PHYSICAL AND CHEMICAL ASPECTS OF VACUUM DRYING OF BERRY RAW MATERIALS

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Abstract: The problem of production of functional products of the natural origin intended for daily regular consumption and having an effect on biochemical reactions and physiological functions through restoration of its microecological status is considered in this article. It is shown, that one of sources of the vital substances for an organism is berry cultures, which play an essential role in nutrition of population. Dry berries practically completely conserve all spectrum of vitamins and biologically active materials that makes them valuable raw materials in various food industry branches. The use of products on the basis of dry berries allows to compensate for the deficiency of some vitamins, edible filaments and other useful substances, and also to normalize an intestinal microflora of an organism. The research purpose consisted in selection of optimum physical and chemical and technological aspects of low-temperature vacuum drying of berries. At performance of tests both standard and original techniques of investigation of technological, physical and chemical, biochemical, microbiological and statistical methods of research of raw materials and finished products properties have been used. Physical and chemical aspects of vacuum drying of berry raw materials are studied. Optimum technological parametres of drying are picked up. It is stated, that drying at higher values of temperature (80°C) proceeds faster in the chamber, thus there is fuller moisture removal from a berry, which positively influences on product shelf life. However there is increasing of specific power inputs on drying of a product and decreasing of quality indicators.

Keywords: vacuum drying, berries, thermalphysic characteristic, drying parametres

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INTRODUCTION

Now one of vital issues of our country is population maintenance with a qualitative and safe foodstuff [1]. Deterioration of ecological conditions observed in last decades is the reason of pollution of a foodstuff pesticides, radionuclides, toxic metals (lead, zinc, mercury, copper, arsenic, cadmium), various nitro compounds (nitrites, nitrates and so forth), antibiotics etc.

Such situation extremely negatively affects the general state of health of the population of our planet. One of the consequences of this situation is disease growth, the speeded up cases of a newborns pathology, and also life expectancy decreasing – now in Russia this index is 65 years while in England and Japan the life expectancy is equal to 76 and 80 years accordingly [2].

A necessary condition for health preservation and level of working capacity of the person, increasing of his life duration is following the balanced diet that means reception by a human body a demanded complex of the nutritious ingredients balanced on a parity and quantity from food [3]. Thus, there is a necessity for restructuration and quality of population nutrition, working out of production enriched various biologically active materials, and also for expansion of possibilities of food consumption with high biological value [4].

In the light of the pointed problem the production of functional products of the natural origin intended for daily regular consumption and having an effect on biochemical reactions and physiological functions through restoration of its microecological status is extremely important [5]. One of the sources of vital substances for an organism is berry cultures which play an essential role in population nutrition.

Biological value of berries is defined not only by its energy value, but also by the high maintenance of pectic substances, macro- and minor components, and also the vitamins which maintenance plays an essential role in preventive maintenance of such diseases as a scurvy, Beriberi etc. [6]. A berry gets special value in northern widths where the nutrition consists mostly of products of acid character (bread, meat, eggs, fish, groats prevail), that results to surplus in an organism of the sour connections causing development of acidosis against infringement of a metabolism. Berries and fruit are the best source of the alkaline bases, allowing to avoid similar diseases [7].

Among all ways of canning (cooking, freezing, degermination), drying is the most perspective method of preservation of products which advantages are: small weight of the exsiccated product, not expensive tare for packing, possibility of long-term storage and transportation without cold application, etc. [8].

Now the most perspective ways of drying are the vacuum drying which is passing at negative pressure, but above triple point of water and the freeze drying proceeding at pressure below triple point of water. Each of ways has advantages and disadvantages. Vacuum drying allows to apply cheaper equipment, to reduce process of drying at the expense of absence of a stage pre-award frosts, and also to reduce power inputs on removal of moisture of 1 kg. Freeze drying, despite lacking of the above pointed advantages, allows to receive a product with very high quality indicators, especially this question concerns preservations of vitamins.

The products received by this methods of drying, are characterised by the smallest contraction, good ability to dehydration and high storage times that is especially important by production of dry berries and berry powders adding into the formula of wide assortment of foodstuff in the edible industry, and also biologically active admixtures in a pharmaceutical industry.

The dry berries manufactured by method of vacuum and freeze drying, can be widely applied in dairy industry at manufacturing of curd cakes, fruit milk, yoghourts, cream, etc. In cookery they are used for kissels, sauces, stuffings, gravies, etc. In confectionery industry berries have found application in fruit and wafer productions as flavouring agents, dyes and stabilizers of fats.

Thanks to the high nutritional value berries represent an integral part of person nutrition. Fresh berries are an irreplaceable source of vitamins, mineral substances, organic acids and sugars that is vital for maintenance of high-grade health. Regular consumption of berries allows avoiding many diseases connected with avitaminosis, to reinforce immunity, and also to raise the general working capacity. Fresh berries contain about 75–90% of water, thus the most part of solid content (80–90%) is carbohydrates among which the most important are laevulose, glucose, sucrose, cellulose, hemicellulose and starch.

The basic share of berries nutrients makes the sugar, substantially influencing their flavour profiles and storage life. Among all presented sugars the sweetest one is laevulose, then – sucrose, and the last place belongs to glucose. Depending on a cultivar and conditions of cultivation the maintenance of sugars can vary on the average from 5 to 12% [9].

Drying is known to be now the most perspective method of product canning, including berries [10]. This way is based on supression of ability to live of organisms and retardation of all biochemical processes as a result of partial or full moisture removal from product. At product drying there is strengthening of substrate to such level at which there are no conditions for a high-grade cellular metabolism in product tissues. The way of drying allows not only to raise safety of qualitative and biochemical indexes of products, but also appreciably to raise their shelf life and to reduce the canning cost price.

Now many ways of drying based on various ways of warmth supply and moisture removal from product are developed. Every way has advantages and disadvantages. Among the basic methods of drying it is necessary to note such as convective, conductive, infra-red, microwave, acoustic, vacuum and sublimation.

Dry berries practically completely conserve all spectrum of vitamins and biologically active materials that makes them valuable raw material in various food industry branches. The use of products on the basis of dry berries allows to compensate for the deficiency of some vitamins, edible filaments and other useful substances, and also to normalize an intestinal microflora of organism. The pectic substances in dry berries help to deduce heavy metals (lead, mercury, cobalt, molybdenum, zinc), and radio nuclides (isotopes of strontium, caesium, yttrium, etc.), and also urea, cholesterol and other harmful substances from organism.

Now the production of fruit powders becomes more and more expanded. The basic advantage of such product is flash restorability at water addition. Application of fruit powders in the food-processing industry has given the chance to expand substantially assortment of manufactured production, and also to raise its biological value at the expense of the big maintenance of vitamins, macro- and minor components and cellulose which give the necessary relish and odour to products.

Berry powders are applied in such areas of food-processing industry as dairy, confectionery and bakery, and also in a pharmaceutical industry by production of biologically active admixtures [10]. Addition of dry berries in production of various products allows improving a consistence to optimise structural characteristics of weight, and also to save utilization of gelling agents.

Berry powders have received special distribution in dairy industry where they are used as fillers in curd cakes, yoghourts, dairy and cottage cheese creams, fruit milk, ice-cream, fruit and milk desserts, melted cheese, etc. Dry scraps of berries are also an irreplaceable component by scented tea production where the weight fraction of dry berries can reach 50%. Dry berries are used as a source of the natural cellulose used at manufacturing of cookies, candy sticks, dietary drugs, desserts, muesli, etc. They are raw materials for reception of aromatic substances, dyes and others biologically active materials.

The aim of the investigation is selection of optimum physical and chemical, and technological aspects of low-temperature vacuum drying of berries. Selection should be based on individual physical and chemical properties of various kinds of this production. At drying it is necessary to consider contents, the cryoscopic temperature, thermal and physical, physical and chemical properties, solid content, etc.

OBJECTS AND METHODS OF STUDY

Objects of study at various stages of work were:
– berries of strawberry, raspberry, black currant, cranberry. The fruit and berry raw material was got: in State Unitary Enterprise "Plodopitomnik-1" (Kemerovo, Russia) during the period from 2010 to 2012; in cities of Tomsk area of crops 2010–2012. In experimental researches the berries which have reached full maturity, healthy, not having bruises were applied;
– granulated sugar;
– laboratory and trial samples of dry berries.

At performance of tests both standard and original techniques of investigation of technological, physical and chemical, biochemical, microbiological and statistical methods of research of raw materials and finished products properties have been used.

Selection and preparation of hallmarks for the analysis, the total maintenance of organic acids, organoleptic indexes, chemical composition, vitaminized and mineral value of berries of strawberry, raspberry, currant black, cranberry were defined in laboratories of the scientific-educational centre and department "Bionanotechnology" of Kemerovo Institute of Food Science and Technology (University), and also in laboratories of the test centre of federal official establishment of the centre of agrochemical service "Kemerovo" (Kemerovo, Russia).

The determination of macro- and minor components was made by method of atomic-absorption spectrophotometry. The method principle is based on ability of the dissociated atoms of elements to capture light in a narrow spectral range.

Thermalphysic characteristics of berries were determined by the first buffer method of two temperature and time intervals [11, 12].

Microstructural researches of strawberry, raspberry, black currant, cranberry berries before drying were made in the institute "Coal and coal chemistry" of the Siberian Branch of the Russian Academy of Science (Kemerovo, Russia). Electronic-microscopic researches were carried out on raster scanning electron microscope JEOL JSM-6390 LA.

RESULTS AND DISCUSSION

Drying process consists in the following. The probed product is kept on pans which are positioned in drying chambers. The chambers are closed from above by caps. The refrigerating unit is switched on from operating console and within 10–15 minutes the installation turns on a winterizing mode. The winterizing mode is fixed on evaporator temperature (the temperature should make no more than minus 35°C). Then the vacuum pump is switched on and the drying condition begins. Owing to low pressure in chambers there is a vaporization of moisture from berries and their drying. The duration of drying process takes from 5 to 6 hours.

According to their properties berries represent colloidal capillary-cellular body. Walls of capillaries of such bodies are elastic and bulk up at moisture absorption. After dehydration such bodies shrink, become fragile and can be transformed into a powder. Physical properties of products appreciably influence on their qualitative characteristics, a storage ability and transportation. The list of these properties is wide enough and includes such indexes as weight, density, size, form, and thermal, structurally-mechanical, optical, electrophysical, sorption indexes, etc.

Weight, size and form are quality factors of many kinds of foodstuff, rationing of these parametres is manufactured for bakery, confectionery products, cheeses, cake cheeses, etc. The defined form and size of any fruit and berry correspond to each economic-botanical or pomological cultivar.

Thermal properties represent a complex of physical quantities defining character and speed of passing of processes of cooling and heating in product. Such properties are heat capacity, thermal conductivity, fusion point and freezing. Thermal characteristics are considered at degermination, cooking, batch, transportation and storage of products, they are basic sizes used by working out of technological modes of cold treatment and at research of influence of low temperatures on foodstuff.

In Table 1 the results of definition of thermal characteristics of probed berries are resulted.

The obtained data testify about authentic correlation between such indexes as solid content, heat capacity and cryoscopic temperature. The increasing of moisture content of a berry conducts to decrease the cryoscopic temperature and to increase heat capacity. So, for example, the strawberry characterized by the smallest solid content (13.13 ± 0.05%), and, hence, and the greatest moisture content, has shown the least cryoscopic temperature which has made minus 0.91 ± 0.02°C and the greatest heat capacity 3961 ± 15 J/kg·K of all probed berries.

The similar heat capacity has been positioned in cranberry (3820 ± 15 J/kg·K), however because of smaller moisture content its cryoscopic temperature has made minus 1.51 ± 0.02°C. The greatest solid content (18.63 ± 0.05%) was revealed in black currant that is the reason of its lowest cryoscopic temperature which has made minus 2.13 ± 0.02°C. However, despite it, heat capacity of raspberry (3654 ± 15 J/kg·K) has appeared lower than in black currant.

At drying point selection, experiments were made at the following temperatures: 60, 70 and 80°C, the size of residual pressure was 4–5 kPa and heat flux density was 5.5 ± 0.3 kw/m. According to the data received during experiments, schedules of relative weight change (Fig. 1), temperatures on a surface (Fig. 2) and in thickness of a berry (Fig. 3) depending on a drying time have been constructed. First 15 minutes the installation turns on operating duty, thus the cooling machine and a vacuum pump works depressing pressure in the chamber from atmospheric to pressure 4–5 kPa.

Table 1. Thermalphysic characteristics of berries

Kinds of berry	Solid content, %	Heat capacity J/(kg·K)	Cryoscopic temperature $t_{I<p}$, °C
Strawberry	13.13 ± 0.05	3961 ± 15	minus 0.91 ± 0.02
Raspberry	17.70 ± 0.05	3654 ± 15	minus 1.51 ± 0.02
Black currant	18.63 ± 0.05	3800 ± 15	minus 2.13 ± 0.02
Cranberry	12.81 ± 0.05	3820 ± 15	minus 1.45 ± 0.02

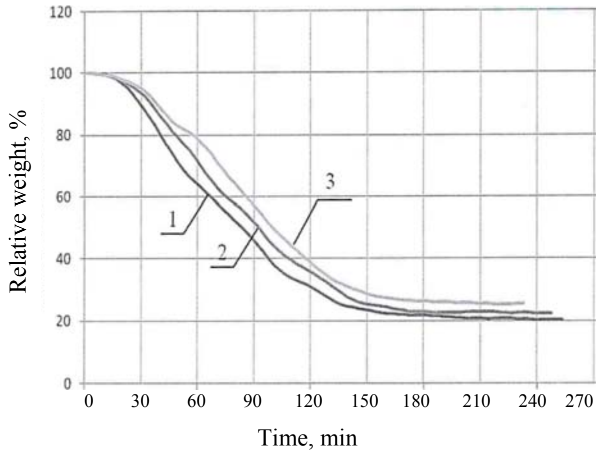

Fig. 1. Schedules of relative weight change of currant at temperatures in the chamber:
1–80°C; 2–70°C; 3 – 60°C.

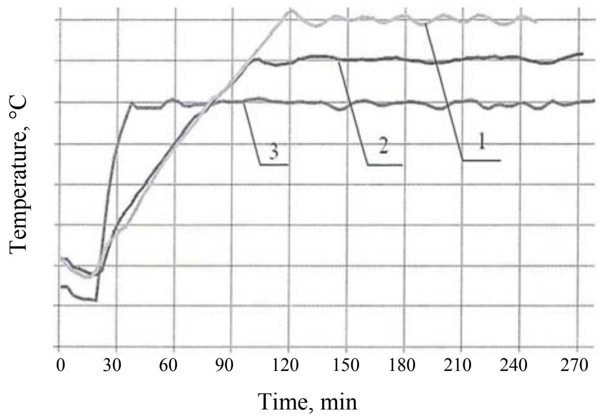

Fig. 2. Schedules of temperature change on a currant surface at temperature in the chamber:
1 – 80°C; 2 – 70°C; 3 – 60°C.

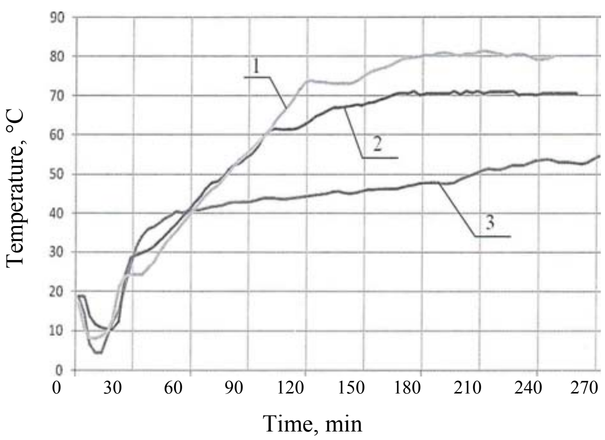

Fig. 3. Schedules of temperature change in thickness of a currant at temperature in the chamber:
1–80°C; 2–70°C; 3–60°C.

At the first stage there is a moisture removal, being in product macrocapillaries. The relative weight of a berry during this period of drying varies slightly – from 100 to 95% from initial weight. At the expense of depressing of residual pressure in the chamber the temperature on a product surface sharply falls on the average to 14–16°C (Fig. 2). The duration of the first stage makes about 15–20 minutes. At the second stage, characterized by constant speed of drying, infra-red lamps of heating are switched on, there is a removal of the basic part of moisture in the product – osmoticly connected moisture and moisture in microcapillaries.

In the experiment with temperature in the chamber 80°C the duration of the drying second stage was 145 minutes from the drying beginning. The relative weight of product by the end of the second stage was 26.2 % from the initial. The temperature on a currant surface reached 80°C in 114 minutes after the drying beginning (Fig. 2) while in depth of a berry the temperature reached this level in 180 minutes after the drying beginning (Fig. 3). Thus, duration of the second period of drying of currant was 100 minutes.

In the experiment with temperature in the chamber 70°C the speed of drying started to drop after 140 minutes from the drying beginning. The relative weight of currant by the end of the second stage was 32.7% from the initial. The temperature on berry surface reached 70°C in 100 minutes, and temperature in depth – in 165 minutes, after the drying beginning. The duration of the second stage of drying was 115 minutes. At drying with temperature in the chamber 60°C, the second stage came to the end in 135 minutes after the drying beginning. The relative weight of currant by that moment was 36.2% from the initial. The temperature on product surface reached 60°C in 54 minutes after the drying beginning. In thickness of product at the end of the second stage the temperature did not reach the necessary value and was 48°C.

Having got the demanded temperature in the chamber, radiant intensity of infra-red lamps drops, in this connection growth rate of a core temperature also decreases, that is shown in Fig. 3.

At the third stage the moisture of mono- and polymolecular adsorption is removed. This kind of communication is the strongest and at the further drying it is removed extremely slowly. The duration of the third stage of dehydration at temperature in the chamber 80°C was 60 minutes, for 70°C this time was 67 minutes, for 60°C – 75 minutes. The relative weight of the exsiccated currant at temperatures in the chamber of 80, 70 and 60°C was 20.5%, 22.4% and 25.4% from the initial accordingly.

In Table 2 the comparative characteristics of drying efficiency such as duration of process of dehydration, moisture weight fraction in a dry berry, specific power inputs on removal of moisture of 1 kg and an organoleptic estimation are resulted.

The presented data allow to make a conclusion, that drying at higher values of temperature in the chamber proceeds faster, thus there is fuller moisture removal from a berry, that positively affects product shelf life, however there is the increasing of specific power inputs on drying of product and decreasing in quality indicators. It is stated, that at currant drying the most rational temperature in the chamber is 70°C. The duration of drying at this temperature is equal to 209 ± 5 mines, the organoleptic estimation thus makes 34 points from 40, in the exsiccated berry the moisture weight fraction is 3.1 ± 0.1%.

The similar experiments with a drying point 60, 70 and 80°C have been made for other kinds of berries. Efficiency factors of drying of strawberry, raspberry and cranberry are presented in Table 3.

It is stated, that strawberry exsiccated at temperature 60°C, is characterized by a high organoleptic estimation – 36 points from 40 and rather low power inputs – 2.96 ± 0.05 kw/kg of a remote moisture. The increasing of temperature to 70°C conducts to falloff of quality indicators, thus duration of drying contracts all for 24 minutes and moisture content of product drops only on 0.3%. Thus, the rational drying point for strawberry was 60°C.

It is concluded, that the rational drying point of raspberry and cranberry is 70°C. Drying at lower temperature, despite increasing of an organoleptic estimation of raspberry and cranberry on 5 and 2 points accordingly, is characterized by longer duration of dehydration process, accordingly for 41 and 45 minutes. At temperature in the chamber 80°C the process duration of drying contracts, but quality indicators considerably drop: for raspberry on 7 points, for cranberry on 6 points. Thus there are hulls on many berries and the power consumption increases considerably on 10.7% for raspberry and on 14.1% for cranberry.

The optimum physical and chemical, and technological aspects of vacuum drying of berries are picked up. The selection is based on individual physical and chemical properties of various kinds of berry production. At drying the contents, the cryoscopic temperature, thermalphysic, and physical and chemical properties, solid content were considered, etc.

Table 2. Comparative characteristics of drying of black currant depending on a drying point

Temperature in the chamber, °C	60	70	80
Duration of drying, min.	223 ± 5	209 ± 5	186 ± 5
Moisture weight fraction, %	7.8 ± 0.1	4.8 ± 0.1	3.1 ± 0.1
Specific power inputs, kw/kg of a remote moisture	3.33 ± 0.05	3.45 ± 0.05	4.20 ± 0.05
Organoleptic estimation, points			
Smell	14	13	8
Consistence	14	12	10
Colour	9	9	8
Total	37	34	26

Table 3. Indexes of drying of berries at temperature selection in the chamber

Temperature in the chamber, °C	60	70	80
Duration of drying, min			
Rasberry	276 ± 5	235 ± 5	197 ± 5
Cranberry	286 ± 5	241 ± 5	212 ± 5
Strawberry	264 ± 5	233 ± 5	189 ± 5
Moisture weight fraction, %			
Raspberry	2.6 ± 0.1	2.5 ± 0.1	2.2 ± 0.1
Cranberry	4.8 ± 0.1	4.3 ± 0.1	4.0 ± 0.1
Strawberry	3.4 ± 0.1	3.1 ± 0.1	2.5 ± 0.1
Specific power inputs, kw/kg of a remote moisture			
Raspberry	3.79 ± 0.05	4.12 ± 0.05	4.56 ± 0.05
Cranberry	3.05 ± 0.05	3.32 ± 0.05	3.79 ± 0.05
Strawberry	2.96 ± 0.05	3.25 ± 0.05	3.44 ± 0.05
Organoleptic estimation, points			
Raspberry	34	29	22
Cranberry	37	35	29
Strawberry	36	27	21

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