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Purification of juices obtained with innovative pulsed electric field and alkaline pressing of sugar beet tissue

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ABSTRACT

This work investigates the purification of juices obtained with innovative pulsed electric field treatment and alkaline pressing of sugar beet tissue. Sugar beets were first sliced into cossettes and treated by pulsed electric field (PEF) at ambient temperature with a strength of $E = 600$ V/cm and an effective duration of $t_{PEF} = 10$ ms to electroporate cell membranes. Electroporated cossettes were then subjected to a double pressing with intermediate preliming using 0.6 g CaO/100 g fresh cossettes to produce mixed prelimed juice (MPJ). Alternatively, electroporated cossettes were pressed without preliming to produce non-limed raw juice (RJ). MPJ and RJ were then purified by liming-carbonation and alternatively by stirred ultrafiltration. Preliming of electroporated cossettes improves filtration and sedimentation characteristics of juices. Moreover, the overall lime quantity required for the liming-carbonation was lower for MPJ (6 kg/m^3) than for RJ (10 kg/m^3). Purified MPJ had a high purity (95.4%), low coloration (570 IU), and low content of colloids (0.95 g/L) and proteins (104 mg/L). Alternatively, non-stirred and stirred ultrafiltration of centrifuged MPJ and RJ were studied using PES membranes with MWCO 10–100 kDa. Specific resistance of deposits and ultrafiltration kinetics were evaluated, as well as the qualitative characteristics of obtained permeates and retentates. Ultrafiltration permits decreasing even more the overall quantity of lime used for MPJ purification. However, the quality of MPJ and RJ permeates was lower than the quality of the same juices purified by liming-carbonation. Results of this work show important advantages of the new sugar beet technology combining pulsed electric field treatment and alkaline pressing.

1. Introduction

Sugar beet juice extraction is usually carried out by countercurrent aqueous diffusion at 70–75 °C for 60–90 min [1]. In spite of the effective thermal cell disintegration facilitating sucrose release, it requires significant energy consumption and promotes formation of colorants by chemical and enzymatic reactions [2]. Furthermore, different undesirable beet components, especially pectins are co-extracted, which reduces raw juice purity complicating subsequent purification and crystallization procedures [2,3]. Alternatively, pressing technology was investigated for juice extraction from sugar beet cossettes [2]. However, very high pressure (up to 100 bar) was needed for the mechanical destruction of sugar beet tissue and effective juice expression [2,4]. Industrial implementation of pressing technology was never realized due to the high sucrose loss in the pulp and engineering difficulties with development of high-pressure presses [2]. Different pretreatments were then investigated to improve pressing of sugar beet cossettes, including heating [5], liming [6–12], and pulsed electric field (PEF) [13–17]. It was shown that these pretreatments induce effective cell rupture and tissue softening thus enhancing pressing yield. The advantages of PEF induced non-thermal electroporation of cell membranes are low energy consumption (2–3 kW h/ton of sugar beets) and extraction selectivity [18,19]. Juice expressed from electroporated sugar beet cossettes is more concentrated, and has higher purity and lower coloration than juice obtained by conventional hot water diffusion [16,20]. Purification of juices obtained from electroporated sugar beet cossettes was earlier studied, including methods of liming-carbonation and ultrafiltration [21–27]. The lower content of colloids in raw juice expressed from PEF treated tissue resulted in better filterability of PEF juice comparing to that obtained by hot water diffusion. However, membrane fouling remained rather high even in stirred mode of PEF juice ultrafiltration [21]. Recently, Almohammed et al. [28] proposed an original extraction process named "*alkaline pressing of electroporated sugar beet tissue*". This process consists in electroporation of cossettes by PEF, following by liming of cossettes and cold pressing. Liming of cossettes accelerates juice expression from

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Nomenclature

A	light absorbance
CaO	juice alkalinity, kg/m^3
C_c	concentration of colloids, g/L
C_j	juice coloration, IU
C_p	concentration of proteins, mg/L
C_s	weight fraction of cake-forming solids, g/g
E	electric field strength, V/cm
F_k	filtration coefficient, s/m^2
J	filtrate flux, m^3/m^2 s
J_{CO2}	CO_2 flow rate, L/h
l	length of UV quartz cuvette, mm
n	number of pulses
N	rotation speed, rpm
P_j	juice purity, %
ΔP	filtration pressure, Pa
r	radial distance of the centrifugal cell bottom from the axis of rotation, m
R_m	membrane resistance, m^{-1}
S	filtration surface area, m^2
S_c	sucrose content, %
t	filtration time, s
t_i	pulse duration, µs
t_{PEF}	PEF duration time, ms
Δt	pulse repetition time, ms
V	filtrate volume, m^3
V_0	initial supernatant volume, m^3
v	filtrate volume per filter surface area, m
v_s	sedimentation velocity, µm/s

Greek symbols

α	specific cake resistance, m/kg
β	optical rotation of filtrate, °
λ	wavelength, nm
μ	filtate viscosity, Pa s
ρ	filtrate density, kg/m^3

Abbreviations

ICUMSA	international commission for uniform methods of sugar analysis
IU	international unit
MPJ	mixed prelimed juice
MWCO	molecular weight cut-off
PEF	pulsed electric field
PES	polyethersulfone
RJ	raw juice (non-limed juice)
VRF	volume reduction factor

electroporated sugar beet tissue and increases the final juice yield on 12%. The maximal juice yield was about 90% demonstrating high effectiveness of this combined expression process. Juice obtained from limed electroporated cossettes had a high quality, but its purification was not yet studied. The aim of this work is investigation how to purify the juice obtained by *alkaline pressing of electroporated sugar beet tissue*. For this purpose, two purification methods were studied: (*i*) liming-carbonation, and (*ii*) dead-end ultrafiltration. These methods were analyzed and compared in terms of juice filterability and qualitative characteristics.

2. Materials and methods

2.1. Chemicals and reagents

Lime powder, hydrochloric acid and absolute ethanol were obtained from VWR (Strasbourg, France). Aluminum sulfate, sodium hydroxide and Bradford reagent were purchased from Sigma-Aldrich (Saint-Quentin Fallavier, France).

2.2. Raw materials

The field-grown sugar beet roots (*Beta vulgaris* L.) were regularly provided by a local sugar beet plant of Tereos (Chevrières, France). They were used immediately or during three days of storage in a lab-scale cooling room at 4 °C. The quality of stored sugar beets was controlled by measuring of moisture and sucrose contents. The moisture content of sugar beets varied in diapason from 74.6 to 76.4% and the sucrose content varied from 17.6 to 18%.

2.3. Juice preparation

The experimental procedure used for juice recovery is presented in Fig. 1. Cleaned sugar beet roots were first sliced into cossettes (1.8 mm × 4.5 mm × 60 mm) using a slicing machine equipped with grater disk CL 50 (robot-coupe, France). Cossettes in the quantity of 1 kg were then placed in a PEF treatment chamber equipped with two stainless steel electrodes and connected to

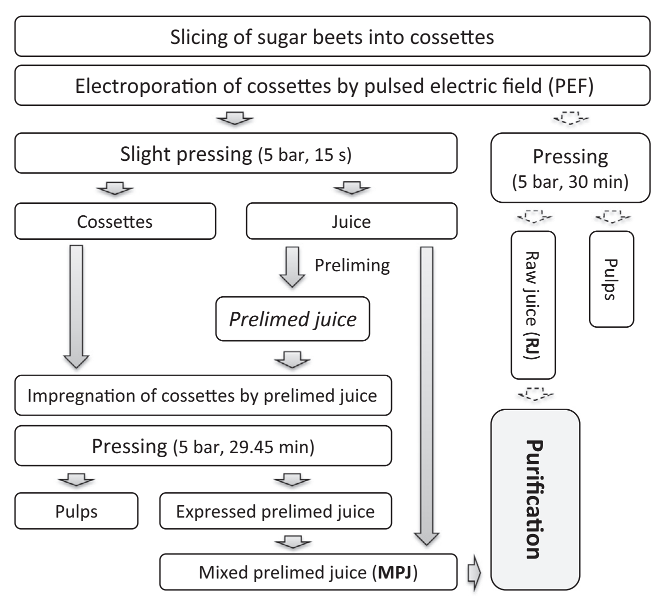

Fig. 1. Flow diagram of sugar beet expression process to produce MPJ and RJ.

a pulse generator of 5 kV–1 kA (Hazemeyer, France). The strength of pulsed electric field was fixed at E = 600 V/cm and the effective duration of electroporation was t_{PEF} = 10 ms. The pulse duration t_i, the pulse repetition time Δt and the number of pulses n were set to 100 µs, 100 ms and 100 pulses, respectively based on the PEF treatment parameters optimized by Mhemdi et al. [16]. Electroporated cossettes were first slightly pressed using a lab-scale press equipped with an elastic diaphragm (Sofralab, France) to express 200 g of juice and to produce slightly pressed cossettes. This operation lasted about 15 s under pressure increased from 0 to 5 bar. Then, one part of this juice (150 g) mixed with 6 g of dry lime at 10 °C (prelimed juice) was soaked by slightly pressed cossettes for the lime impregnation. Soaked cossettes were then pressed at 5 bar at the same lab-scale press to attain a total pressing time of