THEORETICAL RESEARCH ON THE TRANSFORMATIONS UNDERGONE BY SOME FOREST FRUITS BY MEANS OF THEIR KEEPING IN A DEHYDRATED STATE

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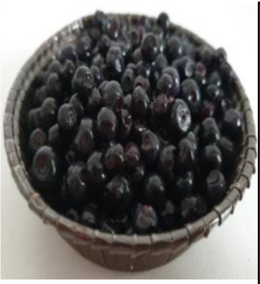
Abstract: *The paper presents a few theoretical aspects on the transformations undergone by forest fruits both while kept in a fresh state, immediately after harvesting, and throughout the technological process of conservation by dehydration. Forest fruits are rich in sugar, vitamins, mineral substances, and the fresh ones have a high water content (85-95%), which can lead to favourable conditions for the growth of the microorganisms responsible for their degradation. Drying (dehydration) is achieved by the evaporation of the water which gradually reaches the surface of the product to be dehydrated, the most common drying method being the one by convection at atmospheric pressure (hot air drying).*
Keywords: *forest fruits, conservation, dehydration.*

1. INTRODUCTION

Berries are small, round, brightly coloured, sweet or sour, seedy and edible fruits. The most common forest fruits are: raspberries, blueberries, blackberries, currants. Fresh fruits are one of the indispensable components of rational human nutrition. The dietary value of the fruits consumed in a fresh state is due to their chemical components, easily accessible to the human body, to which a series of exciting gustatory, olfactory and visual factors add, which make them relished at any time of the day or season. Dried berries are a concentrated source of nutrients. Rich in fibre, abundant in minerals and withal in carbohydrates and calories, they are recommended in the died only in small quantities [5].

2. MATERIAL AND METHOD

- **Blueberry bush** (*Vaccinium myrtillus L.*)is a shrub of the *Ericaceae* family. It may be encountered in Europe, northern Asia, Greenland, western Canada and western United States.
- *Description of the species*: it is a small, think, branchy shrub, with a green, 30-60 cm-long stem. The leaves are short-petiolate, small, oval denticulate (jagged on the margin), green on both sides.



DEHYDRATION (+45…+50^{0}C)- *active principles:*
-Blueberries contain: tannin, pectin, myrtillin, sugars, provitamin A, vitamin A, C, E, vitamins of the B complex, organic acids (citric, malic, oxalic, succinic, lactic). Blueberries are richest in the antioxidants called anthocyanin (the pigment responsible for the blue colour of these berries), copper (which strengthens immunity and plays an antibacterial role), selenium, zinc, iron (which promotes immunity by increasing the hemoglobin and the oxygen concentration in the blood).

a) fresh blueberries b) dehydrated blueberries

Figure 2.1.: Blueberries

The flowers are reddish green, white or rosé, with bell-shaped joined petals, placed on the leaves. It blossoms in May-June.
The fruit, called *blueberry*, is a berry of dark-blue or haze-blue colour, round in shape, with a diameter of 0.5-0.6 cm, juicy, with purple juice, with an agreeable sweet-sour taste.

- *Spreading area*: the blueberry grows in the alpine regions up to the altitude of 2000–2500 m, especially on shady and damp slopes, in coniferous forests, mountain meadows, on cliffs and siliceous soils.
- *Time of harvest*: the fruit are harvested during their maturity period (when ripe) in July-September,

being consumed either dried or fresh.

- *Properties*: blueberries have astringent properties due to the tannin, with a significant content of antioxidants, have antibacterial activity, favourably modifying the intestinal pathogenic flora, as well as antidiarrheal. Blueberries are used to obtain *myrtillata,* a highly appreciated alcoholic beverage, or in cakes and other sweets [6].

- **Red currant** (*Vaccinium vitis idaea*) is a medicinal plant from the Ericaceae family.
- *Description of the species*: the shrub has green leaves only in the warm season; in the autumn, they turn yellow and fall to the ground.

The red currant appears as shrubs with a height of 1-2 m. The bark of the young stems is covered with hairs, and the bark of the older stems is reddish brown, with darker shades, to greyish black. The leaves, serrated on their margin, are relatively round, heart-shaped, with a length of 4-10 cm and a width of 3-7 cm. The flowers, of greenish yellow colour, with a length of 2-2.5 mm, are grouped in clusters made up of 4-8 flowers. The fruit of this plant, of the berry type, are juicy spherical berries, with sour taste, of red or pink colour, with a diameter of 6-11 mm, each fruit containing several seeds.

DEHYDRATION (+45…+50^{0}C)-*active principles:*
-red currant contains tannins, vitamins of the B complex, traces of green volatile oil (up to 0.2%), organic acids (citric, malic), pectin, sugars, anthocyanins, flavonoids, pectins, calcium, iron, potassium, phosphorus, vitamin PP, vitamin C, potassium and magnesium (these substances contribute to the boost of immunity, to the good functioning of the nervous and cardiovascular system, but also to the treatment of the convalescent states).

a) fresh red currants b) dehydrated red currants

Figure 2.2.: Red currants

- *Spreading area*: it grows at high altitudes, in alpine meadows or glows and less often in shaded places (with spruce firs). The cranberry grows on skeletal soils, strongly acidic, having low demands from the soil. It also withstands dryness. In Romania, the cranberry grows in the high areas of the Carpathians Mountains, especially those of Transylvania.
- *Time of harvest*: the red currant fruit ripen in July. An important aspect is also that the harvesting period of the red currant varieties is very short, about 10-12 days.
- *Properties*: red currants have a high content of coumarin substances, are rich in nutrients, have very good properties on the blood vessels, decrease the risk of blood clotting and combat atherosclerosis. Red currants contain glucose and fructose (in a proportion of 4-11%), but also phenolic compounds, organic acids, vitamins (A, B, C, K, PP), mineral salts, tannin, folic acid, pectins. The caloric content is of 56 cal per 100 g fruit, and the glycaemic index is 25 [7, 8].

- **Sea buckthorn** (*Hippophaë rhamnoides* L.), is a highly branched and thorny shrub that grows, in Romania, starting from the coastal sands and gravels to the mountainous regions, sometimes forming quite expanse groves and shrubs.

DEHYDRATION (+45…+50^{0}C)- *active principles:*
-the buckthorn pulp is very juicy, with a granular appearance, leaving oil spots, with a pleasant and aromatic odor, with a sour and astringent taste; it contains large amounts of vitamin C, vitamins A, B1, B2, K, F and P, microelements, essential fatty acids; it contains dry substance in proportion of only 10-20%, the rest of the composition consisting in sugars, organic acids, pectins, flavonoids, cellulose, proteins, oil, beta-carotene, phosphorus, calcium, magnesium, potassium, sodium, iron, all the B-vitamin complex.

a) fresh sea buckthorn b) dehydrated sea buckthorn

Figure 2.3.: Sea buckthorn

- *Description of the species*: the leaves are whole, linear-lanceolate, of greyish-green colour on the upper side and whitish-silver on the lower one. The flowers, dioecious, are small and they appear before the leaves; The fruits are ovoid or globular, 5-10 mm long and 4-8 mm wide, of green colour at the beginning and yellow-orange at full maturity. The plant grows to 2–5 m, has a dark-brown bark. It produces "false" fruit – ovoid, fleshy, orange, 6–8 mm clusters, with a very tough seed. The fruit can remain on the branches over winter. The shrub fructifies for 20-25 years and shoots very strongly every year.
- *Time of harvest*: the proper harvest time for the sea buckthorn is late autumn, even after the first frost. Then, the fruit is ripe, has reached maturity, and its therapeutic properties, due to the large amounts of vitamins, are perfect.
- *Properties*: only ripe fruits are used, both in a fresh and dried state; they are harvested immediately after

ripening until the first frost; in a raw state, they have a sour-astringent taste. Sea buckthorn is used both in food industry, in silviculture, in pharmacy, and as ornamental plant. The buckthorn fruit contain twice as much vitamin C as the rose hip and 10 times more than citrus fruits. In ripe fruits, the content exceeds 400–800 mg per 100 g fresh juice. Other vitamins present in the fruit are A, B1, B2, B6, B9, E, K, P, F. We also find cellulose, beta-carotene (in a much higher percentage than in carrot pulp), microelements such as phosphorus, calcium, magnesium, potassium, iron and sodium, complex oils etc. [9].

2.1. Conservation of forest fruits by drying and dehydration

Drying or dehydration as a product conservation method is based on removing a certain amount of water from the fruit by means of heat, until the physical-chemical state which blocks the vital activities and the microorganisms, but which allows the maintenance of the nutritional and organoleptic qualities is achieved.

Drying is the oldest way of preserving vegetal products, which resorts, with a view to removing water, to solar energy, at which the parameters that influence the elimination of water cannot be controlled. In the process of ***dehydration***, the water is removed in special installations (dryers), which allow the automatic adjustment of temperature, relative humidity and air velocity, depending on the physical-chemical characteristics of the product.

The removal of water from the raw material subjected to dehydration is influenced by the forms under which it is found in the products (free water, colloidally bound water and chemically bound water).

Free water represents over 70% of the total amount of water in the fruits, is found in capillaries and vacuoles, contains a range of dissolved organic substances (carbohydrates, vitamins, organic acids etc.) and mineral salts.

Colloidally bound water (absorbed water and adsorbed water) is strongly retained on the surface and inside the cells, is harder to remove, at dehydration, compared to free water.

Chemically bound water is represented by the water of constitution or of crystallization and can only be removed by the degradation of the finished product (calcination).

The water is removed from the products subjected to dehydration by ***diffusion***. At the beginning of this process, when the moisture content of the product is high, the water is eliminated from the surface by ***external diffusion***. The rate of evaporation of the water, in this stage, is all the higher as the evaporation surface, temperature and speed of the air in the dryer are higher and the humidity is lower. Simultaneously with the external diffusion process, the ***internal diffusion*** goes off, namely the migration of water from the inside outwards, as a consequence of the difference in the osmotic pressure caused by the different concentration in the soluble substances, and of the moisture equalization tendency in all the layers of the products subjected to dehydration.

After this phase, the speed of the external diffusion is higher than that of the internal diffusion, the ***shrivelling*** phenomenon occurs, which leads to the prolongation of the dehydration duration, to the occurrence of breaks and leakages of cell juice. It follows, therefore, that in this phase the temperature and relative humidity of the air in the dryer must be carefully adjusted

Thermal diffusion is the opposite phenomenon of internal diffusion, caused by the temperature difference between the outside and the centre of the product. In the case of dehydration, the temperature differences between the exterior and the interior of the products being relatively small, it is the migration of water from the inside to the outside that prevails, the thermal diffusion having low values.

2.2.1. Phases of dehydration in forest fruits

Given the benefits of dehydration in a globalised economy, ever more products which are currently being marketed in a fresh state will be requested and marketed in a dry state.

The dehydration process is conducted in three successive phases: *preheating*, *dehydration at constant speed* and *dehydration at decreasing speed* (figure 2.4.).

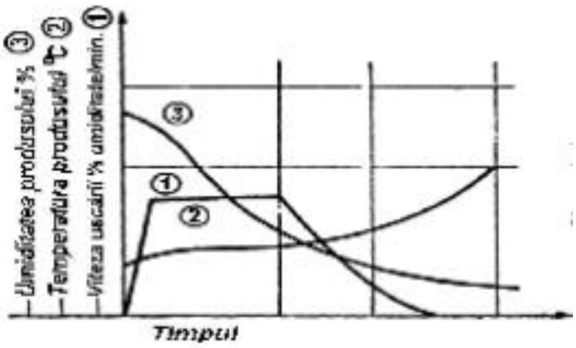


Figure 2.4.: Variation of humidity, temperature and drying speed at dehydration

- the initial or preheating phase is the phase in which the heat is almost completely consumed for heating the product until the equilibrium is reached between the amount of heat transferred to the product and the one consumed for evaporation. In this phase, the temperature of the product rises from the initial one to the one of the drying agent;
- the phase of dehydration at constant speed or the actual dehydration phase, when the evaporation rate depends on temperature, humidity and the speed of the drying agent, but also on the degree of division and structure of the product. In this stage, at the same time as the product temperature rises, the evaporation rate remains constant and it ends when the critical (hygroscopic) moisture on the surface of the product is attained;
- the final phase or of dehydration at decreasing speed is characterised by the fact that the evaporation rate only depends on the internal diffusion, which gradually decreases and ends when the balance moisture is reached, when the relative product moisture is in balance with the relative air humidity at the drying temperature. This moment of the dehydration is important for the quality of the finished product, and it is necessary to lower the temperature to 40-45^{0}C, depending on its thermal sensitivity. Unless this value is observed, the rehydration capacity diminishes, and fleshy structures appear on the surface of the finished product.

2.2.2. Factors influencing forest fruit dehydration

The main factors that influence the dehydration process refer to the nature of the raw material, the parameters influencing the evaporation rate of the water in the product and the preparatory operations undergone by products before dehydration:

Nature of raw material is characterized, for each species separately, and it refers to the chemical composition, structure and texture, colour etc.

Temperature of the air in the dehydration installations is an important factor, which influences the evaporation rate of the water and the quality of the finished product. The higher the air temperature, the evaporation rate increases and the dehydration duration diminishes. The use of high temperatures, associated with the low air humidity in the dryer, favours the phenomenon of shrivelling, the appearance of cracks on the surface of the products, associated with the leakages of juice and the caramelization of sugars.

The optimum level of the dehydration temperature for most fruits is 40-45^{0}C – inlet, and 65-75^{0}C – output.

Relative air humidity directly influences the evaporation rate of the water. The lower the humidity, the pick-up capacity of the water vapours rises, the dehydration speed diminishes and shrivelling is favoured. This phenomenon is prevented by maintaining the relative humidity of the hot air in the installation at 20-30%.

The capacity of hot air to charge with water vapour depends on the saturation limit (absolute humidity) at a certain temperature. Exceeding this limit determines the condensation of vapours in the form of haze and the occurrence of the phenomenon known as "***dew point***" which leads to the dampening of the products subjected to dehydration. The relative air humidity when leaving the dryer ranges between 60-65%.

The air circulation speed through the dehydration period is 3-5 m/s. A speed higher than 5 m/s favours dehydration, reduces fuel efficiency, without absorbing and withal eliminating outside the amount of water corresponding to the level of temperature at a certain time. If the air velocity is too low (below 3 m/s), the air gets super-saturated with water vapour, especially at the beginning of this process, moistening the products and prolonging the dehydration period.

The hot air movement direction in the installation may be: in parallel currents with the raw material; in counter-currents or in currents perpendicular on the travel direction of the raw material.

Other factors influencing the evaporation rate of the water in the products subjected to dehydration are:

- *raw-material scalding* as a preparatory operation to dehydration increases the cell-membrane permeability, due to the modifications undergone by some organic components, favours water diffusion and shortens the dehydration duration;
- *the degree of division of the raw material* – the berries, having small dimensions, only dehydrate when whole (red currants, blueberries, sea buckthorn etc.);
- *the quantity of fresh product incumbent on 1 m^2 drying surface* (seives, grills, conveyor belts), differs depending on the nature of the raw material and on its degree of division. Too small a load reduces the yield of the dryer, while too big a load results in poor-quality products (uneven dehydration), reduces the yield of the installation by prolonging the dehydration time.

2.2.3. Dehydration systems

Drying by convection at atmospheric pressure:

- *conventional drying* is performed in chambers, tunnel dryers, belt dryers, zone dryers;
- *drying in a fluidised layer* consists in driving and mixing the solid particles (raw material) in a hot air current and maintaining them in suspension. The temperature of the fluidising air is chosen according to the product;

- *spray drying* is the most frequently used method for liquid or semi-liquid products which are sprayed and mixed with hot air. As the droplet diameter is very small (10-200 µm), a large evaporation surface and a close contact between the drying agent and the product are achieved; therefore, the drying of the droplets is very fast (1-20 s).

The most common types of dryers used in the food-processing sector are: hot air oven, tunnel-type dryer, tunnel-type dryer with belt, drying installation under vacuum and freeze-drying installation.

2.2.4. Technology of artificial dehydration of forest fruits

Unlike natural drying, where the heat necessary to remove water from products is influenced by the evolution of the external climatic factors, the artificial dehydration allows a strict control of the drying parameters, which can be guided according to the characteristics of the raw material and of the finished product. The fruits are dehydrated in various types of dryers (tunnel-type dryer, zone dryer, belt dryer etc.).

2.2.5. Technology of artificial drying of some forest fruits

The natural drying of forest fruits, under the circumstances of the energy crisis facing humanity, is a serious competition for artificial dehydration, especially in warmer countries, where it can be practiced on an industrial scale.

The natural drying, in addition to its advantages (low costs, use of simple installations, good or very good product quality), also has some disadvantages:

- the drying parameters are largely influenced by the evolution of the external climatic factors;
- the impossibility of processing a large quantity of products in a short period of time;
- the drying duration, in cold and humid periods, is much prolonged to reach the optimum moisture level in the product.

With a view to naturally drying fruits, there are used grids in wood, in wickerwork, mats or grids covered with polyethylene foil or window glass entailing the occurrence of the greenhouse effect underneath, which favours the drying process.

The fruits prepared each according to its specificity are uniformly placed on grills that shall be located in sunny areas away from strong winds, as far as possible from roads, in order to protect them from dust. On clear, sunny days, if the grills are covered with window glass or foil, they shall be opened, so as to create the air currents which remove the humidity around the products and increase the drying speed.

The use of heating systems with solar energy (concentration of solar rays with a system of mirrors) for the natural drying of products ensures the faster heating of the raw material and reduces the drying time.

2.2.6. Effects of dehydration on the products

Following dehydration, the products undergo changes in water content, internal structure and chemical composition:

- decrease in volume and weight: this is mainly a consequence of the removal of water from products and, to a lesser extent, of the loss of soluble dry matter;
- increase in energy value, as a result of the concentration of dry matter;
- migration of the soluble components from the vacuolar juice and their concentration in the external layer (sugaring) occurs simultaneously with the internal diffusion;
- chemical and biochemical modifications, which lead to nutritional losses, as well as colour changes: discoloration, yellowing, browning (in all divided products);
- modification in the internal structure of the tissues, due to the coagulation of proteins, under the action of temperature, which determines the change of hydrophilic colloids;
- the aroma of dried products undergoes modifications, following the volatilization of etheric oils during dehydration.

2.2.7. Packaging, storage and rehydration of dried products

Packaging is a very important stage in the technological flow for maintaining the quality of dehydrated products and it is achieved according to their nature and destination.

If the products are improperly packaged, they change their characteristic properties because of rehydration, contamination with microorganisms, absorption of foreign odours, presence of oxygen and light.

For powdery and porous products obtained by lyophilization, aluminium-foil bags or metallic boxes voided and treated with m-plastics are used.

Dehydrated products in the form of granular flakes are packaged in tightly closed boxes or canisters that provide

good protection against light.
For industrial consumption, these products are packaged in paper or plastic bags welded at the ends and in plywood barrels lined with plastic foil or parchment paper.
Dried products are kept in places with low atmospheric humidity (60-75%), ventilated at the temperature of 5-15^{0}C and in the absence of light.
The shelf life of dehydrated products is 1 year, under quality-maintenance conditions, if the storage parameters are met.
The quality of dried products is determined according to the rehydration capacity, which is the capacity of the products to regain as much of the lost water as possible. The rehydration of lost products is influenced by: the duration and temperature of rehydration, the physical structure of the dried product, the pH of the rehydration water. A porous and rigid structure favours the rehydration process [1, 4].

3. CONCLUSIONS

- Dried fruits are as good a source of vitamins and minerals as their fresh version;
- The pericarp cells of dried fruits have thickened membranes, tightly bound together and devoid of juices and nutrients;
- The drying process removes nevertheless a few water-soluble vitamins, including vitamins B, C, as well as other antioxidants;
- Most fruits have nutritional value, being consumed in both a raw and preserved form as jam, marmalade, compote etc. The fruits are rich in sweet, nourishing substances and vitamins;
- In the drying process of forest fruits, the concentration of nutrients, including of vitamins and minerals, rises;
- Dehydrated berries are rich in nutrients and offer four times as much as energy as the same fresh fruits;
- Dehydrated fruits are easier to digest and more filling than the fresh ones. There is no need to consume large amounts of dehydrated fruits to feel satiated.

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