Development of food products of advanced biological value using infra-red drying of agricultural plant raw materials

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Abstract. The paper considers solutions for producing functional food based on products of infra-red drying obtained with the use of original compact multilevel closet facilities designed to be applied at agricultural enterprises. These facilities originate thermal impulses influencing raw materials by means of controlled infrared radiation emitted by high-temperature linear incandescent lamps and reflected in mirrored surfaces. The facilities ensure effective dehumidification and high-grade preservation of biologically-active agents contented in raw materials. This is due to smooth uniform evaporation of moisture from the material within the entire volume of the facilities, management of heat regime through direct control of material temperature and minimization of material’s contact with atmospheric air during drying. The condition of biologically-active agents in various agricultural products was estimated: raspberry, dewberry, drained white and red grapes. The paper gives organoleptic estimate of alcohol-free beverages with advanced biological value based on infra-redly dried products.

1. Introduction

Technological, climatic, social and other factors determine the need for elaborating technologies of improving food quality as well as create favorable conditions for it. The Government of the Russian Federation approved the "Strategy for improving the quality of food products in the Russian Federation until 2030", which is aimed to improve the health of the population through proper healthy nutrition, ensure the production of quality products by domestic manufacturers. Among the objectives of the Strategy, there is a "priority development of scientific research in the field of nutrition of the population, particularly of preventing the most common noninfectious diseases and developing the production technologies aimed at improving the quality of food products".

The relevance and popularity of functional products and products with high biological value are verified by many developments of formulations and technologies [1-8] and by studies on raw materials [9, 10, 11].

The production of succulent plant materials is distinguished by seasonality. Some fruits and berries should be stored for no more than a day and require immediate sale for fresh consumption or further processing. Quick freezing and drying are the main technologies for preserving the biological value of fresh berries and fruits.

In order to solve the problem of preserving biologically valuable substances in plant raw materials, the authors are developing technologies of infra-red drying in original compact multilevel closet facilities that differ from other structures by controlled thermal radiation reflected in mirror surfaces of
a special form instead of uncontrolled thermal radiation of sources directed on a surface of raw material [12]. This technical solution of the thermal interaction of the source of thermal radiation and the surface of the raw materials to be dried (see Figure 1) allowed the following:
- placing the sources of thermal radiation outside the facility volume where the raw materials are located, thereby, on the one hand, protecting the sources of thermal radiation from evaporated moisture and increase the reliability of the device, and on the other hand, creating a safe environment for drying raw materials with the possible destruction of the radiation source;
- providing a high degree of uniformity of thermal effects on the surface of the raw material due to the peculiar shape of mirror-reflecting surfaces that evenly distribute thermal radiation along the plane of the tier or tray with the raw material;
- significantly reducing the distance between levels of a facility, bringing close the volume load of the infrared drying facility to convective drying devices;
- providing energy costs for the removal of 1 kg of moisture not more than 1.2 kW·h, which is comparable with the performance of high-performance convective drying facilities;
- implementing a local thermal effect on raw materials located on levels of a facility, which allows under incomplete loading of a multi-level facility to use only the necessary part of its thermal power;
- providing the advanced level of maintaining the temperature of drying by direct control of the temperature of raw material during drying, for which a temperature measuring transducer is placed in the surface layer of raw material, the signal of which is the controlling one for the temperature controller of the drying process;
- implementing pulsed temperature conditions of the drying process using relay control of the temperature of raw materials during drying;
- creating technological inexpensive devices that are easy to manufacture and operate.

![Figure 1. Scheme of thermal interaction of the source of thermal radiation and the surface of raw material in a multi-level facility for infrared drying (a) and a general view of the drying facility (b).](image-url)
2. Materials and methods

Drying was performed using infrared drying at various temperature conditions at the Department of General Technical Disciplines of the Academy of Bioresources and Nature Management of FSAEI HE V.I. Vernadsky Crimean Federal University. Drying products using this technology allows saving the content of vitamins and other biologically active substances in the dry product at the level of 80-90% of initial raw material [12]. Facilities realize pulsed thermal effect on raw materials controlled by thermal radiation reflected from mirror surfaces, the sources of which are high-temperature linear incandescent lamps. The facilities provide effective moisture removal and a high level of preserving biologically active substances in raw material, due to the uniform moisture evaporation in the entire volume of the facility, thermal regime maintenance for drying by direct control of the temperature of raw material and minimization of the contact of raw material with atmospheric air during drying [13].

Studies of the content of biologically valuable substances in raw materials and drying products were carried out in the laboratory of enochemistry, winemaking and control methods of the Academy of Bioresources and Nature Management. The object of the study was drained grapes of white and dark varieties: Pinot Blanc, Viognier, Montepulciano, Malbec without fermentation and drained grapes of Montepulciano+Malbec varieties after fermentation, as well as raspberries and blackberries. Grapes of these varieties were harvested at the departmental collection of the department of winemaking and technology of fermentation production of the Academy of Bioresources and Nature Management in 2017.

3. Results and discussion

In dried raspberries, blackberries and drained grapes, the content of phenolic substances was determined, as well as of ascorbic acid as one of the indicators of biological value [14].

According to the recommended consumption of food and biologically active substances, an adequate level of consumption of vitamin C is 70 mg/day, anthocyanins - 50 mg/day, total phenolic substances - 240-290 mg/day.

Biologically active substances of grape berries are not distributed equally. For example, anthocyanins and vitamin C are found in peel and partially in adjacent tissues, tannins and oils, mainly in seeds, phenolic substances in both peel and seeds. Therefore, the ratio of components will affect the quantitative content of biologically active substances. For these studies, drained berries were not divided into fractions of peel, pulp and seeds.

Studies showed that the content of ascorbic acid and monomeric forms of phenolic substances in dried samples highly depended on the temperature regime of drying. The mass concentration of ascorbic acid in dried drained berries of dark-colored grapes was 105 mg/100 g, of light-colored - 62 mg/100 g; in dried raspberries - 290 mg/100 g, in blackberries - 245 mg/100 g.

The mass concentration of phenolic substances in raspberries amounted 1050 mg/100 g, in blackberries - 2900 mg/100 g, in drained grapes from 1200 to 1900 mg/100 g. Biologically active substances of grape berries are not distributed equally. For example, anthocyanins and vitamin C are found in peel and partially in adjacent tissues, tannins and oils, mainly in seeds, phenolic substances in both peel and seeds.

The following forms of anthocyanins were found in raspberry samples under study: cyanidine group (cyanidin-3-O-glucoside, cyanidin-3-O-glucoside, cyanidin-3-O-rutinoside, cyanidin-3-O-sulfosoroside-5-O-ramnoside) - from 30 to 70 mg/100 g berries, depending on the temperature of drying, pelargonidin-3-O-glucoside - not more than 2 mg/100g. Among monomeric phenolic substances, ellagic acid (about 10-18 mg/100 g berries) and pentazide of ellagic acid (6 - 9 mg/100 g) were determined. Quercetin-3-O-glucoside-rutinoside was 10-14 mg/100 g.

In blackberries, myricetin monoglycosides (from 40 to 81 mg/100 g of berries depending on the drying regime) and rutin (6 to 10 mg/100 g) were found. Cyanidins ranged from 72 to 210 mg/100 g in the context of the studied samples.

The retention of ascorbic acid during the IR-drying is 82 – 83% for raspberries and blackberries.
Data on the amino acid content in blackberries drained by infrared drying are shown in table 1.

Table 1. Content of amino acids in dried blackberry, mg/100 g.

| Amino acids            | general | free  |
|------------------------|---------|-------|
| Aspartic acid          | 296.3   | 2.2   |
| Glutamine acid         | 481.8   | 1.3   |
| 4-hydroxyproline       | 36.9    | 1.5   |
| Asparagine             | -       | 37.0  |
| Glutamine              | -       | 1.5   |
| Serine                 | 200.7   | 9.3   |
| Arginine               | 322.0   | 21.2  |
| Glycine                | 144.6   | 0.8   |
| Threonine              | 107.3   | 1.9   |
| Alanine                | 395.5   | 41.4  |
| Proline                | 151.8   | 24.6  |
| Gamma Aminobutyric Acid| 52.9    | 9.1   |
| Valine                 | 55.9    | 1.2   |
| Methionine             | 19.0    | 2.2   |
| Isoleucine             | 43.8    | 1.5   |
| Leucine                | 73.8    | 2.4   |
| Phenylalanine          | 55.2    | 1.3   |
| Cystine                | 12.5    | 3.1   |
| 2-Ethanolamine         | 7.0     | 0.4   |
| Histidine              | 16.3    | -     |
| Lysine                 | 127.5   | 13.6  |
| Cysteine               | 155.3   | 33.5  |
| Tyrosine               | 21.2    | 7.7   |
| Total amount           | 2777.0  | 218.7 |

The content of amino acid in dried raspberries is presented in table 2.

Table 2. Content of amino acids in dried raspberries, mg/100 g.

| Amino acids            | general | free  |
|------------------------|---------|-------|
| Aspartic acid          | 433.3   | 7.2   |
| Glutamine acid         | 636.7   | 7.8   |
| 4-hydroxyproline       | 17.4    | 2.3   |
| Asparagine             | -       | 114.5 |
| Glutamine              | -       | 16.7  |
| Serine                 | 245.6   | 26.4  |
| Arginine               | 283.5   | 30.5  |
| Glycine                | 129.3   | 2.3   |
| Threonine              | 146.2   | 8.6   |
| Alanine                | 297.6   | 43.9  |
| Proline                | 164.6   | 20.2  |
| Gamma Aminobutyric Acid| 122.6   | 36.0  |
| Valine                 | 86.6    | 3.8   |
| Methionine             | 29.2    | 3.7   |
| Isoleucine             | 56.9    | 4.7   |
| Leucine                | 110.0   | 4.6   |
| Phenylalanine          | 90.0    | 1.1   |
| Cysteine               | 11.6    | 2.5   |
| 2-Ethanolamine         | 13.6    | 0.6   |
| Histidine              | 54.4    | 6.0   |
| Lysine                 | 146.4   | 15.3  |
| Cysteine               | 242.9   | 36.4  |
| Tyrosine               | 40.7    | 12.2  |
The amino acid content in the dried drained grapes is presented in table 3.

| Amino acids       | general | free |
|-------------------|---------|------|
| Aspartic acid     | 105.4   | 1.0  |
| Glutamine acid    | 323.6   | 3.0  |
| 4-hydroxyproline  | 39.1    | 2.5  |
| Asparagine        | -       | 1.0  |
| Glutamine         | -       | 6.7  |
| Serine            | 121.7   | 2.3  |
| Arginine          | 122.4   | 3.8  |
| Glycine           | 127.6   | 0.6  |
| Threonine         | 81.3    | 1.0  |
| Alanine           | 113.5   | 2.7  |
| Proline           | 645.1   | 312.5|
| Gamma Aminobutyric Acid | 28.0   | 10.9 |
| Valine            | 50.1    | 1.3  |
| Methionine        | 8.4     | -    |
| Isoleucine        | 33.8    | 0.9  |
| Leucine           | 77.1    | 1.2  |
| Phenylalanine     | 68.1    | 2.6  |
| Cystine           | 9.7     | 0.6  |
| 2-Ethanolamine    | 5.5     | 1.3  |
| Histidine         | 41.1    | 1.3  |
| Lysine            | 124.2   | 8.0  |
| Cysteine          | 253.6   | 1.2  |
| Tyrosine          | 30.2    | 7.7  |
| Total amount      | 2409.7  | 374.2|

The total content of identified amino acids in dried blackberries and raspberries was approximately 2.8 and 3.3 g/100 g respectively, in drained grapes - 2.4 g/100 g.

The obtained data characterize the products of infrared drying as high-quality products with high biological value.

For the production of functional drinks, drained technical grapes is attractive as a source of the following biologically active substances: vitamins, macro and microelements, phenolic compounds, plant fiber, organic acids, pectin substances. The chemical composition of drained grapes is similar to that of grapes, but in a different proportion. The mass fraction of sugars in the sweet drained grapes ranges from 5 to 10%, tartaric compounds - from 0.5 to 2.0%. Moreover, tartaric acid compounds mainly consist of free tartaric acid and potassium bitartrate. Drained grapes contain pentosans (1.0 - 4.5%), minerals (1.2 - 3.6%) and phenolic compounds (up to 11%)

Based on the aqueous extract of dried drained grape, non-alcoholic drinks of high biological value were developed. The use of dried drained grape allows getting the base of the drink with a soluble solids content of 4.5 - 5.9% and titratable acidity of 6.5 - 8.0 g/dm^3. Organoleptic characteristics were characterized by a palatable and slightly diluted taste, attractive appearance, ruby color, with a shine, the aroma was delicate and varietal (corresponded to the grape variety). To give a more pronounced aroma, various natural plant aromatic components were used: extracts of thyme, rose petals, mint, lemon; spicy ingredients: cinnamon, ginger, cloves. Organoleptic analysis was carried out according to three indicators: appearance, aroma, taste. Tasting evaluation of drinks based on the aqueous extract of drained grapes is shown in Figure 2 in points.
Organoleptic estimate, grade

| Estimated samples | 6 | 5 | 10 | 15 | 20 | 25 |
|-------------------|---|---|----|----|----|----|
| Appearance        |   |   | 1  | 2  | 3  | 4  |
| Aroma             |   |   |    | 5  |    |    |
| Taste             |   |   |    |    | 6  |    |

Figure 2. Tasting assessment of drinks based on aqueous extract of drained grapes, points.

Sample 1. Pinot Blanc “Mahito” - to prepare the base of the drink aqueous extract of dried drained grapes of white-fruit variety Pinot Blanc was used, then lemon and mint extract was added. Appearance: transparent yellow liquid with slight opalescence. The aroma was mint with lemon tone, the taste was harmonious, sweet and sour, pleasant. The overall tasting score was 21.51 points.

Sample 2. Pinot Blanc “Cinnamon” - the basis of the drink, as of the previous sample, was aqueous extract of dried drained grapes of white variety Pinot Blanc, to which extract of cinnamon and tea rose was added, as well as bee honey. In appearance it was a turbid yellow liquid. Cinnamon was strongly pronounced in the aroma, honey tones and a faint aroma of tea rose were traced. The taste was sweet and sour, harmonious, honey. This sample was rated at 21.52 points.

Sample 3. Viognier with the aroma of "Lemonade" - the basis of the drink was an aqueous extract of dried drained grapes of white-fruit varieties Viognier with the addition of flavoring "Lemonade". The drink was clear straw-yellow, the aroma was strongly pronounced, the taste was sweet and sour not matching the aroma. The tasting score was 21.57 points.

Sample 4. “Non-alcoholic mulled wine” - the basis for the drink was aqueous extract of dried extract of the Malbec and Montepulciano mixes after fermentation. To give a sweet taste, stevia extract (natural sweetener) was added. The aromatic components were Provence herb, cloves. This drink is low in calories and can be recommended for people with diabetes because it contains no sugars. The drink is transparent, bright ruby, the appearance is attractive. There is aroma of herbs, spices. The taste is sweet and sour, spicy, intense. The organoleptic properties of this sample were evaluated at 21.94 points.

Sample 5. Montepulciano “Barberry” - composition of the drink: aqueous extract of dried drained grapes of dark-berry variety Montepulciano, extract of barberry, flavor “Barberry”. The drink has transparent ruby color, the aroma is appropriate, the taste is sweet and sour, harmonious. Tasting score is 21.76 points.

Sample 6. Malbek base is the drink consisting of aqueous extract of dried drained grape of dark-berry Malbec variety without the use of additional ingredients. The drink has transparent bright ruby color, delicate berry varietal aroma, there is a fine tone of cherry and caramel; the taste is full, harmonious, sweet and sour. Tasting score is 23.84 points.

Sample 7. Malbec with Duchesse aroma – the drink based on aqueous extract of dried drained
grapes of dark-berry Malbec variety, with the addition of Duchess flavoring. The drink has ruby color, pronounced aroma of duchess and sweet and sour harmonious taste. Tasting score is 23.56 points.

Sample 8. Grape drink with the flavor of “Lemonade-Duchesse” - the basis of the drink is aqueous extract of dried drained grape of dark-berry varieties Malbec and Montepulciano in equal proportions with the addition of fragrances “Lemonade” and “Duchesse.” The drink has a transparent ruby color, the aroma corresponds to the flavorings used, the taste is sweet and sour, harmonious. Tasting score is 21.05 points.

Sample 9. Control. Non-alcohol drink based on natural plant materials (juice and aloe pulp), purchased in retail was chosen as the control sample. It is a colorless drink with a slight opalescence, containing small pieces of aloe pulp. The drink had simple aroma with lemonade tones. The taste was sweet and sour, harmonious, pleasant. The presence of suspensions and pieces of aloe pulp did not cause discomfort during the tasting of the drink. The tasting score was 21.05 points.

All of the offered drinks were rated good and excellent. Samples of dark-colored drained grapes received high rate in appearance, since they were characterized by a dark ruby color, which is more attractive compared with yellow and golden yellow. Organoleptic properties of drinks made of dried drained grapes of Malbec variety received the highest degustation rates – 23.56 – 23.84 points.

Thus, the studied samples of drinks possess not only high organoleptic qualities, but also high biological value.

4. Conclusion
The significant share of the biological value peculiar to fresh raw materials is preserved in infrared-dried products. The share of preservation of biologically active substances in various agricultural products: raspberries, blackberries, drained grapes of white and dark varieties ranges from 50 to 83%. It is advisable to create non-alcohol drinks based on products of infrared drying since they have high biological value. Original multi-level compact facilities for infrared drying with controlled reflected thermal radiation are the effective technological equipment for obtaining high-quality infrared drying products in agricultural production.

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