

PARTICULARITIES OF BERRIES' DEHYDRATION BY CONVECTION

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Abstract: *In this paper there are presented the theoretical bases and the technological process's operations of berries' dehydration by convection, obtained from Romania's territory's specific spontaneous flora. There are highlighted the qualitative requirements imposed on the final products, according to the Romanian and European legislation of this domain, as well as the operation principles of the technical equipment used for dehydration by convection of berries.*

Key words: *berries, dehydration by convection, particularities, technical equipment.*

1. Introduction

Romania's geographical location and pedo-climatic characteristics, as well as the relief enabled on its territory the appearance and growth of a wide range of products which belong to the "berries" category. Recent researches showed that berries represent real "stores" of vitamins and substances useful to the human body, directly as food, but also as products used in traditional medicine, or for obtaining components of them, with the "bioproducts" status. It shouldn't be neglected the fact that berries represent, in their wide range, a component of wild fauna's food. Taking into consideration the population's broad interest in berries, many initiatives of introducing some of them into the normal agricultural crops, have and of appeared influencing some physic-chemical characteristics for obtaining as much more profit as possible.

You don't have to be a great specialist to realize that the flavour, the color and the taste of the berries from the spontaneous flora are superior to those cultivated, the multiple possibilities of using them has to stimulate the agricultural growers to persevere in their actions of improvement and growth of this type of horticultural plants.

A big disadvantage of the most of berries is represented by their perishability, so that the term for keeping them in their fresh condition is very short. That is the reason why one has been searching for solutions for preserving and using them through the whole year. At the moment there are used especially two ways of preserving them, dehydration by drying or freezing respectively.

Preserving by drying implies removing an important amount of water (which creates a favorable environment for micro-organism's growth) to a value on which

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the storage is safe but with maintaining all their biochemical characteristics. Generally, in the process of drying, the berries' water content has to be reduced from the initial values of 75-90% to the storage values of 10-18% (Table 1).

The water content of the berries: fresh and dehydrated Table 1

Id	Species	Fruit's water content [%]		Specific heat [kcal/kg°C]
		Fresh	Dehydrated	
1.	Cranberry	79-84	10-12	0,802-0,848
2.	Strawberry	83-93	10-11	0,892-0,919
3.	Blackcurrant	75-86	10-12	0,837-0,865
4.	Redcurrant	79-88	11-13	0,889-0,869
5.	Black cherry	78-86	12-14	0,850-0,867
6.	Sea buckthorn	82-84	11-13	0,826-0,852
7.	Blackberry	75-80	10-12	0,896-0,904
8.	Raspberry	75-91	10-12	0,805-0,840
9.	Rose hip	32-47	10-11	0,682-0,706

In this way a concentration of 4-6 times of the other useful components is provided, the volume and the weight are clearly reduced, the costs of the handling, transportation and storage are reduced proportionally, and their processing is made in hygienic and sanitary conditions according to the specific restrictions of the food domain.

The disadvantages of preserving berries by drying and convection are related to: the relatively high price of the equipment, especially in the case of warm air drying, high expenses for fuel used in producing the drying agent, the need of highly qualified service staff, taking evasive actions for the stuff (fire risks) [3], [4], [6].

2. Material and Method

2.1. The Particularities of Berries' Dehydration by Convection

Berries' dehydration can be made based on more principles, of broad interest being the drying by convection.

Convection represents the transfer of energy from a fluid current (liquid or gas) and the surface of a solid object having the character of a molar transfer. In the

immediate wall's vicinity, in the liquid film named "thermal cross flow", in which a temperature drop takes place, the heat is transferred by conduction, in the other areas of the fluid current, the convection itself is made by mixing the fluid flow with transfer of kinetic energy and impulse energy.

The fundamental law of convection was established by I. Newton:

$$Q = \alpha \cdot S (t_p - t_f) \cdot \tau \quad [J] \quad (1)$$

where:

Q is the quantity of the heat transferred by convection [J];

α – the fluid's coefficient of thermal convection [W/h*m²*K];

$t_p - t_f$ – the temperature difference between the wall's temperature (the solid body's surface) and the fluid's temperature [°C (K)];

S – the area of the contact surface between the fluid and the solid body [m²];

τ – the duration of the process [h].

In the process of berries' drying the convective heat transfer is completed with mass transfer and represents an irreversible

thermodynamic transfer. It results that drying by convection (from the agent to the product) is the process in which the product subject to dry (the berry) comes in contact with the drying environment, from where it takes its energy needed in the process.

The molecules of the drying environment, with the high level of energy, oscillation and translation gives a part of the molecular caloric energy to the products meant for drying. At the same time, the drying environment takes the humidity given by the product, removing it from the dryer [1].

So, the berries' drying by convection can be applied in the following ways:

- Drying in heated air current directly and with circulation in the fluid's mass by natural sorting of the berries which are placed on the dryer's drying surface;
- Drying in heated air current indirectly and with forced circulation through the berries' mass, which have fixed position of move inside the dryer;
- Drying in heated air current by amalgamating it with the fuel's waste gases and with forced circulation in countercurrent with the products which are moving inside the dryer.

For the berries' dehydration a large variety of methods and technologies is used. So, the drying by convection variants (with heated air) in berries' case are the following:

- The artificial in heated air drying, heated directly and with natural sorting in the fruit's mass, which stand on the dryer's drying surface;
- Drying in heated air current indirectly and with forced circulation through the berries' mass, which have fixed position or move inside the dryer;
- Drying in heated air current by amalgamating it with the fuel's

waste gases and with forced circulation in countercurrent with the products which are moving inside the dryer [4].

It can be observed the fact that in the case of berries dried by convection, as a drying environment, is used, mainly, the heated air. But, it can also be used overheated steams or even inert gases (CO_2 or N_2), if they do not influence the quality of the product.

2.2. The Qualitative Requirements Imposed on Berries for Dehydration by Convection

The berries meant for the dehydration by convection process have to be whole, healthy, fresh, without traces of mole, without signs of fermentation, without mechanical damages, or damages made by diseases, insects or other pests, free of foreign taste or/and smell. Depending on how the berries compliance with these requirements, they can stand for the Class extra, Class I, and Class II. Also, the package which comes in contact with the dehydrated berries has to be made out of materials which compliance with the hygienic-sanitary standards.

The dehydrated by convection berries' organoleptic proprieties are specified in the Table 2.

In the case of berries which are to be dehydrated by convection may appear smashing damages, mould, fermentation, or early rotting. Also, among the healthy fruit can exist foreign matters of plant origin, or fruit which is dehydrated because of insects or mites infestation. In Table 3 are presented the maximum limits of the allowed defects in the case of dehydrated by convection berries.

Table 2

The dehydrated by convection berries' organoleptic properties

Characteristics	Admissibility conditions		
	Class Extra	Class I	Class II
Aspect	Berries which are whole, dehydrated of near size (within the same class of quality), healthy, clean (practically without visible foreign matter), without traces of mole, without signs of fermentation, without mechanical damages, without traces of insects, mites or other parasites, without foreign matter, without toxic plant protection.		
	Whole dehydrated berries, of high quality, practically with no defect, except for the superficial, small alterations, on the condition that they do not influence the general aspect, the quality and the preservation of the product and that they are within the maximum limits of the allowed defects.	Whole dehydrated berries, of good quality, with slight defects, on the condition that they do not influence the general aspect, the quality and the preservation of the product and that they are within the maximum limits of the allowed defects.	Whole dehydrated berries which are not within the Class Extra and Class I, but correspond to the abovementioned common features. There are permitted whole dehydrated berries, with defects which are within the maximum limits of the allowed defects, but which keep the essential characteristics of quality and aspect.
Colour	Yellow-orange to dark orange, dark rust, characteristics of the varieties of berries.		
Consistency	Whole dehydrated berries medium-hard.		
Taste and smell	Pleasant, characteristic for whole dehydrated berries', without foreign taste or smell (of fermentation, mole, burning).		

Table 3

The maximum limits of the allowed defects in the case of dehydrated by convection berries

Allowed defects	Admissibility conditions		
	Class Extra	Class I	Class II
Rotted berries, % (mm), max.	2	3	4
Berries attacked by insects or mites, % (mm), max.	1	2	3
Deviation from the main color, % (mm), max.	2	5	10
Dehydrated, broken berries, % (mm), max.	1,0	5	10
Pieces of dehydrated berries, % (mm), max.	1,0	3	6
Foreign matters of plant origin, % (mm), max.	0,25	0,50	1,0

Also in the Tables 4 and Table 5 are mentioned the physico-chemical and microbiological characteristics of the dehydrated by convection berry.

Table 4

The physic-chemical and microbiological characteristics of the dehydrated by convection berries

Characteristics	Admissibility conditions		
	Class extra	Class I	Class II
Humidity, %, max.	5	5	5
Ash insoluble in hydrochloric acid HCl 10%, g/kg, max.	0,5	1,0	1,0

Table 5

The physic-chemical and microbiological characteristics of the dehydrated by convection berries

Characteristics	Admissibility conditions		
	Quality extra	Quality I	Quality II
Salmonella, present/25g	absent	absent	absent
Staphylococcus coagulatus-positive, ufc/g	absent	absent	absent
Bacillus cereus, ufc/g	max. 10	max. 10	max. 10
Yeasts and moulds, ufc/g	max. 100	max. 100	max. 100
Coliform bacteria, NCP/g	max. 10	max. 10	max. 10
Echerichia Coli, NCP/g	absent	absent	absent

The heavy metal and pesticide content of the dehydrated berries has to be within the maximum limits according to the rules in force [5].

2.3. The Technical Process of the Berries' Dehydration by Convection

The general scheme of the technical process of the berries' dehydration by convection is shown in Figure 1.

The most important issues, followed in each of the specified operations in Figure 1, are to be further explained.

• Reception

The Reception represents the quantity and quality control of the acquired berries.

The aims persuaded by the berries' quality reception are: the degree of freshness, the consistency, the degree of maturity, the state of health, the external appearance (shape, size, color) taste and smell, the dry substance.

For example, the quality control of the cranberries is made by an organoleptic exam and laboratory tests, according to STAS 6441-88 "Fresh fruit and vegetables. General methods for quality evaluation" and the collection of samples are made according to SR ISO 847:2004.

• Sorting

The sorting at this stage has as an aim the removal of the berries which are attacked by diseases, altered, mouldy, and with eventual foreign matters. In this way, it is avoided the excessive load of the wash water with foreign matters, the infection of the wash water, the healthy berries and the equipment.

This operation has to be performed according to the conditions of the Good Hygiene Practice and Good Production Practice, so that in the process of production are introduced only the fresh, clean and healthy berries.

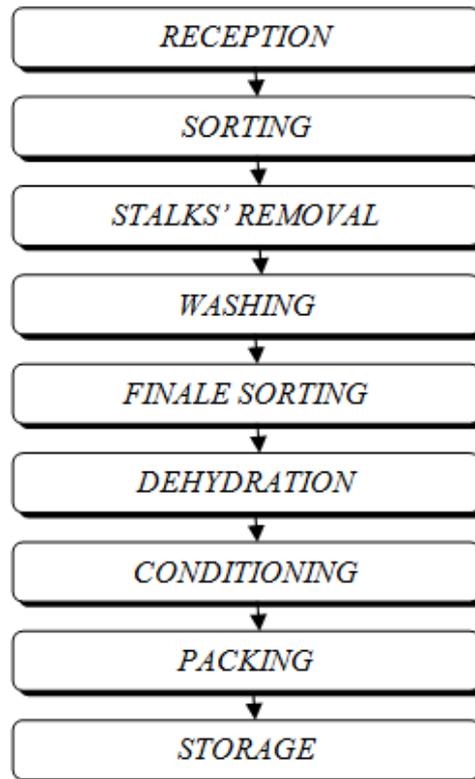


Fig. 1. *The Scheme of the techprocess of the berries' dehydration by convection*

• **Stalks' removal**

The stalks' removal is performed manually, on sorting bands or tables.

• **Washing**

The washing of berries meant to be dehydrated has as an aim the removal of the mineral impurities (sand, dust, dirt), plant debris, as well as a significant part of the micro flora and of some contaminants.

The water used for the berries' wash has to meet the quality standards for drinking, complying with the conditions laid down by the Law 458 dated July 8, 2002 about the quality of the drinking water, modified and completed with the law No. 311/2004 which transposes the Council Directive No. 98/83/CE. So, the main characteristics of the drinking water are:

- Sensory characteristics: odorless, colorless, free of any foreign taste, free of any particulate matter;
- Physical characteristics: the pH has to be between 6.5 and 9.5, the total minimum hardness 5° (German degrees; one German degree represents 10mg/l CaO or 1,142 mg/l MgO);
- Microbiologic characteristics:
 - Uncontaminated from the microbiologic point of view (Escherichia Coli/ 100ml - absent;
 - Enterococci (faecal Streptococci)/100ml - absent;
 - Clostridium perfringens 100ml - absent).

The washing of the berries is performed in washing machines with showers, for which the recommended water pressure is between 1 and 1.5 at.

The efficiency of the berries' washing is visually verified or determined by the number of mezophilic aerobic bacteria, before and after the wash. It is considered that the washing is relevant if the number of the mezophilic aerobic bacteria decreases for at least 10 times. Otherwise, the process of washing the berries has to be intensified by repeating the operation. By minimizing the number of microorganisms on the raw material, at this stage, it is avoided the detrimental actions of the microorganisms during the technological process's further operations and one allows

the achievement of some finished products proper from the microbiologic point of view.

• **Finale Sorting**

The berries' final sorting consists in removing the improper specimens and the foreign matters left, eventually, after the washing. The operation is manually executed, after the visually inspection, on sorting tables.

• **Dehydration**

Table 6

The characteristics of the pilot convective dryer and the tunnel convective dryer

	Specifications / Characteristics	The parameters of the dehydration process	Conclusions
The Pilot Convective Dryer	<ul style="list-style-type: none"> - The berries, whole, are placed in the pilot convective dryer's drying boxes in a uniform thickness, so that the average loading to be around 5.0 kg/m²; - The air speed has to be in the range 3.2 and 3.5 m/s. 	<ul style="list-style-type: none"> - The initial air temperature: 70-73 °C; - The initial air humidity: 20-25%; - The final air temperature: 40-45 °C; - The final air humidity: 60-65%. 	<p>The final humidity of the dehydrated berries has to be 5%. After the dehydration, the berries have to be let to dry in the drying boxes (in the pilot convective dryer's case) or on the gridiron (in the tunnel dryer's case), at room temperature, after that they are unloaded with the help of some small wooden shovels.</p>
The Tunnel Convective Dryer	<ul style="list-style-type: none"> - The berries, whole, are placed in uniform thickness on the gridirons, so that the average loading to be about 5.0 kg/m²; - The air speed has to be in the range 3.2 and 3.5 m/s; - The berries drying is performed in echicurrent (the movement of the carts is performed in the same direction as the air's movement). 	<ul style="list-style-type: none"> - The air temperature in the area where the carts with berries are introduced in the dryer: 70-73 °C; - The air humidity in the area where the carts with berries are introduced in the dryer: 20-25%; - The air temperature in the area where the carts with dehydrated berries leave the dryer: 40-45%; - The air humidity in the area where the carts with dehydrated berries leave the dryer: 60-65%. 	

• **The Conditioning**

The dehydrated berries conditioning consists in:

- Removing the residual stalks;
- Removing the improper, from the qualitative point of view, specimens.

The residual stalks' removal is performed by using a sieve shaker machine. Then, the dehydrated berries are placed on transporting bands, for visual control and removal of improper species or eventual impurities.

• **The packing**

The dehydrated berries' packing is performed in the following sales packages types: polyethylene or polypropylene bags sealed by welding, plastic casseroles for food-grade, tightly closed, or other packages which ensure the quality of preservation.

The sales packages for the dehydrated berries can have a net content of:

- 0.125 kg, 0.250 kg, 0.500 kg, 1 kg, 1.5 kg;
- more than 1.5 kg.

The content of each package has to be uniform, regarding the color, size, variety, and quality of the dehydrated berries.

The packages which come into direct contact with the dehydrated berries, have to be made out of resistant material, clean, free of foreign smell approved under the legal in force sanitary provisions and have to meet the following requirement:

- to ensure the preservation of the product's nutritional, organoleptic, and physico-chemical qualities, also, they have to be waterproof;
- to protect the product from microbiologic or of different nature contamination, not to have inscribed parts in direct contact with the product;
- must be new.

• **The Storage**

The dehydrated berries' storage is performed in clean, dry, well-ventilated places, without rodents or insects, at a maximum temperature of 15 °C, and a relative air humidity of 65-75%.

2.4. Types of Technical Equipment used in Berries' Dehydration by Convection

Taking into consideration the importance of fruit's dehydration by convection (including berries), there are used many types of technical installations that ensure this process; they are based on the following principles.

- Drying in heated air current directly and with circulation in the fluid's mass by natural sorting, of the berries which are placed on the dryer's drying surface;
- Drying in heated air current indirectly and with forced circulation through the berries' mass, which have fixed position or move inside the dryer;
- Drying in heated air current by amalgamating it with the fuel's waste gases and with forced circulation in countercurrent with the products which are moving inside the dryer.

For the berries' dehydration a large variety of methods and technologies is used. So, the drying by convection variants (with heated air) in berries' case are the following:

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- Drying in heated air current indirectly and with forced circulation in through the berries' mass, which have fixed position of move inside the dryer;

- Drying in heated air current by amalgamating it with the fuel's waste gases and with forced circulation in countercurrent with the products which are moving inside the dryer [3].

3. Results and Discussions

Drying is a process of simultaneous mass and heat transfer, being influenced by a series of factors relevant for obtaining a short drying time, a high quality of the finite product and low energy consumption.

The factors which influence the berries' drying process take into account:

- The material to be dried (its nature, quantity, shape and dimensions, initial humidity, the humidity binding form, bulk density, the temperature of the material to be dried, thermal and to oxygen sensitivity, the chemical aggression, brittleness and abrasiveness, toxicity and flammability of the material to be dried);
- The used drying agent (the nature of the drying agent and the way it is obtained, the temperature, the relative humidity and the pressure or the drying agent, the balance humidity air - product, the air's speed and moving direction, the drying agent's flow, the drying agent's impurities content);
- The technical drying installation's particularities (the maximum allowed temperature, the drying duration, the operation-mode, the dust production and its recovery, the drying agent's evacuation or recirculation, the dryer's type).

4. Conclusions

- Berries' preservation by dehydration by convection has many advantages,

starting with the probability of safe keeping for a long period of time, preserving the valuable biochemical components, maintaining the color, flavor, and other physical characteristics;

- The disadvantages regarding the berries' preservation by dehydration by convection are about the high costs of the dehydration process, caused by the price of the technical installations and fuels, the need of highly qualified staff etc.;
- The berries' technical process of dehydration by convection is of medium complexity, involving mechanized operations as well as operations which have to be performed manually, like removing parts of stalks or fruit with defects;
- The qualitative requirement regarding dehydrated berries are rigorous, being included in European norms and Romanian standards. This offers the consumers of this type of products the similar assurance as that of any type of alimentary product.

References

1. Călinescu C.F., 2013. Researches regarding adopting drying technologies in solar installations of horticultural products (in Romanian). Doctoral Thesis, Bucharest, Romania.
2. Mănișor P., Bria N., Ruxandru C., Florescu C., 1967. Machines and technical installations for agricultural products' drying and conditioning (in Romanian). Agro-Silvică Publishing House, Bucharest, Romania.
3. Mihăilă C., Caluianu V., Marinescu M., Dănescu Al., 1982. Processes and industrial technical installations (in Romanian). Technical Publishing

- House, Bucharest, Romania.
4. Paraschiv A., Bărtoiu H., 1977. Methodes of vegetables and fruit's drying into the household (in Romanian). Ceres Publishing House, Bucharest, Romania.
 5. <https://issuu.com/ccivil/docs/tehnologii>
 6. http://www.scrigroup.com/term/caldura-specifica-a-fructelor-de-padure_s62.php. Accessed on 10.06.2017.