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PRESSURE HOMOGENIZATION IN FRUIT-VEGETABLE PROCESSING INDUSTRY*

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A b s t r a c t. The present paper discusses the investigations concerning the possibility of application of pressure homogenization of fruit and vegetable juices using pressure homogenizers and the attempts undertaken to determine the influence of structural and operational factors of pressure homogenizers, in particular those with a geometrical shape of a homogenizing valve and homogenization pressure, onto the degree of dispersing and homogenization of the dispersed phase particles, flavour, colour, smell, and consistency of a product. The investigations carried out proved that pressure homogenization of pomaced juices using pressure homogenizers contributes to the improvement of the quality of the final product.

K e y w o r d s: pressure homogenization, pomaced juices

INTRODUCTION

Most of liquid materials, semi-products or final products used in food processing industry are characterised by high heterogeneity with regard to both their content and the quantity of the components making such systems. The size of the particles of dispersed phase and the distribution of their dimensions determine the stability of such system, rheological properties, and, in case of emulsion, they determine also their microbiological stability [1,7].

The process of receiving heterogeneous, stable, liquid systems (in particular emulsions) can be divided into the following cases (which often occur at the same time): increase of dispersion of the dispersion phase (disintegration); mixing together with a simultaneous addition of an appropriate emulsifier (which is often used) [1,2,7].

Dispersing of the dispersed phase with its simultaneous spread within the entire volume of the system being homogenized is connected with energy supply to the system. The energy required for the production of a system with increased homogeneity may be supplied through shaking, mixing, rotating, forcing through the working elements of such facilities as colloidal mills, pressure homogenizers, stream or ultrasonic dispersers, and membrane emulators.

For the continuous dispersing process, a substitute diameter of the dispersed phase particles being dispersed, determined by Sauter diameter d_{32}, is a density function according to the relation:

$$d_{32} = C E_v^{-b} \ [\mu\text{m}] \qquad (1)$$

where: C - experimental constant determining physico-chemical properties of the dispersion phase, E_v - energy density, b - constant characteristic of a facility.

The above dependence has been verified for continuously working facilities, in which the time for particles to stay in a dispersing zone is very short. Reaching higher values of energy density in the working volume of a dispersing

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facility assures that the final product received has smaller dimensions of the particles in the dispersed phase.

In industrial processing of fruit and vegetable, in the technological lines for pomaced juices production most often colloidal mills are used, which, in many cases, do not assure the degree of dispersing and homogenization of dispersed phase particles that is required, particularly in the case of dispersing vegetal particles with irregular shapes. Among others, it is connected with the fact that in the working chamber of a colloidal mill, in which a turbulent flow of medium being dispersed takes place and which plays a decisive role in the dispersing process, the energy density E_v obtained ranges from 10^5 to 10^8 J/m^2. In the final product, it allows to get the particles of a phase dispersed by the value of Sauter's diameter d_{32}, contained within the ranging from a few to tens of micrometers. Pomaced fruit and vegetable juices received using this method are therefore characterised by high heterogeneity of structure revealed, among others by the tendency for quick separation during storage. Colloidal mills are characterised by low efficiencies as compared with the efficiency of technological lines, which makes it necessary to install a few machines working parallely in one line. Moreover, in order to maintain the nominal dispersing efficiency of the mill requires their working chambers to be frequently cleaned.

AIM OF THE STUDIES

One of the directions to improve the degree of homogeneity of the pomaced juices is by the studies on pressure dispersing and homogenization of particles of the dispersed phase of a product processed in pressure homogenizers installed on a technological line. They are characterised by many times smaller volume of the dispersing zone as compared with colloidal mills. At the same time the values of energy density, volumetric flow intensity and power density obtained in the dispersing zone are also higher. An additional factor, which increases the degree of dispersing in the working chamber of a pressure homogenizer is the cavitation phenomenon occurring there.

Table 1 shows the comparison of power parameters of the two basic systems used for dispersing the heterogeneous liquid systems in food and agriculture industry.

On the account of the extensive action of pressure homogenization process, both positive and negative, onto the quality of a final product, the influence of basic structural and operational parameters, and in particular the design of homogenizing valve and homogenization pressure onto the degree of dispersing and homogenization and the quality of pomaced fruit and vegetable juices has been investigated. The research carried out in literature confirmed the lack of complex data on the application of pressure methods (pressure

Table 1. Basic power parameters of systems used for dispersing the heterogeneous liquid systems in food and agriculture industry [7]

System	System Rotor-Stator		High Pressure System	
Dispersing devices and mechanism	Colloidal mill with smooth working surfaces. Laminar flow	Colloidal mill with profiled working surfaces. Turbulent flow	Pressure homogenizer. Turbulence and cavitation	Jet disperser. Turbulence and cavitation
Size of dispersed particle	$d_{32} = C\,E_v^{-b}$			
	b=1	b=0.2-0.4	b=0.6(0.4-0.9)	b=0.6
$E_v(J/m^3)$	10^5-10^6	10^5-10^8	106-10^8	10^6-10^8
t_{res} (S)	0.1-1.0		10^{-3}	10^{-4}

homogenizers) in processing liquid heterogeneous systems with solid particles making a dispersed phase, examples of which are made by pomaced fruit and vegetable juices [1,3, 6,7]. The attempts to asses the degree of homogenization efficiency, e.g., by measuring viscosity that have been undertaken could not be applied more extensively.

MATERIALS

The object of the study was Polish pressure homogenizer type CHO-20M with the nominal capacity of 2 m^3/h and working pressure of 4-22 MPa. At the first stage of investigations, it was equipped with a flat, two-stage homogenizing valve installed in an industrial tomato and carrot-apple juice processing lines. Preliminary tests on pressure homogenizer installed ahead of a deaeration unit showed that under the rated homogenizing pressure of 14.0 MPa, the efficiency of the homogenizer did not exceed 40% of the nominal efficiency value of the unit. Further tests have been carried out with the homogenizer installed behind the deaeration unit, which makes it possible to obtain the efficiency at the order of 90% of the rated value.

A two-stage homogenizing valve which is a standard equipment of the type CHO-20M homogenizers, during investigations on pomaced juices homogenization evoked automatic increase of homogenizing pressure up to over 20 MPa, which could lead to unit failure. In further investigations two variants of homogenizing valve designs solutions have been used: a single-stage conical valve characterised by the increased resistance to wear and flat homogenizing valve with the increased breadth of the slot of the second homogenization stage. In the course of investigations it has been shown that the flat valve ensured high quality of juices already at the pressure of 5.0-7.0 MPa (Bertuzzi recommended homogenizing pressure of 15-18 MPa for a disperser-homogenizer working in the line for processing pomaced juices [5]). However, at the same time excessive wear has been observed in homogenizing slot, valve head and seat surfaces after a few hours of operation.

As there were no explicit criteria to assess the efficiency of pressure homogenization of fruit and vegetable pomaced juices at this stage of investigations, the quality of homogenized juices and the degree of homogenization has been assessed by determining the following:

- the degree of separation S_R of the product being homogenized, according to the formula:

$$S_R = \frac{h}{H} 100 \quad [\%] \tag{2}$$

where: h and H - height of the transparent layer in the juice sample being tested and total height of the sample, respectively;

- characteristic dimension of dispersed phase particles determined using a microscopic method;
- changes in colour, flavour, and smell of samples being tested.

The size of dispersed phase particles of the studied juice have been determined using a microscopic method according to the Polish Standard PN-75/A-86059.

RESULTS

The results of investigations of the change in the degree of separation of a nonhomogenised tomato juice, juice dispersed in a colloidal mill only, and juice dispersed in a pressure homogenizer equipped with a flat homogenizing valve at the homogenizing pressure of P_h=14 MPa are presented in Fig. 1. The samples of 0.33 dm^3 of pomaced juice tested have been stored in air-tight glass containers at the temperature of 10-14°C. As it is shown by the curves in Fig. 1, during first 11 days (264 h) of storage the increase of the degree of separation in the sample of non-homogenized tomato juice has been noticed - up to 18.9%.

In the samples of juice homogenized by a colloidal mill the degree of separation reached about 12.0%. Further storage of the samples of non-homogenized juice and juice homogenized in a colloidal mill for up to 15 days had

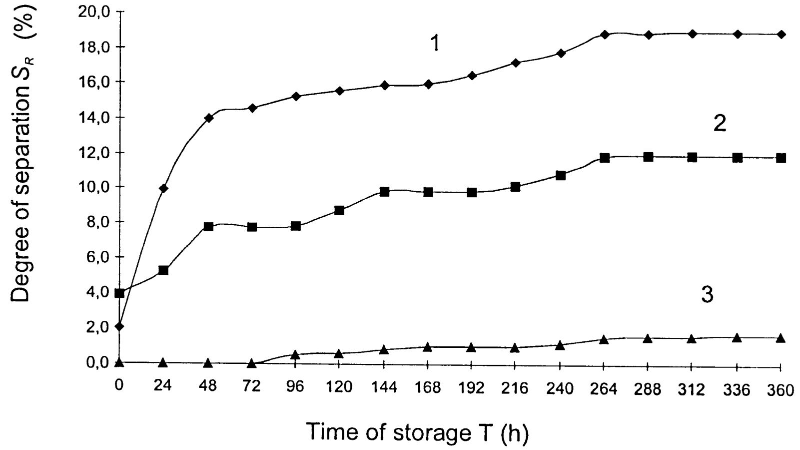

Fig. 1. The change of the degree of separation S_R depending on the method of dispersion and on the time of storage: 1 - tomato juice that has not undergone the dispersion process; 2 - tomato juice dispersed using a colloidal mill; 3 - tomato juice dispersed using a pressure homogenizer (flat valve).

practically no influence on the change in the degree of separation in those samples. In the samples of juice dispersed and homogenized using a pressure homogenizer with a flat homogenizing valve and homogenizing pressure of P_h = 14 MPa, no evident phenomenon of separation has been noticed (degree of separation lower than 3%), which shows its high uniformity as compared with the samples of non -homogenized juice or those of juice processed using a colloidal mill only.

In the next series of tests a conical homogenizing valve has been used. The results of the investigations of the influence of homogenizing pressure and time of storage onto the change in the degree of dispersion of tomato juice being processed are presented in Table 2. In the course of the tests the samples of 0.33 dm^3 have been stored in commercial air-tight glass containers at the room temperature of 18-22°C. The samples for the tests have been taken at the following homogenizing pressures: P_{h1} = 0 MPa; P_{h2} = 4 MPa; P_{h3} = 8 MPa; P_{h4} = 12 MPa; and P_{h5} = 16 MPa.

In the samples of non-homogenized juice and juice homogenized at the pressure of 4 MPa the separation occurred already after 6 h of storage. In the sample of juice that had not undergone homogenization process after 8 days (192 h) of storage the increase of the separation process was observed - up to the level of 20.5% and did not change during further storage.

In the juice homogenized at 4 MPa, the maximum degree of separation, i.e., about 15.2% was observed after 16 days (384 h) of storage. The samples of juice homogenized at 8 MPa had a durable consistency and no separation was noticed practically throughout the entire test period.

Table 2. The change of separation degree S_R of a tomato juice homogenized using a pressure homogenizer with a conical valve

Time of storage (h)	Degree of separation S_R (%)				
	Homogenizing pressure (MPa)				
	0	4	8	12	16
6	11.9	3.3	-	-	-
48	15.2	6.3	-	-	-
96	16.9	8.9	-	-	-
144	19.9	12.6	-	-	-
192	20.5	13.2	-	-	0.5
240	20.5	13.2	-	-	1.3
288	20.5	14.6	-	-	2.0
336	20.5	14.9	-	-	3.3
384	20.5	15.2	-	-	4.0
432	20.5	15.2	-	0.7	5.3
480	20.5	15.2	-	2.0	7.3
528	20.5	15.2	-	2.6	7.3
576	20.5	15.2	-	4.0	6.6
624	20.5	15.2	-	5.3	6.6
672	20.5	15.2	1.0	6.3	7.3
720	20.5	15.2	1.0	6.3	7.3

T a b l e 3. The range of characteristic dimensions of dispersed phase particles

	Without disperser	Colloidal mill	Pressure homogenizer				
			Flat valve, pressure (MPa)	Conical value, pressure (MPa)			
			14.0	4.0	8.0	12.0	16.0
Characteristic dimension (μm)	1.1-26.0	1.0-6.1	0.8-3.01	1.1-21.2	0.9-10.7	0.9-10.2	0.8-6.9

Separation of the system being investigated has been notice in the case of juice samples homogenized in a pressure homogenizer at 12 and 16 MPa. In the case of juice homogenized at 12 MPa, the first traces of separation have been noticed after 18 days (432 h) and the degree of separation process S_R exceeded 3% after 22 days (528 h) (the thickness of transparent layer was about 5 mm). The sample of juice homogenized at 16 MPa has been even more unstable: the beginning of separation has been noticed after 8 days (192 h) of storage. After 14 days (336 h) of storage the value of the degree of separation S_R exceeded 3% and after 28 days (672 h) reached a stable level of 7.3 % (thickness of the transparent layer was 11 mm).

The organoleptic tests (taste and smell) [4] revealed that the samples of homogenized juice produced in a pressure homogenizer differed from those produced in a colloidal mill. Pressure-homogenized juice was more uniform, with greater intensity of characteristic tomato smell and taste, without any foreign flavours or smells. The observations carried out proved that the samples of non-homogenized juice and those of pressure-homogenized juice at $P_h = 4$ MPa had bright colour with red shade and noticeable light traces, whereas samples of juice homogenized at higher pressures had intense, bright-red colour with orange shade.

Table 3 presents the ranges of change in characteristic dimensions of dispersed phase particles depending on the design and operational parameters of the homogenizing device being investigated.

CONCLUSIONS

The results of studies obtained showed a possibility to apply a pressure homogenization method of tomato pomaced juices in industrial practice by the installation of pressure homogenizers in processing lines. Pressure homogenization increases the degree of product uniformity, improves smell and taste, and substantially increases the storage period, without the occurrence of pomaced juice separation.

Application of flat homogenizing valves in pressure homogenizers made it possible to arrive at the degree of separation lower than 3% already at the working pressure of 5.0 - 7.0 MPa, and so at lower power consumption than in case of the application of conical valves. The investigations carried out so far proved that in case of using conical homogenizing valves, which are characterised by a few times higher durability as compared with the flat ones, the recommended homogenizing pressure value is between 8.0 and 10.0 MPa.

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