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Investigation of changes in conductivity of juice during the evaporation process

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Abstract

The creation of this article was the necessity of experimental determination of the electric conductivity of juice depending on the concentration of solids, expressed by the empirical formula, in order to more precisely control specific power supplied to the machine and foaming. Authors of the article held staged experimental studies using apple juice, the juice of red mountain ash, buckthorn and black currant. Found that the relationship between the conductivity of the juice solids content corresponds to the empirical formula of Kohlrausch, however, this formula does not represent the contribution juice acidity value of conductivity, and allows to correlate the specific power input to the device with the concentration of solids. The empirical formulas for the distribution of electrical juice conductivity depending on the acidity and for calculation of the specific power depending on the concentration of dry matter, allows to keep the speed of the foam below its destruction speed in the zone of vigorous reflux.

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Keywords: *electric conductivity, the content of dry substances, power, concentration, evaporation;*

1. Introduction

In the last decade has actively developed the harvesting of wild fruits and berries. At the same time increases the harvesting of agricultural vegetables. There is a consistent trend to not just collect a small volume of products for immediate implementation, but also to the processing of large volumes of plant materials into marketable products.

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Including directly near the place of harvest. It is caused by several reasons, such as rapid deterioration of raw materials[1,2].

It is expedient to process berries and fruits on juice, with the subsequent concentration in vacuum evaporating devices at a temperature of boiling not over 55^{O} C for preservation of the maximum quantity of biologically active agents[3].

It is possible to provide high quality of a concentrate only at of technology of evaporation. The key technological parameters for process of vacuum concentration of juice is temperature of evaporation and the content of solids in evaporated juice. Solids are controlled, as a rule, by means of refractometers of various designs. Thus, it is necessary to carry out regular sampling of evaporated juice that is very difficult because of existence of residual pressure in the device. Refractometers of continuous action can be installed in the equipment, but they are expensive and really can be applied only on big evaporating devices.

Application of ohmic evaporation significantly optimizes the processing of fruits and berries in the final product, however, this device has the same drawbacks as the direct heating devices[4,5], in particular the need for precise control supplied power density, temperature preservation and maintenance of vacuum in during evaporation. This is very problematic for small volume devices because of the need to carry out measurements of dry matter content and associated depressurization apparatus during measurements. In order to eliminate these disadvantages, was a series of studies, one of which is to establish empirical relationships between the electrical juice and solids[2]. Parallel was established empirical dependence of input specific power from the solids concentration (per unit area of the evaporating surface).

2. Materials and Methods.

Studies were conducted using apple juice, juice red ashberry, cassis and sea buckthorn to prove the relationship conductivity diluted juice with its concentration, according to the empirical Kohlrausch formula[7]:

$$\chi_t = \chi_{25} \cdot [1 + \alpha(t-25) + \beta(t-25)^2] \quad (1)$$

Also marked that for small concentrations equivalent conductivity of a strong electrolyte is:

$$\lambda = \lambda_0 - A\sqrt{C} \quad (2)$$

For higher concentrations:

$$\lambda = \lambda_0 - A\sqrt[3]{C} \quad (3)$$

3. Results and Discussion.

Conductometric method of analysis was used. Results are presented in fig. 1-5.

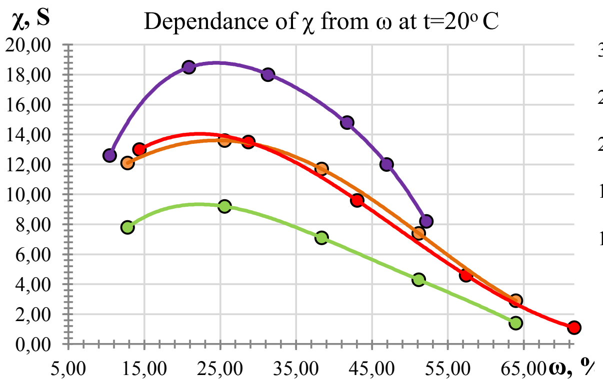

Fig. 1. Dependence of the conductivity from solids content in the juice at t=20° C

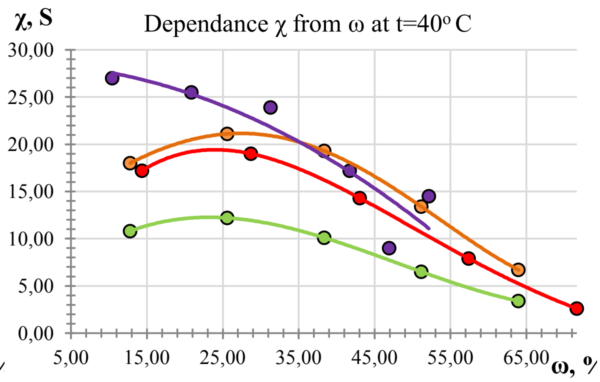

Fig. 2. Dependence of the conductivity from solids content in the juice at t=40° C

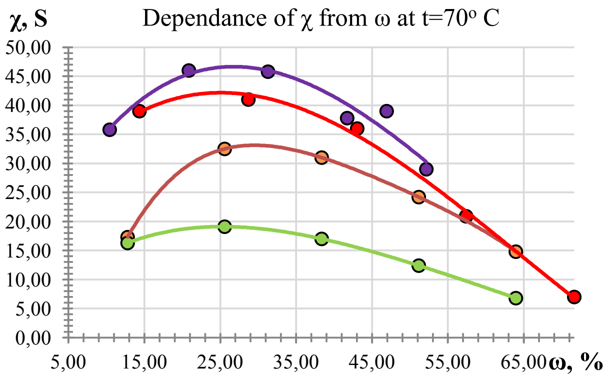

Fig. 3. Dependence of the conductivity from solids content in the juice at t=70° C

where buckthorn (orange line), black currant (violet line), apple (green line), red mountain ash (red line)

Dependence of conductivity on concentration is well expressed as extreme. For the researched area of juices, the extremum is in the range of 25 ... 30% solids content in the entire range of studied temperatures, with a slight shift of the extremum in the direction of increasing solids content with increasing temperature. This is reflected in the studies of other authors[6].

Dependence of conductivity for all juice from temperature in the studied interval of the content of solids mainly has monotonously increasing character (fig. 4-5).

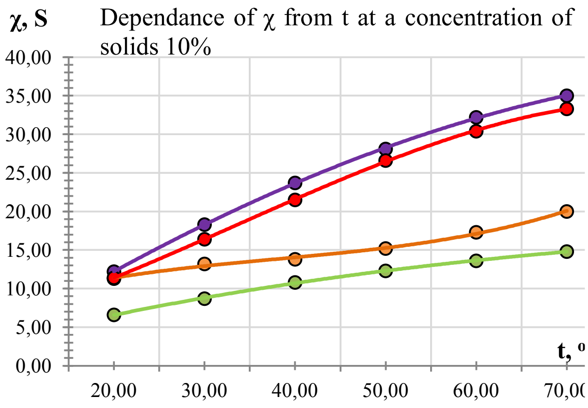

Fig. 4. Dependence of conductivity on temperature at a concentration of solids 10%

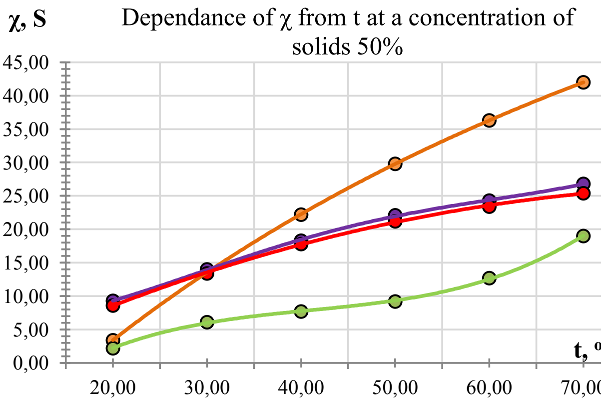

Fig. 5. Dependence of conductivity on temperature at a concentration of solids 50%

where buckthorn (orange line), black currant (violet line), apple (green line), red mountain ash (red line)

Location of electrical conductivity of juices correlates well with the total acidity of juice (table 1), which is particularly well seen in the extremum of electrical conductivity:

Table 1. Arrangement of juice in order acidity decrease in the field of a conductivity extremum

Type of juice	Total acidity, % (At a concentration of solids 25%)	Electrical conductivity, S (At a concentration of solids 25% and 20º C)
Black currant	5.9±0.1	18.8
Red mountain ash	4.2±0.1	14
Buckthorn	3.2±0.1	13.8
Apple	1.8±0.1	9.2

Based on these data it was concluded that the acidity greatly affects the electrical conductivity of the juice. Dependence is linear and can be described (with $R^2 = 0.98$) by a linear equation of the form:

$$\chi = -2.214 + 0.43A \quad (4)$$

where: χ - conductivity of juice in Cm, To - the general acidity of juice in %.

This is probably due to the fact that the process of concentration decreases the amount of free mobile ions in the juice and determine the conductivity to a greater extent the presence of water. Obtained dependence of the specific power delivered throughout the process of evaporation the solution (the surface of evaporation carried to unit of area) from the content of solids at which there is an intensive boiling of juice is started, but the speed of formation of foam does not exceed the speed of foam destruction. I.e. a mode when the device doesn't overflow by foam. Dependence has also linear character and can be described (with R^2=0,98) the linear equation of the form:

$$P = -\alpha \cdot \omega + \beta \quad (5)$$

where P – specific power, which supplied to the evaporator in W/m^2; ω - the concentration of solids,%; α and β - empirical coefficients, calculated experimentally (for apple juice $\alpha = -1319.6$ and $\beta = 26097$).

4. Conclusions

The results indicate a stable electrical nature of the processes occurring during ohmic heating of fruit juices. This contributes to the continuity of the process, simplifies automation and control. The detected direct dependence of the conductivity from solids content allows control over the process without interfering with the evaporation process, eliminating losses due to depressurization during sampling in a traditional way, which is especially important for vacuum evaporators.

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References

1. Kravchenko S. N., Popov A. M. Biological value of the extracts obtained from the dried berries and cranberry pulp, *Izvestia vuzov. Pishevaya tekhnologia*. 2009; **2**: 44-45. (in Russian)
2. Popov A. M., Tikhonov N. V., Tikhonova I. N. Investigation of technological processes for juice concentration and sterilization using the method of direct heating, ISSN 2074-9414. *Techniques and Technology of Food Production*. 2013, **1:** 81-87. (in Russian)
3. Tsapalova I. A., Gubina M. D., Poznyakovskiy V. M. Examination of wild fruits, berries and grasses, Siberian University Press 2002, 2-nd edition, 180. (in Russian)
4. Zareifard, M. R. et al. Ohmic heating behavior and electrical conductivity of two-phase food systems. *Innovative Food Science & Emerging Technologies*. 2003: 45-55.
5. Zhang, L. – Fryer, P. J. Models for the electrical heating of solid-liquid food mixtures. *Chemical Engineering Science* 1993, **48**, 633 – 642.
6. Icier, F. – Ilicali, C. Temperature dependent electrical conductivities of fruit purees during ohmic heating. *Food Research International*. 2005, **38**, 1135-1142.
7. Antropov L. I., Theoretical electrochemistry. High school 1975, 560.