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Content of health-beneficial compounds and sensory properties of organic apple juice as affected by processing technology

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ABSTRACT

Quality of cloudy organic apple juice processed by rack-and-frame press (RFP), water press (WP) or belt press (BP) was evaluated in terms of sensory properties and instrumentally measured colour, content of ascorbic acid (AsA), total soluble solids (TSS), titratable acidity (TA), polyphenols and total antioxidant capacity (TAC).

'Cortland', 'Krista', 'Krameri tuviõun' and 'Talvenauding' apples from Estonia were separately processed into juice by RFP, WP and BP. Juice was pasteurized at 85 °C. Pressing methods had a significant effect on juice quality.

RFP-juices had the lowest TAC and content of health-beneficial polyphenols (chlorogenic acid, (−) epicatechin, (+)catechin, procyanidin B2). BP-juices had the highest content of these polyphenols, but had the poorest sensory quality characterized as less sweet, more sour, bitter and astringent compared to other juices. RFP- and WP-juices had no differences in sweetness, sourness, astringency and bitterness, but WP-juices had the highest intensity of fresh aroma and -flavour, yellowness and clearness. Compared to RFP-juices, WP-juices had higher TAC and content of several health beneficial polyphenols, especially quercetin derivatives. Thus, WP is a good alternative to RFP in order to produce apple juice which would have higher antioxidant capacity, better appearance and higher aroma intensity.

1. Introduction

Health benefits have been reported as a main driver for purchasing organic food (Magnusson, Arvola, Koivisto Hursti, Åberg, & Sjöden, 2003). In Estonia, a strong preference for domestic and organic apples has been reported (Moor, Moor, Põldma, & Heinmaa, 2014). Köpke (2005) has argued that a potential advantage of organic agriculture is that higher concentrations of beneficial secondary plant substances in organically compared to conventionally grown crops are produced. The supporting theory for the presence of higher concentrations of certain antioxidants in organically grown crops is that they are produced by the plant as a defence against insects and fungi, which in conventional systems are avoided by the use of synthetic pesticides (Rosen, 2010). Several polyphenols have health-beneficial impacts on humans, for instance chlorogenic acid has a blood pressure lowering effect (Onakpoya, Spencer, Thompson, & Heneghan, 2015); (−)epicatechin has been shown to support metabolic changes in skeletal and cardiac muscles resulting in greater endurance capacity (Nogueira et al., 2011); (+)catechin is said to be one of the most important phenols in apple which affects molecular mechanisms involved in angiogenesis, regulation of cell death and multidrug resistance in cancers (Zanwar, Badole, Shende, Hegde, & Bodhankar, 2014). Procyanidin B2 has shown good results as a natural dietary compound against breast cancer cells, and also has anti-inflammatory effects and cardiovascular benefits (Shilpi et al., 2015).

However, some polyphenols with health-beneficial properties may cause an undesired astringent taste of apple juice. Schobinger and Müller (1975) compared content of sugar, acid and polyphenols of apple juices with sensory properties: juices with total polyphenols more than 775 ppm (775 mg/L) were considered too

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astringent and juices with total polyphenols less than 300 ppm (300 mg/L) too insipid.

In addition to production method, the processing technology also has an impact on consumer expectations and product quality. It has been pointed out that traditionally-made products generally induce a higher expected liking than industrial products (Monteleone & Bertuccioli, 2006). According to the European Fruit Juice Association (AIJN) Liquid Fruit Market Report (2015), the consumption of fruit from concentrate has decreased over last five years in EU, whereas the consumption of non-concentrate juice has increased. Markowski, Baron, Le Quéré, and Plocharski (2015) assessed the effect of processing technology on apple juice quality and concluded that most of the cloudy juices had a significantly higher antioxidant activity than the clear ones.

In several countries, rack-and-frame press (RFP) is traditionally used by small-scale apple farmers for juice production. Due to the slow process and exposure of mashed apples to the air, considerable amounts of ascorbic acid (AsA) and polyphenols are lost due to oxidation. In order to make the processing faster, many juice producers are implementing water presses (WP) or belt presses (BP). Little data is available discussing the advantages and disadvantages of RFP, WP and BP in terms of juice quality.

The aim of the study was to evaluate the quality of cloudy organic apple juice processed by RFP, WP or BP in terms of selected polyphenols with putative health beneficial properties and sensory quality.

2. Experimental

2.1. Reagents and chemicals

The chemicals of analytical or higher grade: chlorogenic acid, (−)epicatechin, (+)catechin hydrate, phloridzin dihydrate, quercetin-3-*O*-galactoside, quercetin-3-*O*-glucoside, quercitrin hydrate and rutin hydrate were purchased from Sigma-Aldrich (Schnelldorf, Germany). Procyanidin B2, formic acid and methanol were purchased from Fluka (Buchs, Switzerland). 1.1-diphenyl-2-picrylhydrazil (DPPH·), 5.5-dimethylpyrrolidine-*N*-oxide (DMPO), dimethyl sulphoxide (DMSO) and K-superoxide Trolox were purchased from Sigma-Aldrich S.r.l., (Milan, Italy).

2.2. Plant material and juice extraction

'Cortland' and 'Krista' apple cultivars were harvested from Polli (58°08′N 25°32′E) and 'Krameri tuviõun' and 'Talvenauding' cultivars from Vasula (58°27′N 26°43′E) certified organic orchards. Both orchards are located in South Estonian temperate climate zone. 350 kg of apples from 20 apple trees were harvested from each cultivar and stored at 2 ± 2 °C until starch degradation occurred. 'Krameri tuviõun' apples were stored for 4 weeks, 'Krista' for 12 weeks, 'Cortland' for 8 weeks and 'Talvenauding' for 10 weeks. Before processing, all apples with visible symptoms of fungal infection were rejected. 100 kg of sound fruits were used for each press from each cultivar in order to make sure that the sample for each press would be representative, since second grade apples from organic orchards have large biological variation. No technical replications were carried out, since a larger number of apples was not available from the same orchards from all cultivars studied. In addition, results from previous studies (data not presented) have shown that if a standard pressing and pasteurization procedure is used with a large number of apples, the differences between technical batches are not significant. Apples were washed, disintegrated with Voran centrifugal mill RM2.2 (Voran Maschinen GmbH, Pichl bei Wels, Austria) and pressed by using RFP, BP and WP. Before pressing with RFP Voran 100P2 (Voran Maschinen GmbH, Pichl bei Wels, Austria), apple mash was placed into cloth partitions, which were separated by wooden racks and placed as layers into the press by hand, which took about 15 min. After that juice was pressed hydraulically, which took another 20 min. During juice processing by BP Voran EBP 500 (Voran Maschinen GmbH, Pichl bei Wels, Austria), disintegrated apple mash dropped directly onto the belt of the press and the whole juice pressing process took about 2 min. WP Lancman VSPX 120 (Gomark d.o.o., Vransko, Slovenia) straining sack was filled with apple mash, which took about 2 min, the rubber bladder in the middle was filled with water and juice was squeezed through the stainless steel membrane, which took about 20 min. Juices were pasteurized at 85 °C for 1 min by tubular system and packed immediately into airtight 1.4-L aluminium foil bags with Bag-in-box filler BBF6 (Gebhardt Anlagentechnik GmbH & Co. KG, Germany). No enzymatic treatment, centrifugation or ascorbic acid addition was used. Juices were cooled down and preserved in a cool room at 6–10 °C up to three months until analyses.

2.3. Chemical analyses

Total soluble solids (TSS) was measured by digital refractometer PAL-1 (ATAGO CO., Ltd., Japan). Titratable acidity (TA) was determined by titration to pH 8.2 with 0.1 mol/L NaOH and expressed as malic acid. For AsA determination 100 mL of pure apple juice was poured into a titration container and titrated with dichlorophenolindophenol using titrator Mettler Toledo DL50 with autosampler Rondolino and electrode DM 140-SC.

The separation and quantitation of polyphenols was performed on the column SHIM-Pack XR-ODSII, on the UHPLC-MS Shimadzu Nexera X2 system with ESI ion source (Shimadzu Scientific Instruments, Kyoto, Japan). Polyphenol standard solutions 1 g/L were prepared into 500 mL/L methanol in water (Raudsepp, Kaldmäe, Kikas, Libek, & Püssa, 2010). Each calibration point was measured in triplicate. Apple juices were diluted as follows: 2 mL apple juice was diluted to 10 mL with solution 500 mL/L methanol in water. The solutions were centrifuged with Eppendorf Centrifuge MiniSpin (Eppendorf AG, Hamburg, Germany) 12,100×*g* for 10 min and the supernatants were transferred into analysis vials.

The column temperature was maintained at 40 °C, the total flow of the mobile phase was 0.2 mL/min and the injection sample size was 1 μL. The mobile phase gradient contained a mixture of two solvents: 10 mL/L formic acid in water (A) and 10 mL/L formic acid in methanol (B). The multistep gradient slightly modified after Lambert et al. (2015) was used to chromatographically separate the polyphenols: for 0.01–2 min 10 mL/L concentration of mobile phase B was maintained, at 2.1 min the concentration of B was increased to 50 mL/L, from 2.1 to 8 min it was raised to 100 mL/L, from 8 to 12 min to 280 mL/L and maintained until the min 18. By the min 22, the concentration of B was raised to 450 mL/L and by 30 min–990 mL/L. The initial concentration of solvent B was reached at 35.1 min and the column was reconditioned with 10 mL/L of solvent B for 5 min.

Total antioxidant capacity (TAC) was measured in three ways. For TAC caused by freely soluble antioxidants (TAC DPPHsol), 15 mL apple juice was extracted with 15 mL of a 1:1 mixture of EtOH and 0.06 M HCl. For TAC caused by deeply extracted antioxidants, (TAC DPPHacet), a 1:1 mixture of EtOH and acetone, acidified to 10 mL/L with HCl 6M was used. For both extracts, 1.1-diphenyl-2-picrylhydrazil (DPPH·) radical quenching was used, following the method proposed by Picchi et al. (2012). All measurements were made using an EPR MiniScope MS200 Magnettech (Berlin, Germany). The experimental settings of the spectrometer were as follows: field set, 3350 G; scan range, 68 G; scan time, 30 s; modulation amplitude, 3000 mG; microwave attenuation, 4 dB; and