Influence of drying methods on preservation of biologically active substances of garden strawberries being raw material for food enrichment

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Abstract. At present, the preservation of the consumer properties of berry products is an urgent problem. Use of fresh garden strawberries is limited by a short storage period and seasonality. Under optimal storage conditions in a normal atmosphere, the average shelf life of strawberries is from 2 to 9 days depending on the variety. To meet the needs of the population in garden strawberries and meet the physiological needs in a unique complex of biologically active substances, strawberries are subjected to different processing methods. Drying being a type of fruit and berry products processing has the following advantages: a significant increase in the shelf life of products, a decrease in the mass and storage volumes of dried berries, preservation of minerals, carbohydrates, dietary fiber, antioxidants, bioflavonoids and many biologically active compounds in berries. Modern drying technologies allow preserving the content of essential vitamins to its full extent. Comparison of two technologies for drying garden strawberries has established that vitamins and other biologically active substances are well preserved in berries. Berries dried by convective vacuum-impulse method (CVI) are recommended to be used for food enrichment.

1. Introduction

Garden strawberry is one of the most widespread berry crops. It opens the season for fresh fruits filling the winter-spring vitamin gap, and is appreciated for the excellent taste of fruits, medicinal and nutritional properties, and rich biochemical composition [1-4].

Garden strawberries are perishable products and the preservation of their quality is a very important issue [3, 5, 6]. In order to preserve their useful and taste qualities, many processing methods are used. An important direction in the processing of fruit and berry products is the production of dried strawberries. To obtain dried products, in which the natural properties are maximally preserved, a scientifically grounded choice of drying technology is of particular importance [7].
2. Materials and methods

To study the preservation of consumer properties of strawberry, studies aimed to assess the quality of berries dried by convective drying (CD) and a two-stage convective vacuum-impulse method (CVI) were carried out. For control, fresh berries of garden strawberry were examined. The nutritional value of fresh and dried strawberries was determined by conventional methods of analysis.

Convective drying (CD) is the most common method of drying products at the present time. The advantages of the method are its simplicity and the ability to control the temperature of the dried material [6, 8].

Two-stage convective vacuum-impulse drying (CVI) was carried out as follows: the raw material placed on trays in the drying chamber was hot aired at a temperature below the denaturation temperature of biologically active substances in the raw material (airing-heating stage). Then the hot drying was stopped, and a vacuum was created in the drying chamber (vacuum stage) [3, 10]. The stages of heating and vacuuming were alternated until the final moisture content of the product was reached. After each drying cycle including heating and vacuuming stages, the dried material was weighed with the objective to assess the change in the moisture content of the material [7, 11, 12].

3. Results and Discussion

To determine the most optimal type of drying, the quality of dried berries of garden strawberry was assessed (table 1).

| Variety         | Moisture content, % | Titratable acidity, % | Mass fraction of sugars, % |
|-----------------|---------------------|------------------------|-----------------------------|
|                 | Fresh berries CVI    | CD drying               | Fresh berries CVI CD drying | Fresh berries CVI CD drying |
| Vicoda          | 87.2 8.6 9.5         | 1.07 10.0 9.4 6.1      | 61.6 56.1 1.9 14.8 13.7 8.0 |
| Vima-Zanta      | 87.5 8.7 9.5         | 0.98 9.1 8.6 6.0       | 60.6 55.2 1.4 14.1 13.0 7.8 |
| Vima-Rina       | 86.9 8.5 9.4         | 1.18 11.0 10.4 5.8     | 58.6 53.4 2.1 16.4 15.1 7.9 |
| Kama            | 87.2 8.6 9.5         | 1.13 10.5 9.9 5.3      | 53.5 48.8 1.9 14.8 13.7 7.2 |
| Kamarosa        | 86.9 8.5 9.4         | 1.11 10.5 9.9 5.8      | 45.2 41.8 2.0 8.4 6.2 7.8 |
| Korona          | 87.2 8.6 9.5         | 1.02 9.5 9.3 5.9       | 46.2 42.3 1.9 8.2 6.1 7.8 |
| Selva           | 87.5 8.7 9.5         | 0.85 7.9 7.5 4.1       | 31.6 29.1 1.7 7.3 5.4 5.8 |
| Urozhainaya TSGL| 87.0 8.6 9.5         | 1.14 10.5 9.9 6.2      | 48.4 44.6 2.1 9.0 6.7 8.3 |
| Festivalnaya romashka | 86.9 8.5 9.4 | 1.04 9.7 9.2 5.7 | 57.6 52.4 1.7 7.3 5.4 7.4 |
| Medovya         | 87.2 8.6 9.5         | 1.09 10.1 9.6 6.8      | 68.7 62.6 2.1 9.0 6.7 8.9 |
| Elsanta         | 87.5 8.7 9.5         | 1.11 10.3 9.8 6.5      | 65.7 59.8 2.0 8.5 6.6 8.5 |

As a result of studies of the physicochemical parameters of garden strawberries being dried in various ways, it was established that the mass fraction of moisture when using CVI drying varied from 8.5 to 8.7%, and with CD drying within 9.5% in all studied varieties.

The titratable acidity of the studied fresh berries of garden strawberry, ranged from 0.85% to 1.13%. In dried berries with CVI drying, the acidity was in the range from 7.9% to 11.0% and with CD drying – from 7.5% to 10.4%.

Sugars are the most important part of dried berries. They largely determine nutritional value. The content of sugars varied depending on their initial amount in the applied raw materials. The high sugar content after drying was noted in the varieties Vikoda, Vima-Zanta, Vima-Rina, Miodivays and Elsanta with CVI drying 76.4%, 74.7%, 75.0%, 77.7% and 74.2%, and 69.8%, 68.2%, 68.5%, 62.5%, 69.3% and 66.4% with CD drying, respectively. The smallest sugar content was found in the varieties Korona and Kamaros with CVI drying 53.6% and 54.4%, and 34.5% and 48.6% with CD drying.

The preservation of biologically active substances in dried berries was assessed by the content of ascorbic acid, catechins and anthocyanins (Figure 1).
Figure 1. Changes in the content of biologically active substances with different methods of drying strawberries: 1 - Vicoda, 2 - Vima-Zanta, 3 - Vima-Rina, 4 - Kama, 5 - Kamarosa, 6 - Korona, 7 - Selva, 8 - Urozhainaya CGL, 9 - Festivalnaya romashka, 10 - Medovaya, 11 - Elsanta

Strawberry contains biologically active substances with therapeutic and prophylactic effects. The maximum amount of ascorbic acid is in dried berries of the varieties Vicoda, Vima Rina, and Elsanta with CVI drying 471.9 mg/100 g, 464.0 mg/100 g, 452.1 mg/100 g and with CD drying 149.8 mg/100 g, 147 mg/100 g and 143.5 mg/100 g, respectively, and the smallest amount – in the Kama variety with CVI drying 300 mg/100 g and 95.2 mg/100 g with CD drying.

As can be seen from the data obtained, dried strawberries are rich in catechins and anthocyanins. The amount of catechins in dried berries is reduced with CVI drying by 49-50%, with CD drying by 39-40% compared to fresh berries. The amount of anthocyanins in dried berries with CVI drying decreases by 60-61%, with CD drying – by 49-50% compared to their initial content in fresh berries.

It follows from the data in the figure that a higher safety of biologically active substances is a distinctive feature of the two-stage convective vacuum-impulse drying method.
Dried berries are a valuable source of pectin substances that have a radiation-protective and antitoxic effect and are able to bind and remove heavy metals, toxins and radioactive elements from the body. The content of pectin substances in strawberries varied depending on the drying method (table 2).

Table 2. Content of pectin substances in dried berries of garden strawberries depending on drying method.

| Variety     | Soluble pectin | Protopenetin | Mass fraction of fiber, % | Mass fraction of pectin substances, % |
|-------------|----------------|--------------|---------------------------|----------------------------------------|
|             | Fresh berries | CVI drying | CD drying | Fresh berries | CVI drying | CD drying | Fresh berries | CVI drying | CD drying | Fresh berries | CVI drying | CD drying | Fresh berries | CVI drying | CD drying |
| Vicoda      | 0.38          | 3.32        | 2.69      | 0.41        | 2.77        | 2.69      | 0.79        | 6.0         | 5.88        | 1.04        | 7.07        | 6.97        |
| Vima-Zanta  | 0.33          | 2.81        | 2.77      | 0.50        | 3.38        | 3.28      | 0.83        | 6.19        | 6.05        | 1.17        | 7.96        | 7.84        |
| Vima Rina   | 0.77          | 4.67        | 4.62      | 0.67        | 4.52        | 4.40      | 0.22        | 9.19        | 9.02        | 1.41        | 9.59        | 9.45        |
| Kama        | 0.49          | 4.17        | 4.11      | 0.63        | 4.25        | 4.13      | 1.12        | 8.42        | 8.24        | 1.02        | 6.94        | 6.83        |
| Kamarosa    | 0.26          | 2.21        | 2.18      | 0.72        | 4.82        | 4.68      | 0.98        | 7.03        | 6.86        | 1.34        | 9.11        | 8.98        |
| Crown       | 0.37          | 3.15        | 3.11      | 0.64        | 4.32        | 4.20      | 1.01        | 7.47        | 7.31        | 1.27        | 8.68        | 8.52        |
| Selva       | 0.28          | 2.38        | 2.35      | 0.48        | 3.24        | 3.15      | 0.76        | 5.62        | 5.50        | 1.15        | 7.86        | 7.71        |
| Urozhainaya | 0.38          | 3.23        | 3.34      | 0.44        | 3.0         | 2.90      | 0.82        | 6.23        | 6.24        | 1.22        | 8.33        | 8.17        |
| TSGL        | 0.37          | 3.15        | 3.11      | 0.46        | 3.11        | 3.02      | 0.83        | 6.86        | 6.13        | 1.18        | 8.06        | 7.91        |
| Festivalnaya | 0.47          | 4.0         | 3.95      | 0.64        | 4.32        | 4.19      | 1.11        | 8.32        | 8.14        | 1.38        | 9.43        | 9.25        |
| Romashka    | 0.38          | 3.23        | 3.19      | 0.58        | 3.92        | 3.81      | 0.96        | 7.15        | 7.0         | 1.23        | 8.40        | 8.24        |

A high content of pectin substances during drying was noted in the varieties Vima-Rina, Kama, Korona, Medovaya and Elsanta with CVI drying 9.19%, 8.42%, 7.47%, 8.32% and 7.15% and with CD drying 9.02%, 8.24%, 7.31%, 8.14%, and 7.10%, respectively, and the smallest – in varieties Vikoda and Selva with CVI drying 6.0% and 5.62%, with CD drying 5.50% and 5.88%. Pectin substances in dried berries with CVI drying exceeded their content in comparison with conventional drying.

Tables 3 and 4 present data on the content of macro- and microelements in raw materials and products obtained.

The presented data indicate that the garden strawberry dried in different ways contains minerals several times higher than fresh berries. Dried strawberries are rich in micro and macro elements such as iron, copper, zinc, manganese, calcium, potassium, sodium, magnesium, phosphorus, etc.

Table 3. Content of macronutrients in dried berries of garden strawberries depending on drying method.

| Variety     | Calcium, mg/100g | Phosphorus, mg/100g | Magnesium, mg/100g | Sodium, mg/100g | Potassium, mg/100g |
|-------------|------------------|----------------------|--------------------|-----------------|-------------------|
|             | Fresh berries    | CVI drying           | CD drying           | Fresh berries   | CVI drying        | CD drying           | Fresh berries      | CVI drying   | CD drying   | Fresh berries | CVI drying | CD drying   |
| Vicoda      | 44.6             | 256.5               | 246.2              | 23.0            | 141.2            | 139.6              | 16.3                | 104.6         | 99.4        | 19.5         | 72.2        | 99.4        | 136.0        | 848.6        | 833.7        |
| Vima-Zanta  | 42.6             | 244.9               | 235.2              | 27.7            | 170.1            | 168.1              | 16.0                | 102.7         | 97.6        | 20.7         | 76.6        | 97.6        | 136.1        | 849.3        | 839.7        |
| Vima Rina   | 41.4             | 238.1               | 228.5              | 23.5            | 144.3            | 142.6              | 16.4                | 105.3         | 100.4       | 19.5         | 72.2        | 100.4       | 135.0        | 842.9        | 832.9        |
| Kama        | 43.0             | 247.3               | 237.4              | 29.0            | 178.1            | 176.5              | 15.8                | 101.4         | 96.4        | 18.5         | 68.5        | 96.4        | 136.3        | 850.5        | 839.1        |
| Kamarosa    | 46.2             | 265.7               | 255.1              | 26.3            | 161.5            | 159.6              | 16.0                | 100.0         | 97.6        | 19.2         | 71.1        | 97.6        | 137.0        | 854.4        | 845.3        |
| Crown       | 44.6             | 256.5               | 246.0              | 38.3            | 235.2            | 232.5              | 16.5                | 105.9         | 100.7       | 21.1         | 78.1        | 100.7       | 154.3        | 962.8        | 951.8        |
| Selva       | 43.4             | 249.1               | 239.1              | 38.4            | 235.8            | 233.1              | 13.0                | 84.1          | 79.9        | 18.6         | 68.8        | 79.9        | 136.4        | 851.2        | 841.6        |
| Urozhainaya | 44.1             | 253.6               | 243.4              | 27.2            | 167.0            | 165.1              | 14.5                | 93.1          | 88.5        | 21.0         | 77.7        | 88.5        | 136.6        | 852.4        | 842.8        |
| TSGL        | 42.9             | 246.6               | 236.8              | 38.6            | 237.0            | 234.3              | 16.0                | 102.7         | 97.6        | 17.4         | 64.4        | 97.6        | 136.8        | 853.6        | 844.1        |
| Festivalnaya | 44.4             | 255.3               | 245.1              | 33.5            | 205.7            | 203.3              | 16.2                | 104.0         | 98.8        | 20.3         | 75.1        | 98.8        | 136.6        | 853.4        | 842.8        |
| Romashka    | 41.9             | 241.0               | 231.3              | 30.3            | 186.1            | 184.0              | 15.9                | 102.1         | 97.0        | 19.7         | 72.9        | 97.0        | 137.0        | 854.8        | 845.3        |
Table 4. Content of trace elements in dried berries of garden strawberries depending on drying method

| Variety            | Iron, mg/100g | Copper, mg/100g | Zinc, mg/100g | Manganese, mg/100g |
|--------------------|---------------|-----------------|---------------|-------------------|
|                    | Fresh berries | CVI drying      | CD drying     | Fresh berries     | CVI drying      | CD drying     | Fresh berries | CVI drying      | CD drying     | Fresh berries | CVI drying      | CD drying     |
| Vicoda              | 0.58          | 3.25            | 3.26          | 0.092            | 0.576            | 0.567          | 0.16          | 0.93           | 0.81          | 0.295          | 1.56           | 1.51          |
| Vima-Zanta          | 0.91          | 5.11            | 5.12          | 0.073            | 0.457            | 0.450          | 0.20          | 1.16           | 1.01          | 0.408          | 2.16           | 2.08          |
| Vima Rina           | 0.72          | 4.04            | 4.05          | 0.088            | 0.552            | 0.542          | 0.20          | 1.18           | 1.01          | 0.332          | 1.76           | 1.70          |
| Kama                | 1.12          | 6.28            | 6.30          | 0.083            | 1.520            | 0.512          | 0.24          | 1.39           | 1.22          | 0.536          | 2.84           | 2.74          |
| Kamarosa            | 0.69          | 3.87            | 3.88          | 0.098            | 0.614            | 0.604          | 0.22          | 1.28           | 1.12          | 0.285          | 1.51           | 1.46          |
| Crown               | 1.06          | 5.95            | 5.97          | 0.125            | 0.784            | 0.772          | 0.28          | 1.63           | 1.42          | 0.393          | 2.08           | 2.01          |
| Selva               | 0.83          | 4.66            | 4.67          | 0.112            | 0.702            | 0.691          | 0.18          | 1.05           | 0.91          | 0.319          | 1.69           | 1.63          |
| Urozhainaya TSGL    | 1.10          | 6.17            | 6.19          | 0.049            | 0.307            | 0.302          | 0.20          | 1.16           | 1.01          | 0.419          | 2.22           | 2.14          |
| Festivalnaya romashka| 0.76          | 4.26            | 4.28          | 0.040            | 0.251            | 0.246          | 0.24          | 1.38           | 1.22          | 0.305          | 1.16           | 1.56          |
| Medovaya            | 0.48          | 2.69            | 2.71          | 0.069            | 0.433            | 0.425          | 0.24          | 1.40           | 1.21          | 0.433          | 2.29           | 2.22          |
| Elsanta             | 0.85          | 4.77            | 4.79          | 0.097            | 0.608            | 0.597          | 0.25          | 1.45           | 1.27          | 0.427          | 2.26           | 2.18          |

4. Conclusion
The study of the chemical, vitamin and mineral composition of dried strawberries showed a high nutritional value of dried berries of the studied varieties.

Two-stage convective vacuum-impulse drying is a promising method for processing strawberries, which enables to preserve the entire spectrum of biologically active components in dried plant raw materials. It is recommended to use this product as an enrichment additive in manufacturing functional products.

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