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THE STUDY REGARDING CONVECTIVE DRYING PROCESS FOR BERRIES

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Abstract: *The paper presents a method of preserving berries by convective drying. During the drying process decresing the water percentage leads concentrating the other components and forming an unfavorable environment for developing the microorganisms. It is created the possibility of increasing shelf life of berries and obtaining food rich in nutrients. Berries alteration is caused by the action of modifiers agents such as biological agents (microorganisms), biochemical agents (endogenous enzymes) and physical and chemical agents (air, light, or chemicals with antiseptic or antioxidant role. The kinetics of carrying the convective drying process and the thermal influence on the drying process kinetics are shown in the paper. In order to choose an economical drying regime, optimizing the berries drying regime will require finding a minimum drying duration with a minimum consumption of heat.*
Keywords: *berries, conservation, convective drying, modifiers agents*

1. INTRODUCTION

Berries are very popular on the one hand due to their specific taste and flavor and on the other hand due to their special nutritional qualities. The rich content in vitamins (A, B_1, B_2, B_6, C, D, E, K, PP) and nutrients (protides, lipids, carbohydrates, minerals) of berries complement and diversify human diets. Having rich water content, the perishability of the berries is high.
Finding conservation methods by which the organoleptic properties and chemical composition are maintained as close to the fresh fruit is the result of lengthy research. By applying different conservation technologies for berries, the goal is to reduce the intensity of metabolic processes, in particular respiration and sweating, as well as the activity of pathogenic microorganisms which contribute to the onset of degradation processes.
The most popular methods for preserving berries are those based on the use of low temperatures (refrigeration and freezing) and dehydration.

2. MATERIALS AND METHODS

The conservation of berries by convective drying process is a method used to create conditions that increase their shelf-life, as well as increasing their nutrient value. This method of heat conservation for berries is applied to reduce or even disrupt vital functions of microorganisms and maintaining their organoleptic and nutritional characteristics unchanged as much as possible. Berries' shelf-life is influenced by intrinsic and extrinsic factors.

2.1. The intrinsic factors which affect the shelf life of berries are: chemical composition and their physical and thermo physical properties. The dehydration process is influenced by the nature of the berries, by the behavior of their properties under certain temperature conditions, by the degradability of certain active principles under the influence of humidity, by the initial and final moisture content and also by the form in which water is found in berries.
Water status (free or bound) influences the activity of microorganisms in the fruit. Thus, during storage, free water must be maintained at specific values for the species in order to keep product-specific quality attributes similar to the fresh fruit and to ensure the cells and tissues turgidity.
From a chemical point of view, berries contain water and dry substance (organic and mineral substances).
Fresh fruit water content varies according to species, ranging between 70...95%.
Sugars form the main mass of dry substance components of berries (about 90%), the difference being represented by organic acids, tannins, bitter substances and minerals.
The most common sugars are monosaccharides (glucose, fructose), disaccharides (sucrose) and polysaccharides (cellulose, starch and pectin).

The thermo physical characteristics of berries that influence their shelf life are the following:

•*Specific heat ($C_{sp.}$)* is the amount of heat required to raise the temperature of one kilogram of product by 1 °C. The specific heat for berries has large values due to their high water content. The high values of specific heat lead to an intense metabolic activity, quantitative and qualitative losses in fresh fruit, so the knowledge of the specific heat of each fresh fruit's species is required in order to establish optimal storage temperature.

The specialized literature states that the average values of specific heat for the planted berries are between 0.85…0.90. This is expressed in J/ kgK and Kca1/ kg°C and is calculated using the relationship:

$$C_{sp.} = \frac{100 - (0{,}66 \cdot SUT)}{100} [J/kgK] \quad \textbf{(1)}$$

where: C_{sp}. is the specific heat, S.U.T. is the total dry content, in%, and 0.66 is the specific heat of S.U.T.

•*Specific weight ($G_{sp.}$)* or density is the ratio between the berries' mass and volume, being determined by placing them in water at 4 °C, or in a standard solution. The berries' specific weight varies with the species, being caused by the proportion of chemical components and pedoclimatic conditions.

•*Thermal conductivity* is the property of transmitting heat through the mass of the products at a variation in temperature. It is expressed in W/ mK or kcal/ m°C. Berries, having high water content and a low volume of intercellular spaces, have a higher thermal conductivity. As the thermal conductivity gets higher, physiological processes such as breathing and sweat flow faster, causing a lower duration of storage for fresh fruits [1].

2.2. The extrinsic factors affecting shelf-life of berries are the following: biological agents (microorganisms), biochemical agents (endogenous enzymes) and physical and chemical agents (air, light, heat, etc.).

•*Biological agents* which contribute to the alteration of berries are represented by the microscopic fungi and bacteria. Contaminants among the microscopic fungi are molds and yeasts. Molds are fungi with multicellular mycelious structure, usually having powerful degradation power, some of them produce toxins, and through development, they form filament colonies, in various colors. The molds that cause alterations of berries are the ones from *Rhisopus*, *Mucor*, *Aspergillus*, *Penicillium* genera. Yeasts are microscopic unicellular fungi which have a low share in the total microflora and play a minor role in the berries' alteration and do not produce toxins. They decompose the different components of the fruit, causing fermentation. Bacteria are microorganisms with a great power of alteration, with an increased rate of proliferation, some of them being strong toxin producers. Pathogenic or optional pathogenic microorganisms like: *Escherichia*, *Salmonella*, *Shigella*, *Yersinia enterocolitica*, which cause disease or food poisoning may appear accidentally in the fruit's microbiota [2].

•*Biochemical agents (endogenous enzymes)* are a second major class of modifying agents, along with microorganisms which lead to the berries' alteration. Biochemical changes are triggered by the intracellular anaerobic respiration.

•*Physical and chemical agents.* Atmospheric oxygen and light produce undesirable color changes to the berries, shallow dehydration and weight loss, followed by unpleasant commercial aspect. The heat has the effect of speeding the reactions caused by other modifier agents, determining loss of quality and berries' alteration.

2.3. Kinetics of convective drying process

Berries' dehydration leads to the partial removal of their moisture levels. In the study and control of drying processes, product moisture is expressed through the notion of *specific moisture content* which can be:

- Specific humidity content related to dry moisture:

$$W_{usc} = \frac{m_w}{m_{usc}} \cdot 100[\%] \quad \textbf{(2)}$$

where: m_w is the mass of water contained in the product, in kg, m_{usc} is the mass of dry product, in kg.

- Specific humidity content related to wet material:

$$W_{um} = \frac{m_w}{m} \cdot 100 = \frac{m_w}{m_{usc} + m_w} \cdot 100[\%] \quad \textbf{(3)}$$

where: m_w is the mass of water contained the product, in kg; m is the mass of wet product, in kg.

Between these two ways of defining the moisture content there are the following transformation relations:

$$W_{usc} = \frac{W_{um}}{100 - W_{um}} \quad \textbf{(4)}$$

$$W_{um} = \frac{W_{usc}}{100 + W_{usc}} \quad \textbf{(5)}$$

The humidity reduction must not exceed certain limits, as under a certain amount considered as critical, irreversible changes occur during dehydration that make the fruit lose quality. Thus it is considered that free water must be eliminated for the most part, in order to slow the development of chemical processes and microorganism's activity.

However, bound water must be preserved, otherwise by losing its hydrophilic groups of proteins, cellulose and other substances, it tends to form hydrogen bridges between them that cannot be undone after rehydration, hence these irreversible changes reduce the fruit quality [3].

Drying speed $\dot{m}$ is determined as the mass of moisture per area unit in a certain time unit and is expressed by the following relationship:

$$\dot{m} = \frac{dm_{um}}{S \cdot d\tau}\left[kg / m^2 \cdot s\right] \quad \textbf{(6)}$$

Drying speed depends on the following factors: the nature of the product, its form, the initial and final humidity values, drying agent parameters (temperature, speed, humidity), and the method by which the connection between heat and product is established.

The duration of the drying process can be determined roughly based on the drying curve, that estabilishes the link between humidity and the drying time. The drying curve shows two distinct zones, separated by a critical point. The first area represented by a straight line corresponds to the first constant rate drying period and the second, represented by an exponential curve, during which drying speed decreases continuously, corresponds to the second period of drying. In the first period of drying, drying speed depends only on the drying temperature regime and also on the drying agent's humidity and speed. If you maintain a constant agent drying humidity, then the amount of moisture evaporated from the product is proportional to the amount of heat absorbed by product:

$$dm_{um} = \frac{dQ}{r}\left[kg\right] \quad \textbf{(7)}$$

where r is the latent water vaporization heat in kJ/ kg.

According to Newton's equation, the heat quantity absorbed by the product in the $d\tau$ time interval is:

$$dQ = \alpha \cdot S \cdot \left(t - t_{\sup}\right) \cdot d\tau\left[kJ\right] \quad \textbf{(8)}$$

where α is the coefficient of convective heat transfer in W/ m^2K, S is the product's area undergoing drying, in m^2, t is the thermal agent's temperature in °C; t_{sup} is the product's drying surface temperature, in °C. By substituting the expression of heat quantity given by equation (8) in equation (7), the drying rate for the first period is obtained:

$$\dot{m}_I = \frac{dm_{um}}{S \cdot d\tau} = K_t \cdot \left(t - t_{\sup}\right) \quad \textbf{(9)}$$

where $K_t = \frac{\alpha}{r}\left[kg / m^2 sK\right]$ represents the substance transfer coefficient.

For the second drying period it is recognized that the drying speed is proportional to the difference between free and equilibrium moisture, the speed equation for this period being the following:

$$\dot{m}_{II} = \frac{dm_{um}}{S \cdot d\tau} = K_u \cdot \left(\dot{W} - \dot{W}_e\right) \quad \textbf{(10)}$$

where K_u is the evaporation coefficient, and $\dot{W}$, $\dot{W}_e$ representing the humidity of the product at a certain time and in in equilibrium. The kinetics of the dying process is mostly influenced by the thermal regime, the thermal regime being changed over time so that drying takes place on a non-stationary basis. The drying regime is characterized by three main parameters: temperature, relative humidity and speed of drying. These parameters influence both the time necessary for the drying process, as well as the quality of the product that is to be dried.

Considering that the fruit is a capillary-porous medium, experimental analysis has indicated that increasing the temperature of the drying agent from 15°C to 45°C produces an increase in the drying rate of about 2.5 times (Figure 1). Increasing the relative humidity of the drying agent from 17.7% to 75.8% causes a reduction in the drying rate o almost almost 4.5 times (Figure 2), as well as an increase in the diffusion coefficient, the relative humidity influencing the rate of drying, especially in the second part of the process.

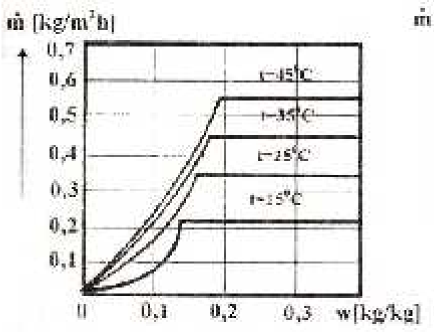

Figure 1 The effect of the drying agent temperature on drying speed

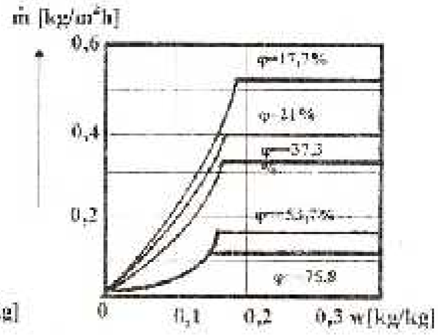

Figure 2 The effect of the drying agent humidity on drying speed

At the same time, increasing the speed of the drying agent (under constant temperature and relative humidity) leads to an increased intensity in the first period of the drying process, while increasing the temperature of the drying agent at a relatively constant temperature, determines an increase in both the drying speed and the diffusion coefficient [4].

3. CONCLUSIONS

- The peculiarities of convective drying process (time, temperature and speed) are influenced by the physical and thermophysical properties of berries and dthe rying agent parameters.
- In order to ensure storage stability and to improve the quality and nutritional value of berries at the same time, without affecting the structure, one can combine the classical convective drying with non-conventional drying methods, based on the use of microwave, infrared radiation and high frequency currents. The advantages of using combined methods of convective drying with microwaves, infrared and high frequency currents consist of rapid heating and high energy efficiency, a well as preservation of fruit nutrition and the possibility of automation and control of the drying process.
- In order to choose an economic drying regime some experimental research is needed for finding the minimum duration of drying with a minimum consumption of heat, depending on the species of berry that is subject to dehydration. Applying the convective drying process techniques requires a shorter duration for the thermal processing of berries and is associated with implications both in terms of reducing the energy costs and preserving the active biological components.

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