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The influence of different the drying methods on chemical composition and antioxidant activity in chokeberries

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A B S T R A C T

Drying has been long known and widely used method of food preservation. The aim of this study was to determine the effect of different drying methods (by freeze-drying (FD), vacuum (VD), convective drying (CD), microwave (VMD) and combined method (CVM)) on the quality factors of chokeberry fruit, including phenolic compounds, antioxidant activity, and color. All products were characterized by water activity which determines their storage stability. The highest content of bioactive compounds and antioxidant activity were determined in freeze-dried samples, compared with fresh fruits (total phenolic in gallic acid equivalents- 8008 mg/100 g dm, anthocyanins- 3917 mg/100 g dm). The increase in air temperature during CD as well as the increase in material temperature during VMD deteriorated dried product quality in terms of the content of phenolic compounds, antioxidant activity, and color, which was correlated with anthocyanin content. A new combined CVM method allowed obtaining high quality dried material compared to the CD and VMD methods applied separately. The drying process affected changes in the appearance and brightening of color, and also increased the contribution of yellow color in the fruits. The results show that the quality of dried chokeberry depends on the method and conditions of fruit drying.

1. Introduction

Chokeberry belongs to the family Rosaceae (*Rosaseae*), subfamily pome (*Pomoideae*). This plant is native to the North America, from where it was brought to Russia and then to other European countries, including Poland. Studies of healthy properties of chokeberry fit into the current trends and consumer interest in healthy diet and lifestyle.

Chokeberry contains a small amount of vitamin C as compared to other berries, however, is rich in polyphenols such as flavonoids (flavan-3-ols>anthocyanins>>flavonols) and phenolic acids (neochlorogenic and chlorogenic acid), with contents reaching 2000–3500 mg/100 g fresh fruit (Danielczuk, 2003). Bitter taste of the fruits is due to the presence of significant amounts of polyphenols, particularly proanthocyanidins whose oligomers have a high affinity to proteins, causing them to shear and inducing the feeling of dryness in the mouth (Oneksiak, 2000; Kolniak, Augustyniok, & Oszmiański, 2009).

Chokeberry fruits can be classified as natural medicines due to their health properties (Kolniak et al., 2009). Chokeberry is useful in treating diseases of the cardiovascular system and of the digestive tract, owing to a high content of biologically-active compounds (Ostrowska & Rzemykowska, 1998) because its products have the highest antioxidant activity and are superior, in this regard, over blueberries, cranberries, black and red currants, raspberries, elderberries and strawberries. Wine from chokeberry has a higher antioxidant activity than the wine from grapes (Jakobek, Seruga, & Krivak, 2011). Chokeberry juice is considered a natural antibiotic and may be used in the treatment of stomach disorders, atherosclerosis, colds and food poisonings. These fruits are also helpful in obesity management due to significant amounts of polyphenolic compounds and dietary fiber. This enables blood glucose level adjustment and has a beneficial effect upon lipolysis and lipid metabolism as well as on the control of appetite (Jankowski, Niedworok, & Jankowska, 1999). In addition, compounds contained in chokeberry prevent damage of β cells of the pancreas which are responsible for insulin production (Oszmiański & Nowicka, 2011).

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Due to its bitter taste, chokeberry is not consumed in the form of raw fruits, but is mainly processed into juices the tart flavor of which is less perceptible. A high content of pectin makes that chokeberry may also be processed into jams, jellies and marmalades. In turn, due to the high content of anthocyanins, chokeberry may be used to produce a natural food coloring, which is used to prepare e.g. jellies (Oneksiak, 2000; Danielczuk, 2003). Furthermore, whole chokeberry fruits may be dried to obtain snack products, additives to cereal products or tea infusions. The drying process affects the appearance of the fruit and their chemical composition. Considering consumer preferences, the appropriate method of drying should be selected, so as to ensure retention of the maximum quantity of bioactive compounds in the product. Choosing the adequate drying method and parameters of this process will provide a product with a high antioxidant activity, only slightly changed appearance compared to fresh fruit, and with a more favorable taste.

The aim of this study was to investigate the influence of different methods of drying and their parameters (freeze drying, vacuum, convection, vacuum–microwave drying and convection-vacuum-microwave) on the content of bioactive compounds, antioxidant activity and color of chokeberry fruit. The use of various drying methods was aimed at identifying which of them ensures the best preservation of these parameters.

2. Material and methods

2.1. Material

Samples of chokeberry (*Aronia melanocarpa* Elliott; 5 kg) were bought from Sady Trzebnickie near Trzebnica at processing maturity in September 2012 and were immediately brought to the University for further processing.

2.2. Drying experiments

Chokeberry fruits were dried with 5 methods: (i) freeze drying – FD (24 h; Alpha 1–4 LSC; Martin Christ GmbH, Osterode am Harz, Germany); (ii) vacuum drying – VD (SPT-200, ZEAMiLHoryzont, Kraków, Poland), (iii) convective drying – CD (convective drier designed and made at the Agricultural Engineering Institute of Wroclaw University of Environmental and Life Sciences), (iv) vacuum–microwave drying – VMD (VM-200; Plazmatronika S.A., Wroclaw, Poland), (v) and combined method: convection-vacuum-microwave drying – CVM.

During FD, the pressure was reduced to 0.960 kPa. The temperature in the drying chamber was −60 °C, while the temperature of shelves reached 26 °C. Drying kinetics for CD and VMD was determined according to sample mass losses measured during drying. The process of dehydration using all the above-mentioned methods was continued until moisture content in the dried samples was 0.05 kg/kg dm. In the case of FD, the samples were kept in the drying chamber for 24 h.

Hot air temperatures during convective drying (CD) were 50 °C, 60 °C, and 70 °C; air velocity was 1.2 m/s. Hot air temperatures were measured using thermocouples located close to the dried samples. The accuracy of the temperature gauge was 0.1 °C. This allowed controlling air temperature to ±1 °C by adjusting autotransformers that supplied heating elements with electric energy.

During the vacuum–microwave drying (VMD), the initial microwave power was set to 240 W, 360 W, and 480 W. The pressure in the VMD chamber varied between 4 and 6 kPa.

Vacuum drying (VD) was conducted at 50 °C and a pressure of 100 Pa, for 24 h.

In convection-vacuum-microwave drying (CVM), the fresh material was dried first at a temperature of 70 °C for 2 h or 6 h to achieve the same dry weight before further final drying. Then, the fruits were dried by vacuum-microwave with 360 W reduced to 120 W or 240 W.

2.3. Determination of water activity

The determination was performed on the Novasina (LabMasterav., Lachen, Switzerland) at 20 °C.

2.4. Analysis of content of total phenolic, anthocyanins and antioxidant activity

The solvent for analysis of total polyphenols was prepared as described previously by Wojdyło, Figiel, and Oszmiański (2009). The determination was performed using the Folin-Ciocalteu method described previously by Gao, Ohlander, Jeppsson, Bjork, and Trajkovski (2000). The results are given in mg of gallic acid/100 g dry matter (dm). Content of anthocyanins was measured according to Hosseinian, Li, and Beta (2008). Results are expressed in mg of anthocyanins/100 g of dm.

The $ABTS^{\circ+}$, and FRAP assay were determined as previously described by Re et al. (1999) and Benzie and Strain (1996), respectively. All antioxidant activity were expressed as millimoles of Trolox per 100 g of dm. Determinations by total phenolic, anthocyanins, ABTS and FRAP methods were performed using a UV2401 PC spectrophotometer (Shimadzu, Kyoto, Japan).

2.5. Color measurement

The color of chokeberry powders was determined using an A5 Chroma-Meter (Minolta CR300, Osaka, Japan), referring to color space CIE L*a*b*. Determination was based on measuring the specific color parameters: L-color brightness, a*- red parameter, b*-participated of a yellow. Data were mean of three measurements.

2.6. Statistical analysis

Statistical analysis was conducted using Statistica version 10 (StatSoft, Krakow, Poland). Significant differences ($p \leq 0.05$) between means were evaluated by one-way ANOVA and Duncan's multiple range test. Results of tables and figures are presented as mean ± standard deviation of two independent technological determinations. All analyses were done in triplicate.

3. Results and discussion

Water activity is a factor that has a significant impact on the stability of dried fruit. A high water activity can lead to a shorter storage time of products, which is due to the possibility of adverse biochemical changes and microbial growth. To eliminate these factors, water activity in dried fruits should range from 0.600 to 0.800, but it is even better when it is below 0.600 (Barbosa-Canovas, Fontana, Schmidt, & Labuza, 2007; Cupiał, Witrowa-Rajchert, & Hankus, 2011).

Depending on the drying method applied, the dried fruits obtained were characterized by water activity ranging from 0.126 to 0.548, which is shown in Table 1. It can be assumed that the obtained products were microbiologically stable. The lowest water activity was determined in chokeberry subjected to FD. Similar results were reported by Cupiał et al. (2011), whereas Sumic, Tepic, Vidovic, Jokic, and Malbasa (2013) demonstrated that the dried sour cherry obtained by the vacuum under different conditions was characterized by $a_w = 0.434–0.916$. The highest result was obtained in the variant with the pressure of 300 mbar and temperature of