CHANGES IN PHYSICALLY-CHEMICAL AND MICROBIOLOGICAL PARAMETERS OF LATVIAN WILD CRANBERRIES DURING CONVECTIVE DRYING

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Abstract
The research focuses on the study of physically-chemical and microbiological parameter changes in Latvian wild cranberries during convective drying. The research was accomplished on fresh Latvian wild cranberries. The following quality parameters were controlled during the experiments: moisture content (oven-dry method), content of vitamin C (LVS EN 14130:2003), content of polyphenol (HPLC), preparation of samples for microbiological testing (LVS EN ISO 7218:2007), enumeration of yeasts and moulds (ISO 21527-2:2008(E)), counting of lactic acid bacteria (LVS ISO 13721:1995), and total plate count (LVS EN ISO 4833:2003A). The research detected the following optimal convective drying parameters of wild cranberries: temperature – +50±1 °C and drying time – 20.3 hours. The moisture content of dried berries equalled to 9.0±0.1%. The content of vitamin C decreased 1.9 times in wild cranberries dried at the temperature of +50±1 °C compared with the content of vitamin C in non-dried cranberries and was 13.05 mg 100 g^{-1} in dry matter. The results of current experiments show, that the content of such polyphenols as gallic, caffeic, and epicatechin acids decreased 9.70, 9.90, and 11.68 times, respectively, during the treatment at temperatures up to +50±1 °C compared with the initial content of these compounds in non-dried berries. The drying temperature substantially influences the microflora development in cranberries. It is possible to decrease significantly the content of LAB, mould, and fungi in berries provided the drying temperature of the wild cranberries does not exceed +50±1 °C, thus prolonging the ready product shelf-life.
Key words: cranberries, convective drying, vitamin C, polyphenols, mould, yeasts.

Introduction

Cranberries are a group of evergreen dwarf shrubs or trailing vines in the genus *Vaccinium* subgenus *Oxycoccos*, or, in some treatments, in the distinct genus *Oxycoccos*. Traditionally they are found in acidic bogs throughout the cooler parts of the world. A cousin of the blueberry, this very tart, bright red berry can still be found growing wild as a shrub, but when cultivated, is grown on low trailing vines in great sandy bogs. Even Latvian swamps are protected from drainage, so that species survival is guaranteed in the future. It is one of the most marketable berries in autumn, which competes with both autumn strawberries, and the artificially cultivated cranberries, or red-bilberries (Поплева, 2000).

Fresh cranberries, which contain high amount of beneficial nutrients, are at their peak from October through December, just in time to add their festive hue, tart tangy flavour and numerous health protective effects. Cranberry juice and dried or frozen cranberries might be consumed after the end of cranberries short fresh season (Cranberries, 2010). Cranberries contain triterpinoids, a range of different organic acids, sugars, basic alkaloids, and anthocyanin dyes. Moisture content in cranberries is approximately 88%; sugar content of cranberries ranges from 5.25 to 7.13 g 100 g^{-1}, where glucose comprises approximately 80% and fructose – 20%. The different organic acids found in cranberries include catechin, glucuornic acid, ascorbic acid, benzoic acid, malic acid, quinic acid, leptosine glycosides, and, of course, citric acid (Birulis, 2008; Bruvere, 2006; Ripa, 1992).

Cranberries also contain vitamin C (as evidenced by the presence of citric acid) and phytochemicals. The importance of vitamin C in the diet is well understood and scientifically proved. 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. Vitamin C is also involved in the metabolism of several amino acids (DeBruyne, 2008; Birulis, 2008; Bruvere, 2006). 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 above +80 °C (Belitz, 2004; Henry and Chapman, 2002).

Many small fruit phenolic compounds are good sources of natural antioxidants and have inhibitory effects on mutagenesis and carcinogenesis. During the past decades, extensive analytical research has been carried out on the separation and determination of phenolic constituents in various fresh fruit products and environmental samples. The unique antibacterial activities of cranberry implicate that cranberry may possess a very different flavonoid and phenolic composition from other kinds of fruits. An efficient separation and quantitation method is essential for understanding the components of flavonoid and phenolic antioxidants in cranberry and their health benefits. Phenolic compounds are not temperature resistant; therefore treatment at elevated temperatures will negatively influence polyphenol compound activity (Chen et al., 2001).

Latvian climate is very suitable for growing cranberries, though several climatic conditions as, for example, temperature variations, rain, winds, elevated air humidity, and others also contribute to the development processes of several diseases. Diseases may cause damage to shoots, leaves, flowers, roots, and berries, thus most of the harvest is subject to qualitative and quantitative factors. Rotting of berries sometimes develops during their growth, but mainly after get hearing the harvest collection (Ripa, 1996).

The microbial biota of land-grown berries may be expected to reflect the soils in which they are grown, although exceptions occur. The actinomycetes (gram-positive branching forms) are the most abundant bacteria in stable soils, yet they are rarely reported on berries. On the contrary, the lactic acid bacteria are rarely found in the soil, but they are significant part of the bacterial biota of plants and plant products. The overall exposure of plant products to the environment provides many opportunities for contamination by microorganisms. The protective cover of berries and the possession of some pH values below which many organisms cannot grow are important factors in the microbiology of the products (Jay et al., 2005).

The main microflora of berries will contain small amount of moulds, yeasts, and lactic acid bacteria (LAB). However, yeasts may be viewed as being unicellular fungi in contrast to the moulds, which are multi cellular; moulds are filamentous fungi that grow in the form of a tangled mass that spreads rapidly and may cover several inches in area; and the LAB is composed of 13 genera of gram-positive bacteria (Jay et al., 2005).

Through the past few years, there has been an increasing demand for high - quality dried berries. These dried fruits are widely used in the bakery industry for a variety of processed products including muffin mixes, breakfast cereals, yogurts, sauces, and snack bars (Beaudry, 2001).

Decrease of water activity and increase of treatment temperature during drying are no acceptable conditions for microorganisms growing and development; activity was retained only by spores.

Fruits and vegetables can be dried using hot air as the drying medium, which is often found as the simplest and most economical method. In hot air drying, four main factors can affect the rate and total time of drying: the physical properties of the food (particle size and geometry), the physical arrangement of the food with air (cross flow, through flow, tray load), the physical properties of the air (temperature, humidity, velocity), and the design characteristics of the drying equipment (Jayaraman et al., 1995).

The aim of the present research was developed after the analysis of the literature: to study changes in physically-chemical and microbiological parameters of Latvian wild cranberries during convective drying. The following tasks were advanced to achieve the set aim:

- to determine experimentally parameters for wild Latvian cranberry convective drying: temperature and drying time;
- to determine the changes in content of vitamin C and polyphenol compounds in cranberries during drying at different temperatures;
- to evaluate changes in microbiological parameters in cranberries during convective drying at different temperatures.

Materials and Methods

The research was accomplished on fresh Latvian wild cranberries harvested in Vidzeme region greenwood bogs in 2009.

During the experiments, berries were cut prior to drying and dried in a chamber with controlled hot air circulation at various temperatures: +30 – +90 °C with the interval of +10 °C. Berries were placed on a perforated sieve (diameter - 0.185 m), with the diameter of a hole – 0.002 m, the sieve area – 0.030 m^2, and load - 6.700 kg m^{-2}. Cranberries were dried till a constant moisture content of 9.0±0.1% for storage time extension.

During the experiments, the following quality parameters of cranberries were controlled using standard methods:

- moisture content was determined using an oven-dry method, where 3.00±0.01 g of berries were cut prior to drying in an oven-drier "Precisa XM105E" till a constant weight (with sensibility ±0.01g) at the temperature of +105±1 °C (Temminghoff and Houba, 2004);
- vitamin C content was determined according to the standard method LVS EN 14130:2003 "Foodstuffs – Determination of Vitamin C by HPLC";
- phenolic compounds were determined using a high-performance liquid chromatography (HPLC) with UV detection (at 280 nm) (Berregi et al., 2003);
- preparation of samples for microbiological testing was conducted in accordance with the standard method LVS EN ISO 7218:2007;
- enumeration of yeasts and moulds in cranberries was analysed according to the standard method ISO 21527-2:2008(E);
- lactic acid bacteria counting was accomplished according to the standard method LVS ISO 13721:1995; and
- total plate count was analysed according to the standard method LVS EN ISO 4833:2003A;

Microsoft Excel software was used for the research purpose to calculate mean values and standard deviations of the mathematical data used in the research. The research includes five reiterations.

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 that of products with lower moisture content. It was determined that the initial moisture content of non-dried wild cranberries is 82.03±0.10%. Therefore it is possible to forecast shorter shelf life for such berries. Thereby cranberries were dried in several temperature conditions ranging from +30±1 °C to +90±1 °C till reaching the moisture

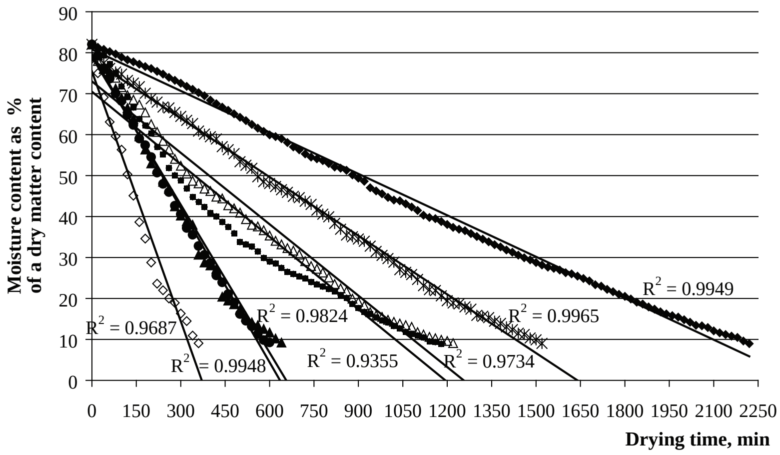

Figure 1. Decrease in the moisture content on a dry matter basis of cranberries in the drying process.

content of 9.00±0.10%. The results of the experiments show that the extended drying time is 37 h at the drying temperature of +30±1 °C and, the short drying time is 6 h and 20 min at the temperature of +90 °C. The chemical composition of cranberries, especially their acidity, mainly influences the drying time. A linear interconnection (Figure 1) was found between the moisture content applying to a dry matter, temperature and the drying time. It means that there exists a correlation between the moisture changes, temperature, and drying time. During the experiments it was found that after drying berries for 4h at +30±1 °C a decrease of moisture content was only by one times lower yonder if drying were occurred at +90±1 °C – the moisture content decrease by four times. It could be explained with the rapid moisture evaporation during processing at the elevated temperatures. After a 9-h-drying, the moisture content of cranberries processed at the temperature of +30±1 °C decreased 1.2 times, while in cranberries dried at the temperature of +90±1 °C the moisture content was 9.00±0.10%. The drying time of cranberries at the temperatures of +80±1 °C and +70±1 °C was found to be very similar (Figure 1), i.e., 10 h, and 10 h and 40 min respectively.

Vitamin C is the least stable of all vitamins and is easily destroyed during processing and storage. The most harmful factors to vitamin C content are the availability of oxygen, prolonged heating in the presence of oxygen, and exposure to light (Cruz et al., 2007). The initial content of vitamin C in wild non-dried cranberries was found to be to 13.05±0.20 mg 100 g^{-1} of fresh weight. Vitamin C is one of most significant compounds in berries; therefore the main task of drying is to maximally keep its quantity. During the experiments it was ascertained that the amount of vitamin C had decreased approximately 12.0 times during processing at the temperature of +90±1 °C (Figure 2). Such results are not acceptable for the development of a product with an elevated nutritive value; therefore other conditions should be search for. The content of vitamin C decreased 1.2 times during processing at the temperature of +30±1 °C, 1.5 times – at +40±1 °C, 1.9 times – at +50±1 °C, 3.0 times – at +60±1 °C, 5.1 times – at +70±1 °C, and 11.0 times – at the temperature of +80±1 °C. Vitamin C was destroyed mainly because berries were processed at elevated temperatures during convective drying and in presence of oxygen. A linear interconnection (Figure 2) was found between the decrease in vitamin C content and the drying time, which means that there exists a correlation between the changes in vitamin C content and the drying time. As the optimal drying parameters of cranberries the temperature not higher than +50±1 °C (the drying time 20.3h) will be acceptable, because if processing temperature increase more than +50±1 °C, the decrease of Vitamin C content is relevant.

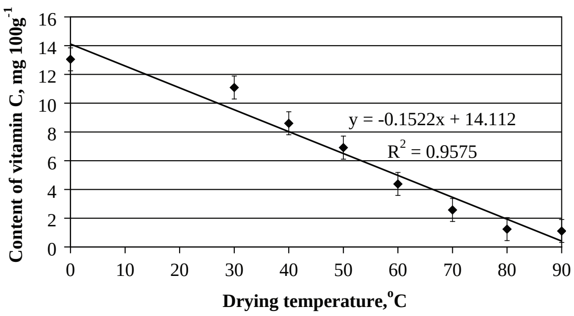

Figure 2. Decrease in the vitamin C content (in dry matter) in cranberries in the convective drying process.

Berries include notable sources of polyphenols. Industrial food processing affects the polyphenol content too (Macheix and Fleuriet, 1998). Our research demonstrated that the content of gallic and caffeic acids in non-dried wild cranberries was higher than the content of catechin and epicatechin acids (Figure 3).

The amount of catechin acid in wild non-dried cranberries was 10.0 times lower the amount of caffeic acid, which could be explained by the individuality of

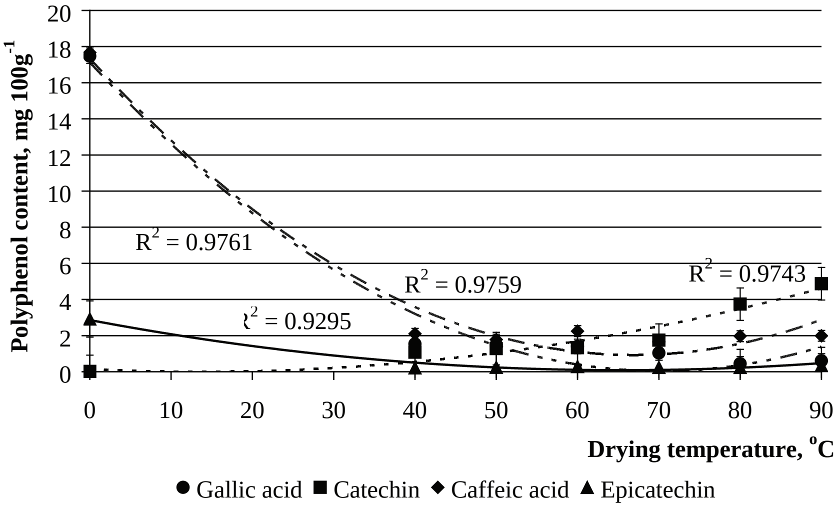

Figure 3. Changes in the polyphenol compounds (in dry matter) in berries during the convective drying.

the cranberries chemical composition. Mathematical data processing showed that there was no linear interconnection between the processing temperature and the changes in phenolic compounds. Therefore polynomial interconnection provides a possibility of foreseeing changes in the pholyphenol content in cranberries during the convective drying. During the experiments it was proved that the processing temperature substantially influences the content of measured polyphenols in cranberries. The content of polyphenols decreased during processing at the temperatures of up to +50±1 °C: gallic, caffeic and epicatechin acids decreased 9.70, 9.90, and 11.68 times respectively compared with their initial content in non-dried berries. Hydroxylgroup oxidation in polyphenol compounds mainly explain the increase in the content of polyphenols during the convective drying of cranberries at the temperature above +70±1 °C (Figure 3). During processing at relatively low temperatures the energetic barrier of activisation energy was stable. Oxidation occurred with benzol ring in compounds, as a result di- and tri- phenols developed from monophenols. Of course, the main factor influencing such changes is pH value of cranberries.

The population of bacteria found on small fruits vary widely. The initial count of predominant microflora is about 10^5 cfu g^{-1}, although low numbers of moulds and yeasts are also present (Jonger, 2005). Appropriate care should start in the bog environment. Contamination may result, for example, from soil, rains, animal contact, etc.

In our research, total count of microorganisms was investigated in convective dried cranberries at several temperatures. The presence of microorganisms was not found if cranberries were dried at the temperature of +70 – 90±1 °C (Figure 4). Therefore vegetative cells of the microorganisms may be damaged during the convective drying.

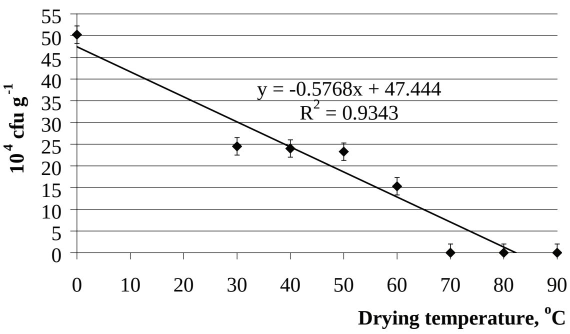

Figure 4. Decreases in the total count of microorganisms in cranberries during the convective drying.

Total count of microorganisms in non-dried wild cranberries was two times higher compared with the same parameters if cranberries were dried at the temperature of +30±1 °C, and three times higher if cranberries were dried at the temperature of +60±1 °C. Decrease in water activity and increase in processing temperature during drying are not acceptable conditions for the growth and development of microorganisms; activity was retained only by spores.

One of the most common species of the genus *Aspergillus* a *Aspergillus niger* fungi was found during the microscopy of non-dried wild cranberries tested microflora. The spores are widespread, and are often associated with organic materials and soil. Since soil is the natural habitat for *Aspergillus niger*, long-term survival in the environment is expected. Human exposures via dermal contact and ingestion routes and environmental exposures may occur at the discharge site because of the establishment of *Aspergillus niger* within the soil (Aspergillus…, 1997).

The lactic acid bacteria (LAB) gram-positive, acid-tolerant, generally non-sporulating, non-respiring rod or cocci associated by their common metabolic and physiological characteristics were controlled in wild cranberries during drying. It was ascertained that the increase of drying temperature inactivated LAB in the tested berries. The content of LAB decreased two times in cranberries processed at the temperature of +30±1 °C compared with the LAB content in non-dried berries, since the elevated processing temperature negatively influences LAB activity. Whereas the content of LAB in berries processed at the temperature of +50±1 °C decreased 13 times. During convective drying, the LAB were not detected at the temperature above +60±1 °C.

Mucor mucedo were detected in non-processed cranberries and cranberries dried at the temperatures of +30 – 50±1 °C. The contamination is explained by the presence of these microorganisms in the air during cranberries growing and short-term storage. The research results show that it is possible to eliminate the content of these microorganisms during processing using elevated temperatures above +50±1 °C.

It is known that both yeasts and moulds cause various degrees of deterioration and decomposition of foods. Moisture and warmth are the most preferable conditions for the development of mould and yeasts. Though, it is possible to decrease the presence of such microorganisms in processed food due to the decrease in the moisture content in food and the increase in the treatment temperature. During our research it was determined that wild cranberries convectively dried at the temperature of +80 – +90±1 °C were not contaminated with the mentioned microflora, as yeasts and moulds are not heat resistant. The content of yeasts and moulds decreased 7 times in cranberries dried at the temperature of +70±1 °C compared with non-dried berries.

Yeasts and *Penicillium italicum* were detected in the microflora of wild cranberries. *Penicillium italicum* is one of the most common causes of fungal spoilage in berries from moss and substratum. The development of such microorganisms could be prevented applying the control of the storage conditions of cranberries.

As the results of experiments show the changes of Vitamin C content are not relevant if drying temperature of cranberry does not exceed +30±1 °C. The content of vitamin C decreased 1.2 times compared with its initial content. Under such conditions the drying time is very long – 39.0 h, which is not economically advantageous. At the drying temperature of +50±1 °C, the changes in vitamin C are not very significant since its content decreases 1.9 times and the drying time is shorter – 20.3 h. Therefore the optimal drying temperature for cranberries is +50±1 °C, excluding consideration of the dynamics of microorganisms. The total count of microorganisms in cranberries dried at the temperatures of +30±1 °C and +50±1 °C was approximately two times lower compared with the initial count of microorganisms in non-dried berries. It is possible to decrease significantly the content of LAB, mould, and fungi in berries if the drying temperature of the wild cranberries does not exceed +50±1 °C, thus prolonging the ready product shelf-life.

Conclusions

1. Optimal convective drying parameters of wild cranberries in a drier with controlled hot air circulation are the following: temperature – +50±1 °C, and drying time – 20.3 hours. The moisture content of dried berries makes 9.0±0.1%.
2. The study ascertained that vitamin C is labile to light, extremes in temperature, and oxygen. The vitamin C content decreased 1.9 times in wild cranberries dried at the temperature of +50±1 °C, compared with its content in non-dried cranberries – 13.05 mg $100g^{-1}$ in dry matter.
3. The study shows changes in the polyphenol content in wild cranberries due to the influence of hot air drying at different temperatures. Even the content of polyphenols decreases during the processing at temperatures of up to +50±1 °C: gallic, caffeic, and epicatechin acids decrease 9.70, 9.90, and 11.68 times respectively compared with the initial content of these compounds in non-dried berries.
4. The drying temperatures substantially influence microflora development in cranberries. It is possible to decrease significantly the content of LAB, mould and fungi in berries if the drying temperature is of wild cranberries +50±1 °C, thus prolonging the ready product shelf-life.

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