Bulletin of the *Transilvania* University of Braşov • Vol. 2 (51) - 2009
Series I: Engineering Sciences

HEAT TRANSFER INTENSIFICATION AT ELECTROPLASMOLYSIS OF BIOLOGICAL TISSUES

V. CIOBANU[1] **A. PAPCENKO**[1] **M. BOLOGA**[1]
I. TSYRDEA[1] **N. POPOV**[1] **G. RUDCOVSCHI**[1]

Abstract: *The influence of the liquid phase fraction in biological tissues on the heat treatment and heat transfer intensification is demonstrated. The necessity is shown to apply a preliminary plasmolysis with the aim to intensify the heat transfer process in biological tissues. The treatment with a pulse current is substantiated. The productivity of the process is determined. as a function of the ratio of conductivities of components of biological tissues for various values of the liquid phase content.*

Key words: *heat transfer, plasmolysis,* biological tissue, liquid content

For the analysis of heat transfer in apparatus for processing primary materials, the thermal conductivity of medium it considered to be an essential factor. The dynamic stability of this parameter depends on the parameters of the conducting mass, on its aggregate state, phase composition, etc. Processing of primary materials of biological origin (those of vegetal or animal origin) is a special case. Temperature as an operative factor is of major importance in the majority of processes of mass and heat transfer; it is a factor of an extensive character and exerts a direct influence on the cellular structure of primary materials of the aforementioned type. The modification of the cellular structure under a strong temperature action on the conductivity of the medium depends on the structure of cellular membranes, on the coagulation properties of the protein layer of cell membranes and the cytoplasm of biological primary materials.

The functioning of apparatus for production of juices, concentrated pastes, powdered vegetables, fruit and marine products strongly depends on the coefficient of thermal conductivity of the used primary material. The processing duration exerts a direct influence on the quality of the final food product, including its marketable condition and price. Moreover, when the process of membrane destruction is performed at temperatures lower than the limit of protein coagulation, this allows to intensify the thermal process and reduce its duration by 15-30 % comparing with the process without preliminary plasmolysis. The essential factor in the intensification of heat transfer during the thermal processing is the liquid content of the primary material. At the initial stage, before the primary material is treated using plasmolysis, the major portion of the liquid is incapsulated in the central vacuoles of the tissue cells and a direct access of the heat is blocked by the cell membranes the cytoplasm rich in proteins. When the temperature exceeds

---

Institute of Applied Physics, Academy of Sciences of Moldova

especially to the liquid in central vacuoles of the tissue. In this case a linear model of the heat transfer through the cellular mass is determined by the coefficient of thermal conductivity when the heat passes through the both components of the primary material: the liquid and the membranes possessing thermal insulation properties. In this case, the model coefficient of the complex thermal conductivity can be determined by the formula:

$$\lambda_{np} = \frac{\lambda_l \lambda_s}{\lambda_l - (\lambda_l - \lambda_s)x}, \tag{1}$$

where λ_1 and λ_s are the coefficients of thermal conductibility of the liquid and of the cellular membrane; x is the percentage of the liquid in the whole volume of the primary material.

The thermal conductivity λ_{np} of the used primary material that was not subjected to plasmolysis is calculated for the case of a stationary heat distribution. Since the coefficients of thermal conductibility for the liquid and for the thermal insulating membrane are approximately fixed and equal to: $\lambda_1 = 0.6$ W/(m·K) and $\lambda_s = 0.1$ W/ (m·K), respectively, and the liquid content, for example, in the vegetal raw material for production of tomato paste is x = 0.9, then the value of thermal conductivity for the primary material after the thermal treatment estimated according formula (1) is, therefore, λ_{np} = 0.4 W/(m·K).

Sometimes, the preliminary treatment of biological media with a thermal agent does not allow performing an effective plasmolysis at a temperature lower than the limit of protein coagulation. Therefore, it is important to perform a plasmolysis pretreatment in the production of powdered materials, pastes and juices before the thermal treatment accompanied by the protein coagulation. One of the effective methods for treatment of biological primary materials is a method where an electric current is used, an electroplasmolysis [1, 2].

The preliminary plasmolysis of biological media with a pulse electric current at temperatures much lower than the limit of protein coagulation leads to kinetic and thermal homogenization of the both heat conducting components in the heterogeneous system with respect to the heat transfer [3], and

$$\lambda_p = \lambda_s + (\lambda_l - \lambda_s)x, \tag{2}$$

where λ_l and λ_s are the same as in formula (1), but the x is the liquid content in the mixture of components involved in heat conduction.

Estimation of the coefficient of thermal conductivity according formula (2) for the vegetal mass of tomato pulp subjected to plasmolysis, is

$$\lambda_p = 0.55 \ \text{W/(m·K)}.$$

For vegetal products with the lower liquid content, the intensification of thermal treatment of food products is much more significant. For example, for $\lambda_l = 0.6$ W/(m·K) and $\lambda_s = 0.1$ W/ (m·K), we can present the dependence of the efficiency of intensification of the thermal process versus the mass of the used biological primary material (Fig.1).

For various biological primary materials, the phenomenon of heat transfer intensification is limited by the maximum value for $x = 0.5$; then the decrease follows for values when $x \neq 0{,}5$. It should be noted that for a primary material having a medium liquid content with respect to the whole material mass, the intensification effect owing to the preliminary plasmolysis becomes maximal.

The efficiency of heat transfer intensification for crushed tomato mass subjected to the preliminary plasmolysis (in percents) is:

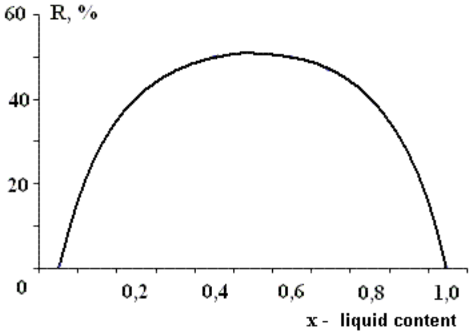

Fig.1. *Dependence of the efficiency of intensification of the thermal process versus the liquid content in biological media*

$$R = \frac{(\lambda_p - \lambda_s)}{\lambda_p} \cdot 100\% = 27.3\%. \qquad (3)$$

It was established that the effect of intensification of thermal treatment was lower, when the value of the liquid content in the biological mass was greater. For example, when the crushed tomato mass was treated by electroplasmolysis, the efficiency of intensification in the technological process of tomato paste concentration amounted approximately to 25% [4, 5]. The effect of intensification at preliminary electroplasmolysis was a little greater when applied for the treatment of mechanically crushed red grapes, where the liquid content varied in the range of $x = 0.75 - 0.85$ [6, 7].

The numerical values for thermal conductivity λ_l and λ_s can vary depending on different biological primary materials and can influence the process efficiency. The efficiency versus the ratio of the conductivities of the primary materials $\varepsilon = \lambda_s / \lambda_l$ can be calculated using the formula:

$$R(\varepsilon) = \frac{[\varepsilon + (1-\varepsilon)x][1-(1-\varepsilon)x] - \varepsilon}{[\varepsilon + (1-\varepsilon)x][1-(1-\varepsilon)x]}. \qquad (4)$$

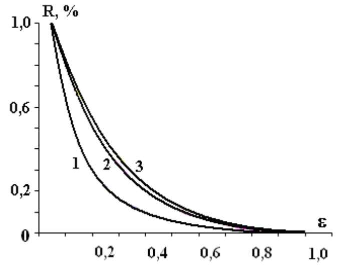

Fig. 2. *Dependence of the efficiency versus the ratio of conductivities* (ε)

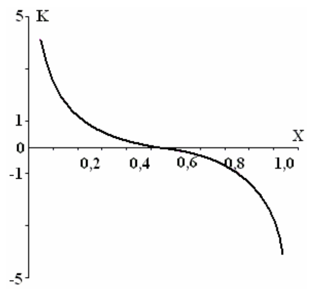

Fig. 3. *Dependence of the rate of variation of the efficiency versus the liquid content*

Figure 2 shows the dependence of the process efficiency on the ratio ε for the fixed values of the liquid content: 1) $x = 0.1$; 2) $x = 0.3$ and 3) $x = 0.5$.

The ratio $\varepsilon = \lambda_s / \lambda_l$ is minimal for a considerable difference between the thermal conductivities of the components, and the efficiency in this case is maximal. For various vegetal products with higher ε values, the decrease in the efficiency leads to technological restrictions of correlations between the regimes of thermal treatment, and the thermal efficiency becomes dependent on the characteristics of the primary material versus the ratio ε .

The values of $K = \partial R / \partial x$, which characterizes the rate of variation of the efficiency for biological media with various liquid content, are of great importance. The dynamics of the thermal process is determined by modifications of the characteristics of the biological medium during processing via decreasing the volume of the liquid owing to dehydration and increasing in the content of the solid phase.

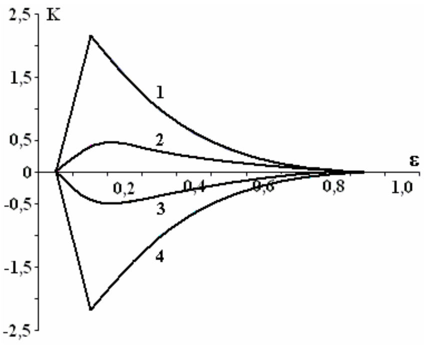

Fig. 4. *Dependence of the rate of variation of the efficiency versus the ratio of conductivities* ε

The dependence of the rate of variation of the efficiency for different liquid content is determined by the relationship:

$$\frac{dR}{dx} = \frac{\varepsilon(1-\varepsilon)^2(1-2x)}{[\varepsilon+(1-\varepsilon)x]^2[1-(1-\varepsilon)x]^2}. \quad (5)$$

The dependence of the rate of variation of the efficiency versus the liquid content is presented in Fig. 3.

The increase in the efficiency and decrease in the rate of its variation via modification of the liquid content presumes that such a technological regime of the thermal treatment should be maintained, which correlates with the liquid content in the primary material. The rate of variation of the thermal efficiency equals to zero for the liquid content $x = 0.5$.

Fig. 4 shows the dependence of the rate of variation of the efficiency versus the ratio ε for four values of the liquid content: 1) x = 0.1, 2) x = 0.3, 3) x = 0.7 and 4) $x = 0.9$.

References

1. Lazarenco, B.R., Fursov, C.P., Sceglov, Iu. A., Bordianu, V. V., Ciobanu, V. G.: *Electroplasmoliz.*, Chişinău. Cartea Moldovenească, 79 p., 1977.
2. Cioban,u V.: *Tehnologii de utilizare raţională a fructelor în mediul rural.* In: Conferinţa Naţională: "Comunităţile rurale şi renaşterea satului", Chişinău, 2005, p. 121-122.
3. Ciobanu, V., Botoşan, N., Berzoi, S.: *Omogenizarea cinetică şi termică în sisteme eterogene prin intensificarea difuziei datorită gradientului presiunii.* In: *Lucrările Conferinţei Naţionale de Termotehnică.* Ediţia a VII-a. Braşov, 23-24 mai 1997, Vol. I, p. 61-67.
4. Rudcovschi, G.V., Botoşan, N.I., Ciobanu, V.G., Berzoi, S.E., Poplavschii, P.P.: *Sposob proizvodstva toma-toproductov.* Opisanie izobreteniea c a. s. SU N 1524214., Ind. Cl.: A23N 1/00, Moscova., 1990, 7 p.
5. Berzoi S., Botoşan N., Ciobanu V., Ţârdea I., Rudcovschi G.: *Procedeu termic de prelucrare a pastei de roşii prin electro-plasmoliză şi centrifugare.* In: Conferinţa a VI-a Naţională de Termotehnică., Iaşi - Chişinău, 24–25 mai 1996, p. 162-163.
6. Ciobanu V., Papcenco A.: *Unele particularităţi la tratarea preventivă a strugurilor zdrobiţi în vinificarea primară.* In: Conferinţa fizicienilor din Moldova. CFM – 2007, Chişinău, 11-12 octombrie 2007, p. 159-160.
7. Ciobanu, V., Papcenco, A., Garanovschii, Al., Zapşa, V.: *Process for Electroplasmolysis of vegetal raw material and apparatus for realization thereof.* Patent MD N 3669, F1, 2007.11.27., Ind. Cl.: A23N 1/00, B01J 19/08. In*: The Official Bulletin of Industrial Property*, Chişinău, N 8/2008, Part 1, p. 21-22.