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Washing steps and the process of saturation of contaminants with moisture in the processing of fruits and vegetables

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Abstract. The process of washing fruits and vegetables is considered. Stages of the process of washing fruits and vegetables. The theory of moisture penetration. Experimental studies of the process of saturation of pollution with moisture. The results of theoretical and experimental studies of the process of saturation of pollution with moisture are analyzed.

1. Introduction

The fruit washing process can be divided into three stages [1-5]:

- the process of saturation of pollution with moisture (soaking);
- the process of intensive removal of pollution by mechanical means;
- the process of removing residual contaminants by flushing with a stream of washing liquid.

The first stage is solved by placing the fruits in a soaking container, where they stay for a certain time. In this process, the contaminants, which are soil particles, are saturated with moisture. In this case, the moisture content of the pollution increases, and the adhesive bonds of the pollution with the surface of the fruit weaken. At the second stage, the removal of contamination occurs with active interaction of elastic working organ with the surface of the fruit.

2. Materials and methods

The first stage is solved by placing the fruits in a soaking container, where they stay for a certain time. In this process, the contaminants, which are soil particles, are saturated with moisture. In this case, the moisture content of the pollution increases, and the adhesive bonds of the pollution with the surface of the fruit weaken. At the second stage, the removal of contamination occurs with active interaction of elastic working organ with the surface of the fruit. The process of removing residual contamination by washing off loose particles with a stream of water is taken place when the stream of liquid interacts with suspended particles of dirt, where they are carried out of the fetus. The figure 1 shows the calculated scheme of the saturation of pollution with water. The penetration of moisture into a capillary-porous body, which is pollution, occurs under the action of hydrostatic pressure. Moisture penetrates the gaps between the dirt particles. Reasoning by analogy with the propagation of heat in the process of heat transfer by thermal conductivity, we distinguish two surfaces inside the saturable body, which have a pressure P and $P + \Delta P$. The potential field of a body is the set of pressure values taken over its volume



at any given moment of time. Mathematically, the pressure field can be expressed in the form of the equation $F(t, x, y, z, \tau) = 0$.

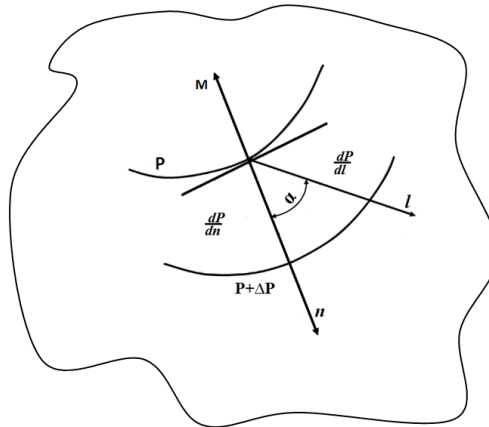


Figure 1. Design scheme for determining the pressure gradient in a porous body.

In general engineering practice, one has to deal with both non-stationary and stationary potential fields. The first of these fields varies in space and time, while the second is only a function of coordinates. A change in the temperature field in space is observed only in directions intersecting surfaces of equal pressure (is potential surfaces, for our case isobaric surfaces), with the most dramatic change taking place in the direction of the normal to the isobaric surface. View limit:

$$\lim_{n \rightarrow \infty} \frac{\Delta P}{\Delta n} = l_n \frac{\delta t}{\delta n} = \text{grad}P \quad (1)$$

where l_n is the unit normal vector; n - normal to the isobaric surface, will be called the pressure gradient. The pressure gradient is a vector normal to the isobaric surface and is numerically equal to the partial derivative of pressure in that direction. Let us take the condition of increasing humidity as a positive direction. Let's define the following: the amount of moisture passing through any point of the isobaric surface of the body in the direction of another isobaric surface should be directly proportional to time, isobaric surface area, pressure difference and inversely proportional to the distance between these isobaric surfaces. Analytically, the above can be written as:

$$d^2 M_\tau = -\eta l_n \frac{\delta P}{\delta n} dF d\tau \quad (2)$$

where M_τ -vector is the amount of moisture passing through the body, kg; η -coefficient of moisture permeability of the body, kg / (cm Pa); F -area perpendicular to the normal to the isobaric surface, m². The quantity (3)

$$m = \frac{d^2 M_\tau}{dF d\tau} = \frac{dM^*}{dF} = \eta l_n \frac{\delta P}{\delta n} \quad , \quad (3)$$

where $M^* = \frac{dM}{d\tau}$ is the vector of moisture flux, kg/s, which we will call the moisture flux density, kg/(cm²). It can be seen from the presented calculation scheme that the derivative of the pressure in the direction l is related to the temperature gradient by the obvious relation [6-13]

$$\frac{dP}{dl} = \frac{\delta P}{\delta n} \cos(n, l) \quad , \quad (4)$$

where $\cos(n, l)$ is the cosine of the angle between the normal to the isobaric surface n and the direction l . In addition, we note that the derivative of pressure in the direction l is determined through the derivatives of pressure with respect to Cartesian coordinates by the formula:

$$\frac{dP}{dl} = \frac{\delta P}{\delta x} \cos(x, l) + \frac{\delta P}{\delta y} \cos(y, l) + \frac{\delta P}{\delta z} \cos(z, l), \quad (5)$$

where $\cos(x, l)$, $\cos(y, l)$ and $\cos(z, l)$ are the cosines of the angles between the direction l and the x , y and z coordinate axes. Taking into account (4), the equation of moisture transfer in a porous body can be written as:

$$dM^* = -\eta \frac{dP}{dl} ds, \quad (6)$$

Moisture permeability η in formula (2), from a mathematical point of view, is a proportionality coefficient, whose role is to equalize the dimensions of the left and right sides (6), and is measured in $\text{kg} (\text{cm}^2\text{Pa})$. Taking into account the dimension of the unit of measurement of pressure $1 \text{ Pa} = 1 \text{ Nm}^{-2} = 1 (\text{kg m s}^{-2}) (\text{m}^{-2}) = 1 \text{ kg} (\text{ms}^{-2})$, we obtain the dimension of the moisture permeability coefficient

$$\frac{\text{kg}}{\text{s} \cdot \text{m}^2} : \frac{\text{kg}}{\text{m} \cdot \text{s}^2} = \frac{\text{s}}{\text{m}}.$$

From a physical point of view, moisture permeability is a physical characteristic of a substance. For various substances with the same pressure gradients, surfaces F and time τ , the amount of moisture passing through the body is determined by the value of η . The higher the moisture permeability, the greater the ability of the substance to transmit moisture. When analyzing the properties of various substances (pollution, in which soil particles predominate) from the point of view of moisture permeability, the following can be noted:

- for bodies with sufficiently large distances between individual particles, for example, soils with a predominance of sand in their structure, moisture permeability will be quite high (pollution will be saturated with moisture quickly enough)
- for bodies with relatively less distance between individual particles, for example, soils with a predominance of clay particles in their structure, moisture permeability will be lower (pollution will be saturated with moisture much more slowly).

As a result of the analysis of equation (6), it was found that the process of saturation of contamination with moisture can be activated and its duration can be reduced by increasing the pressure of liquid on the fruit, it can be achieved by forcibly placing the fruits on the bottom of the soaking containers, since most fruits and vegetables have a density lower than the density of water and float on the surface. Integrating Eqs. (6), we obtain the calculated dependence on the transfer of moisture inside the substance at saturation in the form:

$$M^* = \eta F (P_1 - P_2) \quad (7)$$

or

$$M = \eta F (P_1 - P_2) \tau. \quad (8)$$

To study the soaking process, a special container was made with a sieve set at different depths. The study was carried out according to the method described in [1-5]. As a criterion for the assessment, the relative humidity of the pollution was used, after a certain time. Pollution is applied to the surface of fruits and vegetables in the form of separate drops weighing 0.5 ... 0.6 g (for the Republic of Uzbekistan, pollution on fruits and vegetables is mainly soil particles, of all types of soils, loams and sandy loams prevail). Further, the fruits with contamination are taken out for drying, which lasts for 35 ... 45 min. To control the initial moisture content, individual drops are removed. The derivative of their weighing on an analytical balance. Determination of the initial relative humidity of pollution is carried out after drying the pollution in a fume hood when heated to a temperature of 75 ... 80 °C. The calculation of the initial relative humidity of pollution is made according to the formula:

$$\varphi = \frac{m_{cap} - m_{sux}}{m_{cap}} \cdot 100\% \quad (9)$$

Where m_{cap} is the mass of a wet droplet of pollution, g; m_{sux} is the mass of a dry drop of pollution, g. After soaking fruits and vegetables, wet contaminants are removed from the surface, and the moisture content is determined using a similar method. In work [1] it is indicated that the process of fruit washing is facilitated after reaching the relative humidity by contamination of $\varphi = 75 \dots 80\%$. The experiment was performed with respect to the factors presented in Table 1.

Table 1. Factors taken into account during the experiment.

Factors	Name of the factor	Size	Variation levels		
			-1	0	+1
X ₁	Duration of soaking τ	min	5	10	15
X ₂	Immersion depth h	m	0.2	0.4	0.6

The experiment is carried out according to the D-optimal design of the second order with three repetitions in each experiment. Statistical processing of data is performed according to the technique discussed above [14-21].

3. Results and discussion

As a result of processing the experimental data (appendix), regression equations were derived that characterize the soaking process:

$$\text{For apples } \varphi_y = 35.64 + 16.32x_1 + 11.23x_2 + 11.4x_1x_2 - 0.88x_1^2 - 2.56x_2^2; \quad (10)$$

$$\text{For carrots } \varphi_m = 31.25 + 14.21x_1 + 10.15x_2 + 8.42x_1x_2 - 1.68x_1^2 - 3.61x_2^2; \quad (11)$$

$$\text{For beet roots } \varphi_k = 28.84 + 19.52x_1 + 13.42x_2 + 12.24x_1x_2 - 1.32x_1^2 - 3.64x_2^2. \quad (12)$$

Analysis of the equations shows that the achievement of humidity $\varphi \geq 75\%$ is reached 15 ... 20 minutes after the start of soaking when the fruits are deepened to a depth of 0.2 ... 0.4 m. Therefore, for further research, we will assume that fruits and vegetables should be soaked for 15 ... 20 minutes. The results obtained are in fairly good agreement with the results of theoretical studies. The general form of equations (10), (11) and (12) corresponds to equation (8). After carrying out a number of transformations in order to bring the regression equations to equation (8), we determine the value of moisture permeability η 1.45 ... 1.52 s/m.

4. Conclusions

The fruits are easier and faster to wash when the relative humidity of the contaminants $\varphi = 75 \dots 80\%$. Duration of soaking to achieve $\varphi = 75 \dots 80\%$. 15-20 min (depending on the type of soil).

Depth of immersion of the fetus 0.2-0.4 m.

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