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# Processing of sea buckthorn fruits by electro-osmosis under pressure

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ABSTRACT

Recently, the electrotechnologies based on the effect of electric field on some basic processes in the food engineering have gained an increased interest. This paper focuses on experimental study and modeling of juice separation from sea buckthorn fruits by pressing in a DC electric field (electro-osmosis under pressure). Carotenoids, polyphenols, flavonoids, enzymes, and other compounds from the processed fruits are distributed between the pulp and the juice separated at cathode and anode. This distribution was experimentally established using a specially designed setup and characteristic analytical methods. Process dynamics were characterized by experimental curves describing the time evolution of juice yield and temperature of processed material bed. Mathematical models with adjustable parameters fitted based on experimental data were developed in order to scale up the process.



## 1. Introduction

In recent years the interest on sea buckthorn (SB) has strongly increased, especially due to its potential to support the treatment of many human diseases (Bal et al., 2011; Li and Beveridge, 2003; Li and Schroeder, 1996; Patel et al., 2012; Rohi-Boroujeni and Kiani, 2015; Singh et al., 2003, 2006, 2008; Sovová et al., 2010; Suryakumar and Gupta, 2011). Numerous studies on processing of SB fruits and leaves to juice, oil, dried pulp and seeds have been reported in the related literature. These products and their derivatives exhibit a high therapeutic activity acting as antioxidant (Gao et al., 2000; Geetha et al., 2002; Gill et al., 2012; Istrati et al., 2016; Maheshwari et al., 2011; Michel et al., 2012; Rösch et al., 2004), anticancer (Grey et al., 2010; Oppermann et al., 2015; Padmavathi et al., 2005; Zeb, 2006), cardioprotective (Malik et al., 2011; Suomela et al., 2006), hepatoprotective (Geetha et al., 2008; Maheshwari et al., 2011), radioprotective (Goel et al., 2002; Sureshbabu et al., 2008) or antimicrobial (Gill et al., 2012; Gupta et al., 2011; Michel et al., 2012) agents. All these effects are related to the complex composition of SB products. Table 1 and Fig. 1 contain data on yield and composition of SB products processed by HOFIGAL S.A. (Romania).

Juice separation is the first step in the processing of SB fruits. Various mechanical devices, *e.g.*, vacuum filters, screw and belt presses, are commonly used for this process (Chauhan et al., 2001; Isobe et al., 1997; Orsat et al., 1996). Separation processes implying ultrasonic, electric or magnetic fields have been employed in a few specialized sectors (Muralidhara, 1990). Electrotechnologies based on DC or pulsed electric field can be very effective for juice extraction and dehydration of food wastes (Bazhal and Vorobiev, 2000; Isobe et al., 1997; Ng et al., 2011; Orsat et al., 1996).

Electro-osmosis is the phenomenon of liquid motion through a porous material/liquid slurry as the effect of a constant voltage (DC) applied across the solid/liquid medium. The liquid flows towards the cathode, whereas negatively-charged particles move towards the anode (Bazhal and Vorobiev, 2000; Isobe et al., 1997; Ng et al., 2011; Orsat et al., 1996; Visigalli et al., 2017; Xue et al., 2017).

Drainage and suction curves for juice separation from fruits by pressing with and without DC electric field are compared in Fig. 2. Juice extraction under pressure is a case of liquid drainage from a porous structure, where the liquid which is not subjected to capillary forces can be released from the system by increasing the pressure until a limit concentration is attained (solid curve 1 in Fig. 2). This limit concentration, $u_{cp}$, represents the juice content in the porous structure corresponding to the capillary forces characterized by a capillary pressure difference $\Delta p_{cp}$. If the extraction

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**Table 1**
Yield and composition of Romanian SB products.

| No. | Product/Compound | Unit | Mean value | Standard deviation |
|---|---|---|---|---|
| 1 | Extractable juice (j) from fruit (f) | $kg_j/kg_f$ | 0.660 | 0.070 |
| 2 | Pulp (p) | $kg_p/kg_f$ | 0.195 | 0.018 |
| 3 | Seeds (s) | $kg_s/kg_f$ | 0.145 | 0.011 |
| 4 | Pulp oil (po) | $kg_{po}/kg_p$ | 0.085 | 0.007 |
| 5 | Seed oil (so) | $kg_{so}/kg_s$ | 0.108 | 0.014 |
| 6 | C vitamin (Cv) in juice | $g_{Cv}/kg_j$ | 11.8 | 0.949 |
| 7 | A vitamin (Av) in juice | $mg_{Av}/kg_j$ | 7.5 | 0.775 |
| 8 | E vitamin (Ev) in seed oil | $g_{Ev}/kg_{so}$ | 1.5 | 0.632 |
| 9 | E vitamin in pulp oil | $g_{Ev}/kg_{po}$ | 3.3 | 0.866 |
| 10 | Soluble solid (ss) in juice | $g_{ss}/kg_j$ | 16.5 | 2.345 |
| 11 | Total carotenoids (ca) in juice | $g_{ca}/kg_j$ | 0.076 | 0.060 |
| 12 | Total carotenoids in pulp oil | $g_{ca}/kg_{po}$ | 7.6 | 1.0 |
| 13 | Total flavonoids (fv) in juice | $g_{fv}/kg_j$ | 3.5 | 2.5 |
| 14 | Total flavonoids in fresh fruit | $g_{fv}/kg_f$ | 2.7 | 1.5 |
| 15 | Total flavonoids in leaves (l) | $g_{fv}/kg_l$ | 9.0 | 1.0 |
| 16 | Proteins (pr) in leaves | $kg_{pr}/kg_l$ | 0.200 | 0.173 |
| 17 | Proteins in seeds | $kg_{pr}/kg_s$ | 0.220 | 0.200 |
| 18 | Proteins in juice | $g_{pr}/kg_j$ | 5.1 | 0.922 |

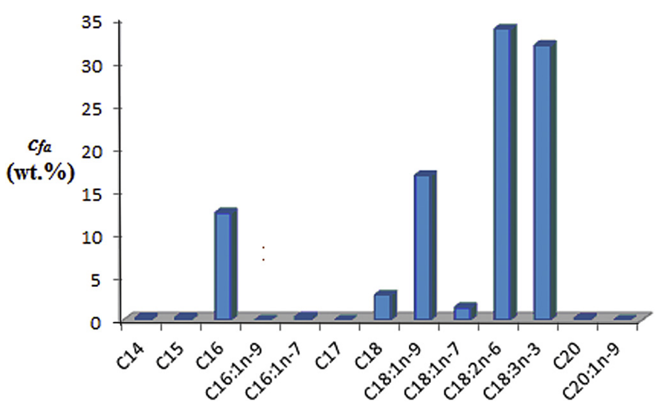


**Fig. 1.** Mean concentration of fatty acids in the oil extracted from Romanian SB seeds: (C14) myristic; (C15) pentadecanoic; (C16) palmitic; (C16:1n-9) *cis*-7 hexadecenoic; (C16:1n-7) palmitoleic; (C17) margaric; (C18) stearic; (C18:1n-9) oleic; (C18:2n-6) linoleic; (C18:3n-3) linolenic; (C20) arachidic; (C20:1n-9) eicosenoic.

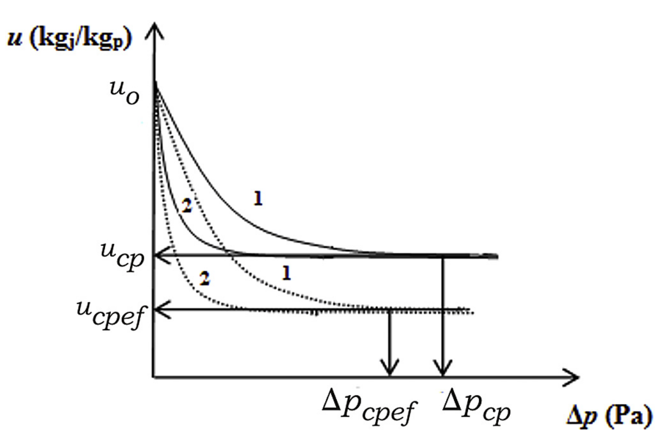


**Fig. 2.** Drainage and suction curves for juice extraction from fruits: (1) drainage curve; (2) suction curve (solid line: separation under pressure; dotted line: separation under pressure and DC electric field).

under pressure occurs in the presence of DC electric field (electro-osmosis under pressure), then the movement of some species from juice towards anode and cathode will diminish the level of liquid tied to the porous structure and the liquid will be removed from the structure until $u_{cpef}$ ($<u_{cp}$) limit concentration will be achieved (dotted curve 1 in Fig. 2). Solid and dotted drainage curves 1 in Fig. 2 reveal an increase in the driving force in the presence of electric field, *i.e.*, $u_0$-$u_{cpef} > u_0$-$u_{cp}$, resulting in enhanced juice yield and separation rate. Suction curves 2 depicted in Fig. 2 are sharper than their corresponding drainage curves 1 as effect of a faster separation by suction.

This paper has aimed at measuring and modeling the mass dynamics of juice separated from SB fruits by pressing and electro-osmosis under pressure. Moreover, experimental data on the distribution of main classes of compounds in the pulp and the juice collected at anode and cathode have been reported.

## 2. Materials and methods

SB fruits grown in ecological conditions were provided by HOFIGAL S.A. (Romania). They were frozen for three days at a temperature of about −20 °C, then thawed at 18 ± 2 °C and milled to a size of 0.5–1 mm. Tests of juice separation by pressing and electro-osmosis under pressure were performed in the experimental setup shown in Fig. 3.

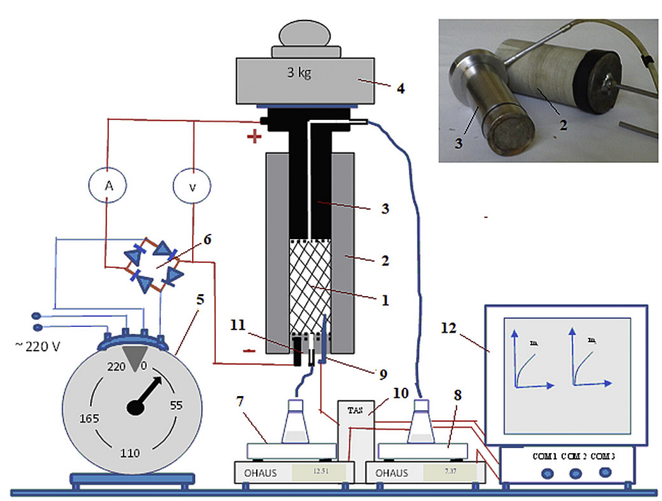


**Fig. 3.** Experimental setup: (1) vegetal material bed; (2) cylindrical teflon case; (3) stainless steel piston; (4) pressing weight; (5) autotransformer; (6) bridge rectifier; (7), (8) balances; (9) thermocouple; (10) temperature acquisition system; (11) cathode contact; (12) computer.