Quick freezing of garden strawberries to obtain biologically active ingredients

O M Blinnikova¹, I M Novikova¹, O V Perfilova¹ and D A Blinnikova²
¹Michurinsk State Agrarian University, 101, International st., Michurinsk, 393760, Russia
²Pirogov Russian National Research Medical University (RNRMU), 1, Ostrovitianov st., Moscow, 117997, Russia
E-mail: o.blinnikova@yandex.ru

Abstract. The results of the comparative analysis of the effectiveness of modern technologies for freezing strawberries showed their prospects and the need to use them to obtain biologically active ingredients of diets. The optimal mode of freezing of garden strawberries was established, which contributed to the greatest extent to the preservation of the original qualitative characteristics of berries - 35 °C below zero, followed by low-temperature storage at a temperature of 18 °C below zero. The authors established the correlation between the amount of juice loss and changes in the organoleptic characteristics of defrosted berries. The regression equations were obtained that characterized the change in cryoresistance and complex organoleptic assessment from the duration of low-temperature storage of frozen berries. The optimal shelf life of frozen berries was 12 months.

1. Introduction
Today the problem of food delivery to the population located at a distance from the places of production is quite urgent [1, 2]. At the same time, the use of modern efficient technologies for storing fruits, vegetables and berries allows not only ensuring their safety from the organoleptic point of view, but also preserving the required amount of vitamins and micro- and macroelements. Cold processing of vegetable raw materials provides greater preservation of nutrients, compared to other canning methods. The most progressive way is fast freezing. Freezing blocks a number of redox processes, inactivates pathogenic microflora and reduces the activity of free water in food, which allows preserving biologically active substances and components that determine nutritional and energy value with greater efficiency than with heat preservation [3-7].

Design of food products enriched with physiologically valuable functional ingredients of fruit and berry raw materials and their all-season production is impossible without the availability of a raw material base, which in turn necessitates the selection of varieties of berries and fruits suitable for freezing [8-10]. It is also necessary to establish optimal freezing regimes, which make it possible to preserve their native nutritional value as much as possible.

In order to determine the suitability of strawberries for freezing, we selected a variety that belonged to the highest quality category according to the results of a complex organoleptic assessment. Moreover it was characterized by a high content of soluble solids (not less than 10%), pectose (not less
than 0.5%) and provided maximum daily satisfaction of the human body needs for ascorbic acid and antioxidants [11-12].

2. Materials and methods

New picked berries were inspected for quality, separating substandard ones. They were sorted by color, calibrated by size. Strawberries at least 2.0 cm in diameter were picked removing sepals. Then, the berries were washed with cold running water. Then the berries were laid out on stainless steel trays to drain the remaining water from the berries and blown with air at a speed of 10 m/s to remove the remaining moisture. The prepared berries were quickly cooled to a temperature of 0.5°C in refrigerating chambers.

In order to establish the optimal freezing regime, which contributed to the greatest extent to the preservation of the original quality characteristics of strawberries, three temperature regimes were investigated: -24°C; -35°C and -40°C. Freezing was carried out in a quick-freezing (fluidization) apparatus in a vibrating-fluidized layer 4 cm thick to the final temperature in the center of the berry -20°C.

The frozen strawberries were placed in plastic containers weighing 500 g, hermetically packed and stored in low-temperature refrigerating chambers at -18°C. In order to determine the shelf life of frozen berries and the loss of nutrients, long-term storage (for 15 months) was carried out. Before the analysis, the berries were thawed in a refrigerating chamber at a temperature of 2°C.

3. Results and Discussion

In order to establish the optimal temperature regime for freezing, we studied the effect of the freezing temperature on the quality characteristics of strawberries of the Corona variety. Figure 1 presents the results.

\[\text{Figure 1. The effect of freezing temperature on the quality characteristics of berries}\]
The comparative analysis of the effect of shock freezing temperature on the quality characteristics of garden strawberries showed good preservation of the consumer properties of fresh berries. After thawing, the strawberries frozen at -35°C and -40°C had good appearance, completely retained the shape and integrality of the berries. Cryoresiccence, i.e. the loss of juice was minimal. The color of these berries was intense, uniform. The consistence was quite dense and juicy when chewing. The taste was pleasant, harmonious and sweet.

The berries frozen at -24°C had slightly reduced quality characteristics compared to berries frozen at -40°C and -35°C. The lack of shine and less saturation of the color of the berries was noted as well as slight decrease in shape retention and the increase in juicing. The consistence of the berries was less dense. The taste and flavor of the frozen berries were close to the taste and flavor of fresh berries.

As a result of the studies, it was found that the optimal technological mode of freezing strawberries, which retained the original consumer properties, was shock freezing at a temperature of -35°C and -40°C. Freezing to a temperature of -35°C was less energy-consuming and cost-effective.

To obtain biologically active ingredients of the diet, the berries were frozen at a temperature of -35°C. In order to establish the expiration date, organoleptic, physicochemical and microbiological studies were carried out every 3 months. Before the studies the berries were thawed in a refrigerating chamber at a temperature of 2°C.

The analysis of the organoleptic characteristics of strawberries was carried out on a 5-point scale according to the indicators of appearance, color, consistence, taste and flavor which were most changeable during freezing and long-term storage (Table 1).

**Table 1.** The results of the organoleptic assessment of the quality of quick-frozen of the garden strawberries of Corona variety

| Storage time | Average score of the assessed indicator | Comprehensive assessment (quality) |
|--------------|----------------------------------------|----------------------------------|
|              | value of the indicator taking into account weighting coefficient |                                |
|              | Appearance K=0,2 | Colour K=0,2 | Consistence K=0,5 | Taste K=0,7 | Flavour K=0,4 |                                |
| Initial quality | 5,0*±0,32 | 5,0±0,32 | 4,2±0,32 | 4,8±0,48 | 4,6±0,48 | 9,30 (premium) |
| 3 months | 5,0±0,32 | 5,0±0,32 | 4,2±0,32 | 4,8±0,48 | 4,6±0,48 | 9,30 (premium) |
| 6 months | 4,8±0,32 | 4,6±0,32 | 4,6±0,48 | 4,2±0,32 | 1,84 |
| 9 months | 4,8±0,32 | 4,6±0,32 | 4,6±0,48 | 4,2±0,32 | 1,84 |
| 12 months | 4,6±0,48 | 4,6±0,48 | 4,6±0,48 | 4,2±0,32 | 1,84 |
| 15 months | 4,4±0,00 | 4,4±0,00 | 4,4±0,00 | 4,0±0,00 | 1,84 |

*- assessment of indicators in points, **- assessment of indicators taking into account the weighting coefficient

During storage, garden strawberries of the variety Corona perfectly retained their original quality and during the first 12 months of storage they belonged to the premium quality category according to the results of a comprehensive organoleptic assessment. They almost unchanged after defrosting. They had an attractive appearance, bright color, dense consistence, harmonious taste and flavor and after 12 months of storage belonged to the premium quality category. There was a slight decrease in the quality of berries in terms of such indicators as the appearance of strawberries, berry consistence, taste and flavor. After 15 months of storage, the berries belonged to the first quality category [10].

Mainly the results of the tasting assessment depended on the loss of berry juice during defrosting.
The results of the studies of the cryoresistance of garden strawberries during storage, calculated as a percentage of the initial mass of frozen berries, showed that the loss of juice during defrosting increased significantly after 12 months of storage. Thus, the loss of juice after the specified period of low-temperature storage was 5.3%. After 15 months, the water-holding capacity of strawberries decreased, as a result of which the juice loss was 8.2%.

Experimentally, we established the correlation between the amount of juice loss and a change in the organoleptic characteristics of defrosted berries (Figure 2). With a moisture loss of more than 15%, an unacceptable deformation of the shape occurred as well as the softening of the consistence. Taste and flavor received a satisfactory and unsatisfactory assessment [8, 9].

![Figure 2. Interdependence of cryoresistance and complex assessment of garden strawberries on the duration of low-temperature storage](image)

We obtained the regression equations that characterized the change in the complex assessment from the duration of low-temperature storage of frozen strawberries:

\[ y = -0.12x + 9.452 \quad R^2 = 0.951 \]

and the change in cryoresistance from the duration of low-temperature storage of frozen strawberries:

\[ y = 0.85x + 2.93 \quad R^2 = 0.932 \]

According to the study of the correlation of such organoleptic indicators as appearance, color, consistence, taste and flavor and cryoresistance, a gradation of the suitability of berries for freezing was established: 1 - with a loss of juice up to 5% - category “excellent suitability”; 2 - with a loss of juice from 5.1 to 7.5% - “good suitability”; with a loss of juice from 7.6 to 12% - “satisfactory suitability” and more than 12% - “unsuitable for freezing” [10].

This research made it possible to determine that garden strawberries of the variety Corona belonged to the category “excellent suitability” for freezing.

The change in the nutritional value of berries in the process of low-temperature storage at a temperature of -18°C is presented in Table 2. Freezing allows preserving the natural properties of berries as much as possible, as the biochemical processes of metabolism in tissues slow down. However, during storage frozen berries undergo certain changes in properties and chemical composition. Rapid freezing and long-term low-temperature storage of strawberries led to a decrease in monosaccharides and sucrose, and, consequently, in the total amount of sugar and increase in the titratable acidity of berries [11].

As a result of low-temperature exposure, the content of ascorbic acid in berries decreased. The destruction of catechins and anthocyanins was less intense. The loss of vitamins during storage was explained by irreversible hydrolytic processes under the influence of tissue enzymes. According to the results this process occurred less intensively in the first 12 months. With further storage of frozen berries, the loss of vitamins and vitamin-like substances was more significant, and therefore the recommended shelf life was 12 months from the date of production [12].
Table 2. Changes in the nutritional value of garden strawberries during freezing and during low-temperature storage

| Indicator                          | Storage period, months |
|------------------------------------|------------------------|
|                                    | 0          | 3          | 6          | 9          | 12         | 15         |
| Monosaccharides,%                  | 5.9±0.03   | 5.7±0.02   | 5.5±0.03   | 5.1±0.03   | 4.5±0.02   | 3.8±0.02   |
| Disaccharides,%                    | 1.9±0.02   | 1.7±0.02   | 1.6±0.03   | 1.3±0.02   | 1.2±0.02   | 1.0±0.02   |
| Total sugar,%                      | 7.8±0.06   | 7.4±0.05   | 7.1±0.05   | 6.4±0.04   | 5.7±0.04   | 1.8±0.04   |
| l oses, %                          | 5.1        | 9.0        | 18.0       | 26.9       | 38.5       |
| Tritratable acidity, %             | 1.02±0.02  | 1.10±0.01  | 1.17±0.02  | 1.25±0.01  | 1.35±0.01  | 1.46±0.02  |
| Soluble pectin,%                   | 0.37±0.02  | 0.35±0.02  | 0.34±0.02  | 0.31±0.02  | 0.29±0.02  | 0.27±0.02  |
| Protopectin, %                     | 0.64±0.02  | 0.62±0.02  | 0.60±0.02  | 0.55±0.02  | 0.54±0.02  | 0.50±0.02  |
| Total amount of pectin substances,%| 1.01±0.05  | 0.97±0.04  | 0.94±0.05  | 0.86±0.04  | 0.83±0.04  | 0.80±0.04  |
| losses, %                          | 4.9        | 7.8        | 14.1       | 15.6       | 21.9       |
| Ascorbic acid, mg / 100 g          | 73.3±0.12  | 58.1±0.12  | 54.8±0.11  | 51.8±0.09  | 45.9±0.09  | 37.3±0.07  |
| losses, %                          | 20.7       | 25.2       | 29.3       | 37.4       | 49.1       |
| Catechins, mg / 100 g              | 312±0.42   | 289±0.33   | 275±0.33   | 264±0.33   | 251±0.33   | 236±0.21   |
| losses, %                          | 7.4        | 11.9       | 15.4       | 19.6       | 24.4       |
| Anthocyanins, mg / 100 g           | 51.7±0.04  | 50.4±0.04  | 48.8±0.02  | 47.9±0.02  | 46.6±0.03  | 44.5±0.05  |
| losses, %                          | 2.5        | 5.6        | 7.4        | 9.9        | 13.9       |

4. Conclusion

The study of the comparative effectiveness of modern technologies for freezing berries to obtain biologically active ingredients of diets was performed. The presented results show that garden strawberries of the variety Corona are suitable for freezing, since they are able to sufficiently preserve their original quality after thawing. The studied organoleptic, physicochemical and microbiological indicators of the quality of these berries are stable for 12 months from the date of production. As a result this period can be considered as guaranteed.

The use of the freezing process is the most effective way to preserve berries and maximize their nutritional value. The production of quick-frozen berry products allows expanding the range of traditional and new types of food, including functional purpose. It also creates the conditions for year-round operation of processing enterprises, reduces the loss of raw materials during canning, transportation, storage and processing. Moreover it increases labor productivity in the preparation of meals in the public catering network.

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