrose concentration, purity and coloration) and pulp (sucrose content, dry matter) were studied. Results were compared to that of conventional diffusion process industrially practiced in sugar beet factories (Fig. 1b).

## 2. Materials and methods

### 2.1. Process description

Fig. 1 presents the alternative sugar beet extraction process investigated in this work (Fig. 1a) vs. conventional hot water extraction technology (Fig. 1b). Alternative process consists in pulsed electric field (PEF) treatment followed by two consecutive extraction steps: pressing of electroporated slices and diffusion of pressed slices. The obtained juices were mixed and used for analysis and the exhausted pulp was pressed (Fig. 1a). Conventional extraction process is carried by diffusion in hot water (Fig. 1b).

### 2.2. Slices preparation

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 determined by drying 20 g of fresh tissue at 105 °C to constant weight was about 78%. The sugar content measured by means of a digital refractometer PR-32a (ATAGO Co., LTD, Japan) was 18%. Slicing was performed using a pilot slicing machine equipped with industrial knives (Maguin, France). The Silin number, which is equal to the length of 100 g of slices, was about 12 m.

### 2.3. Pulsed electric field treatment

Slices in a quantity of 1 kg were placed between two electrodes in the PEF treatment chamber and 1.5 kg of previously expressed sugar beet juice was added in order to remove the air between cossettes to and to improve the electrical contact. Cold (ambient temperature = 10 °C) PEF treatment was carried out using a PEF generator 5 kV–1 KA (Hazemeyer, France) delivering near rectangular monopolar pulses. The electric field strength and the PEF treatment duration were set to $E = 600\ \mathrm{V\ cm^{-1}}$ and $t_{PEF} = 10$ ms based on the optimization made by Mhemdi et al. (2014). The pulse duration $t_i$ and the pulse repetition time $\Delta t$ were set to respectively 100 μs and 10 ms. Pulses protocol ($t_i$, $\Delta t$) and all the output data (voltage $U$, current $I$) were collected using a data logger and software developed by Service Electronique UTC (Fig. 2). The energy input of PEF treatment was equal to 2.76 ± 0.16 W h/kg. After PEF treatment, the slices were separated from the added juice and then pressed.

### 2.4. Pressing of electroporated slices

Pressing experiments were conducted using a laboratory press chamber equipped with an elastic diaphragm (Fig. 2). The initial quantity of slices used for each pressing experiment was 1 kg. The pressure was set to 5 bars. The extracted juice was collected and weighed continuously by an electronic balance. In order to follow the pressing kinetics, an acquisition computer system was used to measure and to record the mass of juice recovered every 5 s. The juice yield was defined as the mass of juice recovered from 100 g of sugar beet cossettes. It was expressed in % (g of juice/100 g of sugar beet cossettes). The pressing kinetics are presented in Fig. 3. Results show that the application of a short (10 ms) PEF treatment ($E = 600$ V/cm) at 20 °C enhances the expression kinetic and increases significantly the juice yield. For instance, the juice yield from untreated slices did not exceed 25%, while it attained 50% after pressing of PEF pretreated slices during about 4 min (Fig. 3). Therefore, pressing ($P = 5$ bars, $t_{pressing} = 4$ min and $T = 20$ °C) of electroplated slices leads to extract 50% of expressed

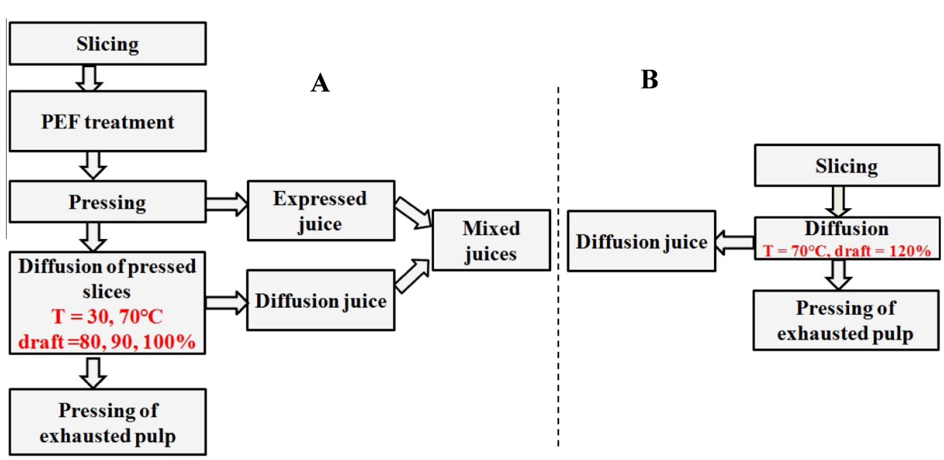


**Fig. 1.** (A) Schema of the new extraction process and (B) control experiment schema (conventional process).