Journal of Engineering and Applied Sciences 13 (24): 10406-10416, 2018
ISSN: 1816-949X

Improvement of the Process of Drying Tea Semi-Finished Products from Vegetable Raw Materials (Blooming Sally Narrow-leaved *Epilobium angustifolium*)

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Abstract: A modern alternative to tea, produced on an industrial scale is made by tea drinks with wild grasses in their composition. The blooming sally is quite popular in this respect. It is known that the stimulation of plant raw materials as well as decoctions and extracts based on them with a high content of phenolic compounds of polymer forms (tannins) is due to the course of oxidation reac-tions with the formation of flobafenes. Therefore, the process of drying plant raw materials containing tannins of this group should be conducted as quickly as possible. Thus, the study of the influence of temperature regimes drying the leaf on the phenolic substances of tea from the kaprewa narrow-leaved is relevant. It is shown that in order to achieve the same moisture content, the drying process at a low drying agent temperature (500°C) should be conducted for a long time up to 3 h or more. At the same time, an increase in its temperature to 2000°C makes it possible to minimize the process time to 25 min. When the coolant is supplied at 1000°C, the material is dehydrated for 40-50 min. With an increase in the temperature load up to 1500°C, an increase in the quantitative content of leucoanthocyanins by about 40-80% occurs with a simultaneous decrease in the number of polyphenol forms on average by 20-40% (in comparison with the traditional drying temperature of 500°C); an increase in the output of coloring substances from the spray material, a significant increase in the content of phenolic acids and as a result, a total increase in the total amount of phenolic compounds in the finished beverage. The best results of the organoleptic evaluation of tea from blooming sally were obtained samples dried at the temperature of drying agent 100 and 1500°C. They were distinguished by a delicate herbal fragrance and residual tartness in the aftertaste. The high drying temperature (2000°C) leads to destruction of phenolic acids and negatively influences the formation of organoleptic parameters of tea from the spray.

Key words: Vegetable raw materials, blooming sally narrow-leaved *Epilobium angustifolium*, *Epiphany angustifolium*, infrared-convective drying, tea from spray, phenolic compounds

INTRODUCTION

The urgency of development of the food industry is connected with the decision of problems of imbalance of a food of the population, a lack of functional food stuffs, decrease in the cost price of manufacture of foodstuff of mass consumption. To date, there has been an increase in demand for natural products, providing the need for protein, carbohydrates, vitamins, minerals and other essential elements of food. In modern conditions, non-traditional technologies for processing plant raw materials, the production of concentrates, dry products, etc. are of great interest. The introduction and effective operation of these technologies is limited by the lack of reliable methods and apparatus for drying. Thus, the task of searching for new and rationalizing existing methods for obtaining dry dispersed materials during processing of plant raw materials is actual.

A modern alternative to tea, produced on an industrial scale is tea drinks with wild grasses in their composition. Such products are produced mainly by regional enterprises of small capacity. Quite popular in this respect is blooming sally (popular names: Ivan-tea, Kopor tea).

The history of “Koporsk tea” began in Russia in the 19th century. At that time, the popularity of the Russian

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herbal beverage obtained by brewing the fermented leaves of the *Epilobium angustifolium*, a perennial herbaceous plant from the Kipreiny family was very high.

The name of the drink came from the village of Koporye near Petersburg. In Koporye, the creation of a fermented willow-tea or "Kopor tea" was founded. After 1917 the enterprise in Koporye went bankrupt (Korsun *et al*., 2013).

At present, the pure culture of small-leaved spraying used as an ingredient for food and feed purposes is obtained by microclonal propagation recommended in both domestic and Foreign agricultural science. This method allows obtaining a material of a certain micronutrient composition in large quantities and in a short time (Shapiro, 2015; Constantin *et al*., 2013; Abdelwahd *et al*., 2008).

The chemical composition of the Cyprian is sufficiently studied in the world science (Nikolaevich *et al*., 2016; Orlov and Mitina, 2015; Toth, 2009; Bisset and Wichtl, 1994). In Russia, the spray is not a pharmacopeia plant and some of its species are introduced into the culture as decorative (Korsun *et al*., 2013; Krasnoborov *et al*., 2000). However, Russian scientists have made a great contribution to the standardization of small-leaved kaprels and the development of projects of pharmacopoeial articles (Polezhaeva, 2007; Polezhaeva *et al*., 2005a-c, 2007; Valov *et al*., 2010).

Thus, the spray has a wide range of biologically active components. The mineral composition is represented by more than 20 chemical elements, among which iron, copper and manganese predominate (Polezhaeva *et al*., 2005a-c, 2007; Valov *et al*., 2010).

The hydrodistillation essential oil of the flowering part of the spray contains a significant amount of linalool, eugenol (Polezhaeva, 2007a-c). About 100 g of dry biomass of cyprus meets the daily human need for essential amino acids in the range of 5-10% (Polezhaeva *et al*., 2007). The terrestrial part contains vitamins (mainly vitamin C) and substances that have provitamin activity (rutin) (Polezhaeva, 2007; Zlobina, 2009). The carbohydrate fraction of the chemical composition of spray is represented by polysaccharides (branched a glucan, starch, mucus), pectin, lignin (Polezhaeva *et al*., 2005a-c). Organic acids are concentrated in the leaves (Polezhaeva *et al*., 2005a-c). The fatty acid series is very diverse with predominance of palmitic and linoleic acids (Maksyutina *et al*., 2010; Guil-Guerrero *et al*., 2001).

Separate attention should be paid to the phenolic complex of Cyprus. It includes a wide range of substances such as simple phenols, phenolcarbon acids, flavonoids, tannins, ellago and gallotanines (Schmandke, 2004; Feldman, 2005; Kaskoniene *et al*., 2015; Monschein *et al*., 2015; Toth *et al*., 2009; Barakat *et al*., 1997).

Most phenols of a number of flavonoids quickly react with various radicals, therefore, they are effective oxygen traps and exceed in this respect the most important antioxidant ascorbic acid. The antiradical activity of flavonoids with respect to the oxygen radical anion is due to the catechol groupe of ring B and also to the formation of intermediate products of their oxidation (Kostyuk and Potapovich, 2004).

The period of vegetation of spraying significantly affects the content of phenolic compounds in its ground parts (Polezhaeva *et al*., 2005a-c, 2007; Maruska *et al*., 2014).

Domestic and foreign scientists conducted numerous studies of therapeutic and immunomodulating properties of a complex of biologically active substances of Cyprinus narrow-leaved (Schmandke, 2004; Kaskoniene *et al*., 2015; Barnaul, 2008; Jones *et al*., 2000; Shikov *et al*., 2006; Sillo *et al*., 2014; Stajner *et al*., 2007).

Various methods have been developed for the production of tea from spraying which include drying the herbal raw material under vacuum for 3-6 h at a temperature of 30-550°C (Emelyanov *et al*., 1999; Danshin and Emelyanov, 2004) by convection for 1.5-3 h at a temperature of 50-600°C (Shamurin, 2015; Zavorokhina *et al*., 2014; Ponomarev and Veselkov, 2012) and also under natural conditions in the open air for 6 h (Metelyov and Metelyova, 2013).

It is known (Abdrahimova and Valieva, 2012) that the stimulation of plant raw materials as well as decoctions and extracts based on them with a high content of phenolic compounds of polymer forms (tannins) is due to oxidation reactions and the formation of dark-colored products flobafenes. The latter do not have physiological properties, so, the drying process of plant raw materials containing tannins of this group should be carried out as quickly as possible (Abdrahimova and Valieva, 2012).

Thus, the study of the influence of temperature regimes of drying the leaf on the phenolic substances of tea from the angustifolia spruce is relevant and is the aim of these studies.

MATERIALS AND METHODS

Objects and methods of research: The objects of research were: samples of the dried leaf of *Epilobium angustifolium* which differed in the temperature parameters of radiation-convective drying. Vegetable raw materials were harvested in the Summer of 2017, zoned in the Kemerovo Region; tea made from blooming sally, obtained by brewing a sheet with hot water (5 min after boiling) and infusion for 5 min (i.e., by the technology of making regular tea).

Experimental studies of the drying process were carried out in the moisture analyzer MX-50. The spectrophotometric characteristics of the teas were obtained on a spectrophotometer PE-5400UF in the wavelength range in the UV and visible part of the spectrum. With spectrophotometry, the concentration of the tea solution was 0.05%. In the tea samples, the quantitative content of coloring and polyphenolic substances, leuco-anthocyanins and the total content of phenolic compounds were determined analytically.

Coloring matter: An acidified 96% ethyl alcohol and concentrated hydrochloric acid are added to an aliquot of the sample to be analyzed. The volume of the analyte is 25 cm^3. The resulting mixture was centrifuged for 15 min at 1500 rpm. The optical density is determined in the supernatant at a wavelength of 530 nm. Control solution is distilled water. The optical density readings are multiplied by the conversion factor (K = 1056.7) (Gerzhikova, 2002).

Polyphenolic substances: Determination of the content of polyphenolic substances is based on the reaction of the analyte in an alkaline medium in the presence of iron of citric-ammoniacal brown water, followed by photocolorimetry at 600 nm against distilled water (Yerumanis modification) (Ermolaeva, 2004).

Leukoanthocyanins: To an aliquot of the extract, butanol is added, acidified with hydrochloric acid. After thorough mixing, the test tube is placed in a boiling water bath and after 30 min in a glass with cold water. A solution that has not been subjected to a temperature treatment serves as a comparison benchmark. Photocolorimetry uses a light filter with a transmission maximum of 540 nm (Ermolaeva, 2004).

Total content of phenolic substances: The colorimetric reaction is carried out with a Folin-Chokalteu reagent while the mixture is basified with a solution of soda. Photocolorimetry is carried out using a red light filter (Ermolaeva, 2004).

The studies were conducted no less than in 3-fold repetition, processed by standard methods of mathematical statistics. The confidence interval was <5%.

RESULTS AND DISCUSSION

During the preparation of dry fermented leaves, the following process chain was adhered to:

- Collection of raw materials
- Sheet pressing into blocks
- Freezing of raw materials (for the purpose of conservation and organization of the process at the right time)
- defrostation
- Shredding of leaves
- fermentation
- infrared-convective drying of leaves
- packing

Leaves were harvested during the flowering of the plant, passing a hand along the stem from the top down from the inflorescence. Further, the leaves were compressed into blocks in order to minimize the amount of raw material for its subsequent low temperature storage.

The next stage of production is the freezing of leaves. When freezing, the speed of the process assumes a decisive role. A slow freezing process is recommended with the aim of maximizing damage to cell membranes by ice crystals. The freezing process retains structural and enzymatic properties in the raw materials for a long time. The defrosting process was performed by natural defrosting in room conditions at a temperature of 20-22°C.

Before fermentation, it is recommended to destroy cell membranes as much as possible. This is done both manually and mechanically. In the proposed technology, the process is performed by cutting on an improved top, used in the technology of meat products. The feature of the top is the cutting mechanism, consisting of alternating output gratings and double-edged knives with three gratings and two blades creating four cutting planes. The raw material is cut under the pressure created by the supercharger-screw (screw). Specificity of plant raw materials required to modernize both the supercharger and the tops of the top.

To analyze the granulometric composition of the crushed raw material, a set of sieves was used. The results of the analysis are shows in Fig. 1.

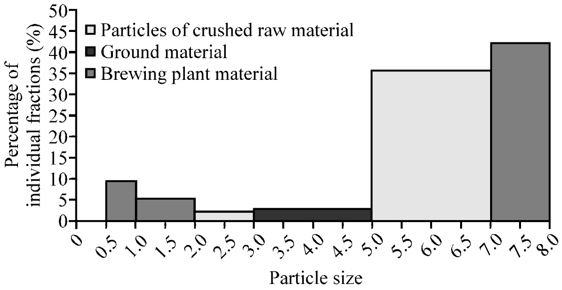


Fig. 1: Histogram of the distribution of particles of crushed raw material by size

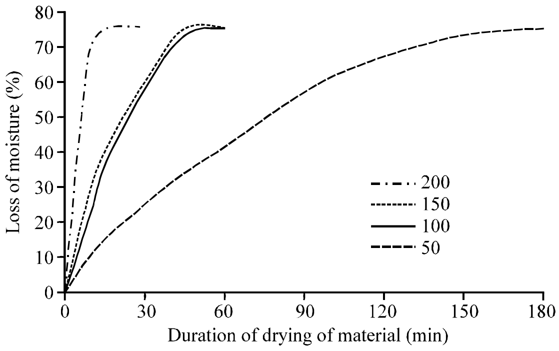


Fig. 2: Drying curves of the crushed fermented material of the leavening sheet

It has been established that in the ground material there are no particles smaller than 0.5 mm which cause the presence of turbidity in the beverage during brewing. The percentage of fine fractions of particles with a diameter of 0.5-5.0 mm is small. At the same time, the majority of the granules of the crushed material of the Cyprian leaf have particles of medium size which contributes to good consumer qualities when brewing plant material.

Fermentation of raw materials is a process of changing the biochemical composition of a plant under the influence of intracellular enzymes. Fermentation was carried out in a traditional way, adopted in tea technology. The fermentation temperature was 30±20°C, duration 3 h.

The most important process that affects the quality of tea is the drying of raw materials. In the research of Khudonogova *et al.* (2012) it is shown that the convective method of drying using pulsed infrared radiation favorably affects the preservation of biologically active substances of medicinal raw materials. Increasing the drying temperature to 600°C makes it possible to inactivate the action of enzymes that destroy glycosides. A further increase in the temperature factor (up to 900°C) contributes to the prevention of the destruction of vitamin C from oxidation (Khudonogova *et al*., 2012).

An infrared-convective method for drying the leaves of the spray was used at different tem-peratures. To study the drying process, a moisture analyzer MX-50 (manufactured by A and D, Japan) certified in the Russian Federation in accordance with GOST 24789-03 was used. Curves for drying the shredded material are shows in Fig. 2.

It is shown that in order to achieve the same moisture content, the drying process at a low temperature (500°C) must be carried out for a long time up to 3 h and more. At the same time, an increase in temperature up to 2000°C allows to minimize the process time to 25 min. At 1000°C the material loses excess moisture within 40-50 min.

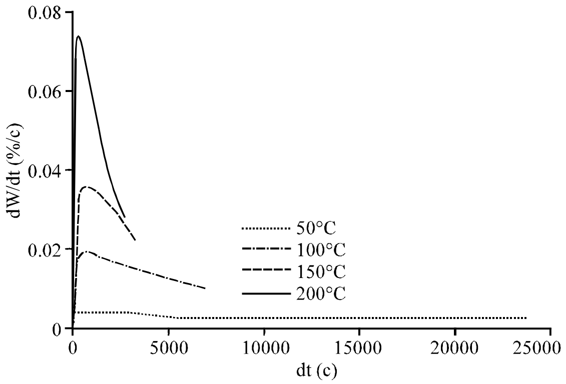


Fig. 3: Change in drying speed dW/dτ of ground fermented material of the leaf of the spray in time

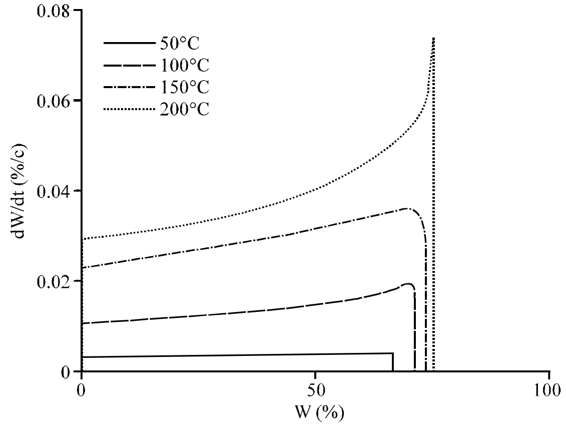


Fig. 4: Dependence of drying speed dW/dτ of ground fermented of the leaf material from the moisture content of W (%)

Curves of drying kinetics (Fig. 3 and 4) demonstrate the presence of physico-mechanical moisture in the material, the removal of which is most rationally carried out by the radiation-convective method.

The results of studies on the influence of the drying temperature of the material on the phe-nolic composition of tea from the spray are presented in Fig. 5 and 6. Experimental data are expressed as a percentage of the studied index of a sample dried at a temperature of 500°C.

Figure 7 shows the spectrophotometric characteristics of tea-kettle solutions at a wavelength of 260 nm and an extract concentration of 0.05%. The diagram contains the peak values of the studied index in the range 250-300 nm.

The results of the study of the kinetics and mechanism of internal heat and mass transfer during the convective radiation drying of tea semifinished products were obtained (average particle size 4, 5 mm). The main factors influencing the efficiency of the drying

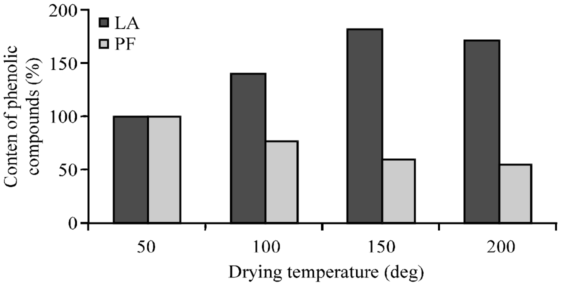


Fig. 5: Change in the content of Leukoanthocyanins (LA) and Polyphenolic substances (PF) in tea from spraying, depending on the drying temperature of the sheet

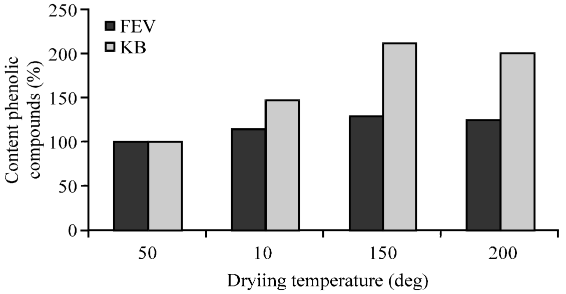


Fig. 6: Change in the content of total phenolic substances (FEV) and coloring substances (KB) in tea from spraying, depending on the drying temperature of the sheet

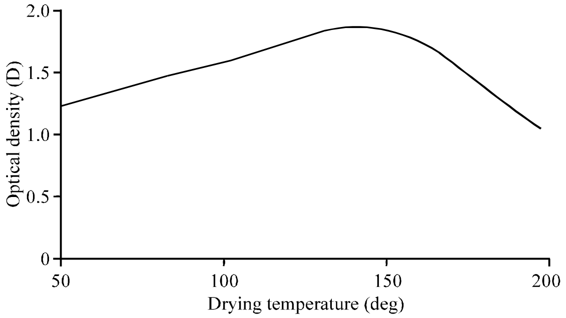


Fig. 7: Spectrophotometric characteristics of tea solutions from the spray depending on the drying temperature of the sheet

process were adopted: temperature of the drying agent Tca = 423.473 K and heat flux density E_p = 2, 8, 3, 6 kW/m^2. To obtain the dependence of the rate of drying dW/dτ or dc/dτ, kg/(kg sec) from humidity W or solids content c, kg/kg experimental data are described by the dependence of the form:

$$dc/d\tau = -1/(4a_k(1-c)^3+3b_k(1-c)^2+2c_k(1-c)+d_k) \tag{1}$$

Table 1: Kinetic coefficients of functional dependences of the speed of drying process of tea semifinished products

Factor/Coefficient	Tc.a. = 423 K	Tc.a. = 448 K	Tc.a. = 473 K
A_k	-43,24375	41,9584375	50,606875
B_k	255,0135	-277,339375	-332,90625
C_k	-336,9589	475,0004	558,2569
D_k	63,0115625	-95,701875	-114,6975
E_k	-349,884125	641,71825	761,687
F_k	383,5072	-1 129,00	-1 306,72
G_k	-21,093125	72,81625	87,5734375
H_k	89,76925	-497,36825	-589,048875
K_k	4,959	902,5025	1 038,07
L_k	-1,92125	-20,9553125	-25,59375
M_k	28,9675	148,307375	176,999
N_k	-102,7545	-286,0546	-329,0762

Summarizing the research data in the range of variation of Ep for the efficiency of engineering calculations and the convenience of mathematical modeling of the process, the kinetic coefficients of the drying process are determined by the method of exact hit at the nodal points.

The value of the reliability of the approximation was not <R^2 = 0.99. The dimension of the coefficients is equal to the ratio of the dimension of the function to the dimension of the argument (or theproduction of the arguments), depending on the type of the equation. Taking into account that c, kg/kg, the dimension A_k, D_k, G_k, L_k, -[s/(kW^2/m^4)]; B_k, E_k, H_k, M_k -[s/(kW/m^2)]; C_k, F_k, K_k, N_k -s.

$$dc/d\tau = -1/\left[\begin{array}{l} 4.(A_k.E_p^2+B_k.E_p+C_k).(1-c)^3+3.(D_k.E_p^2+ \\ E_k.E_p+F_k).(1-c)^2+2.(G_k.E_p^2+H_k.E_p+K_k).(1-c)+ \\ (L_k.E_p^2+M_k.E_p+N_k) \end{array}\right] \tag{2}$$

where, A_k, B_k, C_k, D_k, E_k, F_k, G_k, H_k, K_k, L_k, M_k, N_k, -kinetic coefficients (Table 1). Two characteristic periods of dehydration are observed at the velocity curves. The first period corresponds to an increase in the dewatering rate to a maximum due to the removal of predominantly free moisture from the particle surface at high Tca and volumetric radiation energy supply. As a result of intensive evaporation in the first period, overheating of the product is eliminated. At a certain moment in the region of the inflection point, a smooth transition of the structure to the capillary porous body with high porosity occurs due to drying of the partitions and their cracking and as a result a network of microcapillaries is formed, the steam movement through which is carried out by effusion. Since, in the optically thin layer the penetration depth of infrared radiation exceeds the thickness of the particle, the volumetric infrared energy supply leads to a practically, uniform volumetric evaporation of moisture throughout the product. Further, the value of the drying rate decreases with the transition to moisture removal of

Table 2: Hygroscopic characteristics of tea semifinished products

W_K (kg/kg)	Wg^1 (kg/kg)	Wg^2 (kg/kg)	$W\varepsilon^1$ (kg/kg)	$W\varepsilon^2$ (kg/kg)
0.05	0.401	0.367	0.28	0.271

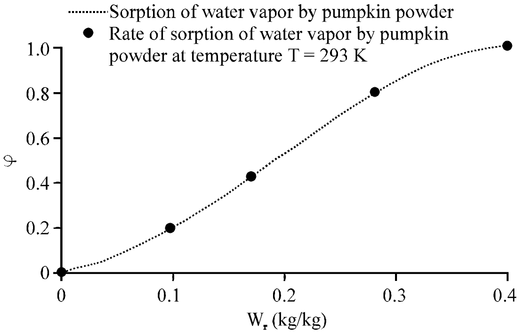


Fig. 8: Isotherm of sorption of water vapor by pumpkin powder at temperature T = 293 K

polymolecular adsorption. In the second period, the particle size practically does not change, the heating of the material intensifies, cracking and pore formation occur in the material and the evaporation zone deepens.

The results of studies on the development of a rational regime for the intensification of heat and mass exchange processes in the convection radiation drying of tea semifinished products are obtained. In the variants of the values of the influencing factors, the experimental drying time τ_c to the adopted W_k.

The results of the analysis of literature sources and studies of the statics of the dehydration process and the complex properties of tea semifinished products are obtained. The hygroscopic properties were studied and the sorption isotherms shows in Fig. 8 were constructed as an exaple.

We take the moisture content of the powder reached in the drying chamber, W_K = 0.05 kg/kg (Table 2). Experimental data on hygroscopic humidity W_g, kg/kg at relative air humidity $\varphi = 1$ have been adjusted. Humidity W_g, kg/kg was determined from the point of intersection of the continution of the rectilinear section of the isotherm in the region $\varphi = 0.8$ with a straight line $\varphi = 1$.

Table 2 shows, W_g^1, kg/kg with T = 293K and W_g^2, kg/kg with T = 323 K. The boundary between the moisture enclosed in the volume of micro and macrocapillaries, pores, immobilization and osmotic moisture and moisture, adsorption, $W\varepsilon^1$, kg/kg with T = 293K and $W\varepsilon^2$, kg/kg at T = 333 K.

Table 2 is designed to estimate the total amount of moisture removed during drying and to classify the relationship of moisture with the dry substances of the semifinished tea.

Table 3: Values of empirical coefficients of dependences of relative humidity of air from equilibrium humidity of a pumpkin powder and temperature

Variables	Values
a	-0,03719
b	-14,07113
c	0,0176975
d	9,1989325
e	0,00028
f	0,65386
g	-0,0000025
h	0,0046325

On sections of isotherms $W_p = W_K$ at the sorption of water vapor, a layer of monomolecular adsorption is formed that is hydrate complexes (the Coulomb character of hydration) are formed due to the adsorption of solvate molecules of water by the molecules of the outer and inner surfaces of the micelles of the products while releasing the heat of hydration. During the hydration of sub sequent layers, the previous adsorption layers on the site $W_K<W_p<W\varepsilon$, water molecules are also in an oriented state which characterizes polymolecular adsorption in which moisture absorption is also, accompanied by the release of heat. The site $W\varepsilon \leq W_p \leq W_g$ corresponds to the absorption of moisture without the release of heat during its own swelling. For the site $W \leq W_p \leq W_g$ also, characterized by the presence of liquid in the volume of micro and macrocapillaries, pores due to the effect of wetting without the release of heat. Approximating functional dependencies are obtained:

$$\varphi(W_p, T) = (a.T+b).W_p^3 + (c.T+d).W_p^2 + (e.T+f).W_p + (g.T+h) \tag{3}$$

where, a-h empirical coefficients (Table 3). The driving force of sorption is the difference in chemical potentials $\Delta\mu$ which in the hygroscopic region is equal to the binding energy of moisture with the material:

$$E\tilde{n}\hat{a} = -\Delta\mu = -R.T.\ln((a.T+b).W_p^3 + (c.T+d).W_p^2 + (e.T+f).W_p + (g.T+h)) \tag{4}$$

By differentiating the Gibbs-Helmholtz equation from W_p at T = const ($\Delta F = \Delta E - T \cdot \Delta S$ where ΔE change in internal energy; $T \cdot \Delta S$ change in bound energy; ΔS entropy change) we obtain:

$$(\partial \Delta F/\partial W_p)_{T,P} = (\partial \Delta E/\partial W_p)_{T,P} - T.(\partial \Delta S/\partial W_p)_{T,P} \tag{5}$$

When differentiating Eq. 5 by T, we obtain:

$$\partial(\partial \Delta F/\partial W_p)_{T,P}/\partial T = -(\partial \Delta S/\partial W_p)_{T,P} \tag{6}$$

As a result, we obtain a dependence for the differential change in entropy of bound water:

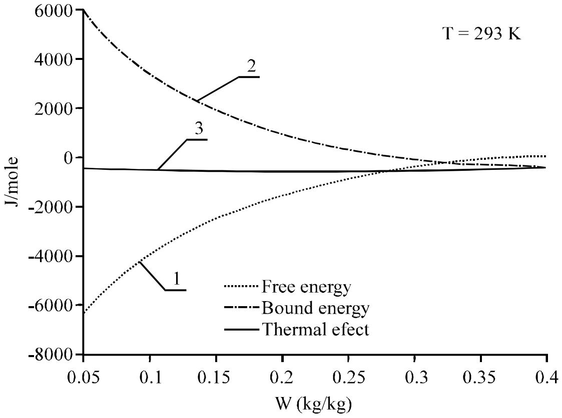


Fig. 9: Dependences of the differential change in the free energy; 1) The bound energy; 2) And the thermal effect and 3) Of the sorption of water vapor by the ground tea semifinished product

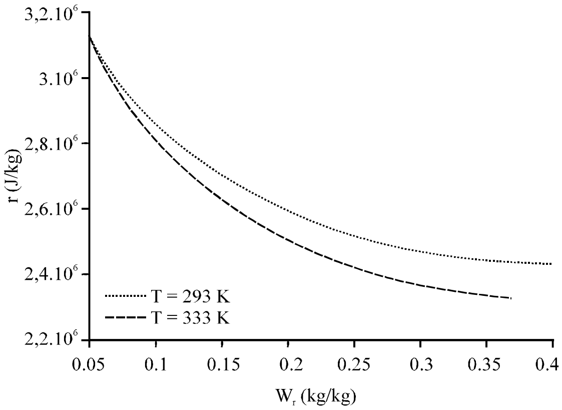


Fig. 10: Dependence of the specific thermal energy of evaporation on the equilibrium moisture content

$$(\partial \Delta S/\partial W_p)_{T,P} = -\partial (R.T.\ln\varphi)/\partial T \tag{7}$$

Let us determine the numerical values of the free energy $\partial \Delta F/\partial W_p$, related energy $-T\cdot(\partial \Delta S/\partial W_p)$ and internal energy (heat effect) $\partial \Delta E/\partial W_p$ process of sorption (Fig. 9). The nature of the differential change in bound energy in the humidity range is due to the system's striving for thermodynamic equilibrium. Negative values of the differential change in internal energy during sorption indicate the presence of thermal effects.

When modeling the processes of moisture removal taking into account the phenomena of moisture binding with materials, the thermal energy of evaporation r (Fig. 10), entering into the differential heat transfer equation can be represented as the sum of the heat of wetting r_{cm} (determined by the differential change in free energy) and the heat of vaporization of free water r'. Amount of heat energy r, for evaporation of 1 kg of moisture, J/kg:

$$r = r' + r_{cm} + r_{эНМ} = 3118,4581.10^3 - 2286,66.T - 55,(5).R.T.\ln\phi + 55,(5).T.(\partial \Delta S/\partial W_p) \tag{8}$$

It is concluded that for intensification of drying of tea semifinished products, it is advisable to increase the mass transfer surface by dispersing the product and using volumetric variants of the energy supply.

With the use of data from literature sources, the thermoradiation and optical characteristics of semifinished tea were analyzed.

The results of mathematical modeling and calculation of temperatures in the dried particle during convection radiation drying of tea semifinished products are obtained. When constructing the model, we assume that in the course of drying a uniform volumetric energy supply for a planar particle of small size d_e = 4, ..., 6 mm equally throughout the outer surface of the particle. The mathematical model is based on the finite difference solution of the differential heat transfer equation taking into account the kinetics of the drying process, material properties and thermodynamic parameters, etc. In the case of volumetric energy supply, the differential heat transfer equation for a one-dimensional problem has the form:

$$c'(W).\rho(W).\frac{\partial t}{\partial \tau} = \frac{\partial}{\partial x}\left(\lambda(x,t,W)\frac{\partial t}{\partial x}\right) + \varepsilon.r(x,t,W).\rho(W).\frac{\partial W}{\partial \tau} + w(x,t,W) \tag{9}$$

Where:

x = Depth coordinate in thickness $d_б$ mm particle m
$\varepsilon = 1$ = Coefficient of phase transformations
w (x, t, W) = The distribution function of the bulk density of the absorbed radiation energy over the depth of the optically thin layer

The initial value of the coordinate x, corresponding to the particle surface $X_n = 0$. The final x, corresponding to the particle surface $X_k = d_e$. For the second coordinate in drawing up the difference grid and solving the differential equation, we take the moisture content of the product W, kg/kg (or solids content c, kg/kg) coordinate $W = W_H, ..., W_K$ (or c = Cn, ..., Ck). The initial value of the coordinate W (or c), At the start of the drying process, $\tau = 0$: W_H (Cn = $1-W_H$). The final value of the coordinate W (or c), at the end of the drying process $\tau = \tau_c$: W_K (or Ck = $1-W_K$). Taking into account the assumption that the structure of the particle is isotropic, the thermal conductivity does not depend on x, we take the average thermal conductivity behind the sign of the differential and trans form the expression, dividing both sides of the equation into $c'(W)\cdot\rho(W) = c_v$, then we get:

$$\frac{\partial t}{\partial \tau} = \overline{a}(t,W)\cdot\frac{\partial^2 t}{\partial x^2} + \frac{r(t,W)\overline{\rho}(t,W)}{\overline{c}_v(t,W)}\cdot\frac{\partial \overline{W}}{\partial \tau} + \frac{w(x,t,W)}{\overline{c}_v(t,W)} \tag{10}$$

We transform and then omit the sign of the mean and variable parameters:

$$\frac{\partial t}{\partial W} = \frac{a}{\partial W/\partial \tau}\cdot\frac{\partial^2 t}{\partial x^2} + \frac{r.\rho}{c_v} + \frac{w}{\overline{c}_v \partial W/\partial \tau} \tag{11}$$

At the initial time $\tau = 0$, at the initial humidity W_H, the temperature of all spatial points of the product particle is the same and corresponds to $t_0 = T_{prod}$. Initial conditions: $W = W_H$, $t = t_0$.

When the model is implemented, the final conditions of the previous section at the current humidity W are the initial conditions for the next section at the next step moisture value W. The boundary conditions at the material boundary with the drying agent:

$$-\lambda(W)\frac{ft}{fx} = E_{s.border} + \alpha(Tca - t_{x=0\,(syrface)}) \tag{12}$$

Where:

α = Heat transfer coefficient ($W/m^2\cdot K$)

$t_{x=0\,(surface)}$ = Surface temperature of a particle

$Ke_{n.border}$ = The incident heat flux with volumetric irradiation (W/m^2)

For the convenience of differentiation in the numerical implementation of the model, we replace the moisture content W concentration of solids c. The differential equation of parabolic type was solved by a fundamental method of finite differences in the environment of specialized software Mathcad Professional under a rational regime, the temperature function is determined from de and changing with time as (Fig. 11). To analyze the temperature field, we compare it with the dependencies for the drying rate. During a period of intensive removal of free moisture, the material particles practically do not heat up, the energy is expended on the evaporation of free moisture.

Removing free moisture from the surface of the particles with a volume energy supply eliminates overheating of the product during the initial stage of the process. The change in temperature is determined by the type of moisture bond with the material. There is a slight decrease in the temperature of the material (on 3, ..., 5 K) due to intensive moisture recovery with increasing evaporation rate of free moisture.

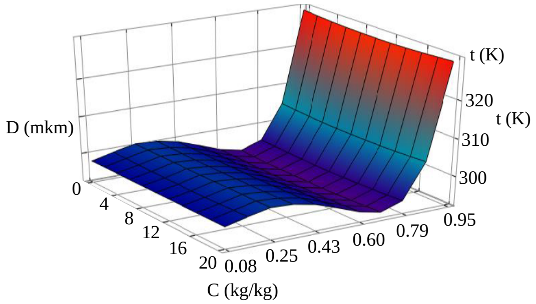


Fig. 11: The field of distribution of temperature values in a particle during drying (rational mode: Tca = 473 K and E_p = 3.6 kW/m^2)

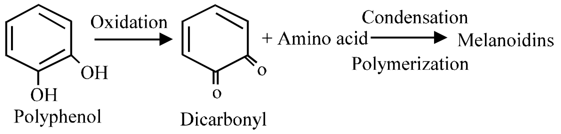


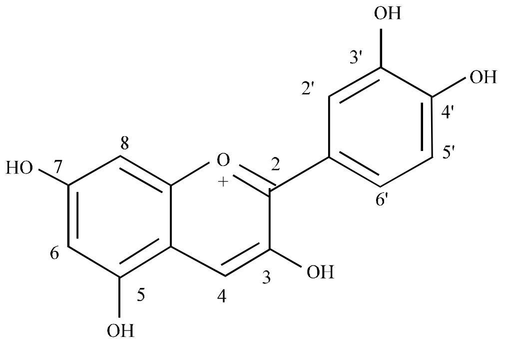
Fig. 12: The reaction of melanoidinformation with aminoacids

Further, the product temperature increases which is due to the removal of moisture associated with the material by thermal effects. Analysis of the field, confirms the earlier conclusions about the mechanism of internal mass transfer. The obtained results of experimental studies made it possible to draw the following conclusions.

The decrease in the quantitative content of polyphenolic compounds (Fig. 5) can be explained by a number of reasons. First, in the process of temperature exposure under the influence of air oxygen from polyphenols, inactive forms are formed-flobafenes: phenols→quinones→flabbafens and melanins. In addition, polyphenols upon heating enter the reaction of melanoidinformation with amino-acids (Fig. 12).

The precursors of the condensed tannins of plant raw materials are leucoanthocyanins, so, the decomposition of polyphenols leads to an increase in the number of these compounds (Fig. 5).

In turn with increasing temperature load, during drying of the leaves of the spray, the coloring substances in the extracts are released (Fig. 6). Anthocyanidins occupy the main share of the coloring matter of plant raw materials, having in their structural skeleton the flavilia cation in which the oxygen atom in the pyran ring has a free valence (Fig. 13) (Abdrahimova and Valieva, 2012).



Cyanidin

Fig. 13: The structural skeleton the flavilia cation in which the oxygen atom in the pyran ring has a free valence

In the process of fermentation of plant raw materials, the pH of the cell juice changes to the acidic side which contributes to saturation of the extracts obtained with red shades. In addition, the color of the broths also depends on the copying (the presence of other phenolic compounds, mainly flavones) and the presence of sugar residues.

From the literature (Logvina and Yurin, 2015) it is known that phenolic acids in plant extracts with spectrophotometry give the shoulder of the short-wave band at 254-275 nm. The data in Fig. 5 indicate that an increase in the temperature load to 100 and 1500°C when drying the leaves of the spray produces a significant increase in phenolic acids in the extract. Judging by the qualitative characteristics (optical density of extract solutions) this effect is within 27 and 50%, respectively, at a drying temperature of 100 and 1500°C. However, a further increase in the temperature factor leads to the destruction of these compounds.

As a result of chemical transformations, the redistribution of individual fractions of phenolic compounds with a certain increase in the total content of phenolic substances occurs in the drying process (Fig. 6).

To determine the consumer properties of readymade beverages, an organoleptic analysis of tea samples from Cyprenia was carried out (for comparison, traditional granular black tea was used). The descriptors were evaluated according to GOST 32573-2013. The best results of the or ganoleptic evaluation of tea from Cyprenia were obtained by samples, the drying of the material for which was carried out at 100-1500°C (Table 4). These samples differed in a harmonious aroma with a light herbaceous note and residual tartness in the aftertaste. You-co-temperature drying (at 2000°C) had a negative effect on the organoleptic index of ready-made beverages from Cyprus. There was a rough roughness and imbalance of taste.

Table 4: Organoleptic characteristics of black tea and tea from blooming sally

Name descriptor	Characteristic	
	Black tea	Tea from blooming sally
Appearance of tea	Bright, clear, clean, color from dark red to dark brown	Bright, clear, clean color dark brown
Flavor and taste of tea	Delicate aroma, tart taste Pleasant flavor with tart taste	Tart taste, pleasant aroma
Color of tea leaf tea	Homogeneous,brown-redor brown	Homogeneous, brown-red
Appearance of tea granular	Fairly even, spherical or oblong form	Fairly even, spherical and oblong form

As a result of the conducted experimental studies on the influence of temperature regimes of drying the leaf on the phenolic substances of tea from the narrow leaved canopy, the following conclusions can be drawn. An increase in the temperature of infrared-convective drying of the spray material up to 2000°C makes it possible to minimize the process time to 25 min. At 1000°C the material loses excess moisture for 40-50 min.

With the increase in the temperature load up to 1500°C, the following changes occur in the phenolic complex of tea from blooming sally: an increase in the quantitative content of leucoanthocyanins by about 40-80% while reducing the number of polyphenol forms by an average of 20-40% (compared to the traditional drying temperature of 500°C).

An increase in the output of coloring substances from the blooming sally material by 1.5-2 times, a significant increase in the content of phenolic acids and as a result, a total increase in the total amount of phenolic compounds in the finished beverage.

Samples of tea obtained from a sheet of spray dried at temperatures of 100-1500°C were characterized by a well-balanced aroma with a light herbaceous note and residual tartness in the aftertaste.

The high drying temperature (2000°C) leads to the destruction of phenolic acids and negatively affects the formation of organoleptic parameters of tea from the spray.

CONCLUSION

Thus, based on the studies carried out, it is possible to consider the infrared convective method of drying the leaves of spraying using high temperatures of 100-1500°C to produce tea with a high content of phenolic substances.

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