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THEORETICAL RESEARCHES ON THE TRANSFORMATIONS UNDERGONE BY SOME FOREST FRUITS THROUGH THEIR STORAGE IN A FROZEN STATE

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Abstract: *The paper presents a few theoretical aspects regarding the transformations which the forest fruits undergo along the technological process of conservation, by freezing. The forests fruits are rich in sugar, vitamins, mineral substances – the fresh ones having a high water content (85-95%), which may lead to favourable conditions to the development of the microorganisms responsible for their degradation. The cold conservation of the forest fruits is based on cryoanabiosis (congelation and storage in a frozen state).*
Keywords: *forest fruits, conservation by congelation.*

1. INTRODUCTION

Fresh fruits are one of the indispensable components of rational human nutrition. The nutritional 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 gustative, olfactive and visual exciting factors add, which make one relish them with pleasure at any moment of the day or season [1].
The forest fruits that come from the spontaneous flora contain a series of components presenting a specific industrial interest. In addition, many of them contain a number of active principles, medicinally interesting, as well as natural dyes, which can be isolated.
By their content rich in nutrients necessary for the body, the forest fruits have a particularly important role in human nutrition [3].
Frozen berries are a good option, sometimes even better than the fresh ones. Usually, they are frozen immediately after having been harvested, hence the vitamins and antioxidants are preserved [4].
Despite the general idea that frozen fruits don't have just as many health benefits, ample evidence contradicts this view. Ever since 1998, Food & Drug Administration has confirmed that the frozen fruits offer the same nutrients and benefits for health as the fresh ones.
Frozen berries have a high content of phenolic compounds, a low energy content, a high iron content, a high content of C and E vitamins, a high content of potassium and other minerals, and a low sodium content.
The forest fruits are some of the best sources of polyphenols that have beneficial effects on the human health and they contain more polyphenols than any other plant.

- The forest fruits, such as blue- berries, blackberries and raspberries have a high content of antioxidants, such as anthocyanins, which help keep free radicals under control;
- The forest fruits are rich in fibres,including soluble fibres that help reduce the number of calories absorbed from mixed meals [5].

Most fruits contain a lot of sugar, in the form of fructose, which has just as many calories and is just as dangerous to health as table sugar. Forest fruits contain less sugar. For instance, blueberries contain 7.3% sugar, while cherries contain 14.6% sugar. Blackberries contain 8.1% sugar, while grapes have 18.1%. Forest fruits are rich in antioxidants. Among all fruits, the berries contain the highest amounts of antioxidants. These substances protect against heart diseases, cancer and aging. One of the antioxidants is vitamin C which also has other benefits [4].

2. MATERIAL AND METHOD

Some of the aspects highlighted above, specific to some species of berries, will be presented below.

- **Blueberry bush** (*Vaccinium myrtillus*)

Blueberry fruit harvesting takes place at staggered intervals, once with their maturation, and it extends over a period of 4-7 weeks, depending on their variety, on the general climate of the growing area.

CONGELATION (-25...-40^{0}C)
-Blueberries are rich in tannin, pectins, organic acids (malic, citric, oxalic, lactic, succinic acid), but their greatest richness is the provitamin A and the vitamin C.

a) fresh blueberries

b) frozen blueberries

Figure 1: Blueberries

Their conservation in a fresh state for consumption or industrialization can be done for 4 weeks in cold stores, at tem-peratures ranging between 0 and 2^{0}C. At temperatures of 4-5^{0}C they can be kept for -8 days, and at 20-22^{0}C only 2-3 days [2].

- **Sea buckthorn** (*Hippophae rhamnoidas*)

The optimal time for harvesting sea buckthorn is determined according how the fruit are used. The harvesting will be carried out when the fruit reach the maximum weight and most active substances are accumulated. By calendar, the harvesting is made from the second half of August to mid-October. After this date, the fruit are overripe, sink, easily crush and part of them crack when harvested.

CONGELATION (-25...-40^{0}C)
-The color of sea buckthorn is orange or yellow, its pulp very juicy, with a grainy appearance, which leaves spots of oil, with a pleasant and aromatic odour, sour and astringent taste, rich in vitamin C.

a) fresh sea buckthorn

b) frozen sea buckthorn

Figure 2.: Sea buckthorn

In a fresh state, they can be kept for 3-4 weeks in cold storage at the temperature of 0^{0}C. For this, it is required that the fruit be unharmed, harvested before full maturity, in dry and cool weather, in small packages and in a thin layer of 5-6 cm.

- **Red currants** (***Ribes rubrum***)

The red current fruit ripen in the month of July, the harvesting period of the red current varieties is very short, about 10-12 days. The optimum harvesting time is determined according to the destination of the fruit, to the colour and taste of its berries. The red currants intended for fresh consumption and for congelation are harvested at full maturity.
The red currants for preparing jam are harvested when the berries on top of the cluster are not yet well coloured. The fruit intended for preparing juice are harvested at the moment of full ripening, when the yield in the juice is higher [6].

CONGELATION (-25...-40^{0}C)
-The sour and astringent taste of red currants is due to its rich content in vitamin C, potassium and magnesium, in phytonutrients and antioxidants.

a) fresh red currants

b) frozen red currants

Figure 3: Red currants

Red currants: anthocyanins, poly-phenolic substances, vitamin C, anti-oxidants in frozen version-an important source of vitamins which can be consumed at any time of the year. It is one of the most advantageous consumption methods.
Frozen red currants can be stored for up to 12 months at temperatures between -18 and -25^{0}C. After defrosting, immediate consumption is recommended, without further freezing. Thus, the taste is intact, as well as the intake of vitamins and minerals from the fruit [7].

2.1. Conservation of forest fruits by congelation

Using low temperatures, below the freezing point of the water in the cell juice, ensures that the initial features of the products conserved by this method are maintained for a longer period of time.
Congelation is the technological process by which most of the water in the cell juice of a product changes into ice crystals. Congelation involves treating the products with temperatures ranging between -30^{0}C and -40^{0}C, temperature at which water turns in a relatively short time into ice. The freezing temperature is specific to each product, depending on the concentration of the cell juice, specific heat, thermal conductivity, product size (whole or split), temperature difference between product and cooling agent, speed at which the refrigerant circulates through the device.
Frozen products generally retain their tissue integrity and natural features, while the physico-chemical and microbiological changes are reduced or blocked. The congelation must be guided so that the product passes as quickly as possible to the maximum crystallization phase of water, which ranges between -2 and -5^{0}C, until the equilibrium temperature of -18^{0}C is reached, at which the product is stored until disposed.
The freezing process includes three phases: refrigeration until the freezing point of the cell juice is reached; freezing the juice and lowering the product temperature to the one at which it is preserved (figure 4).

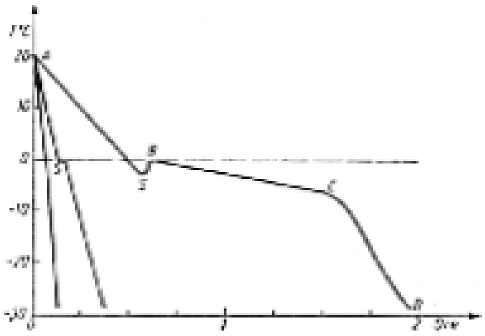

Figure 4: Freezing curves

- In phase A-S, the refrigeration occurs until the crystallization temperature of water, a value that raises the product temperature to point B, which is considered freezing point;
- In phase B-C (-2…-5^{0}C), the actual congelation occurs, a phase in which the water is turned into ice crystals in a proportion of 60-75%;
- In phase B-C, the temperature drops until the equilibrium temperature is attained in the product.

The freezing speed influences the final quality of frozen products, on which the shape and size of the ice crystals which form in the freezing process depend. If the freezing process is slow, the product temperature gradually drops below 0^{0}C, the ice crystals form in the intercellular spaces (extracellular ice). Under these conditions, the water in the cells diffuses through the cell membranes, and a great number of ice crystals, of small size, quite evenly distributed, form in the intercellular spaces and within the cells. In this way, the water inside the cells no longer has time to migrate in the lacunar spaces, the crystals don't perforate the cell membranes, thus avoiding the loss of juice when defrosting.
In the frozen products subjected to temperature fluctuations, water molecule changes occur between the ice crystals (migrating recrystallization) or the neighbouring ice crystals might merge, with negative effects on the product quality. In order to avoid these phenomena, it is necessary to maintain the storage temperature as constant as possible (-18^{0}C).

2.2. Freezing methods and devices

Depending on how the heat is taken from the food by the refrigerating agent, the congelation can be achieved by several methods:

- congelation in cold air stream;
- congelation in contact with cooled metallic surfaces (indirectly);
- congelation in direct contact with the refrigerant.

Congelation in cold air stream is the most widespread for foodstuffs, it can be made in tunnel-type installations, freezing devices and it can be used on all types of packaged and unpackaged products. The main problem is to ensure a supply of coolness adequate to rapid freezing, by reducing the temperature at -25^{0}C…-40^{0}C and the intense air circulation through the device, of 4-6 m/s.
The devices achieve step cooling, a system that allows the reduction of weight losses due to water evaporation, by maintaining a small temperature difference between the cooling environment and the air that comes into

contact with the product. Moreover, the air used for freezing must provide a relatively high humidity.

- Congelation in a fluidised layer. This procedure is based on the forced circulation of an air current from bottom upwards through the products, imparting to them a permanent motion and fluid-like properties. Every piece of product comes into contact with the cold air, hence the name of *individual freezing*.

Congelation by indirect contact with the refrigerant is made in the heat exchangers, in two systems:

- in a fixed layer, when the product congelation occurs between cooled metallic plates;
- in a mobile layer, when the particles of product come in contact with a cooled metallic cylinder.

Congelation by direct contact with the refrigerant is made in specially constructed freezing plants, where the refrigerating agent (freon 12, liquid nitrogen, carbon dioxide) comes into contact with the product by immersion aspersion, conversion and steam currents. This freezing system has the advantage that the heat transfer speed is very high (minimum 10 cm/h), which has favourable effects on the quality of the end product (aroma, taste, firmness), and the product does not freeze in a compact block, but individually.

2.3. Freezing Technology

The raw material intended for freezing is subjected, according to the particularities it displays, to a succession of operations: receptive, calibration, division, antioxidant treatments etc., operations which form the technological flow.

➢ 1. *Reception of raw material* is made from the quantitative and qualitative point of view and must be introduced as soon as possible in the technological process. The refrigeration of the raw material before freezing (in cold rooms or by the hydro-cooling method) helps to maintain the firmness of the products, reduces the leakages of juice when removing the pips and increases the efficiency of the freezing plant.

➢ 2. *Calibration* is a quality factor that influences the duration of freezing and diminishes the risk of agglomeration of the individually frozen particles. The bonding-agglomeration phenomenon appears due to the latent heat differences of the smaller particles in relation to the bigger ones, which have different temperatures when exiting the refrigerator.

➢ 3. *Washing* has the role of removing all impurities and microbial flora on the surface of the products. Cleaning is a complex phase of preparing the raw material, which consists in removing injured or diseased portions, inedible portions (seminal house, clusters, pips, stalks, peels, skins etc.).

These operations can be performed manually, requiring a high consumption of labour force, or in a mechanised way, with suitable machines for this purpose.

➢ 4. *Division* consists in cutting the raw material into pieces, discs, noodles, cubes etc., in order to achieve a uniform and fair congelation.

➢ 5. A*ntioxidant treatments*. At the freezing and storage temperature of -18^{0}C the enzymatic activity is not completely stopped, but only slowed down. The complete inhibition of enzymes is achieved at much lower temperatures (-40^{0}C) by storing the frozen products in vacuum, by keeping them in an inert atmosphere etc. The inactivation of the enzymes which produce modifications of colour, taste, odour and can go up to product alteration is achieved by *physical treatments (scalding with water or steam); chemical treatments*, by using enzyme inhibiting substances (citric acid, ascorbic acid, sulphur dioxide, sugar etc.).

➢ 6. *Congelation*, a process carried out at temperatures of -25…-40^{0}C, when free water is transformed into smaller or bigger ice crystals, according to the congelation speed.

Although individual congelation is qualitatively higher, a number of products are frozen in block (fruit as such or with sugar). Block congelation is more frequently used in the oxidation-sensitive fruit, given the protective role of sugar, especially as syrup.

➢ 7. *Packaging* is generally made after freezing, using the following types of packages:

- small packages of 0.5-1.00 kg: polyethylene bags, polyethylene lined boxes, which are intended for individual consumers;
- medium-capacity packages: polyethylene bags of 2.5 kg for the fruit frozen in block. Both small and medium capacity packages, in order to be transported, are places in cardboard boxes;
- large or transport packages: bags of polyethylene or paraffinized paper, polyethylene-lined cardboard boxes of 10-20 kg and rarely palette boxes of 500 kg for large consumers.

When freezing a pre-packaged assortment, such as block fruit, fruit with sugar etc., the package should allow the volume growth of the product. The volume size can be of 8.2% for the fruit in syrup with the concentration of 30% and of 5.2% for the fruit in syrup with a concentration of 50%. The order of the technological phases in fruit freezing is shown in figure 2.5.

Frozen products are stored in the temperature range of -18^{0}C...-40^{0}C, a temperature which is maintained until these products reach the consumer.

For the individually frozen assortment, 10% agglomerated fruit are admitted; and for the assortment with sugar, 4-6 fruit parts and one part of crystal sugar or syrup with the concentration of 40% are required.

The storage time at the temperature -18^{0}C...-40^{0}C is of 9-10 months for the individually frozen blueberries, and 12-16 months for those in sugar syrup.

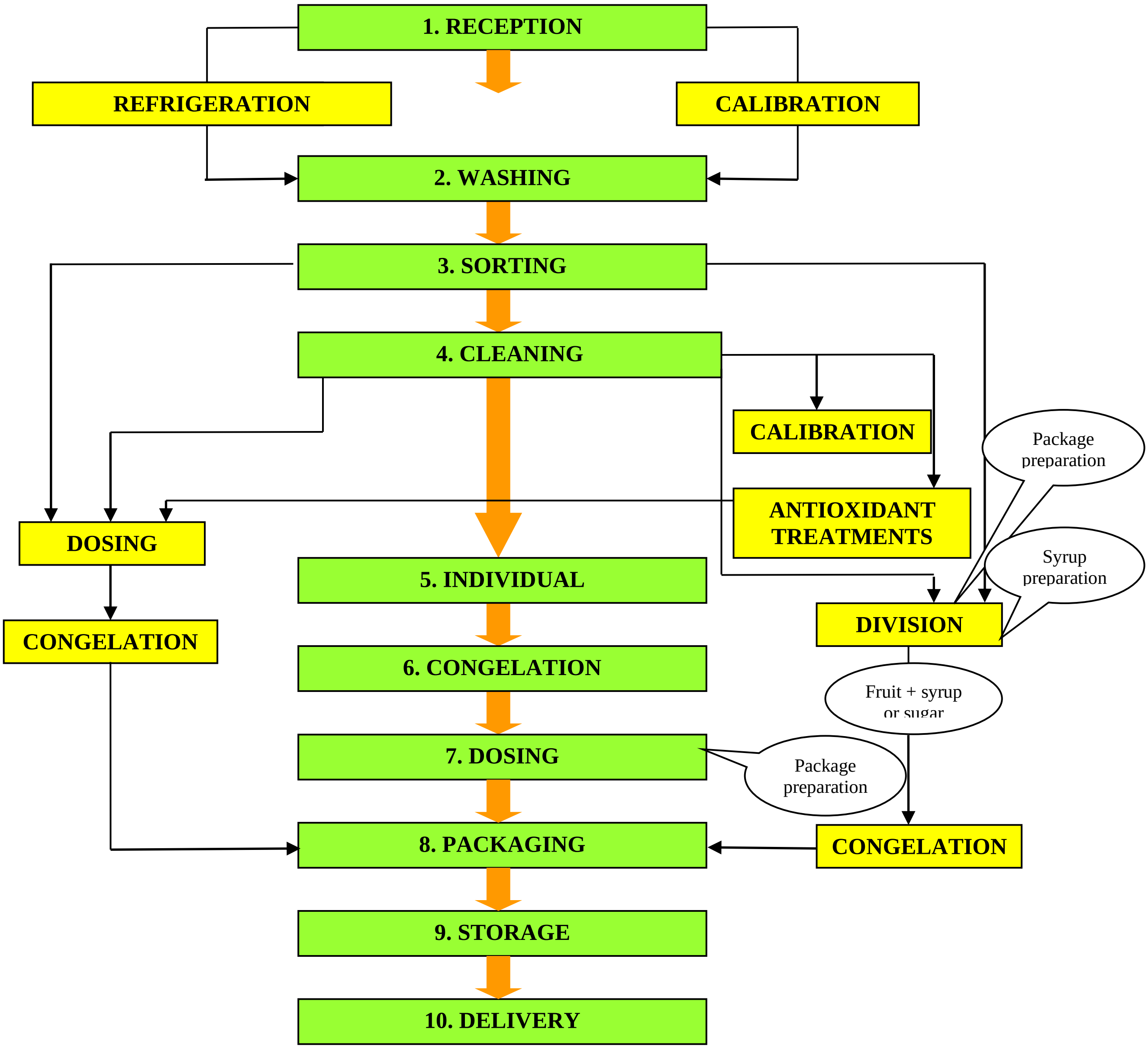

Figure 5: Technological phases of forest fruit congelation

2.4. Modifications undergone by frozen products

During the freezing and after defrosting, physico-chemical modifications appear in the fruits. In this way, their firmness decreases following the formation of ice crystals that tear and break the cell, the volume of the products subjected to freezing increases by 10-15% compared to the initial one, due to the formation of ice crystals; and by defrosting it decreases by 20-30%, because of the water resulted from defrosting, which is not completely reabsorbed in the tissue mass. The loss weight from defrosting, because of the water leaks, where a number of organic substances are dissolved, determines a slight reduction in the food value of the products, a change in taste and aroma.
From a chemical viewpoint, the content in total dry matter of frozen products shows a relative increase, compared to the same products, kept fresh. During the storage of frozen products, the content in sugars and organic acids undergoes slight changes, the process of respiration being blocked at low temperatures (-18^{0}C).

2.5. Storage, transportation and marketing of frozen products

The frozen products are stored in cold stores at the minimal temperature of -18^{0}C, the storage time ranging

between 4-24 months, depending on the particularities of the product.
For the transportation of frozen fruits, refrigerated vehicles are used. The long-distance transport is made only with refrigerated vehicles, equipped with cold-production aggregates with motor, compressor and condenser, fitted on the front of the semi-trailer or on the roof, in the utility cars, and the evaporator on the inside (on the front under the ceiling). When marketing frozen products, refrigerated aggregates are used (refrigerated showcases, freezers, closed shelves) which attain temperatures ranging between 12…-18^{0}C.

3. CONCLUZIONS

- Frozen forest fruits have a high content of phenolic compounds, a low energy content, a high iron content, a high content of vitamins C and E, a high content of potassium and other minerals and a low sodium content;
- During the storage of frozen berries, the content in sugars and organic acids undergoes minor changes, the process of respiration being blocked at low temperatures (-18^{o}C);
- By congelation, as ice block, the forest fruits lose their initial form after defrosting, but keep most of the nutrients, vitamins, mineral salts, such as albumins and fats;
- One of the benefits from freezing fruits is the long-term maintenance of their quality;
- By freezing the fruits, their validity is considerably increased.
- As a result of their studies, the researchers have found there is no noticeable difference between the number of nutrients and vitamins existing in fresh fruits compared to frozen fruits, because they are frozen immediately after harvesting and have no time to lose their properties.
- Regardless of the form in which berries are consumed, the nutritionists recommend that they be part of the daily menu, because they help the body function properly.

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