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ADVANCED RESEARCH ON THE DEHYDRATION OF THE BLACK CHOKEBERRIES (*Aronia melanocarpa* Linn.)

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Abstract

Five varieties of black chokeberries were analysed at fresh, intermediate (after the osmotic treatment) and dried stages, (after dehydration) comparing their soluble solids, total sugar, titratable acidity, vitamin C, phenols and anthocyanins content. The study aims to find various correlations between the osmotic treatment and the sensory & nutraceutical qualities of fruits and time & energy savings, as well. The hypertonic solutions were represented by a natural concentrated fruits juice in the ratio 1:2, 1:3 and 1:7 and by an inverted sugar syrup in the same ratios. Uncrushed berries were used, at the temperature of 50° C into syrup immersion and convective dehydration, subsequently.

Key words*: Aronia, bio-compounds, hypertonic solution, osmotic treatment, weight reduction.*

INTRODUCTION

Aronia melanocarpa Linn., known as black chokeberry belongs to the *Rosaceae* family which originates from the eastern parts of North America and East Canada (Kulling and Rawel, 2008). Aronia has been traditionally used in Native American medicine (Erichsen-Brown, 1989) by the Forest Potawatomi people for the treatment of colds and preparation of nutritious and lasting foodstuff, while berries and the bark as an astringent (Smith, 1933). The black chokeberries are used for juice, jam and wine production and are a source of natural pigments (Bridle and Timberlake, 1997). Chokeberries are rich in nutritious ingredients, including dietary fibres, organic acids, sugar, fat, proteins, minerals and vitamins (Juranovic et al., 2017). The chokeberry's polyphenols content is higher than the content of other berries (e.g., blueberry, cranberry, etc.), which exhibits various physio-logical activities, such as antioxidant, anti-inflammatory, anti-diabetic, anti-cardiovascular diseases and so on (Banjari et al., 2017; Cebova et al., 2017; Turcan and Todiras, 2003; Zhu et al., 2020). One quarter to one-third of the fruits and vegetable production goes waste due to the lack of proper retailing and adequate storage capacity. Preserving food to extend its shelf-life, is a central preoccupation of the food industry and on this matter, the real challenge starts immediately after production. Nowadays, a renewed interest exists in the use of more traditional preservation methods and the ways they can be combined with newer technologies. Food preservation is the process of treating food to stop or slow down its spoilage caused or accelerated by the activity of micro-organisms (fungi, bacteria, etc.). The preservation retards cell oxidation and inhibits the natural ageing and discoloration that can occur during food preparation, such as the enzymatic browning reaction (Yadav and Singh, 2014) observed after cutting different kinds of fruits and vegetables.

Widely spread methods used for food-materials preservation are: drying (convective dehydration), freezing, freeze-drying, spray drying, vacuum-packing, canning, syrup preservation (osmotic dehydration), sugar crystallization, food irradiation, adding preservatives or inert gases (e.g., carbon dioxide) etc., while others are modern methods, such as the ultrasonic vacuum pre-treatment silver nano-particles treatment or pulsed electric field assisted osmotic dehydration. A successful application in the preservation of fruits is represented by

osmotic dehydration (O.D.). This method is used from ancient times till nowadays when the new technologies transformed it into an innovative method. O.D. is a method of preservation that involves partial moisture loss from food-materials to improve their shelf-life.
It is done by immersing food materials either in whole or units into a hypertonic solution which allows diffusion of solutes from the food material into the solution concurrently with solid impreg-nation into the food material (Ciurzynska et al., 2016).
As Tiwari (2005) has mentioned, osmotic dehydration is the phenomenon of water removal from a lower concentration of solute to a higher concentration through a semi-permeable membrane, resulting in the equilibrium condition on both sides of the membrane.
In osmotic dehydration, the basic hypertonic solutions used are generally sugar syrup with fruits and sodium chloride or brine with vegetables (Bonatsou et al., 2016). In the osmotic process, the water flows out from fruits or vegetables tissues to the solution and along with water some components of fruits and vegetables (minerals, vitamins, fruit acids etc.), also, they move towards the solution, while the sugar/ salt migrates towards the fruits and vegetables (Fernandes et al., 2016).
The osmotic dehydration method is preferred to others due to their vitamins & minerals, organic acids, colour (pigments) retention properties (Ahmed et al., 2016; Osorio et. al., 2007). The O.D. treatment saves energy and prevents oxidative browning (Chandral and Kumari, 2015).
The osmotic dehydration can be an independent or pre-treatment process improving functional and nutritional properties and it can precede processes such as freezing, deep-frying, pasteurization, air-drying, vacuum drying, microwave drying, or freeze (Masztalerz et al. 2020).
Mass transfer and kinetic parameters play major roles in determining the extent of preservation, water loss, solid impregnation, as well as during O.D. as functions of immersion time, solution concentrations and temperatures antioxidant activity status of food-materials (Azeez et al., 2019).

MATERIALS AND METHODS

In this study, 5 varieties of *Aronia melanocarpa* have been used: *Galitianka, Hugin, Merlom, Nero* and *Viking.* The berries of the *Merlom* variety have been supplied by the Institute of Research-Development for Fruit Trees Cultivation, Pitesti - Maracineni, Arges County and they were organically cultivated (without chemical pesticides & fertilizers), following with strictness all rules and regulations of Organic Farming in the U.E. *Galitianka* and *Viking* chokeberry varieties have been provided by a private farm, located in Dorohoi, Botosani County, while *Hugin* and *Nero* varieties of *Aronia* sp. have been cultivated at the Institute of Research-Development for Processing and Marketing of Horticultural Products-"Horting", Bucharest.
*Aroni*a fruits were harvested in September 2020 and stored in a refrigerator at 5°C until processing. Each variety has been supposed to be a specific experiment in which the main variables were the compounds of the osmotic solute and the ratio. In the case of two varieties (*Nero* and *Hugin*) was intentionally extended the immersion time into the syrup, in order to record the possible changes in the chokeberries' tissue.
The experiment has followed 2 directions:
- to compare the processes appearing in the *Aronia* fruits in case of osmotic dehydration (O.D.) to the convective one;
- to establish the composition of hypertonic solution, ratio and O.D. time for obtaining the most valuable results, in the sense of sensory & nutraceutical qualities of *Aronia* berries and time & energy savings.
In this regard, the fruits were divided into 2 samples, for each variety:
- the berries are osmotically treated before the convective dehydration;
- the berries are convectively dehydrated, without osmotic dehydration.
Before the osmotic treatment, the chokeberries were sorted, washed and softly blotted for removing water drops. Below is a detailed of how the experiment has been prepared for each variety of *Aronia melanocarpa:*
1. *Merlom* (organic berries)
a) Immersion into concentrated natural fruit juice, ratio 1:2 (one-part berries to two-parts

hypertonic solution). Chokeberries' immersion time into the juice was 5 hours at 50°C (inside dryer) and 15 hours at room temperature (T).
b) Immersion into inverted sugar syrup, ratio 1:2 for 5 hours (inside dryer) at 50°C and 15 hours at room T.
c) Immersion into inverted sugar syrup, ratio 1:7 for 5 hours at 50°C and 15 hours at room T.

2. ***Galitianka***

a) Immersion into inverted sugar syrup, ratio 1:2 for 5 hours at 50°C and 15 hours at room T.
b) Immersion into inverted sugar syrup, ratio 1:3 for 5 hours at 50°C and 15 hours at room T.

3. ***Viking***

a) Immersion into inverted sugar syrup, ratio 1:2 for 5 hours at 50°C and 15 hours at room T.
b) Immersion into inverted sugar syrup, ratio 1:3 for 5 hours at 50°C and 15 hours at room T.

4. *Hugin*: immersion into concentrated natural fruit juice, ratio 1:3.
The immersion time of the berries into the juice was 8 hours at 50°C and 15 hours at room T.

5. ***Nero***: immersion into concentrated natural fruit juice, ratio 1:7.
The immersion time of chokeberries into the juice was 8 hours at 50° and 15 hours at room T.
The compounds of the hypertonic solution for the osmotic dehydration were:

1. The natural concentrated fruit juice contains: concentrated sour cherry juice (61°BRIX) concentrated apple juice (68,1°BRIX) and organic inulin of agaves (Fig. 1). The concentration of the osmotic agents and the osmotic solution was monitored by an Abbe refractometer (Zeiss JENA, Germany). The osmotic solution was prepared in the concentration: of 60% concentrated sour cherry juice + 20% concentrated apple juice + 20% organic inulin of agaves.

Figure 1. Concentrated sour cherry & apple juice and organic inulin of agaves

2. The inverted sugar syrup contains: sugar, lemon juice and plain water. The syrup used for treating the organic chokeberries (those of *Merlom* variety) has contained only organic ingredients. The syrup was prepared by boiling 10 minutes 1 kg of sugar with 500 ml of plain water adding the juice of one lemon. The black chokeberries were immersed into the syrup when their temperature reached 50°C. The biochemical and physical analyses of *Aronia* berries at their initial stage (fresh fruits), intermediate phase (after osmotic dehydration) and final stage (dried fruits, after convective dehydration) were conducted at the Institute of Research - Development for the Processing and Marketing of Horticultural Products -"Horting".
Total soluble solids (TSS) were determined by refractometric method, according to the STAS 5956-71 for vegetable and fruit products. Titratable acidity (TA) was determined according to the STAS 5952-79 for vegetable and fruit products regarding the determination of titratable and volatile acidity. Total sugar (TS), expressed in inverted sugar (%) was determined by the Bertrand method (Heinze and Murneek, 1940). Vitamin C was determined by spectro-photometric method, using 2,6-dichlorophenol, indophenol after xylene extraction for obtaining the amount of ascorbic acid existing in vegetable and fruit products, according to the STAS SR ISO 6557-2. Total anthocyanin content (TAC) was determined using the differential pH method (Lee at al., 2009). Total phenol content (TCC) was determined using Folin-Ciocalteu method (Johansen, 1940). The research on *Aronia* berries' behaviour to different dehy-dration methods was conducted using only uncrushed (entire) fruits. Drying uncrushed fruit maintains a higher level of antioxidant bioactive components (especially anthocyanins), than drying the crushed fruits (Oszmianski and Lachowicz, 2016). To the values obtained at the above determinations, the confidence interval (95%) and the standard error were calculated.
The chokeberries were dipped for 5 hours, and 8 hours, respectively (only *Nero* and *Hugin* varieties), into the osmotic solution of the above concentration at the temperature of 50° C and then other 15 hours at room temperature for all varieties. From time to time, the fruits were softly agitated. The osmotic dehydration is faster in fruits when syrup is circulated (Hawkes and Flink, 1978). It is important to

use an optimum ratio of solution to sample for the economic considerations and not only. In general, as the solution to sample ratio increased, the osmosis rate increased up to a certain level and then its level decreased. Chaudhari et al., (1996) and Ispir & Togrul (2009) concluded that water loss and solid gain were dependent on temperature and osmotic solution concentration.

The reported temperature limit is 60° C (Petkovic et al., 2019). Le Maguer (1988) and Ponting (1973) have however reported enzymatic browning and flavour deterioration above 49° C. In the osmotic dehydration, a simultaneous flux of water and solutes from and into the material takes place. This method can be used as a pre-treatment before air drying to reduce from 30% to 70% of the water content of the food (Ruskova et al., 2016).

Osmotic dehydration preceding air-drying decreases colour changes and increases flavour retention in dried fruits (Lenart and Lewicki, 1988).

After the osmotic treatment, the berries were quickly rinsed and dried with an absorbent paper. Then, the fruits were weighted for calculating their weight reduction after the osmotic treatment and spread on the trays of the dryer (Figure 2).

Figure 2. *Aronia* berries on dryer's trays

The *Aronia*'s berries osmotically treated have been ground at the intermediate stage (after O.D.) using a Heinner grinder (http://www.heinner/ro/uploads/support/2f4b5-User-manual - HCG 200DGIX2.pdf). The black chokeberries from all varieties have been dried by a convective method in a professional dryer (B. Master model SR 18381, 2018, made in Italy, the Company Tauro Essicatori SRL) at the temperature of 50°C. B. Master dryer is made of stainless steel with 4 compartments, heating and ventilation unit with electric resistance, three-phase electric, automatic ventilation module and non-stick paper "Dry silk" (Figures 3 and 4).

The dryer is furnished with 40 trays which provide a drying surface area of 14 m².

The characteristics of B. Master dryer: maximum capacity -160 kg; average daily output; 40/60 kg; external dimensions - 192Wx140Hx82D cm; weight when empty - 190 kg; heating power levels available -3.4,5.1 and 7.5 kW; electric fan -400 mm; electric fan power -60 W; temperature control - electronic with LED display; moist air discharge control-slatted shutter; supply-220/ 400 V-50 Hz (https://www.tauro-dryers.com/en/b-master-line/b-master).

Figure 3. B Master professional dryer in order

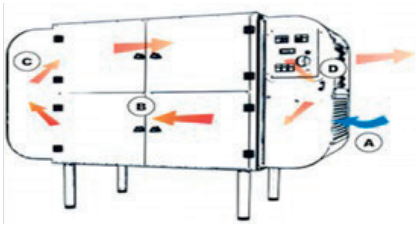
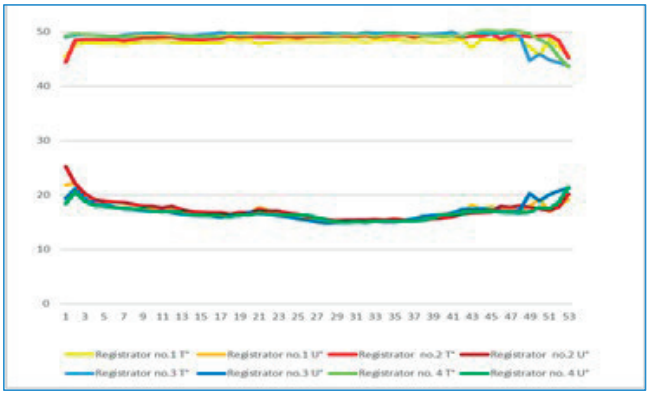


Figure 4. Air distribution inside B. Master dryer: A - air entrance area; B - lower drying level (2 compartments); C - upper drying level (2 compartments); D - humidity exhausting area

RESULTS AND DISCUSSIONS

In the Figure 5 appears the variations of temperature (T) and humidity (U) levels, depending on the dehydration phase and recorders' place inside the dryer. In the first 3 hours of dehydration, although the dryer was set up at the working temperature of 50° C, the recorders have noticed a lower temperature and higher humidity, due to the changes happening

inside berries' tissues and due to the changes of T & U between fruits and air dryer. At the end of the dehydration, when the dryer was set off, the T & U have turned to their initial values.
The curves of the chart show very slight differences in temperature & humidity inside dryer, as since the recorders have been placed near equidistantly on the trays. Airflow inside the dryer provides uniform temperature & humidity. The main indicators of fresh, osmotically treated (intermediate stage) and dried chokeberries (final stage) were analysed, as are represented in the Tables 1-3.



Recorders distribution inside dryer: no.1- right side, bottom- upper level; no.2 - left side, middle -upper level; no.3 - right side, bottom - lower level; no.4- left side, top - lower level.

Figure 5. Variations of temperature and humiditsy during dehydration

Of all fresh chokeberries (Table 1), the highest soluble solids content was represented by *Viking* (26.9°Brix), followed by *Merlom* (25.6°Brix) and the lowest content was obtained by *Nero* (12.2°Brix). The highest sugar amount was obtained by *Viking* (9.25%), followed by *Galitianka* (7.27%), whisle *Nero* obtained the lowest amount (4.09%). As regards the titratable acidity, the highest level was found at *Hugin* (1.04%), followed by *Merlom* (0.92%), while *Nero* obtained the lowest acidity (0.61%).
The best amount of vitamin C was found at *Hugin* (44.02 mg/100g), followed by *Nero* (39.02 mg/100g), while *Merlom* obtained the lowest amount of vitamin C (24.64 mg/100g). Concerning the anthocyanins, the highest content was represented by *Merlom* (454.41 mg cyd,3-glu/100g), followed by *Galitianka* (437.24 mg cyd,3-glu/100g) and the lowest content was obtained by *Nero* (220.87 mg cyd,3-glu/100g).
The highest content of phenol content was found at *Merlom* (1217.18 mg GAE/100g), followed by *Galitianka* (746.77 mg GAE/100g), while *Nero* has obtained the lowest content of total phenolics (342.38 mg GAE/100g).

Table 1. The main indicators of fresh Aronia berries

Variety	Total soluble solids (°BRIX)	Total sugar (inverted sugar %)	Titratable acidity (g malic acid/100 g)	Vitamin C (mg ascorbic acid/100 g)	Total anthocyanin content (mg cyd. 3-glu/100 g)	Total phenol content (mg GAE equiv./100 g)
Galitianka	23.00 - **A**	7.27 - **A**	0.66 - **A**	37.61 - **A**	437.24 - **A**	746.77 - **A**
Hugin	20.20 - **A**	6.06 - **A**	1.04 - **B**	44.02 - **A**	322.82 - **A**	636.88 - **A**
Merlom	25.60 - **A**	7.60 - **A**	0.92 - **A**	24.64 - **A**	454.41 - **A**	1217.18 - **A**
Nero	12.20 - **B**	4.09 - **B**	0.61 - **A**	39.02 - **A**	220.87 - **A**	342.38 - **A**
Viking	26.90 - **A**	9.25 - **B**	0.77 - **A**	36.95 - **A**	342.68 - **A**	675.65 - **A**
Average ($\bar{x}$) / **Std. error**	**21.58** / **2.61**	**6.85** / **0.86**	**0.80** / **0.08**	**36.45** / **3.93**	**355.6** / **37.32**	**723.77** / **141.30**

Legend: **A-** statistically no significant difference: **B** - statistically significant difference

After the osmotic treatment (Table 2), using as a hypertonic solution the inverted sugar syrup, the highest soluble solids value was found at *Viking* (34.1°Brix, ratio 1:3), followed by *Galitianka* (34.0° Brix, ratio 1:3). The highest sugar amount was obtained by *Galitianka* (12.38 %, ratio 1:3), followed by *Merlom* (11.83 %, ratio 1:7).

The best amount of vitamin C was gained in the berries of *Galitianka* (63.60 mg/100 g, ratio 1:3 and 62.21 mg/100 g, ratio 1:2), followed by *Viking* (53.71 mg/100 g, ratio 1:3 and 51.75 mg/100g, ratio 1:2).

The highest content of anthocyanins was represented by *Merlom* (514 mg cyd, 3-glu/100 g, ratio 1:7 and 508.98 mg cyd, 3-glu/100 g, ratio 1:2), followed by *Galitianka* (505.58 mg cyd, 3-glu/100 g, ratio 1:3 and 492.20 mg cyd, 3-glu/100 g, ratio 1:2).

The highest phenolic content was gained in the *Merlom* berries (1745.69 mg GAE/100 g, ratio 1:7 and 1700.65 mg GAE/100 g, ratio 1:2), followed by *Viking* berries (982.38 mg GAE/100 g, ratio 1:3 and 971.3 mg/100 g GAE, ratio 1:2).

In the case of fruit juice hypertonic solution, the highest soluble solids value was reached by *Merlom* (28.2° Brix, ratio 1:2), followed by *Nero* (26.2° Brix, ratio 1:7). The highest sugar amount was obtained by *Merlom* (9.21 %, ratio 1:2), followed by *Hugin* (8.29 %, ratio 1:3). Relating the vitamin C amount, the highest content was reached by *Hugin* (60.43 mg/100 g, ratio 1:3), followed by *Nero* (43.12 mg/100 g, ratio 1:7). The highest content of anthocyanins was got by *Merlom* (519.48 mg cyd, 3-glu/100 g, ratio 1:2), followed by *Hugin* (308.71 mg cyd, 3-glu/100 g, ratio 1:3). The highest polyphenolic content was obtained by *Merlom* (1686.18 mg GAE /100 g, ratio 1:2), followed by *Hugin* (772.98 mg GAE/100 g, ratio 1:3).

Table 2. The main indicators of Aronia berries osmotically treated (intermediate stage) in 2020

Variety	O.D. treatment		Total soluble solids (°BRIX)	Total sugar (inverted sugar %)	Vitamin C (mg ascorbic acid/100 g)	Total antho-cyanin content (mg cyd. 3-glu/100 g)	Total phenol content (mg GAE equiv./100 g)
Galitianka	sugar syrup	ratio 1:2	33.20 - **A**	9.28 - **A**	62.21 - **B**	492.20 - **A**	865.30 - **A**
		ratio 1:3	34.00 - **B**	12.38 - **B**	63.60 - **B**	505.58 - **A**	895.50 - **A**
Hugin	fruit juice	ratio 1:3	25.30 - **B**	8.29 - **B**	60.43 - **B**	308.71 - **B**	772.98 - **A**
Merlom	fruit juice	ratio 1:2	28.20 - **A**	9.21 - **A**	39.15 - **B**	519.48 - **B**	1686.18 - **B**
	sugar syrup	ratio 1:2	31.00 - **A**	11.24 - **B**	38.73 - **B**	508.98 - **A**	1700.65 - **B**
		ratio 1:7	32.00 - **A**	11.83 - **B**	39.20 - **B**	514.26 - **B**	1745.69 - **B**
Nero	fruit juice	ratio 1:7	26.20 - **B**	7.24 - **B**	55.12 - **A**	215.70 - **B**	500.42 - **B**
Viking	sugar syrup	ratio 1:2	33.50 - **B**	9.73 - **A**	51.75 - **A**	403.27 - **A**	971.30 - **A**
		ratio 1:3	34.10 - **B**	10.22 - **A**	53.71 - **A**	407.58 - **A**	982.38 - **A**
Average ($\bar{x}$) / **Std. error**			**30.72** / **1.14**	**9.94** / **0.56**	**50.21** / **3.39**	**430.64** / **35.90**	**1124.49** / **154.09**

Legend: **A**- statistically no significant difference: **B** - statistically significant difference

After the osmotic dehydration, specific changes in the black chokeberry indicators appeared. Thus, near to all *Aronia melanocarpa* varieties, the values of the main indicators have increased, while others have slightly decreased (Table 3).

As the values appear in the Tables 2 and 3, the ratio of 1:7, followed by 1:3 has determined the highest levels of soluble solids, sugar, vitamin C, anthocyanins and phenols intake.

In the case of the berries maintained 8 h into the hypertonic solution (*Nero* and *Hugin* varieties), a higher rate of anthocyanins removal was noticed. Anthocyanins are very sensitive to temperature; light and immersion time and they have weak stability. A longer

time of osmotic dehydration decreases the quantity and quality of fruit pigments (Landim et al, 2016). The process of osmotic dehydration leads to the stransfer of anthocyanin pigment and flavouring constituents to the osmotic solution. Due to their rich quantity of pigments and volatile consti-tuents, the osmotic solutions can be used as raw materials for developing natural additives (Osorio et al., 2007). In order to obtain accurate results, one variety of *Aronia* (*Nero*) was analysed in 2019 and 2020 (Table 4). The berries were organized both years into 2 experimental samples, following 2 directions of the research. The first sample was represented by the fruits osmotically treated and the second by the fruits without osmotic treatment. The berries of both samples were dehydrated convectively using B. Master professional dryer. Between the study of 2019 (Toma Singh et al., 2019) and that of 2020 at *Nero* variety existed few variables:

- different place of cultivation: in 2019 the *Aronia* berries of *Nero* variety were supplied by the Institute of Research - Development for Fruit Trees Cultivation, Pitesti - Maracineni, Arges County, while in 2020 the black chokeberries have been cultivated at the Institute of Research - Development for Processing and Marketing of Horticultural Products - "Horting", Bucharest.
- fruit integrity: in 2019 the fruits osmotically treated were crushed (pricking the berries - Figure 6 of the first sample and partially sectioning the berries of the second sample - Figure 7), while in 2020 for the osmotic dehydration uncrushed (entire) fruits have been used (Figure 8). In the case of the black chokeberries convectively dehydrated, without osmotic treatment, in 2019 and 2020 only uncrushed fruits were used.
- osmotic dehydration time: in 2019 the *Aronia* berries have been immersed for 4 hours into the concentrated natural juice at 50°C, while in 2020 the chokeberries have been immersed for 8 hours at 50°C and 15 hours at room temperature before their convective dehydration. The extension of fruit immersion time into the natural juice aimed to determine potential improvements as regard the weight reduction & shorter time of dehydration and higher values of sensory & nutraceutical quality of the fruits.

Figure 6. Pricking Chokeberries

Figure 7. Sectioning chokeberries

Figure 8. Uncrushed chokeberries in natural juice with inulin

Table 3. The modifications of main indicators of *Aronia* berries after osmotic dehydration in 2020

Variety	O.D.-Treatment		Total soluble solids (°BRIX)	Total sugar (inverted sugar %)	Vitamin C (mg ascorbic acid/100 g)	Total anthocyanin content (mg cyd, 3-glu/100 g)	Total phenol content (mg GAE equiv. /100 g)
Galitianka	sugar	ratio 1:2	*↑ 44.35 % - **A**	↑ 27.65 % - **A**	↑ 65.40 % - **A**	↑12.57 % - **A**	↑15.87 % - **A**
	syrup	ratio 1:3	↑ 47.83 % - **A**	↑ 70.29 % - **A**	↑ 69.10 % - **A**	↑15.63 % - **A**	↑19.92 % - **A**
Hugin	fruit juice	ratio 1:3	↑ 25.24 % - **A**	↑ 36.80 % - **A**	↑ 37.28 % - **A**	*↓4.37% - **A**	↑ 21.37 % - **A**
Merlom	fruit juice	ratio 1:2	↑ 10.16 % - **A**	↑ 21.18 % - **A**	↑ 58.88 % - **A**	↑14.32% - **A**	↑ 38.52% - **A**
	sugar	ratio 1:2	↑ 21.09 % - **A**	↑ 47.89 % - **A**	↑ 57.18 % - **A**	↑12. 01 % - **A**	↑ 39.71% - **A**
	syrup	ratio 1:7	↑ 25.00 % - **A**	↑ 55.66 % - **A**	↑ 59.1 % - **A**	↑13.17% - **A**	↑ 43.41% - **B**
Nero	fruit juice	ratio 1:7	↑ 114.75 % - **B**	↑ 77.01 % - **B**	↑ 41.26 % - **A**	↓ 2.34 % - **B**	↑ 46.16% - **B**
Viking	sugar	ratio 1:2	↑ 24.54 % - **A**	↑ 5.19 % - **A**	↑ 40.05 % - **A**	↑ 17.68 % - **A**	↑ 45.40 % - **B**
	syrup	ratio 1:3	↑ 26.77 % - **A**	↑ 10.49 % - **A**	↑ 45.36 % - **A**	↑ 18.94 % - **A**	↑ 43.76 % - **B**
O.D. Fruits Average Gain ($\bar{x}$)			**↑ 37.75%**	**↑ 39.13**	**↑ 52.62 %**	**↑ 9.51 %**	**↑ 34.90 %**
Std. Error			**8.82%**	**10.84%**	**7.14%**	**2.66%**	**s 5.12%**

Legend: *↑ - increase; ↓ - decrease of initial values (fresh berries)
A - statistically no significant difference: **B -** statistically significant difference

Table 4. Comparison between the results obtained at *Nero* variety in 2019 and 2020

Year	STAGE	Total soluble solids (BRIX °)	Total sugar (inverted sugar %)	Vitamin C (mg ascorbic acid/100 g)	Total phenol content (mg GAE equiv./100 g)
2019	initial (fresh)	18.00	26.17	33.57	1000.10
	after O.D. 1:2 - pricked berries	29.04	41.47	38.80	1420.20
	after O.D. 1:3 - sectioned berries	28.01	37.77	36.94	1306.40
2020	initial (fresh)	12.20	4.09	39.02	342.38
	after O.D. 1:7 - entire berries	26.20	7.24	55.12	500.42

As the results obtained at *Nero*, an interesting aspect is connected to the fruit integrity. Better values were obtained at the uncrushed chokeberries. Between the crushed chokeberries, the pricked berries obtained higher values than those partially sectioned. It means that the mass and solutes kinetics are favourited by the maintenance of fruit integrity. The cell membrane allows a more efficient transfer from and into berry and osmotic solution in case the fruit integrity is not affected or less affected. Since there are more benefits of uncrushed berries, it conducts to time saving & lighter labour involvement. In the study of 2020, to all *Aronia melanocarpa* varieties, after 50 h of convective dehydration, the humidity level and weight reduction gain varied on the variety, type of osmotic solution, ratio and immersion time, as is shown in Tables 5 and 6 and Figures 10 and 11. In the Table 5, the highest weight reduction gain of dried chokeberries was obtained by the osmotically treated berries of all five cultivars. Among them, the berries immersed in the osmotic solution, the ratio of 1:7, followed by the ratio of 1:3 offered the best results, for all cultivars of *Aronia melanocarpa* found in this study. The berries immersion time at 50°C has shown that the weight reduction gain increased with extension time into the osmotic solution: the berries maintained 8 h into the hypertonic solution have obtained the best results. As the values show, it's proven that, as regards the humidity level and weight reduction gain of the dried berries, the greatest results were given by the immersion time in the osmotic solution (8 hours of berries immersion have offered a higher weight reduction gain than 5 hours of immersion). Considering the berries time immersion into the osmotic solution and the ratio, the humidity level and the weight reduction gain were mainly determined by the immersion time. Thus, the comparison between *Nero* and *Merlom* varieties shows that after 8 hours of berries immersion into fruit juice despite 5 hours of immersion in the same kind of solution, at the same ratio (1:7), has clearly pointed out a decrease of 12.52% in case of humidity and an increase of 12.71% in case of weight reduction gain. As regards, the type of hypertonic solution, *Galitianka* and *Viking* has been used only inverted sugar syrup, at Hugin and *Nero* only fruit juice, while at *Melrom* both types of hypertonic solution, inverted sugar syrup, respectively fruit juice. The *Merlom* chokeberries have been immersed for 5 hours at the ratio of 1:2. The difference consisted only in the type of hypertonic solution. Watching the results becomes easy to understand that the berries immersed in the inverted sugar syrup have got a level of humidity slightly reduced (with 0.19%) and a weight reduction gain slightly increased (with 1.59%). In the Table 6, the average humidity value of the dried chokeberries osmotically treated is near half of the average humidity value found in the dried chokeberries which were not osmotically treated before the convective dehydration. The result is according to the information provided by other researchers. They have mentioned in their studies that the osmotic treatment applied to different fruits and vegetables substantially decreased the time of convective dehydration. This aspect has a direct and very important effect on energy saving and on the organoleptic and nutraceutical properties of fruits and vegetables. Khan (2012) considers that the osmotic dehydration process prior to drying reduces dehydration time, and retains many nutrients and organoleptic attributes, providing important characteristics to the finished products. So, the minimally processed fruits obtained through O.D. have recorded about 20-30% moisture reduction, while intermediate moisture fruits obtained from O.D. have recorded about 30-70% moisture reduction (Yadav & Singh, 2014). According to Sharma et al. (2003) and Falade et al. (2007) during

osmotic dehydration always water loss is favoured over solid uptake leads to mass loss of the fruit. According to their experiments, all these parameters depend on the concentration of syrup and syrup to fruit ratio. Fruit ratio from 1 to 2, there was considerable change in water loss from 18.09% to 23.18%, mass loss from 9.26% to 20.06% and solid gain from 13.59 to 16.38%.

This process leads to the transfer of anthocyanin pigment and flavouring constituents to the osmotic solution. They also used osmotic solutions containing pigments and volatile constituents as raw materials for developing natural additives (Osorio et al., 2007).

In conclusion, the inverted sugar syrup appears more efficient for the dehydration process; it is less expensive and very easy to prepare; it has a better sweetening power than that of sugar or ordinary sugar syrup itself. On the other hand, it's important to specify that a concentrated fruit juice provides more benefits to our health (vitamins, minerals, amino acids, enzymes), improving substantially, also, the sensory characteristics (taste, aroma & colour). Comparing the behaviour of *A. melanocarpa* varieties to the convective dehydration process, Tables 5 and 6 and Figures 10 and 11 reveal very good results at *Nero* chokeberries, followed by *Hugin* and satisfactory results at *Viking*. The black chokeberries have been analysed at the dried stage (finally dehydrated) as concern the humidity level and the organoleptic characteristics (colour, features, taste/aroma). The main bio-chemical indicators of dehydrated chokeberries (sugar, vitamin C, anthocyanins & total phenolics) will be the subject of further research. After dehydration, the main modifications observed were shrinkage of cells, plasmolysis and folding of the cell wall (Mayor et al., 2011; Sette et. al., 2016).

After the convective dehydration, the Aronia berries pre-dehydrated through osmosis have obtained a nice & glossy aspect (Figure 9), due to the increase of carbohydrates and their shape & porosity look better, than the *Aronia* berries classically dehydrated, without osmotic treatment (Toma et al., 2019).

The osmotic dehydration has increased elongation and decreased roundness and compactness (Suelen et al., 2016).

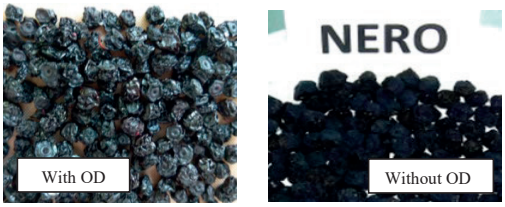


Figure 9. Dehydrated chokeberries:
Left side - after O.D.; Right side - without O.D.

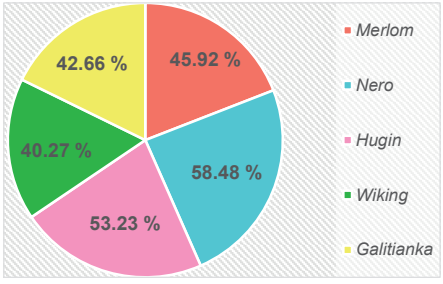


Figure 10. Average weight reduction gain* of dehydration to osmotically treated chokeberries
(*Of dried chokeberries without O.D.)

Figure 11. Weight reduction gain* after convective dried chokeberries - osmotically treated
(*Of dried chokeberries values without O.D.)

Table 5. The effects of the osmotic solution, ratio and immersion time on *A. melonocarpa* weight reduction gain

Variety	O.D.-Treatment		Humidity (U° after 50 hours of convective dehydration at 50°C) %
Galitianka	sugar syrup	ratio 1:2	6.49
		ratio 1:3	5.14
Galitianka	Non O.D.		10.14
Hugin	fruit juice	ratio 1:3	7.76
Hugin	Non O.D.		13.81
Merlom	fruit juice	ratio 1:2	6.83
	sugar syrup	ratio 1:2	6.64
		ratio 1:7	6.07
Merlom	Non O.D.		11.89
Nero	fruit juice	ratio 1:7	5.31
Nero	Non O.D.		12.79
Viking	sugar syrup	ratio 1:2	9.09
		ratio 1:3	7.54
Viking	Non O.D.		13.92
O.D. Berries Average ($\bar{x}$)			**6.74**
Std. error			**0.54**
Non-O.D. Berries Average ($\bar{x}$)			**12.51**
Std. error			**0.48**

Table 6. Levels of humidity after dehydration

Aronia melanocarpa cultivars	Osmotic solution	Ratio	Immersion time at 50°C	Weigh reduction gain* *of dried berries without O.D.
Merlom	fruit juice	ratio 1:2	5 h	42.56 %
Merlom	sugar syrup	ratio 1:2	5h	44.15 %
Merlom	sugar syrup	ratio 1:7	5 h	51.05 %
Nero	fruit juice	ratio 1:7	8 h	58.48 %
Hugin	fruit juice	ratio 1:3	8 h	53.23 %
Viking	sugar syrup	ratio 1:2	5 h	34.70 %
Viking	sugar syrup	ratio 1:3	5 h	45.83 %
Galitianka	sugar syrup	ratio 1:2	5 h	36.00 %
Galitianka	sugar syrup	ratio 1:3	5 h	49.31 %

The hypertonic solution used after the osmotic dehydration is very valuable. It is rich in fruit solutes which were released into the liquid, especially vitamins, minerals, acids, enzymes and pigments (anthocyanins), as mentioned by Ahmed et al. (2016) and Osario et al. (2007).
The Fig. 12 shows how the colour turns into a specific shade on the base of the ratio: a higher ratio determined a paler colour.

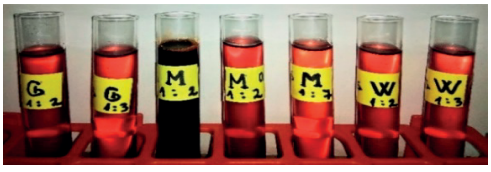


Figure 12. Stand with syrup/juice tubes after O.D.: From left to right: *Galitianka* - syrup ratio1:2; *Galitianka* syrup ratio 1:3; *Merlom* - juice ratio 1:2; *Merlom* - syrup ratio 1:2; *Merlom* -syrup ration 1:7; *Wiking* - syrup ratio 1:2; *Wiking* - syrup ratio 1.3.

The improved syrup/juice can be successfully used to prepare toppings, creams, jellies, toffies, cakes, etc. The osmotic syrup can be concentrated and reused at least 5 times without adversely affecting the fruit concentration (Bolin et al., 1983), flavour, colour, appearance and texture (Bongirwar and Sreenivasan, 1977). By partial osmosis dehydration, the product could be preserved for up to 1 year depending on conditions and packaging material and also gives the best results.

CONCLUSIONS

The *Aronia*'s berries osmotically treated before the convective dehydration obtained higher values to all bio-chemical indicators, comparing with the chokeberries dehydrated without osmotic treatment: average soluble solids gain: 37.75%; average sugar gain:

39.13%; average vitamin C gain: 52.62%; average anthocyanins gain: 9.51%; average phenols gain: 34.9%.

The increase of soluble solids conducts to a faster dehydration time and energy saving.

This aspect is very important because the vitamins (e.g., vitamin C) and other valuable bio-compounds remain in the berry's tissue and their bio - degradation due to the drying process is reduced to a minimum. The increase of sugar leads to a better taste and visual aspect, offering a longer shelf-life, as the sugar has a well-known role in food preservation.

The process of osmotic dehydration is more efficient in case the fruit integrity is not affected or the less it is. The average humidity of the dried chokeberries osmotically treated is near half of the average humidity value found in the dried fruits which were not osmotically treated before the convective dehydration. This is an important aspect for energy saving.

The highest weight reduction gain of dried chokeberries was obtained by the osmotically treated berries to all varieties.

The humidity level of the black chokeberries and their weight reduction gain was mainly determinate by the immersion time into hypertonic solution. The weight reduction gain has increased with fruits extension time into the osmotic solution.

The ratio of 1:7, followed by 1:3 has determined the highest levels of soluble solids gain, sugar, vitamin C, anthocyanins and phenols intake.

A longer time of osmotic dehydration decreases the anthocyanins' content due to their weak stability.

The inverted sugar syrup provided the highest gain of sugar and soluble solids to *Aronia*'s berries, while the concentrated fruit juice provided the best phenols' intake, vitamin C and anthocyanins to the fruits.

The hypertonic solution used after the osmotic dehydration is rich in fruit solutes released into the liquid (vitamins, minerals, enzymes, pigments, etc.)

Comparing the behaviour of *A. melanocarpa* varieties to the convective dehydration process, very good results have been obtained at *Nero* chokeberries, followed by *Hugin* and satisfactory results at *Viking.*

The differences found at the main bio-chemical indicators of *Aronia* varieties are due specially to soil and climate conditions, different technologies of cultivation and harvesting time.

The osmotic treatment is one of the best methods for fruits preservation because it improves their nutritional and sensory parameters. Moreover, since no preservatives were used, it does not affect the human body. This process is economical, gaining large savings of energy.

The osmotic dehydration can be used to reduce the post-harvest losses, to extend the shelf-life and to diversify the uses of the final products. This process could be used on small scale for the development of self-entrepreneurs and home scale industries. Consumption of such nutritional and valued products could be popularized through exhibitions and media.

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