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Effect of different drying techniques on physical properties, total polyphenols and antioxidant capacity of blackcurrant pomace powders

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ABSTRACT

The effect of freeze-drying (FD), convective (50 °C–90 °C; CD), microwave vacuum (120W, 240W, 360W, 480W; MVD) and combined (CD-MVD) drying on the physico-chemical properties of blackcurrant pomace powders was examined. A relationship was analysed between moisture content, water activity, solubility, true and bulk density, porosity, colour, total polyphenolic compounds, and antioxidant capacity and drying parameters. The lowest water activity was noted after CD suggesting that CD is more effective in water removal from pomace than MVD or CD-MVD. CD decreased solubility of powders to significantly greater degree than MVD and CD-MVD. Drying processes improved the colour of the blackcurrant pomace powders in comparison to the raw material. Power function between the temperature of the process and the changes in chroma was established, whereas a rational function was found during MVD. Functional relation between the temperature and total polyphenolic content and antioxidant capacity was found.

1. Introduction

Blackcurrant (*Ribes nigrum* L.) is rich in many substances that are beneficial to human health. They include notably polysaccharides, unsaturated fatty acids, vitamins, organic acids, anthocyanins and flavonoids (Cyboran et al., 2014; Liu, Kallio, & Yang, 2014). Due to a unique composition of polyphenolic compounds, including anthocyanins, blackcurrants are one of the most interesting berry fruits. Poland is the leading exporter of both fresh and processed blackcurrant; its exports account for about 80% of global exports of frozen blackcurrants and for 90% of global exports of blackcurrant juice concentrate (FAOSTAT, 2015). Blackberry pressing leaves a by-product - pomace - which is a valuable source of polyphenolic compounds with proved excellent antiradical properties (Kapasakalidis, Rastall, & Gordon, 2006). Pomace is highly perishable as it contains water left over after fruit processing. The dewatering of blackcurrant pomace using selected drying technologies may help to improve its durability and preserve its valuable biologically active components. Taking into account that the application of natural components in foodstuffs is one of the most popular current trends in food engineering, blackcurrant pomace powders, which are obtained as a result of grinding of dried blackcurrant pomace, can be added as an attractive and healthy natural ingredient in a wide range of food products. Numerous drying technologies previously applied to fruit dehydration affected overall quality in terms of physical and chemical properties of the products as compared to raw material (Chong, Law, Figiel, Wojdyło, & Oziembłowski, 2013). The physical properties have practical relevance to handling and storage due to the specific particle size distribution and air pores included in the material after drying. The analysis of physical properties such as true and bulk density, porosity, colour, texture etc. of food powders might have an impact

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on the choice of the appropriate drying method or a proper dryer. Furthermore, the evaluation of e.g. bulk density might determine the container size and the strength of the reconstructed foodstuff (Bhandari, Bansal, Zhang, & Schuck, 2013).

Blackcurrant has been used as a colouring agent in food industry (Kozák, Békássy-Molnár, & Vatai, 2009). Thus, of great importance is the effect of drying on changes in colour. Colour is one of the most important attributes of the quality of dried foods, because it is part of their visual appearance and is one of the first criteria taken into account by consumers when choosing a new product (Bonazzi & Dumoulin, 2011). Some of the previous studies have shown that differences in the heat treatment of fruit (in the drying method applied) appear to be more strongly correlated with differences in colour and aroma than with differences in flavour (Brennan, Hunter, & Muir, 2003). Among drying methods, convective drying is considered to cause the greatest loss in colour (Nawirska, Figiel, Kucharska, Sokół-Łętowska, & Biesiada, 2009), whereas freeze-drying can be recommended as a method allowing colour retention. The latter drying technique is considered as the most expensive (Ratti, 2001).

A very promising technology, both in terms of product properties and cost-effectiveness, is to use combined drying methods to prevent the decrease in antioxidant capacity and total phenolic compounds in fruits (Michalska, Wojdyło, Lech, Łysiak, & Figiel, 2016). MVD is usually applied in combination with convective pre- and postdrying (Krulis, Kuhnert, Laiker, & Rohm, 2005). The pre-drying of raw material using convective drying in hot air allows processing more material in a smaller vacuum-microwave installation used to finish drying. If MVD is applied from the beginning, intensive water evaporation from the material being dried may exceed the vacuum pump capacity. The pre-drying by the convective method before finishing drying with MV reduced the total cost of dehydration and improved the quality of dried products (Figiel, 2010).

No scientific work has yet been reported on the combined drying of blackcurrant pomace. Therefore the aim of this study was to determine the effect of the drying method on the physicochemical properties of blackcurrant pomace powders.

2. Materials and methods

2.1. Reagents

The 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt, potassium persulfate and Trolox® were from Sigma-Aldrich (Switzerland).

2.2. Materials

Frozen blackcurrants were acquired from a local market (initial moisture content: 2.3 kg H_2O/kg dm (dry matter)). The fruit was ground using a Thermomix (Vorwerk, Germany) and pressed in a laboratory hydraulic press (SRSE, Warsaw, Poland) (yield of pomace production approx. 20%). The pressed product, pomace, was thoroughly mixed and immediately dried using different drying methods.

2.3. Drying methods

Blackcurrant pomace (≈500 g) was dried using freeze-drying (FD) (OE-950, Hungary) for 24 h at 65 Pa. Convective drying (CD) was performed in a pilot-scale laboratory dryer (Michalska et al., 2016). Samples (≈100 g) were dried at the following air temperatures: 50 °C, 60 °C, 70 °C, 80 °C and 90 °C with a constant air velocity of 0.8 m/s until the moisture level in the pomace fell to 0.02 kg/kg dm.

Microwave vacuum drying (MVD) was carried out in a Plazmatronika SM 200 dryer (Wrocław, Poland) at constant power modes: 120 W, 240 W, 360 W and 480 W at 4–6 kPa (Calín-Sánchez et al., 2015). The temperature of the sample surface was measured using an infrared camera Flir i50 (Flir Systems AB, Sweden) immediately after samples were removed from the dryer.

Combined drying (CPD-MVFD) started with convective pre-drying (CPD) of 100 g of blackcurrant pomace at temperatures 50 °C, 60 °C, 70 °C, 80 °C and 90 °C which lasted until reaching the pre-established moisture content of ca. 0.25 kg/kg dm; this was followed by MV finish-drying (MVFD) with microwave power adjusted to 480 W. The drying was finished when the moisture content of the samples fell below 0.065 kg/kg dm.

All drying experiments were performed in duplicate. The kinetics of CD, MVD and CD-MVD were determined based on the mass losses of 100 g pomace samples whose moisture content had been previously measured. Dried blackcurrant pomace samples were pulverized for 30 s in a MKM 6003 grinder (Bosch GmbH, Germany) at ambient temperature, vacuum packed and stored at −18 °C for further analyses.

2.4. Physical and chemical analyses

2.4.1. Moisture content and drying kinetics

The moisture content and the drying kinetics were determined as described by Michalska et al. (2016). Table Curve 2D Windows v. 2.03 (Systat Software, USA) was used when fitting basic drying models to the measured moisture ratios with the highest possible values of the determination coefficient R^2 and the lowest values of mean square error (MSE). The fitted models (Lech et al., 2015) included the effect of independent variables: drying time (t) and hot air temperature (T_A) for CD ($MR_{CD} = f(t,T_A)$), drying time (t) and magnetron power (P) for MVD $MR_{MVD} = f(t,P)$ and only drying time (t) was considered for combined drying (CD and MVD) because only one magnetron power level (480 W) was applied at the final stage ($MR_{CD\text{-}MVD} = f(t)$).

2.4.2. Colour

The colour of the blackcurrant pomace powders obtained using different drying methods was determined as described by Michalska et al. (2016). The total colour change (ΔE^*) was computed according to the equation described by Šumić, Tepić, Vidović, Jokić, & Malbaša (2013).

2.4.3. True density, bulk density and porosity

True density (ρ_t), bulk density (ρ_b) ($n = 3$; expressed as kg/m^3) and porosity ($n = 3$; expressed as %) of the samples were measured as described by Michalska et al. (2016).

2.4.4. Water activity

Water activity (a_w) was measured in triplicate using a water activity meter AquaLab DewPoint 4Te (Decagon Devices Inc., United States). Results were expressed as an average.

2.4.5. Solubility of powders

Exactly one g of each powder (dry matter) was dispersed in 100 mL of deionized water by blending (13 500 rpm) for 2 min with an X 620 homogenizer (CAT, CAT Scientific, Inc., USA). Dispersed blackcurrant powders were centrifuged (5000 rpm for 5 min) and 25 mL of each supernatant were dried at 60 °C for 48 h (Pol-Eko Aparatura, Poland) (Cano-Chauca, Stringheta, Ramos, & Cal-Vidal, 2005). The solubility of powders was determined in duplicate by measuring a weight difference (%).