

# RESEARCH AND EXPERIMENTAL DETERMINATION OF THERMO PHYSICAL PROPERTIES OF HIGHLY FOAMING SOLUTION

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**Abstract---***In the article discusses about basic properties of licorice root, and also, by experimental method, the basic thermophysical characteristics of licorice root are determined.*

**Keywords---***Licorice, licorice root, thermophysical characteristics, technical raw materials, thermostat, potentiometer, sensor.*

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## I. INTRODUCTION

In connection with the intensive development of the agro-industrial complex, the question of the most rational use of natural plant resources for the needs of the national economy is acute. Among the vegetable raw materials harvested and used in the CIS countries, a special place belongs to licorice. The economic importance of licorice root is difficult to overestimate, it has long been widely used in medicine, industry and agriculture, as well as being exported as medicinal and technical raw materials. Licorice root is one of the oldest medicines that has successfully passed the test of time and in modern scientific medicine is used as a classic tool that improves the taste of a variety of medicines. Licorice root is used in pulmonary diseases-bronchitis, whooping cough, tuberculosis; as an enveloping and mild laxative; it successfully treats stomach ulcers, is used as an antidote for drug poisoning, etc. Licorice is one of the few plants whose sweet taste is due to the presence of substances that are not sugars. In China, licorice root is valued on a par with the legendary ginseng.

In East Asian countries, licorice root and the extract derived from the root is part of very many medicines. Ancient Arabic medicine valued licorice root very highly, hence in the XII century it penetrated into medical reference books. Abroad, the field of application of licorice root is rapidly expanding. A number of countries have established a whole industry for the processing of licorice root. The need for licorice root extract both domestically imported and exported is constantly growing. Currently, some processes of licorice root processing have been studied and equipment for these processes has been developed. In our country grows several species of licorice. The main thickets of licorice are in the Amu Darya river basin.

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## II. FORMULATION OF THE PROBLEM

Harvested in the flowering stage, the stems and leaves are equated to alfalfa hay in fodder qualities. Waste extract production (meal) can be used for the preparation of paper pulp (USA), which was used for the manufacture of substitutes for glass and earthenware for single use. In Germany, extracted licorice root is used as a fertilizer because it contains up to 1,75% nitrogen and up to 18% minerals. In addition to medicine, licorice root extract is widely used in the food industry in the manufacture of certain types of confectionery, chewing sweets, halva, in the production of kvass, effervescent waters, tonic drinks and in the tobacco industry for tobacco sauce. In recent years, condensed extract has been used on a large scale in industries such as non – ferrous metallurgy (lead – zinc production; to suppress sulfuric acid mist in electrolysis baths). Diversity the use of licorice root extract in the chemical industry (as a foaming component of fire extinguishers,) the manufacture of artistic ink, wax, Shoe Polish and dyes also enhances its practical value.

Licorice root and its concentrated extract for many years is the subject of traditional exports to countries such as the CIS, USA, England, Japan, Germany, GDR, Hungary, Bulgaria, which in different years bought and still buy from us licorice root and extract from it.

Industrial product-licorice root extract is a thick mass of brown color, weak peculiar smell and sweet taste with residual bitterness. When shaken with water forms a colloidal, strongly foaming solution. Licorice root extract is valued for its content, glycyrrhizic acid, as well as a number of other related substances:

Flavonoids-13,0 ÷ 4,0%;

Saponins, tannins-9,7 ÷ 28,2%;

Extractives of 22,8 ÷ 44,1 kHz;

Glycyrrhizin-7,3 ÷ 23,6;

Glucose-0,3 ÷ 11,0;

Fiber – 9,7 ÷ 28,2;

Starch to 34,0 %;

Ascorbic acid-11,0 ÷ 31,2 mg %;

Essential oil-0,03 %;

Asparagine-1,0 ÷ 4,0;

Fat-like – 0,2 ÷ 4,7;

Resinous – 1,75 ÷ 4,12;

Protein – 6,18 ÷ 10,13;

Gums-1,5 ÷ 5,5;

The bitterness is insoluble in water and 3,0 ÷ 3,6;

The bitterness of instant – 1,8;

Ash total-4,9 ÷ 9,7.

Thick licorice root extract is obtained by extracting the root with hot water followed by extraction.

To improve the technological processes of processing licorice root, it is necessary to know the properties of intermediate products, which include licorice extract. Among the properties of licorice root extract, an important place is occupied by thermophysical properties, which are widely used in the calculation of heat treatment parameters.

Thermophysical characteristics (TPC) - coefficients of thermal conductivity, thermal conductivity, volumetric heat capacity and density of licorice root extract vary significantly during heat treatment. In this regard, the availability of

information about their changes in the process of heat treatment allows deeper study of the laws of physical and chemical changes occurring during evaporation of licorice root extract and scientifically justify the rational modes of the evaporation process, leading to a high quality product.

The study of TPC of colloidal capillary-porous and dispersion media is carried out in two directions:

- the first direction – experimental determination of TPC by known methods based on the solution of boundary value problems of thermal conductivity;
- the second is the analytical determination of TPC on the basis of theoretical ideas about the mechanism of heat transfer in model structures typical for real solids and dispersed systems. These models can not accurately reflect the structure of real bodies and therefore the calculations according to theoretical formulas are approximate to a certain extent and especially since the TPC of licorice root extract of different concentrations have not been determined so far.

In the literature [1,2] there is information about a number of methods and devices for the study of TPC of different materials. Methods of experimental studies of TPC can be classified according to a number of features:

- 1) generality of theory;
- 2) similarity of operating modes;
- 3) the amount of information obtained from one experience;
- 4) test temperature range;
- 5) the nature of the materials under study;
- 6) the principle of measuring temperature and amount of heat, etc.

Methods of measuring TPC can be divided into 4 main groups, using as a classification feature the generality of the theory and principles of measurement:

- 1) balanced;
- 2) stationary mode;
- 3) regular mode;
- 4) non-stationary (irregular) mode.

Each of them has, as a rule, limited application due to specific thermal measurements of the properties of different materials in nature.

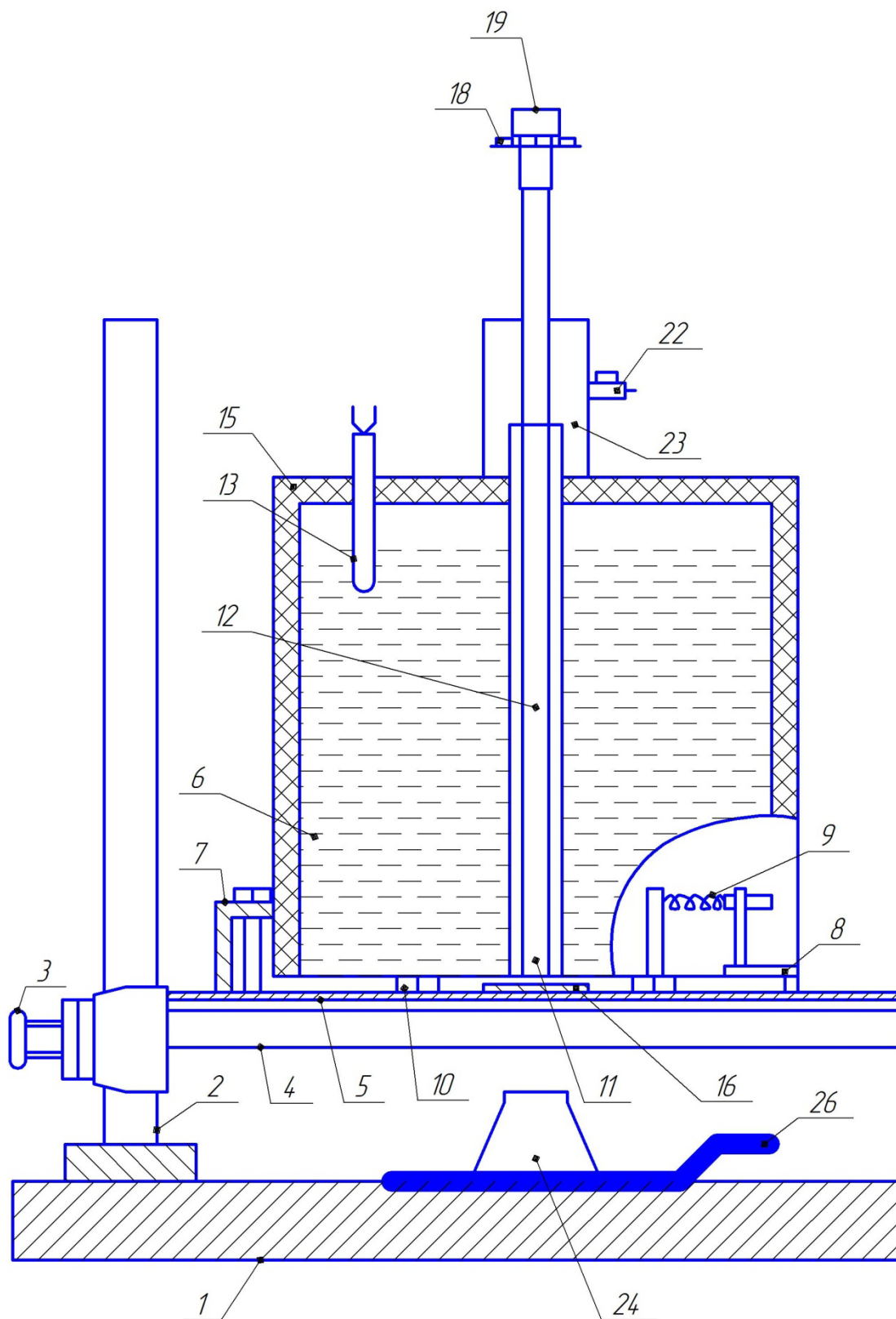
The device is designed to measure the density, are called density meters. According to the design and principle of operation, there are float density meters, piezometric, weight, membrane, radioisotope.

When choosing the method of determination of TPC, the following prerequisites were taken into account: provision of initial and boundary conditions of heat transfer in the experiment, corresponding to a specific technological process.

The applied method should be complex, which allows for one experiment, with one sample and one instrument to determine the three thermophysical characteristics.

The experimental stand for determining TPC includes a device for cooling and automatic insertion of the probe into the test material at a predetermined depth, an potentiometer and an thermostat . The rigidity of the design eliminates accidental movements of the sensor in the test material. Thus, one of the main requirements of this technique of measuring TPC – accurate knowledge of the location of the sensor and the time of its input. This device allows you to automatically turn on the measuring equipment at the time of Fixing the sensor in the extract. It greatly facilitates the experimental studies of TPC materials, has low inertia and good reproducibility of experimental results.

The schematic diagram of the device is shown in figure 1.



**Figure.1.** Schematic diagram of the installation for determining the thermo physical characteristics of licorice root extract.

It consists of a base 1, a bracket 2, on which a screw 3 is fixed frame 4 with a platform 5 (the latter can move in height depending on the specified depth of fixation of the sensor). On the platform 5 there is a vessel with thermal insulation 15, in which the melting ice 14 is placed. In the center of the vessel, a tube 2 is welded, in which the sensing element 12 is located. For convenience of carrying out experiments the thermally insulated vessel is made removable. It is mounted on the plate with a support angle 7, mounting, screws 10 and 8 lever with a spring 9. In the upper starting position, the thermocouple sensor 12, fixed in the carriage 25, is held by the petals 21. At the moment of giving a pulse to the electromagnet 19, the rod 20 of the electromagnet rises, the petals 21 release the carriage 25, which under the action of the load 18 slides along the guides 17 installed on the frame 23. Carriage 25 moves with a sensor in the test material 24. When moving, the thermocouple sensor breaks through the paper sheet 16, which is provided to exclude convective heat flows in the tube 11. In the lowest position, the platform with the load 18 includes a microswitch 22, which includes a secondary measuring device, which was used as potentiometer. The cold ends of the thermocouples are thermostated, they are placed in a tube 13, located in water with melting ice.

The samples were heated in a double-walled cylindrical vessel with a thermal insulation layer in a water bath. Measurements were made after the sample reached the set temperature during heating. The time interval between the two measurements depended on the cooling time of the thermocouple sensor in a thermally insulated vessel in an ice-water bath.

The TPC of the extract is most affected by concentration and temperature, so the experiments were conducted at a temperature range from 25°C to 75°C and a concentration of 15% SV to 65% SV. The solution of different concentrations was prepared as follows: distilled water and concentrated extract were mixed in certain ratios; the dry matter content was determined on the Refractometer. The dependence of the refractive index of the extract on the content of extractive substances was experimentally found for the determination of dry substances in the extract by the refractometric method.

To approximate the experimental conditions to the production conditions and prevent the possibility of increasing the data dispersion due to changes in the dispersion of the mass, the prepared sample was heated once in the thermostat to the desired temperature and a series of measurements was carried out. During the measurements, the sensor, which had a temperature of 0°C, was instantly immersed in the test mass, its heating was automatically fixed by the potentiometer. After reaching a steady temperature, the sensor was removed from the sample.

To obtain an empirical equation of the form

$$y = (t, SV) \quad (1)$$

where:

$\lambda$  - thermal conductivity,  $W/m \cdot K$ ;

$\alpha$  - thermal conductivity,  $m^3/sec$ ;

$c\rho$  - volumetric heat capacity,  $kJ/m^3 \cdot K$ ;

$\sigma$  - density of licorice root extract,  $kg/m^3$ ;

SV - concentration of licorice root extract

$t$  - process temperature, °C

A six-level lattice plan was implemented with a temperature range of 25 °C to 75 °C and a concentration of 15% to 65%. Based on the processing of experimental data by the least squares method, the equation in the form of polynomials of the second degree is obtained:

$$y = b_0 + b_1 \cdot CB + b_2 \cdot t + b_3 \cdot CB \cdot t + b_4 \cdot CB + b_5 \cdot t^2 \quad (2)$$

Program to determine the coefficients of the equation provided for the calculation of the correlation coefficient S. the Estimation of the equation coefficients, respectively, for thermal conductivity, thermal diffusivity, volumetric heat capacity and density are given below.

The equation and correlation coefficients for determining the thermal conductivity coefficient  $\lambda$ , W/m\*K, are:

$$\begin{aligned} b_0 &= 0,715 & b_1 &= 0,316 \cdot 10^{-5} & b_2 &= 0,645 \cdot 10^{-7} \\ b_3 &= 0,263 \cdot 10^{-6} & b_4 &= 0,135 \cdot 10^{-4} & b_5 &= 0,362 \cdot 10^{-4} \\ S &= 0,9689929 \end{aligned}$$

The equation and correlation coefficients for determining the coefficient of thermal conductivity 106,  $m^2/sec$  are equal to:

$$\begin{aligned} b_0 &= 0,710 & b_1 &= 0,147 \cdot 10^{-5} & b_2 &= 0,183 \cdot 10^{-7} \\ b_3 &= 0,661 \cdot 10^{-6} & b_4 &= 0,523 \cdot 10^{-4} & b_5 &= 0,391 \cdot 10^{-5} \\ S &= 0,9811622 \end{aligned}$$

The equation and correlation coefficients for determining the volumetric heat capacity CP  $kJ/m^3 \cdot K$  of licorice root extract are:

$$\begin{aligned} b_0 &= 4232 & b_1 &= -0,338 \cdot 10^{-1} & b_2 &= -0,1283 \cdot 10^{-2} \\ b_3 &= -0,6839 \cdot 10^{-3} & b_4 &= -0,3827 \cdot 10^{-1} & b_5 &= -0,1504 \\ S &= 0,9810658 \end{aligned}$$

The coefficients of the equation and correlation for determining the density  $\rho$   $10^3, kg/m^3$  of licorice root extract are equal to:

$$\begin{aligned} b_0 &= 1,0983 & b_1 &= -0,6826 \cdot 10^{-5} & b_2 &= -0,7187 \cdot 10^{-3} \\ b_3 &= -0,3545 \cdot 10^{-3} & b_4 &= -0,1733 \cdot 10^{-1} & b_5 &= -0,3553 \cdot 10^{-1} \\ S &= 0,9722788 \end{aligned}$$

Calculation of numerical values of coefficients was carried out using application package MATLAB. On the basis of the averaged data (tables 1-5), graphs of the dependence of the TPH of licorice root extract on temperature and concentration are constructed, which are presented in figures 2-6.

Table - 1

**Experimental values of thermal conductivity of licorice root extract**  
( $10^{-3} W/m^2 \cdot K$ )

Temperature °C	Concentration (CB), %					
	15	25	35	45	55	65
25	678	659	639	615	582	534
35	693	665	644	626	596	539
45	719	673	658	639	609	545
55	727	680	670	653	621	553
65	735	688	679	668	637	569
75	748	699	692	680	652	576

Table - 2

Experimental values of the coefficient of thermal conductivity of licorice root extract ( $10^{-8} m^2/sec$ )

Temperature, °C	Concentration (CB), %					
	15	25	35	45	55	65
25	0,165	0,163	0,160	0,159	0,157	0,147
35	0,169	0,167	0,165	0,163	0,160	0,148
45	0,175	0,172	0,172	0,169	0,166	0,155
55	0,179	0,175	0,175	0,172	0,170	0,157
65	0,182	0,181	0,182	0,180	0,171	0,159
75	0,188	0,185	0,185	0,184	0,176	0,162

Table-3

Experimental values of volume heat capacity coefficient of licorice root extract ( $KJ/m^3 \cdot K$ )

Temperature, °C	Concentration (CB), %					
	15	25	35	45	55	65
25	4092,7	4121,7	4026,4	3830,9	3566,9	3842
35	4092,2	4076,5	4012,8	3780,5	3547,7	3373,1
45	4091,7	4034,6	3943,9	3718,3	3535,2	3267,2
55	4057,2	3967,7	3940,6	3714,9	3529,5	3254
65	4023,4	3950,7	3938,3	3667,4	3518,7	3246,2
75	3963,3	3924,3	3927,5	3660,1	3518,6	3240,2

Table-4

Experimental values of specific heat coefficient of licorice root extract ( $J/kg \cdot K$ )

Temperature, °C	Concentration (CB), %					
	15	25	35	45	55	65
25	3812	3581	3361	3097	2849	2601
35	3825	3598	3375	3109	2875	2625
45	3842	3612	3497	3122	2893	2637

55	3859	3631	3509	3135	2905	2652
65	3865	3645	3522	3108	2925	2674
75	3878	3665	3546	3123	2942	2689

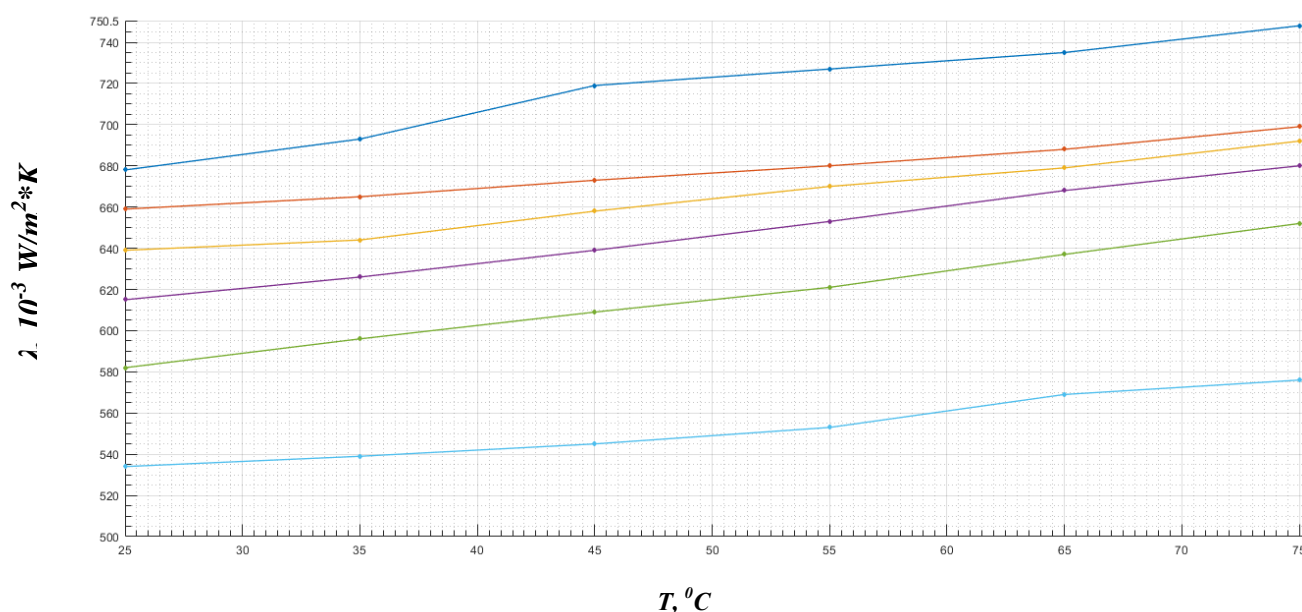
Table-5

Experimental values of the density coefficient of licorice root extract ( $kg/m^3$ )

Temperature, $^{\circ}C$	Concentration (CB), %					
	15	25	35	45	55	65
25	1073	1151	1198	1237	1252	1285
35	1070	1133	1189	1216	1234	1257
45	1065	1117	1185	1191	1222	1239
55	1053	1090	1180	1185	1215	1227
65	1041	1079	1175	1180	1203	1214
75	1022	1058	1164	1172	1196	1205

Analysis of changes in thermal characteristics of the temperature at different concentrations shows that the thermal conductivity and thermal conductivity of licorice root extract with increasing concentration decreases and increases with increasing temperature. The CP complex of the extract decreases with increasing concentration and temperature, the density of licorice root extract decreases with increasing temperature and increases with increasing concentration.

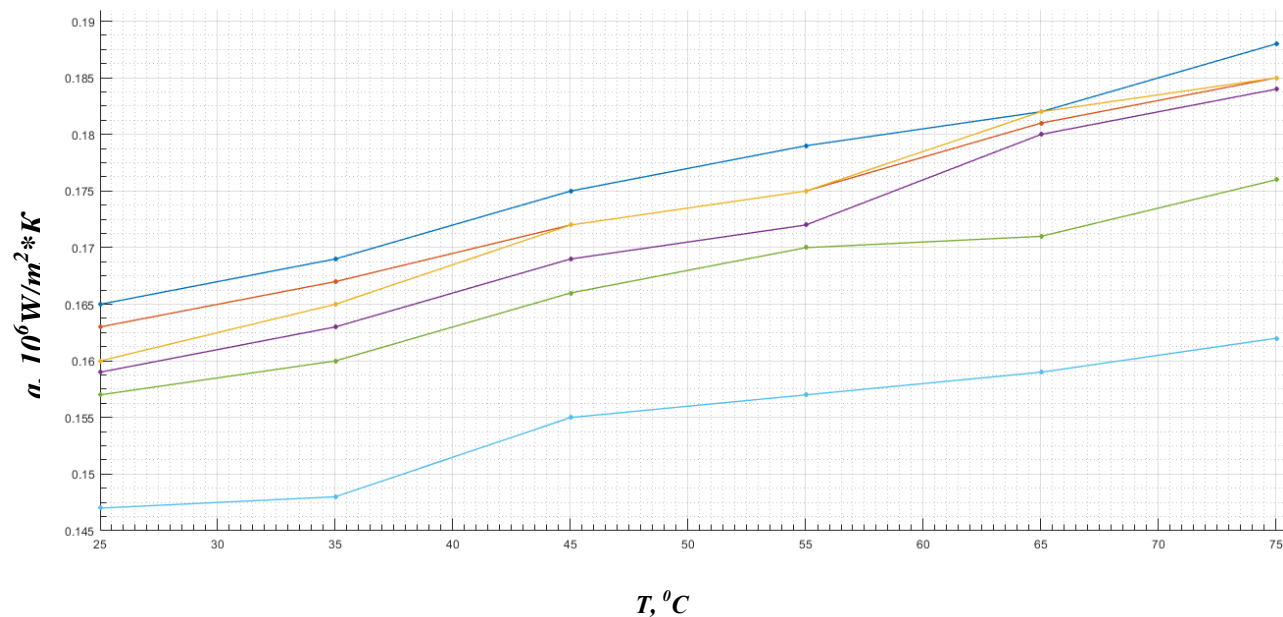
As a result of the performed researches the basic regularities of change of TPC of liquorice root extract in the course of heat treatment are revealed and empirical dependences of TPC of extract on temperature ( $25^{\circ} \div 75^{\circ}C$ ) and concentration ( $15\% \div 65\%$ ) which can be used for calculation and at the analysis of evaporation process are offered.





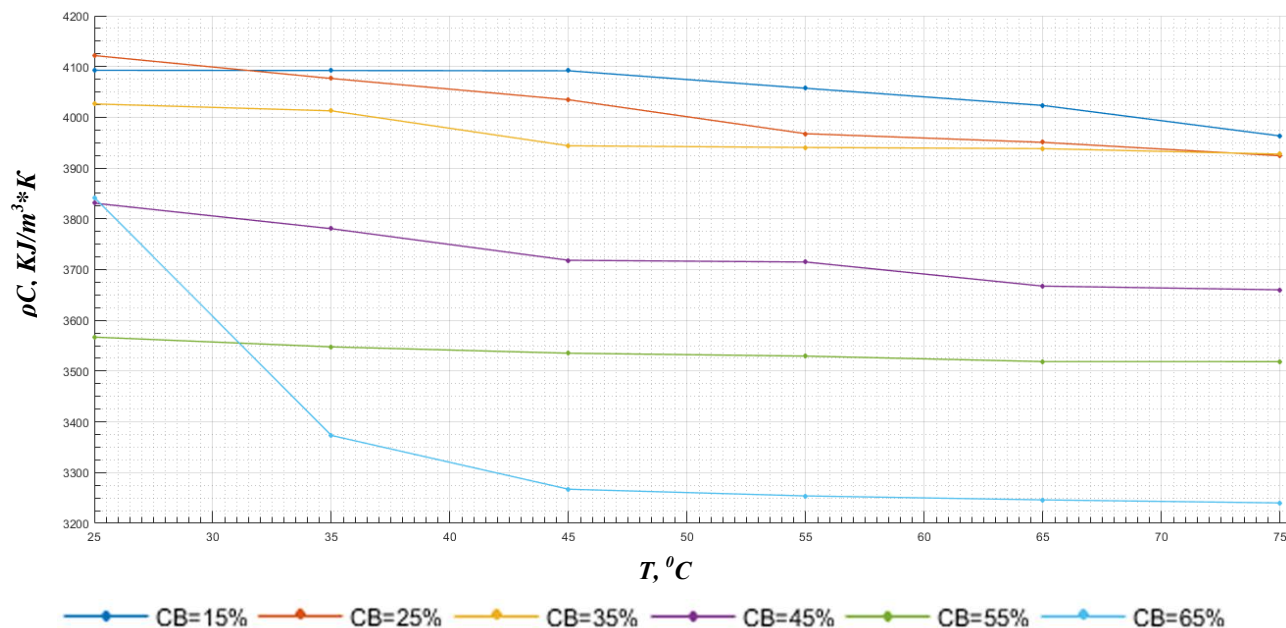
—●— CB=15% —●— CB=25% —●— CB=35% —●— CB=45% —●— CB=55% —●— CB=65%

**Figure.2.** Dependence of the thermal conductivity coefficient of licorice root extract on the temperature at different concentrations of the evaporated extract

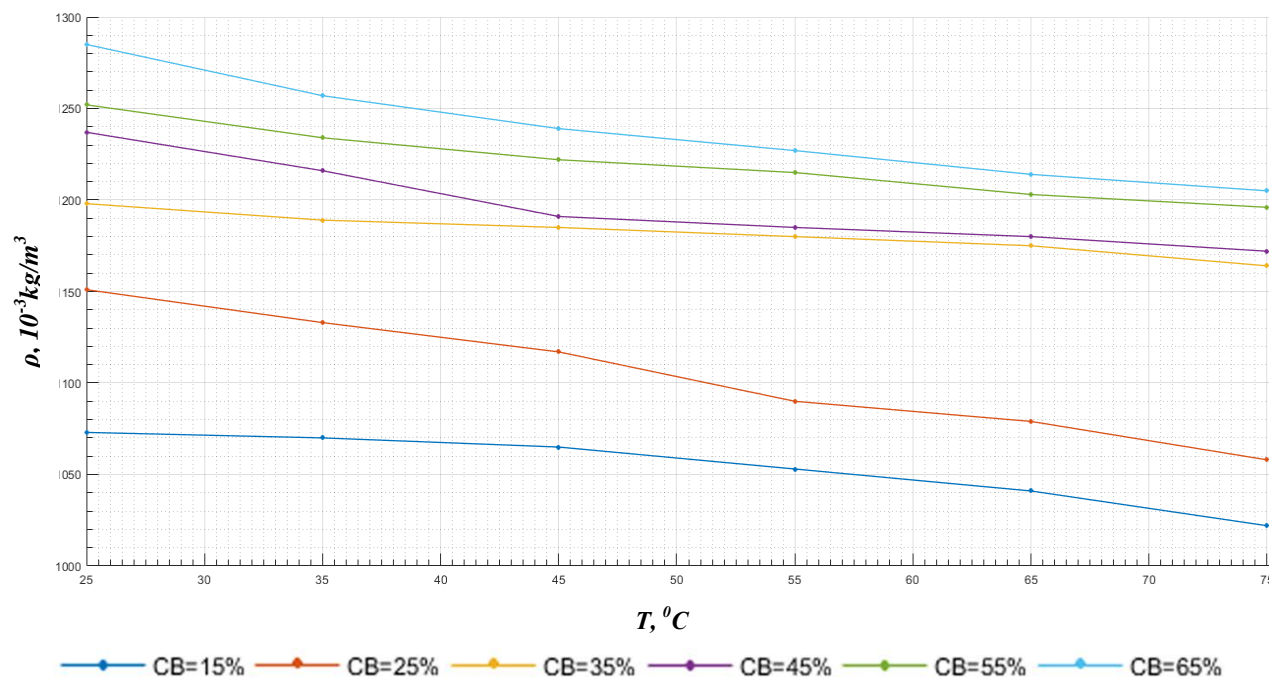


—●— CB=15% —●— CB=25% —●— CB=35% —●— CB=45% —●— CB=55% —●— CB=65%

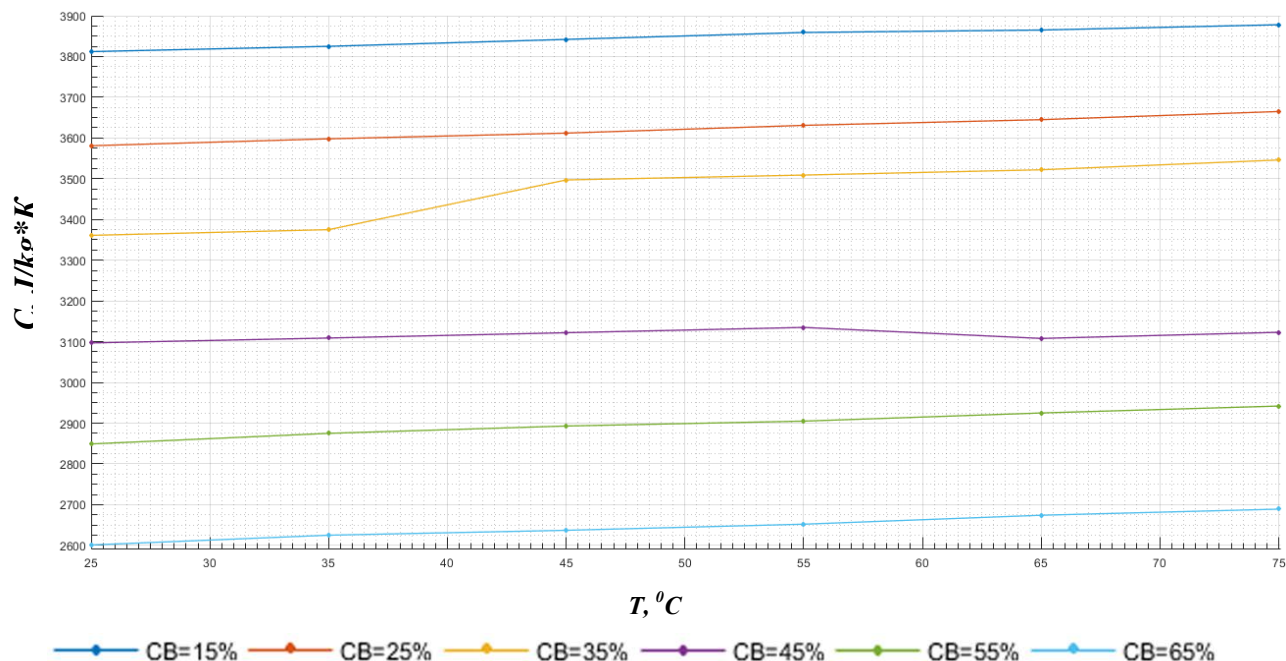
**Figure.3.** Dependence of temperature-conductivity coefficient of licorice root extract on temperature at different concentrations of evaporated extract



**Figure.4.** Dependence of the volume heat capacity coefficient of licorice root extract on the temperature at different concentrations of the evaporated extract



**Figure.5.** Dependence of licorice root extract density on temperature at different concentrations of evaporated extract



**Figure.6.** Dependence of specific heat coefficient of licorice root extract on temperature at different concentrations of evaporated extract

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