Experimental-statistic modelling of temperature dependence of solubility in the extraction of ocimum basilicum plants

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Abstract. In this paper, the temperature dependence of solubility in the extraction of natural extract from the leaves of the plant Ocimum basilicum was studied. In extraction, the effect of the separation temperature level and the raw material-solvent hydromodule were studied. The percentage of extracts obtained and the amount of solutes were determined by the proportional method. Physicochemical properties of the concentrate obtained from the leaves of the basil plant were studied. There are experimental statistical modelling methods in mathematical modelling. In this case, the results of experiments obtained at this object are used in the creation of a mathematical model of the technological process. Flow motion was studied for solution analysis. The importance of studying flow motion is to determine the parameters that must be taken into account in modelling. The results of the experiments are presented in tabular form. The regression equation was constructed and the correlation coefficient was determined. The results obtained by the graph modelling method were analysed. The result is a graph drawn on the model of a mathematically calculated function.

1. Introduction
Due to the high growth of food industry and pharmaceutical production, many artificial extracts have been synthesized and these extracts are widely used in food products. Compared to natural extracts, their biological activity, taste and vitamins are insufficient [1].

Many natural food extracts contain biologically active substances, vitamins, amino acids, carbohydrates, aromatic substances and mineral salts. Pigments are composed of anthocyanins, carotenoids, chlorophyll and xanthophylls. Natural extracts are obtained mainly from plant raw materials, secondary raw materials from vegetables and fruits. Natural solutions are mainly obtained by extraction methods. Ethyl alcohol solution, water, vegetable oil, etc. are used as extractants [2,3].

In folk medicine, the aqueous extract of chopped basil leaves, juice, young twigs and aboveground parts has anti-inflammatory, wound healing, antitussive, diuretic, insect repellent, antiperspirant and disinfectant properties. Basil extract in water is used in inflammatory diseases of the upper respiratory tract, chronic gastritis, eneroocolitis and food poisoning [4].

2. Research objects and methods
Soxhlet extractor is widely used to extract beneficial bioactive substances from plants. Soxhlet extractor has a simple constructive structure. This is the most convenient extractor to separate from the plant because it is exposed to low temperatures. In turn, this is effective in maintaining product quality. The main working part in a soxlet extractor is the soxlet. This is because the solvent dissolves the separated
substance in the soxhlet. Soxhlet extractor is made of stainless steel and glass. This is because the solvent does not interact with the extractor material. The solvent is circulated in the apparatus until the process is complete. That is, when heat is exposed to the solvent, it evaporates and moves upwards. The steam liquefies in the refrigerator and falls on the soxhlet. The solvent removes the solute with it. In this way the solvent is circulated several times in the apparatus.

For extraction, the operating condition of the soxlet extractor is first checked. Before starting the extractor, make sure that the apparatus is assembled correctly. Make sure all parts of the device are safe [5-8].

The object of study for the experiment was selected Ocimum basilicum leaves, a solvent, ie alcohol of different percentages.

The percentage of extracts obtained, the amount of substances in the extract basil, the amount of substance was determined using general methods.

The ratio of the extracts obtained and the amount of soluble substances were determined by the proportional method. For example, 100 ml of basil extract was added to 200 ml of 70% ethyl alcohol and 220 ml of extract at 10 °C. The solution was found to be 63% alcohol solvent, 37% solvent. The proportions of the other concentrates were calculated in the same order.

3. Results and their discussion

The experiments were performed to determine the dependence of solubility (x) on temperature (y). The results are presented in Table 1.

To discuss the results obtained, we can formulate a graph of it. By analysing which graph is closer to the obtained graph, we can construct a regression equation for mathematical modelling. The graph based on the results is shown in Figure 1.

![Figure 1. Experience-based graph](image)

Based on the results obtained, the following results were obtained by discussing the temperature dependence of the solubility of alcohol:

We write the regression equation in the form \( y = b_0 + b_1 x \). From this we define \( b_1 \) as follows:

\[
b_1 = \frac{N \sum_{i=1}^{N} x_i y_i - \left( \sum_{i=1}^{N} x_i \right) \left( \sum_{i=1}^{N} y_i \right)}{N \sum_{i=1}^{N} x_i^2 - \left( \sum_{i=1}^{N} x_i \right)^2}
\]

(1)

We determine \( b_0 \) from the following formula:

\[
b_0 = y - b_1
\]

(2)
For this we present the experimental data and the calculation results in the form of Table 1. The last two columns of table 1 are \( \sum_{i=1}^{N} (X_i + y_i)^2 = \sum_{i=1}^{N} x_i^2 + 2 \sum_{i=1}^{N} x_i y_i + \sum_{i=1}^{N} y_i^2 \) is used only to check the calculations according to the formula.

To determine \( b_0 \) and \( b_1 \), we use the sums in Table 1:

\[
b_1 = \frac{9 \cdot 20723 - 360 \cdot 451.7}{9 \cdot 20400 - 360^2} = 0.44
\]

\[
b_0 = \frac{451.7 - 0.44 \cdot 360}{9} = 32.6
\]

Table 1. Experimental results

| Number of experiments | x    | y    | x^2  | xy   | y^2   | x+y  | (x+y)^2 |
|-----------------------|------|------|------|------|-------|------|---------|
| 1                     | 0    | 33.5 | 0    | 0    | 1122.22 | 33.5 | 1122.25 |
| 2                     | 10   | 37.0 | 100  | 370  | 1369.00 | 47.0 | 2209.00 |
| 3                     | 20   | 41.2 | 400  | 824  | 1697.44 | 61.2 | 3745.44 |
| 4                     | 30   | 46.1 | 900  | 1383 | 2125.21 | 76.1 | 5791.24 |
| 5                     | 40   | 50.0 | 1000 | 2000 | 2500.00 | 90.0 | 8100.00 |
| 6                     | 50   | 52.8 | 2500 | 2645 | 2798.10 | 102.9 | 10588.41 |
| 7                     | 60   | 50.8 | 3600 | 3408 | 2226.24 | 116.8 | 13642.24 |
| 8                     | 70   | 64.3 | 4900 | 4501 | 4134.49 | 134.3 | 18036.49 |
| 9                     | 80   | 69.9 | 6400 | 5592 | 4886.01 | 149.9 | 22470.01 |
| \( \Sigma \)          | 360  | 451.7| 20400| 20723| 23859.05| 85705.05|

We determine the selected correlation coefficient according to the following formula:

\[
r^* = \frac{b_1 s_x}{s_y} = b_1 \frac{N \sum_{i=1}^{N} x_i^2 - (\sum_{i=1}^{N} x_i)^2}{N \sum_{i=1}^{N} y_i^2 - (\sum_{i=1}^{N} y_i)^2}
\]

We calculate by setting the appropriate values: \( r^* = 0.44 \sqrt{\frac{9 \cdot 20400 - 360^2}{9 \cdot 23859.05 - 451.7^2}} = 0.99 \)

The magnitude of the correlation coefficient is very close to 1, so the relationship between \( y \) and \( x \) is practically linear and appears as follows:

\[
y = 32.6 + 0.44x
\]

It was found that the graph of the calculated function was almost close to the curve obtained experimentally. The resulting function graph is shown in Figure 2.
4. Conclusion
Mathematical modelling is an effective tool for determining optimal control parameters, especially when the laws of physical and chemical processes are sufficiently studied. In this case, the control parameters are determined by calculating the mathematical model of the object over a wide range of external influences.

From the evaluation of physical and chemical phenomena occurring in the extraction process and its analysis, to the evaluation of integrals, taking into account the interactions between the individual levels. The description obtained in this way can be considered as a mathematical model of the process, characterizing the most general features of the process.

The modeled graph is very close to the graph line defined in the experiment. Given that the relative error is 0.05%, the solubility in production can be controlled by temperature.

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