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Pectin recovery from sugar beet pulp enhanced by high-voltage electrical discharges

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ABSTRACT

This work discusses the valorization of sugar beet pulp (SBP) for pectin extraction using high-voltage electrical discharges (HVED) as a pre-treatment technology. The parameters of HVED (pulse amplitude U and number of pulses n) were varied. Better pre-treatment conditions were $U = 40$ kV and $n = 100$ giving a total energy consumption $Q_e = 76.2$ kJ/kg. After the HVED pre-treatment, a subsequent acidified water extraction of pectin was carried out varying the pH and temperature. Obtained results show the pectin yield increase from 42.6% for untreated SBP to 53.4% for HVED treated SBP at better extraction conditions ($T = 90\,^\circ$C, pH = 2) and duration of one hour. Fourier transform infrared (FTIR) spectroscopy and gas chromatography mass spectrometry (GC–MS) techniques were used to characterize the pectin extracts. They showed similar functional groups and chemical composition between the standard of sugar beet pectin and the extracted molecules from untreated and HVED pretreated SBP.

1. Introduction

Sugar beet pulp (SBP) is a residue recovered after sucrose extraction from sugar beet slices. It is compressed, dried and usually used for cattle feed due to its high content in fibers (Asadi, 2007). Several alternative ways were recently proposed for the valorization of sugar beet pulp based on a biorefinery concept (Günan Yücel and Aksu, 2015; Hamley-Bennett et al., 2016; Vučurović and Razmovski, 2012; Ward et al., 2015). Yapo et al. (2007) reported the promising potential of sugar beet pulp as great pectin source owing to its high pectin content (25–30% dry weight basis) and its availability in large quantities (van der Poel et al., 1998). Pectic substances are the natural polysaccharides present in the cell wall structure. They are composed by galacturonic acid, rhamnose, arabinose and galactose (Drusch, 2007; Gromer et al., 2009). Pectin is usually extracted from apple pomace and citrus peels (Kurita et al., 2008; Min et al., 2011; Pourbafrani et al., 2010). It is used in many food applications as gelling agent for jams and jellies, as thickener, and as emulsifier in dairy products. It is also used in medical industry to reduce heart disease and in cosmetic products due to its gelling properties (Pagan et al., 2001). Traditionally, pectin is extracted from raw materials by hot acidified water (at temperatures 70–90 °C and pH 1–3) during 1–6 h (Iglesias and Lozano, 2004; Kalapathy and Proctor, 2001). Pectin can also be extracted using galacturonase enzymes (Bonnin et al., 2002; Donaghy and McKay, 1994). Different alternative treatments like extrusion (Ralet et al., 1994; Shin et al., 2005), microwaves (Fishman et al., 2000; Kratchanova et al., 2004), ultrasound (Bagherian et al., 2011; Minjares-Fuentes et al., 2016), instant controlled pressure drop (Rezzoug et al., 2007), and subcritical water (Tanaka et al., 2012) can increase importantly the extraction yield of pectin from treated tissue. In the last decade, electrohydraulic high-voltage electrical discharges (HVED) were proposed as a non-thermal and low-energy consuming treatment for the recovery of valuable compounds from different biomass feedstocks, like grape by-products (Boussetta et al., 2012, 2011, 2009; Brianceau et al., 2016; Liu et al., 2011; Rajha

Abbreviations: DM, dry matter; FTIR, fourier transform infra-red; GC–MS, gas chromatography–mass spectrometry; HVED, high-voltage electrical discharges; SBP, sugar beet pulp.

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Nomenclature

B	Normalized pectin content
C_f	Final pectin content, g pectin/100 g DM
C_i	Initial pectin content, g pectin/100 g DM
C_t	Instant pectin content, g pectin/100 g DM
D	Diffusion coefficient, m^2/s
dt	Time of one pulse, s
E_p	Energy of one pulse, kJ
I	Current strength of electric field, A
m	Product mass, kg
n	Number of pulses
Q_e	Energy input of HVED pre-treatment, kJ/kg
r	Radius of the spherical particles, m
t	Pectin extraction time, min
t_{HVED}	Total time of HVED pre-treatment, min
U	Voltage of electric field, V
Y_{pectin}	Yield of extracted pectin, %

Greek symbols

α	Liquid–solid ratio
λ	Wavelength, nm

et al., 2014), olive kernels (Roselló-Soto et al., 2014), rapeseeds (Barba et al., 2015) and sesame cake (Sarkis et al., 2015). Electrohydraulic discharges can have different characteristics depending on the geometry of electrodes, distance between the electrodes, liquid conductivity, etc. Pulsed corona discharges are characterized by streamers formation. Streamers formed at needle electrode propagate toward the ground electrode. However, in pulsed corona discharges, the streamers do not reach the ground electrode (Locke et al., 2006). Several phenomena occur during this process including formation of bubbles near the needle electrode, UV radiation, radicals and reactive species formation. If streamer reaches the ground electrode, then the arc discharge is produced. Several supplementary effects may be produced by the pulsed arc including intense bubble cavitation, high-pressure shockwaves, and high liquid turbulence (Barba et al., 2016). HVED can cause particle fragmentation and cell tissue damage enhancing the extraction of cell compounds. The aim of this work is to develop an original pectin recovery method from sugar beet pulp by combined HVED and acidified water extraction.

2. Materials and methods

2.1. Chemicals and reagents

Hydrochloric acid, sulfuric acid, sodium hydroxide, and ethanol were purchased from VWR (Strasbourg, France). Galacturonic acid, glucose, arabinose, mannose, rhamnose, xylose, galactose, carbazole, silver carbonate, acetic anhydride, pyridine, BSTFA, methanolic hydrochloric acid and potassium bromide were obtained from Sigma–Aldrich (Saint-Quentin Fallavier, France). Dichloromethane was obtained from Fisher Scientific (Illkirch, France). Sugar beet pectin standard was obtained from Megazyme (Wicklow, Ireland).

2.2. Valorization process of sugar beet pulp

Fig. 1 presents the proposed valorization process of sugar beet pulp (SBP) for pectin recovery. The investigated process consisted of applying HVED pre-treatment to the grinded product

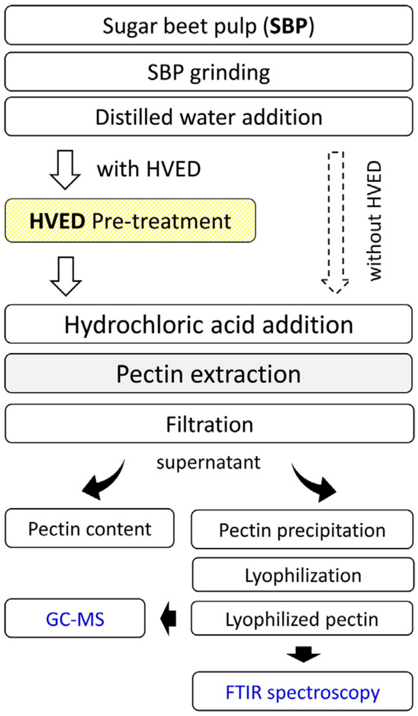

Fig. 1 – Valorization diagram of sugar beet pulp (SBP) for pectin recovery.

in distilled water, followed by acidic extraction of pectin. The used procedure is described below.

2.2.1. *Raw material preparation*

Sugar beet pulp (SBP) were kindly provided by APM Déshy Company (Pleurs, France) in the form of pellets and stored at room temperature until use. The moisture content of SBP was about 8%. Ten grams of SBP was grinded using a coffee grinder (Home, China) for 30 s to obtain fine powder. The energy of the grinding process was 540 kJ/kg (specified power of used grinder is 0.18 kJ/s). The surface weighted mean of the power particles was 202.9 μm, estimated using a laboratory Mastersizer 2000 instrument (Malvern instruments, UK).

2.2.2. *HVED pre-treatment*

HVED equipment includes a batch cylindrical chamber connected to a high-voltage pulse generator of 40 kV-10 kA (Tomsk Polytechnic University, Russia). The used pre-treatment chamber of one liter contains a stainless steel cylindrical needle (diameter = 10 mm) and a grounded plate electrode (diameter = 45 mm). The distance between the electrodes was fixed at 5 mm during all extractions. The grinded product (10 g) and distilled water at 20 °C (200 g) were introduced into the pre-treatment chamber. The pulse voltage was fixed at U = 15, 30 and 40 kV. The length of the pulse depends on the nature of the media between the electrodes. In our case, it was approximately 10 μs. The pulses were delivered every 2 s (frequency 0.5 Hz). The number of pulses n was varied from 0 (control sample) to 500 pulses. The temperature of the suspension was controlled every 100 pulses. The heating was less than 2 °C during the whole HVED treatment. The specific energy input Q_e (kJ/kg) of HVED pre-treatment was calculated according to Eq. (1):

$$Q_e = \frac{E_p \times n}{m} \quad (1)$$