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Vitamin C content in Latvian cranberries dried in convective and microwave vacuum driers

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Abstract

Cranberries belong to a group of evergreen dwarf shrubs or trailing vines in the genus *Vaccinium* subgenus *Oxycoccus*. Traditionally they grow in acidic bogs throughout the cooler parts of the world; when cultivated are grown on low trailing vines in great sandy bogs. The research focuses on the study of vitamin C changes in Latvia grown wild (*Vaccinium oxycoccus L.*) and cultivated (*Vaccinium macrocarpon Ait.*) cranberries during convective and microwave vacuum drying. Latvian wild cranberries and cultivated cranberry varieties 'Early Black', 'Ben Lear', 'Stevens', 'Bergman' and 'Pilgrim' from Kurzeme region harvested in 2010 were used for experiments. Mechanical and thermal pre-treatment of fresh berries was applied for better water evaporation in drying process. During experiments the berries were dried: in a convective air dryer by controlled hot air stream circulation velocity of 1.2 m s^{-1} at temperature +50±2 ºC. The berries were placed on the perforated sieve (diameter 0.185 m, diameter of holes – 0.002 m); the moisture content of dried berries was 9.0±0.1%. Following quality parameters were analysed during experiments: moisture content (oven-drying method) and vitamin C content (LVS EN 14130:2003). Experimentally it was ascertained that drying time of berries by various drying methods mainly depends on the pre-treatment manner. During the drying process moisture content of cranberries decreased from on average 86.94% to 9.00%, about ~10.00 times. Vitamin C is the least stable of all vitamins and it can be easily degraded during processing and storage. The most harmful factors to vitamin C content are the presence of oxygen, prolonged heating in the air ambiance and exposure to light. The initial content of vitamin C in wild and cultivated fresh cranberries was differing, which mainly depends on varieties' individuality. Current research proved that vitamin C content loss in cranberries processed by microwave vacuum drying method comparing with drying in convective cabinet type dryer was smaller.

Keywords: Cranberries; vitamin C; steam-blanching; convective drying; microwave vacuum drying.

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1. Introduction

Cranberries belong to a group of evergreen dwarf shrubs or trailing vines in the genus *Vaccinium* subgenus *Oxycoccus*. Traditionally they grow in acidic bogs throughout the cooler parts of the world; when cultivated are grown on low trailing vines in great sandy bogs. Berries are rich in a vitamin C, organic acids, minerals, aroma, and phenol compounds. Many cultivars and native species of berries exist with substantially higher antioxidant levels than others [1, 2]. Cranberries and their products have been historically associated with many positive benefits for human health. For many decades, cranberry juice has been widely used as a folk remedy to treat urinary tract infections. Cranberry juice extracts have also been suggested to exhibit anticancer effects and to inhibit the oxidation of low-density lipoprotein *in vitro*, potentially preventing the development of heart diseases [3]. Cranberries contain flavonoids including proanthocyanidins, anthocyanins, and flavonols, which may protect bone against resorption. The antioxidant capacity of proanthocyanidin has been reported to be stronger than vitamin C, vitamin E, and catechins [4]. Cranberries contain vitamin C (as evidenced by the presence of citric acid) and phytochemicals. Vitamin C is also an important antioxidant. It is important to recall that the antioxidants β-carotene and vitamin E protect water soluble substances from oxidising agents; vitamin C protects water soluble substances the same way [5]. Vitamin C is stable, since the pH value of a product is about 4, yet this vitamin is unstable due to product processing / storage conditions: air oxygen, light, and temperature +80 °C [6]. The importance of vitamin C in the diet is well understood and scientifically proved. Vitamin C is also involved in the metabolism of several amino acids [5, 7, 8 and 9]. Drying is one of the oldest methods of food preservation and it is a difficult food processing operation mainly because undesirable changes in quality because the removed water from a food product using conventional air drying, may cause serious damage to the dried product [10]. It is the most common and most energy-consuming food preservation process. With literally hundreds of variants actually used in drying of particulate solids, pastes, continuous sheets, slurries or solutions, it provides the most diversity among food engineering unit operations. Air-drying, in particular, is an ancient process used to preserve foods in which the solid to be dried is exposed to a continuously flowing hot stream of air where moisture evaporates. The phenomena underlying this process is a complex problem involving simultaneous mass and energy transport in a hygroscopic, shrinking system. Air-drying offers dehydrated products that can have an extended shelf life of a year but, unfortunately, the quality of a conventionally dried product is usually drastically reduced from that of the original foodstuff [11, 12]. Microwave drying is rapid, more uniform and energy efficient compared to a conventional hot air drying. In this case, the removal of moisture is accelerated and, further-more; heat transfer to the solid is slowed down significantly due to the absence of convection. Also because of the concentrated energy of a microwave system, only 20–35% of the floor space is required, as compared to conventional heating and drying equipment. However, microwave drying is known to result in a poor quality product if not properly applied [13, 14]. Water accounts for the bulk of the dielectric component of most food systems especially for high moisture fruits and vegetables. Hence, these products are very responsive to microwave applications and will absorb the microwave energy quickly and efficiently as long as there is residual moisture. Microwave application for drying therefore offers a distinct advantage. Proteins, lipids and other components can also absorb microwave energy, but are relatively less responsive. A second advantage of microwave application for drying of vegetables is the internal heat generation [15]. For the better water evaporation during drying process there are known many vegetable and fruit pre-treatment methods such as: halving or slicing [16], blanching in hot water [17], steam-blanching in order to inactivate enzymes activity [18] and perforation with needle (of 1 mm diameter) [19]. The current research focuses on the study of vitamin C changes in Latvia wild grown as well as cultivated cranberries during convective and microwave-vacuum drying.

2. Materials and methods

The research was accomplished on fresh Latvian wild (*Vaccinium oxycoccus L.*) grown and cultivated cranberries (*Vaccinium macrocarpon Ait.*) harvested in Kurzeme region in the first part of October, 2010: The varieties of were: 'Early Black', 'Ben Lear', 'Stevens', 'Bergman' and 'Pilgrim'. Three methods were used for pre-treatment of berries: perforation (3.000±0.001 kg), halving (3.000±0.001 kg) and steam-blanching (3.000±0.001 kg). The berries before drying in a cabinet drier were pre-treated using all three methods and berries dried in vacuum-microwave drier – using two pre-treatment methods – steam-blanching and halving. Part of berries (3.000±0.001 kg) was dried in vacuum-microwave drier without pre-treatment (whole berries). Perforation of berries was realised manually by a needle (1 mm diameter) about 20 pricks equally on all berry area; halving was realised manually by knife; steam-blanching was realised using "TEFAL VC4003 VITAMIN+" (Tefal, Chine) stew pot at temperature +94±1 ºC for a time established in previous experiments (for maximal preservation of vitamin C). For air drying experiments, a cabinet dryer "Memmert" Model 100-800 (Memmert GmbH + Co. KG, Germany) was used; drying parameters were as follows temperature 50±1 °C and air stream velocity 1.2±0.1 $m \cdot s^{-1}$. Berries were placed on a perforated sieve (diameter − 0.185 m), with the diameter of the holes – 0.002 m. For drying experiments in vacuum microwave, a dryer „Musson-1" (OOO Ingredient, Russia) was used. The necessary amount of microwave energy (magnetron minutes) was calculated using empirical formulas when the initial moisture of product is known and the final is estimated. The final mass of cranberries after drying was calculated using Formula 1 [20]:

$$M_2 = M_1 \cdot (100 - w_1)/(100 - w_2), \tag{1}$$

where:
M_1– mass of berries before drying, g
M_2 – mass of berries after drying, g
w_1 – initial moisture content of berries, %
w_2 – final moisture content of berries, %
The evaporated moisture amount was calculated using Formula 2 [20]:

$$\Delta M = M_1 - M_2, \tag{2}$$

where:
ΔM – mass of evaporated moisture, g

The amount of microwave energy (amount of doses) required for drying was calculated using Formula 3 [20]:

$$X = \Delta M / k, \tag{3}$$

where**:**
X **–** amount of microwave energy, doses (one dose is approximately 42 kJ)
k – 16 g – the mass of water vapour evaporated by one magnetron minute.

The power of installed magnetrons each of hour is 640 W [20]. Prior to the drying process the dryer was programmed at pressure (70 mm Hg upper and 56 mm Hg lower), rotation speed of cylinder – 6 rpm, amount of cycles – one cycle, amount of stages – four stages. The supplied microwave power was programmed at 4-3-2-1 magnetrons per drying stage. The temperature of cranberries at the drying process reached approximately +36±2 ºC. Berries were dried till final moisture content 9.0±0.1%. The following quality parameters of cranberries were controlled using standard methods: moisture content (oven-drying method at +105±1 ^{o}C) [21] and analyses of vitamin C content (LVS EN 14130:2003) [22]. Data are expressed as mean ± standard deviation; variance analysis, homogeneity were used for the evaluation of changes of vitamin C in cranberries during drying depending on pre-treatment methods. Each experiment was carried out in triplicate.

3. Results and discussion

The moisture content is the main parameter of food products which influences the storage time. It is known that the shelf life of products with high moisture content is shorter than of products with lower moisture content. The initial moisture content of fresh cranberries is shown in Table 1; the significant differences in moisture content of cranberries depending on variety were not found. For shelf life extension cranberries were dried up to the moisture content of 9.0±0.1%. As a result, providing of 3.000±0.001 kg load of berries in vacuum-microwave drying cylinder, the drying time was 82±2 min. Therefore current experiments demonstrate the pre-treatment methods don't significantly influence drying rate in vacuum-microwave drier. However, the pre-treatment of berries significantly influences moisture diffusivity from berries during convective drying. In the experiment it was established, that the drying time for halved berries was 36±1 h, for steam-blanched it was 38±1 h and for perforated it was significantly longer – about 74±1 h. Moisture content during the drying process of cranberries decrease on average from 86.94% up to 9.00% − that is about ~10.0 times.

Table 1. Moisture content of fresh cranberries

No.	Variety of cranberries	Moisture content, %
1	Wild	85.91±2.40
2	'Stevens'	86.52±3.12
3	'Bergman'	88.19±2.85
4	'Ben Lear'	87.36±2.91
5	'Pilgrim'	87.36±2.12
6	'Early Black'	86.31±3.73

The nutritional importance of vitamin C as an essential water-soluble vitamin is well established. Also, due to its redox potential, ascorbic acid facilitates intestinal absorption of iron and functions as a cellular antioxidant alone and coupled to the antioxidant activity of vitamin E. Therefore, adequate intake of vitamin C from foods and/or supplements is vital for normal functionality of the human body [23]. The vitamin C content found in fresh cranberries is summarised in Figure 1. Similar vitamin C content was detected in cultivated cranberries: varieties 'Stevens', 'Bergman' and 'Ben Lear'; it was on average by 10 mg·100 g^{-1} or by 21% (in dry matter) higher comparing to vitamin C content in wild cranberries. The lowest vitamin C content was detected in wild cranberries and cultivated cranberries of the variety 'Early Black' (Figure 1), 46.98±2.83 and 47.48±2.75 mg·100 g^{-1} (in dry matter), respectively. Such difference mainly can be explained with individuality of the variety and growth conditions. Vitamin C is the least stable of all vitamins and it can be easily destroyed during processing and storage. The most harmful factors to vitamin C content are the oxygen presence, prolonged heating in air ambiance, and exposure to light [24].Vitamin C is one of the most significant compounds in berries; therefore the main task of drying is to preserve its quantity maximally. The following drying conditions for processing of cranberries in microwave-vacuum drier were selected: the first drying stage at 4 magnetrons – energy of 2100 kJ, the second stage at 3 magnetrons – energy of 2520 kJ, the third stage at 2 magnetrons – 1260 kJ and the fourth stage at 1 magnetron – 756 kJ. Temperature in microwave-vacuum drier was 36±2 °C. The temperature in cabinet dryer for maximal preservation of biological compounds was established of 50±1 °C [25].

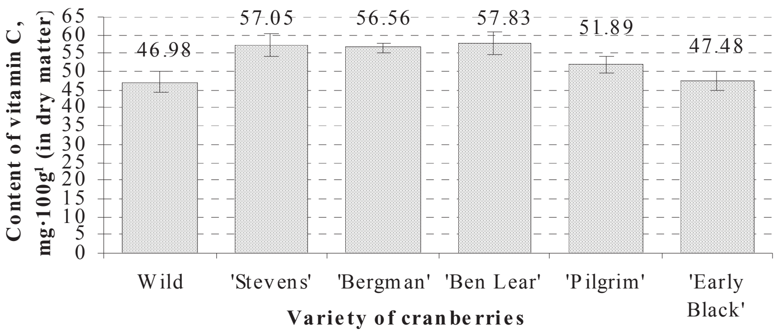

Fig. 1. Vitamin C content in dry matter of fresh cranberries

The mechanical and thermal pre-treatment of berries was used because the berries' waxy skin presents a high resistance to mass transfer. In the present research it was found that there is no correlation between changes in content of vitamin C, cranberry variety and pre-treatment method of cranberries, in case drying in vacuum microwave drier was applied (Figure 2). It was ascertained that the pre-treatment is not necessary for wild, 'Ben Lear' and 'Pilgrim' berries processing in vacuum microwave drier in order to preserve vitamin C, so, whole berries could be dried. During drying the content of vitamin C decreased in whole wild, 'Ben Lear' and 'Pilgrim' variety cranberries by 1.57, 2.12 and 4.05 times respectively (Figure 2) comparing to vitamin C content in fresh berries (Figure 1). It is advisable to use halving of berries prior to drying to reduce the loss of vitamin C in cranberry varieties 'Bergman' and 'Early Black' during microwave vacuum drying, i.e. vitamin C content decreased by 2.13 and 3.04 times respectively comparing to fresh berries. More suitable pre-treatment method for cranberries of variety 'Stevens' was assessed steam-blanching before drying, in this case vitamin C content decreased 3.72 times comparing to the initial, while drying whole berries the vitamin C content decreased by 5.79 times. Such changes in vitamin C content mainly depend on cranberry chemical composition, enzyme activity and vitamin C location in berries.

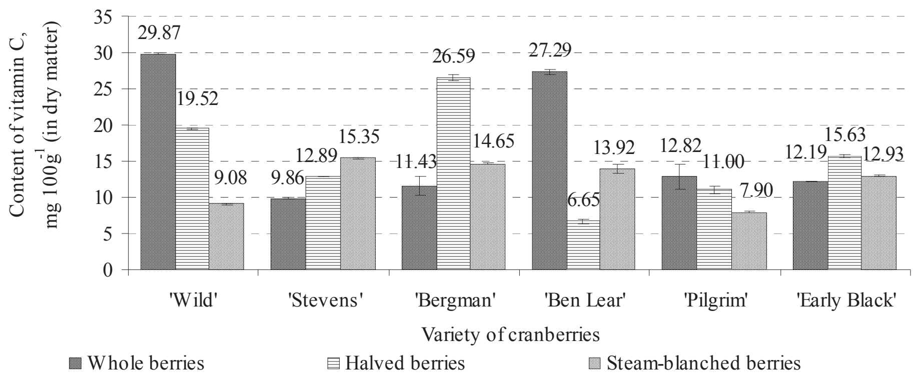

Fig. 2. Vitamin C content in vacuum-microwave dried cranberries of different varieties depending on the pre-treatment method

In the present experiments correlation was not found between vitamin C losses, cranberry variety and cranberries pre-treatment method during cranberries drying in convective drier (Figure 3) similarly to vacuum microwave drying method for cranberry processing.

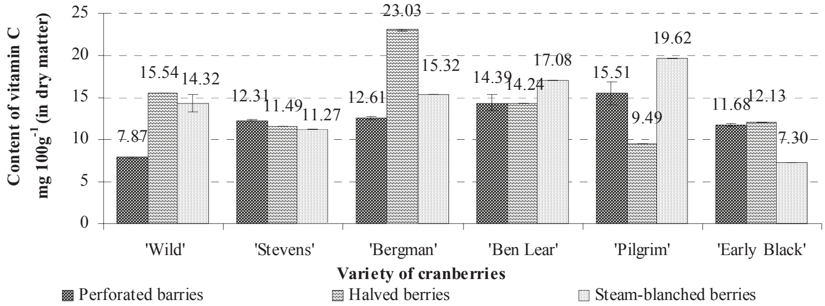

Fig. 3. Vitamin C content in convective dried cranberries depending on the variety and pre-treatment method

Vitamin C losses in berries pre-treated by perforating were significant (Figure 3) comparing to vitamin C changes in berries pre-treated by other methods. It was established, that the pre-treatment method such as berries perforating is not recommendable for preservation of vitamin C during convective drying of cranberries. Such pre-treatment process is difficult and labour-consuming; drying time was longer as well (74±1 h), and economically it is not beneficial. Perforating could be advisable only for cranberries 'Stevens' processing in cabinet convective drier, however vitamin C losses in cranberries pre-treated in such way was very similar to halved or steam-blanched cranberries: vitamin C content decreased by 4.63, 4.97 and 5.06 times respectively comparing to vitamin C content in non-processed cranberries. Halving, as a pre-treatment method for vitamin C preservation in berries during convective drying is more recommendable for wild, 'Bergman' and 'Early Black' variety cranberries; i.e. vitamin C content decreased during drying of berries by 3.02, 2.46 and 3.91 times respectively comparing to the initial content of vitamin C in fresh berries. Steam-blanching is more recommendable for cranberries of variety 'Ben Lear' and 'Pilgrim' prior to drying in a convective drier, because in such way pre-treated berries the vitamin C content decreased by 3.39 and 2.64 times respectively comparing to the initial vitamin C content. With the probability of 95%, detected by means of the analysis of variance, it may be presumed, that pre-treatment method of cranberries influenced vitamin C decrease (the vitamin C content decrease − mg·100 g^{-1} was used as the dependent variable) during convective and vacuum-microwave drying ($P=0.00 < \alpha=0.05$). In the present research it was proved, that vacuum microwave drying method could be recommended for drying of cranberries, it is found to be less time-consuming and simpler way of processing. Processing time of berries in a vacuum-microwave drier was shorter (82±2 min) comparing to drying in a convective cabinet drier (36−74 h) and vitamin C decrease was smaller.

4. Conclusions

The pre-treatment method does not significantly influence moisture content decrease from berries during drying in a vacuum-microwave drier (drying time was 82±2 min); however the drying time for convective dried halved berries was 36±1 h, for steam-blanched − 38±1 h and for perforated − 74±1 h. Very similar vitamin C content was detected in fresh cultivated cranberries of the varieties: 'Stevens', 'Bergman' and 'Ben Lear' comparing to vitamin C content in fresh wild cranberries. The lowest vitamin C content was detected in fresh wild cranberries and cultivated fresh cranberries of the variety 'Early

Black'. Correlation was not found between vitamin C losses, cranberry variety and cranberries' pre-treatment method during drying in convective and in vacuum microwave driers. With the probability of 95%, detected by means of the analysis of variance, it may be presumed, that pre-treatment method of cranberries influenced vitamin C decrease during convective and vacuum-microwave drying ($P=0.00 < \alpha=0.05$). Vacuum microwave drying method could be recommended for drying of cranberries, it is found to be less time-consuming and simpler way of processing: drying time of berries in a vacuum-microwave drier was shorter (82±2 min), pre-treatment is not necessary comparing to drying in a convective cabinet drier (36−74 h) and vitamin C decrease could be smaller.

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