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A comparative study between spiral-filter press and belt press implemented in a cloudy apple juice production process

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ABSTRACT

In this study, advantages and disadvantages of the innovative, low-oxygen spiral-filter press system were studied in comparison with the belt press, commonly applied in small and medium size enterprises for the production of cloudy apple juice. On the basis of equivalent throughput, a higher juice yield could be achieved with spiral-filter press. Also a more turbid juice with a higher content of suspended solids could be produced. The avoidance of enzymatic browning during juice extraction led to an attractive yellowish juice with an elevated phenolic content. Moreover, it was found that juice produced with spiral-filter press demonstrates a higher retention of phenolic compounds during the downstream processing steps and storage. The results demonstrates the advantage of the use of a spiral-filter press in comparison with belt press in the production of a high quality cloudy apple juice rich in phenolic compounds, without the use of oxidation inhibiting additives.

1. Introduction

Cloudy apple juice has an increasing market value in the not from concentrate (NFC) segment due to the fact that it is a convenient food product with a natural fresh appearance, texture, and flavour (Grimi, Mamouni, Lebovka, Vorobiev, & Vaxelaire, 2011). This goes together with an increased consumer awareness of their potential positive health effects, often connected to their phenolic content (Will, Roth, Olk, Ludwig, & Dietrich, 2008). Antioxidative phenolic compounds are related to the protection against cancer, cardiovascular diseases, diabetes, osteoporosis and neurodegenerative diseases (Pandey & Rizvi, 2009).

Considerable proportions of phenolic compounds are lost during conventional production processes of cloudy apple juice (Van der Sluis, Dekker, Skrede, & Jongen, 2002). With the current conventional process technology, losses of 50–90% of the phenolic are most of the time unavoidable (Will et al., 2008). This understanding has let the adjustment of conventional process technology (Renard et al., 2011) or the development of novel production equipment (Sinha, Sidhu, Barta, Wu, & Cano, 2012). Innovations aimed, amongst others, at the avoidance of oxidative degradation of phenolic compounds (Van der Sluis et al., 2002).

Oxidative degradation of phenolic compounds can be suppressed by minimising exposure to air of the mashed fruit and the juice obtained (Markowski, Baron, Mieszczakowska, & Płocharski, 2009). Special modifications of the processing equipment should be made to process the product under an inert atmosphere, which is hard to achieve using conventional juice pressing equipment like decanter, horizontal rotary press, and belt press (Markowski et al., 2009). Furthermore, pressing under inert atmosphere is often not sufficient due to the presence of dissolved oxygen of intercellular origin released during the milling of the fruit. This can also lead in the post-pressing stages and storage to oxidative degradation of phenolic compounds. Dissolved oxygen removal requires an additional degassing of the juice. For this purpose, vacuum-deaeration (dissolved oxygen removal by headspace pressure reduction), gas sparging (displacing the dissolved oxygen by a inert gas), or ascorbic acid addition are often used in juice

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industry, but requires additional processing steps, equipment and/or consumables (Garcia-Torres, Ponagandla, Rouseff, Goodrich-Schneider, & Reyes-De-Corcuera, 2009).

Recently, a novel juice extraction system was introduced which allows (1) performing a solid–liquid separation of the mash (into juice and pomace) under low-oxygen conditions, and (2) partial dissolved oxygen removal based on headspace pressure reduction in one operation: a spiral-filter press (Siewert, Ludwig, & De Paepe, 2013). The aim of this study was to compare the innovative, emerging spiral-filter press technology with the belt press commonly applied in small and medium size enterprises (SME's). With the objective to develop an attractive, yellowish and cloudy apple juice without of any additive, the comparison was based upon juice yield and the juice quality characteristics: turbidity, haze stability, % sediment, colour, total soluble solids, and phenolic composition. Furthermore, the difference in behaviour of the cloudy apple juice obtained with spiral-filter press and belt press in respect of the juice quality characteristics was studied throughout the post-pressing stages applied in cloudy apple juice making: juice buffer tank residence, pasteurisation, and storage.

2. Materials and methods

2.1. Experimental setup and pilot scale machinery

All experiments were performed on the same lot of apple fruit (cv. 'Jonagored', caliber 80/85, 1200 kg, stored under Ultra Low Oxygen conditions during 10 months, firmness 13.7 ± 1.9 kg cm^{-1}), obtained from a local fruit sorting company and stored at normal atmosphere in a cold storage room (4 °C) until processing (minimum 2 days before processing). All experiments were performed on two consecutive days to avoid inter-day differences in fruit quality.

An overview of the experimental set-up is given in Fig. 1. All outlined experiments were conducted on pilot-scale (about 90 kg) and in triplicate, as independent technical replicates. The pursued process scheme consisted of all essential processing equipment applied in SME's for the production of cloudy apple juice: rasp mill, press (belt press, spiral-filter press), JBV, pasteurisation system and storage room.

2.1.1. Rasp mill

A washer/elevator/rasp mill combination (KWEM 1000, Kreuzmayr Maschinenbau, Wallem, Germany) with a maximum throughput of 2400 kg h^{-1} was used for washing and shredding the apples into mash. For each experiment, apples from cold storage were directly emptied into the water bath filled with fresh tap water from where the fruits were elevated (elevator speed scale '3.25' equivalent to 650 kg h^{-1}) by flight conveyor into a fruit mill, rotating at a constant angular speed. The ground fruit was ejected into the feed hopper of the belt press or the buffer tank of the spiral filter press and directly pressed. The throughput of the belt press and spiral-filter press was adjusted to the throughput of the rasp mill (650 kg h^{-1}). Doing so, the residence of the mash in the feed hopper of the belt press and buffer tank of the spiral-filter press was minimised.

2.1.2. Belt press

A single-belt press (KEB 750, Kreuzmayr Maschinenbau, Wallem, Germany), commonly applied in SME's, with a belt working width of 688 mm and a maximum throughput of 1500 kg h^{-1} (mash mass flow rate) was used. The mash was ejected by the rasp mill, dispended by the feed hopper as a thin layer of about 15 mm on the belt, and pressed between the flexible perforated belt and rollers of different size (1 main roller, 6 additional rollers) under atmospheric conditions. The mesh opening of the belt was 500 μm. The time of circulation of the belt was 120 s, corresponding with a throughput of about 650 kg h^{-1}. The applied pressure to the belt was 3×10^5 Pa. The extracted juice was collected via a juice-drip sheet and juice tray positioned under the rollers under atmospheric conditions. At the end of the pressing section, the pomace was scraped from the belt. The belt was continuous cleaned with a brush cleaning system and a water jet cleaning device with a volumetric flow rate of 180 L h^{-1}. The phase of constant belt speed, constant mass flow rate juice and constant total soluble solid (TSS) value of the juice effluent was taken as the steady-state phase of the belt press system.

2.1.3. Spiral-filter press

A one-stage system (VaculIQ 1000, VaculIQ, Hamminkeln, Germany) with a maximum throughput of 1000 kg h^{-1} (mash mass flow rate) was used, of which a diagram is given as supplementary data (Supplementary data 1). The mash ejected by the rasp mill into the conical buffer tank is fed to the extraction cell by means of an eccentric screw pump, further called 'feed pump', with a flow rate of 650 kg h^{-1}. Subsequently, the mash is picked up by a plastic multi flight screw conveyor, further called 'spiral', rotating at 1.8 rad s^{-1}. The spiral had 4 channels with a constant inclination of 38°. Due to the feed pump pressure and the spiral rotation, the mash moves continuously upwards through the juice extraction cell. The rotating spiral is externally enclosed by a filter element with a mesh opening of 100 μm. Around the outside of the filter, an absolute underpressure of 15×10^3 Pa is applied. This underpressure drives juice extraction and the transformation of the mash into pomace with the filter as a separation layer. Clogging of the fine sieve pores is avoided by the silicon lips on spiral which continuously scrapes off the inside of the filter. The raw juice is discharged by a small side channel pump, further called 'vacuum pump', which simultaneously provides the negative pressure in the extraction cell. The pomace leaves the system at the top of the spiral, where an ejection section is located. The processing phase characterised by a constant feed pump pressure, constant underpressure in the extraction cell and constant TSS value of the juice effluent was taken as steady-state phase.

2.1.4. Juice buffer vessel

A prototype of a portable juice buffer vessel (JBV) with a capacity of 30 L (VaculIQ, Hamminkeln, Germany) was employed to collect the raw juice discharged from the spiral filter press or belt press under atmospheric conditions or, if filled with a food-grade H_2CO_3 gas (Messer Gourmet, Zwijndrecht, Belgium), under low-oxygen conditions. Furthermore, the JBV was used to transport the raw juice to the pilot-scale pasteurisation system, which was not physically connected to the press systems. For both belt press and spiral-filter press, the raw juice was sent to the JBV when they had reached their corresponding steady-state phases. That was 250 s and 120 s after start of the belt press and spiral-filter press respectively. Previously, the juice from the press systems was redirected to drain by means of a three-way valve. Three different process schemes were studied, which were conducted as independent experiments (Fig. 1). The raw juice coming from the belt press was only collected in the JBV under atmospheric conditions (case 0, AC). For the raw juice from the spiral-filter press, two cases were evaluated: collected under atmospheric conditions (case 1, AC), and under low oxygen conditions (case 2, LOC). The total filling times of the JBV in combination with the belt press was 265 s, and in combination with the spiral-filter presses 215 s, independent of the applied environment in the JBV (AC or LOC). After filling of the JBV, it was transported and coupled to the pasteurisation system. In all cases, the valve to the pasteurisation system was opened 300 s after start of filling the JBV with raw juice. Hereby, the