DRYING DYNAMICS OF DIFFERENTLY PREPARED FRESH CRANBERRIES AND BLUEBERRIES USING IR DRYING

Aivars Aboltins, Janis Palabinskis
Latvia University of Life Sciences and Technologies, Latvia
aivars.aboltins@lbtu.lv, janis.palabinskis@lbtu.lv

Abstract. Cranberries (*Oxycoccus palustris*) and blueberries (*Vaccinium corymbosum*) are berries rich in polyphenols known to promote health in various ways as a diuretic, to prevent cancer, to improve the function of the cardiovascular system and digestive tract. Containing a relatively large amount of vitamin C, they can significantly enhance the effects of antibiotics. One method of long-term preservation is to dry them. Drying conditions also have a significant effect on product quality. As the berry skin inhibits the removal of moisture, it is necessary to find a simple and convenient way to prepare the berries to speed up the drying process in low-heated air. An IR beam dryer with a drying temperature of 41 ºC was chosen as an experimental device. The moisture output of whole berries and needled pierced berries was compared. The results of the experiment showed that the moisture removal of whole berries is linear, which means that the skin of the berries plays an important role. The slope was $k = 17.7 \cdot 10^{-3}$ (change in weight (g) in relation to drying time (min)). The pierced cranberries showed an exponential dynamics of moisture removal. This means that the holes in the casing play a very important role in drying the berries faster. After 22 hours of drying, moisture from pierced cranberries was removed almost 3 times more than from whole berries (64.4% vs. 26.5%). Blueberries have a similar situation, but they dry faster because their skin is thinner.

Keywords: cranberries, blueberries, drying, temperature.

Introduction

Drying is a basic method for preserving various products. An important aspect of drying is energy consumption, drying time and reduction of quality losses. One of the drying methods that has gained a lot of popularity in recent years, also at the industrial level, is infrared (IR) drying, especially at low temperatures, which helps preserve the quality of the product. Due to the research carried out on this type of drying and its advantages over other drying methods, it has started to be implemented. Research shows that infrared has effective moisture diffusion and higher thermal sensitivity than air drying, which is the most widely used method [1].

The infrared drying method has shorter drying times, and better product quality than hot air drying [2,3] at the same temperature.

There are many studies on drying of different products: mushrooms [3-5], fruits [6-9], vegetables - carrots [10; 11], potatoes [12], rhubarb cubs [13] and etc.

Several studies have found that drying agricultural materials with infrared radiation is one of the most effective, as the heating occurring in it is able to promote the rate of dehydration of products and also helps improve their quality. Infrared drying is practical due to the even distribution of heat, fast drying speed and the simplicity of the equipment used. In infrared drying, infrared radiation penetrates the material and is converted into heat energy, thus removing water more evenly. Infrared drying provides more even heat distribution than convection. It is especially widespread in the biological drying of various herbs, teas, medicinal plants and other thin materials [14-23].

It is emphasized that infrared drying has a higher energy efficiency compared to hot air drying [24]. The theoretical aspects of leaf drying in the infrared environment are discussed [25].

Berries are rich in vitamins, minerals and antioxidants. For these reasons, berry consumption is important throughout the year. Since the berries are harvested once a year, it is important to choose a good preservation technique to later produce healthy and tasty edible berry products. Therefore, the issue of their preservation over a longer period of time, minimally reducing their quality during storage, becomes relevant. In addition, their storage costs should also be observed.

We can find in the literature that drying using infrared rays is a modern technology that preserves berries, preserving most of their nutrients, vitamins, smell, and taste [26-30]. Blueberries and cranberries are one of the most common berries in Latvia. Our task is to preserve them for as long as possible and so that they do not lose quality during storage and processing.

Blueberries and cranberries are berries with their surface covered with a denser shell that prevents moisture from being easily removed from the inside of the berry. This significantly affects the drying speed and time, especially when drying at low temperatures. Therefore, the question of how to process the berries before drying arises. The given study compares the drying dynamics of whole and pierced berries under the same drying conditions.

Materials and methods

Whole cranberries (*Oxycoccus palustris*) and blueberries (*Vaccinium corymbosum*) were selected for the research. Some of them were left whole, but some of them were pierced in 20 different places Fig.1.

Fig. 1. **Whole and pierced berries used in the experiment**

An IR drying equipment was used for drying the samples, which was described in the study of carrot drying [10]. The drying procedure of the studied samples is analogous to drying of rhubarb [13] and the drying and rehydration studies of carrots [11]. Each sample was weighed with a *Kern EW 1500-2M* scale with a weighing accuracy of ± 0.01 mm before being placed in the drying machine and between drying times. In order to determine the change in mass during drying, the weight of the samples to be dried was controlled after certain time intervals by removing the samples from the drying equipment and then putting them back. Each sample was weighed every 60 minutes for the first 8 hours every drying day. The duration of the experiment was 54 hours. A *Memmert* convection drying cabinet was used to determine the dry matter of the samples.

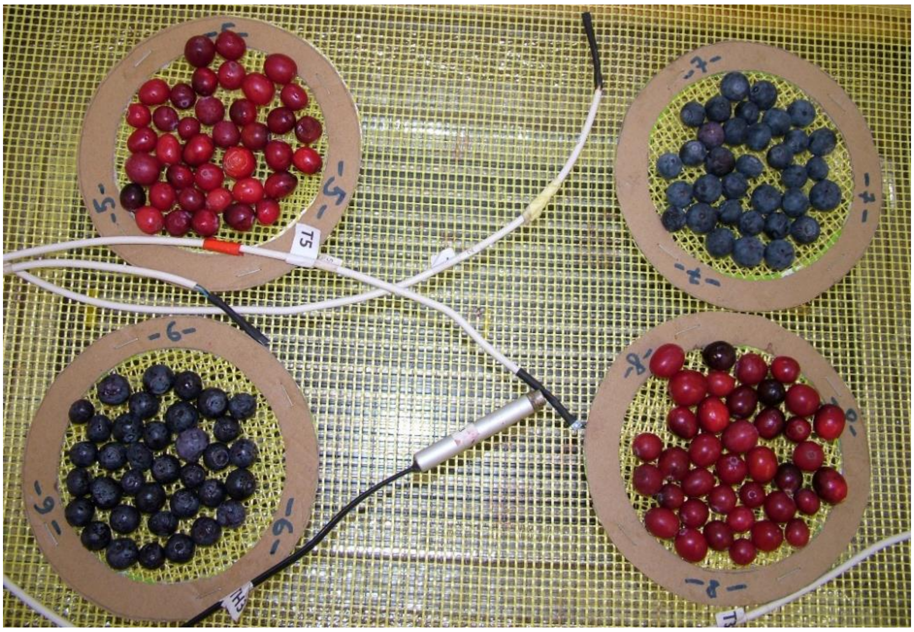

Fig. 2. **Placement of samples in IS drying equipment:** 5, 6 – whole; 7, 8 – pierced

The drying temperature in the equipment was 41 ± 0.3 ºC during the experiment. Determination and registration of drying air parameters was carried out by data loggers KM120 with 16 sensors, 12 of which were temperature sensors TSIC 506 with a measurement accuracy of ± 0.1 ºC and 4 temperature and relative humidity sensors HYT 939 with a measurement accuracy of ± 0.2 ºC (Fig.2).

Results and discussion

Comparing the berries before (Fig. 2) and after drying (Fig.3) shows that the pierced berries have shrunk and significantly reduced their volume. The unpierced berries have changed their shape much less. This shows that the main output of moisture occurs at the places of the holes, and this causes the berries to shrivel.

Fig. 3. **Samples at the end of the experiment**

After 22 hours of drying, the moisture content of the whole cranberries decreased from 87% to 64.5%, while the moisture content of the pierced berries reached 26.5%, it is almost 3 times more moisture was removed from the pierced berries than from the whole berries. The situation is similar for blueberries, where after 22 hours of drying, the moisture difference in the samples is 34% versus 4% in the pierced berries, Fig.4.

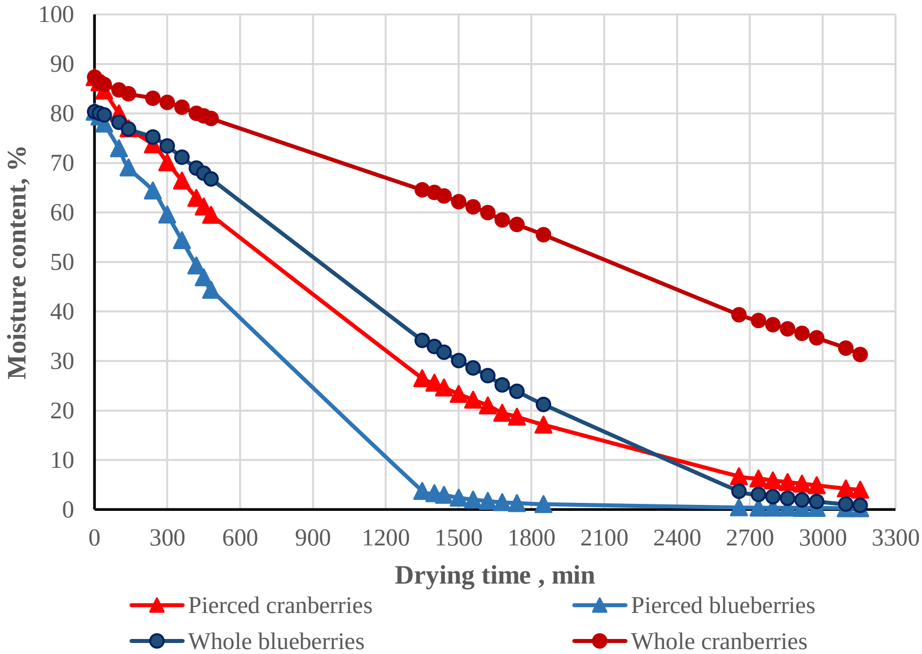

Fig. 4. **Moisture content in berries during drying**

Looking at the moisture change in the samples, it can be seen that in the whole berries it occurs linearly, especially in cranberries, Fig 4. The slope for cranberries was $k = -17.7 \cdot 10^{-3}$ and for blueberries $k = -27.4 \cdot 10^{-3}$. This indicates that whole blueberries dry about 1.5 times faster than cranberries, at a correlation of $r > 0.98$.

This could be explained by the influence of the berry skin, where the moisture transport is determined by diffusion through the skin. Moreover, this linearity is much more pronounced in cranberries, which could be explained by a thicker skin than in blueberries.

Exponential drying dynamics can be observed for pierced berries, and it is much more pronounced for pierced blueberries. Drying pierced blueberries is up to 2 times faster than drying of pierced cranberries.

Changes of the moisture content Δm during the time difference Δt describe the drying rate v expressed in (1):

$$v = \frac{\Delta m}{\Delta t}, \tag{1}$$

where Δm – moisture content, g;
t – time, min;
v – changes of the moisture content rate, g·min^{-1}.

Looking at the drying rate (Fig. 5) during the first 8 hours of the experiment, it can be seen that it is significantly higher (2-3 times) for the pierced berries than for the whole berries. This can also be explained because the most moisture is removed through the holes in the berry shell. It is higher for blueberries because the shell is thinner and diffusion through it is greater than for cranberries. This is also confirmed by the drying rate of the whole berries.

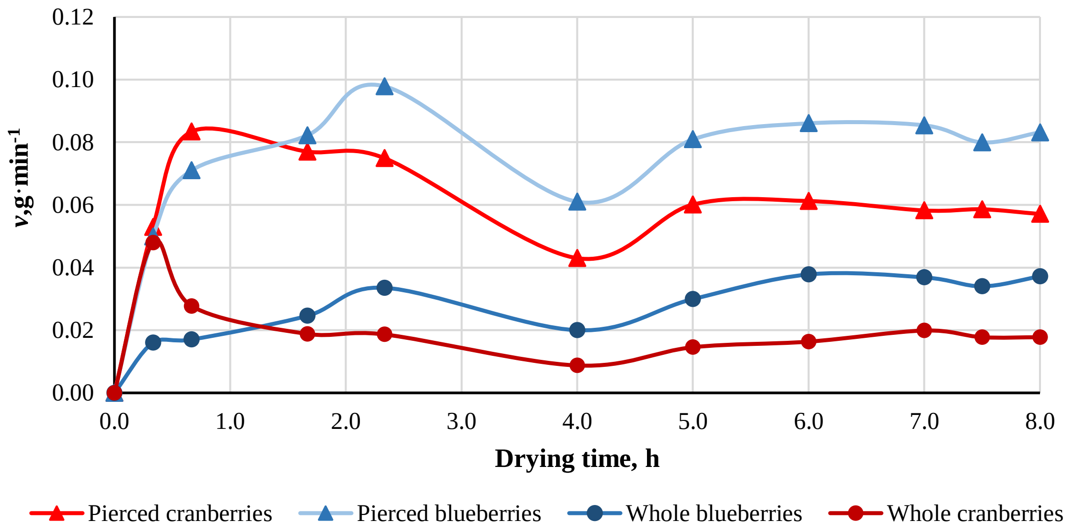

Fig. 5. **Drying rate *v* of berry samples during 8 hours of drying**

The moisture removal was measured in the experiment for 8 hours every day, the average drying rate at the beginning of each day was determined in Fig.6.

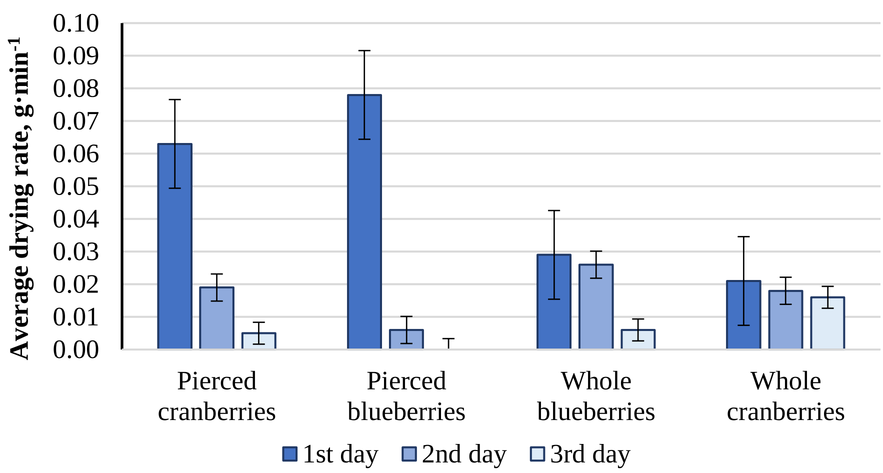

Fig. 6. **Average drying rates for the first 8 hours of each drying day**

Comparing the changes in the drying rate of whole blueberries and cranberries, it can be seen that it decreases insignificantly for cranberries throughout the experiment. On the other hand, for blueberries, it significantly decreased on the 2nd day of drying.

For pierced berries, the highest drying coefficient is observed at the beginning of the drying process. Within 24 hours, it decreased more than 3 times for cranberries and more than 10 times for blueberries.

Conclusions

1. The study shows the importance of pre-treatment of berries, especially thick-skinned berries, using IR drying at low temperatures (<50 ºC).
2. After 22 hours of drying, the moisture content of whole cranberries decreased from 87% to 64.5%, while the moisture content of pierced berries reached 26.5%, it is almost 3 times more moisture was removed from pierced berries than from whole berries. For blueberries, this ratio is even higher, from 80% at the beginning to 34% (whole berries) and 4% (pierced berries) after 22 hours of drying.
3. The drying rate during the first 8 hours of the experiment is significantly higher (2-3 times) for pierced berries than for whole berries. This is explained by the fact that most moisture is removed through the holes in the berry skin. It is higher for blueberries because the skin is thinner and diffusion through it is greater than for cranberries.

Author contributions

Both authors have contributed equally to the study and preparation of this publication. All authors have read and agreed to the published version of the manuscript.

References

[1] Riadh M, Ahmad S, Marhaban M, Soh A. Infrared heating in food drying: An overview. Drying Technology. 2015, 33(3), pp. 322-335.

[2] Roratto, T. B., Monteiro, R. L., Carciofi, B. A. M., & Laurindo, J. B. An innovative hybrid-solar-vacuum dryer to produce high-quality dried fruits and vegetables. LWT–Food Science and Technology, 2021, vol140, 110777. DOI: 10.1016/j.lwt.2020.110777

[3] Wang Q., Li S., Han X., Ni Y., Zhao D., Hao J. Quality evaluation and drying kinetics of shitake mushrooms dried by hot air, infrared and intermittent microwave-assisted drying methods, LWT-Food Science and Technology, 2019, vol 107 pp. 236-242

[4] Rubina T., Aboltins A. Drying characteristics of mushrooms // 20th International scientific conference “Engineering for rural development”: proceedings, Jelgava, Latvia, May 26 - 28, 2021/Latvia University of Life Sciences and Technologies. Faculty of Engineering. Jelgava, 2021. Vol. 20, pp. 557-563.

[5] Buğday, Z.Y. , Ertan, K. , Zeren, S., Sahin S,. Servet G. Drying of mushrooms by alternative technologies Turkish Journal of Agriculture and Forestry 2023, vol 47, (6), pp. 851-871.

[6] Kayacan S., Karasu S., Akman P. K., Goktas H., Doymaz I., Sagdic O. Effect of different drying methods on total bioactive compounds, phenolic profile, in vitro bioaccessibility of phenolic and HMF formation of persimmon. LWT-Food Science and Technology, 2020, 118, 8, 108830. DOI: 10.1016/j.lwt.2019.108830

[7] Aboltins A., Palabinskis J. Fruit drying process investigation in infrared film// Agronomy Research. No.14(1), 2016, pp. 5-13.

[8] Sadeghi E., Asl A., Movagharnejad K. Optimization and quality evaluation of infrared-dried kiwifruit slices Food Sciences & Nutrion 2020, 8, pp.720-734

[9] Lin Q., Zong X., Lin H., Huang X., Wang J., Nie S. Based on quality, energy consumption selecting optimal drying methods of mango slices and kinetics modelling 2023, Food Chemistry:X 17, 106600, DOI: 10.1016/j.fochx.2023.100600

[10] Aboltins A., Rubina T., Palabinskis J. Shrinkage effect on diffusion coefficient during carrot drying // Agronomy Research. Vol.16 (Special Issue 2), 2018, pp. 1301-1311.

[11] Rubina T., Aboltins A., Palabinskis J., Jotautiene E. Study of drying and rehydration kinetics of carrot cylinders // 17th International scientific conference “Engineering for rural development”: proceedings, Jelgava, Latvia, May 23 - 25, 2018/Latvia University of Life Sciences and

Technologies. Faculty of Engineering. Latvian Academy of Agricultural and Forestry Sciences. Jelgava, 2018. Vol. 17, pp. 1488.-1493.
[12] Onwude D., Hashim N., Abdan K., Janius R., Chen G. The effectiveness of combined infrared and hot-air drying strategies for sweet potato, Journal of Food Engineering 2019, vol 241, pp.75-87
[13] Rubina T., Aboltins A., Palabinskis J. Drying characteristics of rhubarb cubes at low temperature // 18th International scientific conference “Engineering for rural development”: proceedings, Jelgava, Latvia, May 22 - 24, 2019/Latvia University of Life Sciences and Technologies. Faculty of Engineering. Jelgava, 2019. Vol. 18, pp. 1249-1256.
[14] Abbaspour-Gilandeh, Y.; Kaveh, M.; Fatemi, H.; Khalife, E.; Witrowa-Rajchert, D.; Nowacka, M. Effect of Pretreatments on Convective and Infrared Drying Kinetics, Energy Consumption and Quality of Terebinth. Appl. Sci. 2021, 11, 160, 7672. DOI: 10.3390/app11167672
[15] Belwala T., Cravottob C., Prietoc, M., Venskutonise P., Daglia M., Devkota H., Baldi A., Ezzath S., Gomez-Gomez L., Salamah M., Campone L., Rastrelli M., Echave J., Seid Mahdi Jafari S., Cravotto G. Effects of different drying techniques on the quality and bioactive compounds of plant-based products: a critical review on current trends. Drying Technology 2022, v.40 (8), pp.1539-1561
[16] Wu B., Liu C., Liu M., Pan Z., Zhou C., Ma H. Study of infrared dry-blanching and dehydration on leaf vegetables. Journal of Food Science and Biotechnology, 2019, 38, pp. 46–51. DOI: 10.3969/j. ISSN.1673–1689.2019.12.007
[17] Aboltiņš A., Kic P. Research in some medical plant drying process // 15th International scientific conference “Engineering for rural development”: proceedings, Jelgava, Latvia, May 25 - 27, 2016/Latvia University of Agriculture. Faculty of Engineering. Jelgava, 2016. Vol.15, pp. 1145-1150
[18] Kic P., Aboltins A. Drying process of two special plants // 13th International scientific conference “Engineering for rural development” : proceedings, Jelgava, Latvia, May 29 - 30, 2014/Latvia University of Agriculture. Faculty of Engineering. Jelgava, 2014. Vol.13, pp. 137-142
[19] Aboltins A., Tomsu J., Kic P. Red clover drying coefficient dependences on air velocity at constant drying temperature // Agronomy Research. Vol.16(2), 2018, pp. 313.-319.
[20] Aboltins A., Kic P. Influence of air velocity on drying dynamics of alfalfa // 17th International scientific conference “Engineering for rural development”: proceedings, Jelgava, Latvia, May 23 - 25, 2018/Latvia University of Life Sciences and Technologies. Faculty of Engineering. Latvian Academy of Agricultural and Forestry Sciences. Jelgava, 2018. Vol. 17, pp. 1470.-1475.
[21] Nalawade S., Ghiwari G., Hebbar H. Process efficiency of electromagnetic radiation (EMR)-assisted hybrid drying spearmint (Mentha spicata L.), Journal of Food Processing and Preservation, 2019 ; 43:e14190, DOI: 10.1111/jfp.14190
[22] Borda-Yepes V., Chejne F., Daza-Olivella L., Alzate-Arbelaez A., Rojano B., Raghavan V. Effect of microwave and infrared drying over polyphenolcontent in Vaccinium meridionale (Swartz) dry leaves, Journal of Food Process Engineering, 2019, 42 pp.10 DOI: 10.1111/jfpe.12939
[23] Lihua Ye L., EL-Mesery H., Ashfaq M., Shi Y., Zicheng H., Alshaer W. Analysis of energy and specific energy requirements in various drying process of mint leaves Case Studies in Thermal Engineering 2021, 26 101113 DOI: 10.1016/j.csite.2021.101113
[24] Thamkaew G, Sjöholm I , Galindo F. A review of drying methods for improving the quality of dried herbs. Critical Reviews in Food Science and Nutrition. 2021, 61(11), pp. 1763-1786.
[25] Borda-Yepes V., Chejne f., GranadosD., Rojano B., Raghavan V. Mathematical particle model for microwave drying of leaves, Heat and Mass Transfer, 2019, 55:p. 2959–2974 DOI: 10.1007/s00231-019-02626-w
[26] Aboltins A., Palabinskis J. Vartukapteinis K. Studies of berry drying process in infrared film dryer// 16th International scientific conference “Engineering for rural development” : proceedings, Jelgava, Latvia, May 24 - 26, 2017/Latvia University of Agriculture. Faculty of Engineering. Latvian Academy of Agricultural and Forestry Sciences. Jelgava, 2017. Vol.16, pp. 1515-1520
[27] Adak N., Heybeli N., Ertekin C. Infrared drying of Strawberry, Food Chemistry 2017, v.219, pp.109-116
[28] Geng Z., Zhu L., Wang J., Yu X., Li M., Yang W., Hu B., Zhang Q., Yang X. Drying sea buckthorn berries (Hippophae rhamnoides L.): Effects of different drying methods on drying kinetics,

physicochemical properties, and microstructure. Frontiers in Nutrion. 2023, v.(10) p 11. DOI: 10.3389/fnut.2023.1106009

[29] Zhou Y., Stanizewska I., Liu Z., Zielinska D., Xiao H., Pan Z., et al. Microwave-vacuum assisted drying of pretreated cranberries: Drying kinetics, bioactive compounds, and antioxidant activity. LWT-Food Science and Technology, 2021, (146), pp. 1-8

[30] Lu Z., Staniszewska I., Zielinska D., Zhou Y., Nowak K., Xiao H., Pan Z., Zielinska M. Combined Hot Air and Microwave-Vacuum Drying of Cranberries: Effects of Pretreatments and Pulsed Vacuum Osmotic Dehydration on Drying Kinetics and Physicochemical Properties Food and Bioprocess Technology 2020, 13: pp.1848–1856