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INTENSIFICATION OF THE TECHNOLOGICAL PROCESS OF FRUIT JUICE CLARIFICATION BY THE PEO and GPAA FLOCCULANTS

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Abstract

Based on the conducted research, an innovative method of fruit juice processing is proposed, which consists of using hydrodynamically activated polymeric flocculants polyethylene oxide (PEO) and hydrolysed polyacrylamide (GPAA). The mechanism of hydrodynamic control of the flocculation capacity of flocculant molecules was set up and its understanding allowed to intensify the technological process of fruit juice clarification significantly. Effective devices that allow, under conditions of convergent flow and in an oscillating hydrodynamic field, to dramatically increase the intensity of the technological process of clarification of colloidal dispersed systems, which is undoubtedly of both scientific and practical importance in solving problems of food technology and engineering ecology have been investigated. It has been proved that PEO and GPAA flocculants activated in an oscillating hydrodynamic field are promising reagents for the purification of fruit juices, for example, apple juice, due to the reduction of the content of such hazardous elements as heavy metals (arsenic, cadmium, lead, mercury, nickel) in the juice.

Keywords: polymeric flocculants; clarification; purification; fruit juice; macromolecular chains; hydrodynamic field; velocity gradient.

ІНТЕНСИФІКАЦІЯ ТЕХНОЛОГІЧНОГО ПРОЦЕСУ ОСВІТЛЕННЯ ФРУКТОВИХ СОКІВ ФЛОКУЛЯНТАМИ ПЕО І ГПАА

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Анотація

На основі проведених досліджень запропонований інноваційний спосіб оброблення фруктових соків, який полягає у використанні гідродинамічно активованих полімерних флокулянтів поліетиленоксиду (ПЕО) і гідролізованого поліакриламіду (ГПАА). Встановлено механізм гідродинамічного управління флокуляційною здатністю молекул флокулянта, що дозволило суттєво інтенсифікувати технологічний процес освітлення фруктових соків. Створено ефективні пристрої, які дозволяють в умовах збіжної течії та в осцилюючому гідродинамічному полі різко підвищити інтенсивність технологічного процесу освітлення колоїдно-дисперсних систем, що має наукове і практичне значення для вирішення задач харчових технологій та інженерної екології. Доведено, що флокулянти ПЕО і ГПАА, активовані в осцилюючому гідродинамічному полі, є перспективними реагентами для глибокого очищення соків (на прикладі яблучного) від важких металів (миш'як, кадмій, свинець, ртуть, нікель).

Ключові слова: полімерні флокулянти; освітлення; очистка; фруктовий сік; макромолекулярні ланцюги, гідродинамічне поле; градієнт швидкості.

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Introduction

The current demand for juice products in Ukraine and on the world market prompts to solve the issue of intensification of juice production [1–9]. Producers need to solve many organisational and technological problems to ensure that juice products meet international standards. The predominant production of clarified fruit juices has become widespread in the world due to significant advantages (technological and consumer) compared to unclarified juices, as clarified juices have increased biochemical stability (this contributes to an increase in shelf life), long-term transparency, and better thirst quenching [7].

The analysis of the market and statistical data shows that apples are the main raw material for juice production in Ukraine, and, accordingly, apple juice ranks first among juices from other fruit and berry crops [10]. Fruit juice clarification techniques commonly involve physical methods such as straining, settling, and separation, as well as biochemical methods that utilize enzymes and other biologically active substances. Additionally, physicochemical methods are often employed [4–6; 8]. If physical and biochemical methods of clarification of fruit juices have been sufficiently researched [11; 12], further research is still required for physicochemical methods, especially the flocculation method.

The process of separating the colloidal system of fruit juice into sediment and clear juice is called clarification when using the flocculation method. Juices as soon as they are received can be immediately clarified using organic and inorganic substances such as bentonite, flocculants like gelatin, polyvinylpyrrolidone, polyacrylamide, or polyethylene oxide [7; 13]. Methods for clarifying fruit juice in practice have both advantages and disadvantages. Advantages include the effective removal of colloidal compounds present in fruit juice and low reagent costs. However, these methods have limitations on their use and can be costly. These findings have been supported by studies conducted by [14–15]. All of these factors are necessary to find more efficient clarification agents that can meet technological and economical standards, while also satisfying production requirements for enhancing the transparency, stability, and safety of juices. They can also aid in intensifying the clarification process of fruit juices. Polymeric flocculants are extensively used for the purification of drinking water [13], the concentration of cell suspensions in biotechnology [18; 19], and the treatment of wine materials and wines [20–23]. First of all, it concerns the clarification of juices using synthetic flocculants such as polyethylene oxide (PEO) and hydrolysed polyacrylamide (GPAA). It is also very important that PEO is a safe substance that is allowed to be used in food technology [24]. Polymeric flocculants are effective reagents that can purify various liquids from heavy metals [17]. The precipitation of heavy metals from liquid using polymeric flocculants can help improve the safety of fruit juice [25].

The main characteristics of flocculants that significantly affect the intensity of flocculation are their molecular weight, the flexibility of the polymer chain, the quality of the solvent and their concentration in the solution [25]. As the molecular weight of the flocculant increases, its flocculating effect generally increases, too. This allows for a reduction in the optimal concentration of the flocculant needed to clarify the liquid. The increase in effect is due to large macromolecules being able to bind more particles in a floccule by using polymeric bridges between the particles. Calculations demonstrate that a doubling in macromolecule size leads to a significant increase in flocculation intensity, potentially by one or two orders of magnitude. This suggests that the flocculating effect of similarly-weighted macromolecules is reliant on the size of the macromolecular surface area, or its conformation, which is influenced by chain flexibility. Chain flexibility can be altered by the influence of a hydrodynamic field on a macromolecular coil [26–29]. The impact of a longitudinal hydrodynamic field on the flocculating behaviour of macromolecules is simplified to the fundamental principle. The degree of elongation (or folding) of a flexible macromolecule can be characterized by the β parameter, which is equal to the ratio of the distance between the ends of the macromolecule h to its contour length L. From the standpoint of thermodynamics and physical kinetics, parameter β is more fundamental than the Flory chain flexibility parameter f: the fact is, that upon reaching a certain critical value of β_{cr}, the theory of dissipative structures and Prigogine's bifurcation come into play. Furthermore, the means by which β_{cr} is attained is insignificant as even a solitary macromolecule experiences diminished stability due to the presence of rotational isomers, which cause it to align [25–28].

The foregoing allows us to state that under the influence of a tensile hydrodynamic field, it is possible to enhance the ability of macromolecules to flocculate without altering the molecular weight of polymer flocculant. This enhancement results in increased flocculation intensity and reduced optimal concentration. Thus, we propose innovative devices for hydrodynamic impact on the ability of macromolecules to flocculate (Pat. 57599 Ukraina (2011), Byul. 5. Device for clarification of food liquids using flocculants; Pat. 42034 Ukraina (2009), Byul. 12. Device for separation of liquid food products and materials).

Therefore, increasing the intensity and degree of clarification of fruit juices can be improved by utilizing flexible-chain water-soluble polymers, which demonstrate an increase in flocculation action when exposed to a tensile hydrodynamic field. This method has been observed in studies [25; 30–33].

The revealed possibility of hydrodynamic control of the flocculation capacity of flocculant macromolecules in solution allows for increasing the intensity of the technological process of clarification of colloidal dispersed systems, which is undoubtedly of both scientific and practical importance in solving problems of food technology and engineering ecology.

Thus, a significant reserve for improving the efficiency of the flocculation processing of fruit juices (and other liquids) lies largely in the improvement of technological processes for processing of juice products using hydrodynamically activated polymer flocculants.

Thus, *the purpose of this work* is to prove, based on experimental studies, the possibility of intensifying the technological process of fruit juice processing, on the example of apple juice, which consists in using an innovative method of hydrodynamic control of the flocculation ability of macromolecules in the conditions of convergent flow and in an oscillating hydrodynamic field.

Experimental part

Materials and methods

In the work it is carried out the experimental studies of natural freshly obtained apple juices from the following Jonathan (winter variety). Apples of the removable maturity were used. Apples were stored in a chamber at a temperature of 18 °C for no more than 5 days. Polymeric flocculants chosen include polyethylene oxide (PEO) with molecular weights of $4 \cdot 10^6$ (WSR-301), $7 \cdot 10^6$ (WSR-303) and polyacrylamide (GPAA) with a molecular weight of 10^7 and 14 % degree of hydrolysis (Praestol). The concentration of the flocculant in apple juice was chosen such that the inequality was fulfilled $[\eta]_0 \cdot C > 0.8$ (where $[\eta]_0$ is the intrinsic viscosity; C – concentration of the flocculant).

Content of heavy metals of apple juice was determined by spectral (STE-1 analyser (in Ukrainian CTE-1)), atomic absorption (F115-PK (in Ukrainian Ф115-ПК) and AAS-1 spectrometer), spectrophotometric (SF-26 analyser (in Ukrainian СФ-26) methods (GOST 51309-99), and mercury was determined using the RAF-1 analyser (in Ukrainian РАФ-1) (GOST 26927-86).

Flocculation by polymers in fruit juice (without hydrodynamic influence) was studied in 0.2-litre glass cylinders. The cylinder was filled with juice to the mark of 200 ml, then injected the required amount of flocculant solution, closed the cylinder and tipped it five times with an interval of about 2 seconds. After the fifth tipping, a stopwatch was started and the time taken for the border separating the clarified juice and settling floccules to reach the 140 ml mark was measured. From the time the front moved and the distance between the marks, equal to $51 \cdot 10^{-3}$ m, the average juice clarification speed was found. The speed of juice clarification was also determined by the change in the optical density of the juice over time (with an interval of 10 min).

The effects of the hydrodynamic field on the flocculating ability of macromolecules were evaluated as

$$F_{\dot{\varepsilon}} = \left(\frac{n_{c0} - n_{c\dot{\varepsilon}}}{n_{c0}} \right) \cdot 100\,\%, \qquad (1)$$

where n_{c0} and $n_{c\dot{\varepsilon}}$ – optical densities of apple juice with flocculant without the influence of the hydrodynamic field and after hydrodynamic activation, respectively ($n_{c0} \equiv n_{c\dot{\varepsilon}}$ at $\dot{\varepsilon} \to 0$).

The structural scheme of the flocculator with the flow of fruit juice through the channels with holes is shown in Fig.1. It contains a tank with juice 1, a mixer of juice with flocculant solution 2, a tank with flocculant solution 3, a dispenser 4, a flow chamber 5 with one or more parallel channels with holes (Fig.2), large and small diameter tubes. Fig. 2 shows the design of flow channel with holes through which fruit juice with flocculant flows. Large vessel 1 with a diameter of 0.1 m with small holes 2 with a diameter of $3 \cdot 10^{-4}$ m, 3 and 4 – inlet and outlet branch pipes.

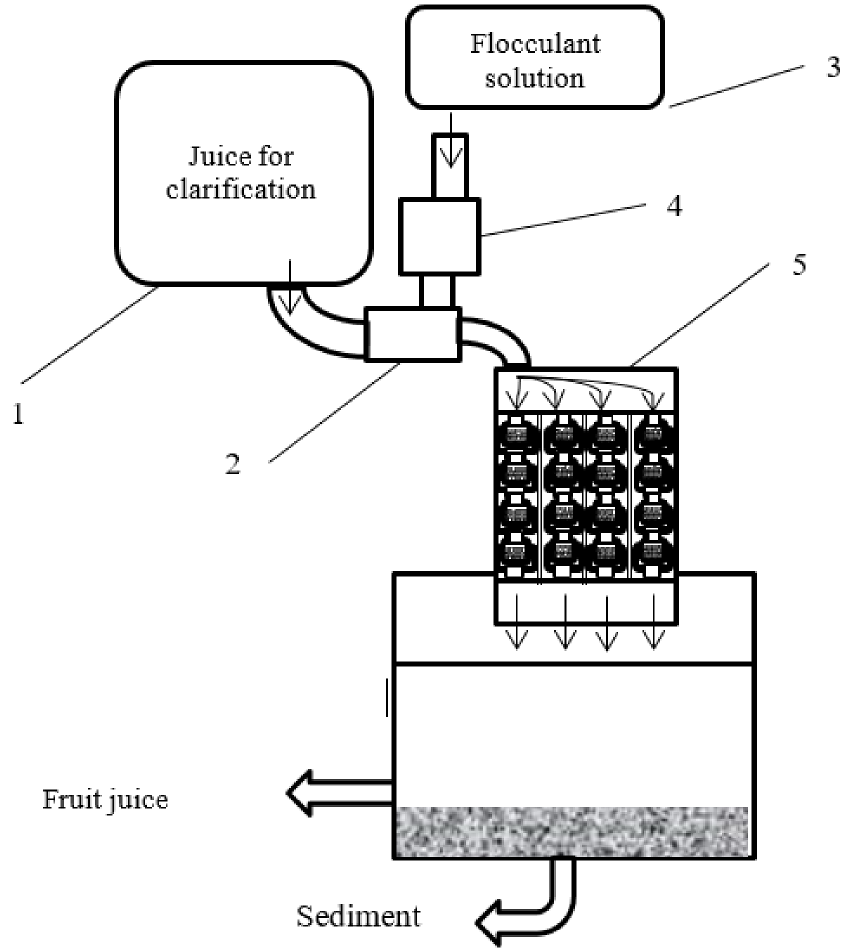

Fig. 1. Structural diagram of a flocculator with fruit juice flowing through flow channels with holes
1– tank with juice for clarification; 2– mixer of juice with flocculant solution; 3 – tank with flocculant solution; 4 – dispenser; 5 – flow chamber with parallel channels

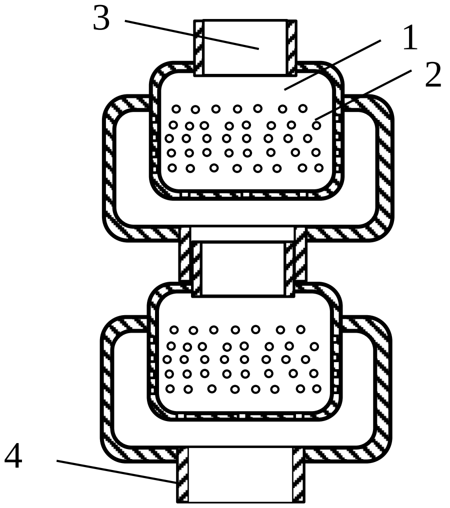

Fig. 2. Schematic diagram of the flow channel of the flocculator with holes
1– large vessel with a diameter of 0.1 m; 2– small holes with a diameter of $3{\cdot}10^{-4}$ m; 3 and 4 – inlet and outlet branch pipes

An alternative method of hydrodynamic activation of flocculants (increasing their flocculating capacity) was also used. Scheme of the flow module of hydrodynamic activator with oscillating hydrodynamic field in Fig. 3.

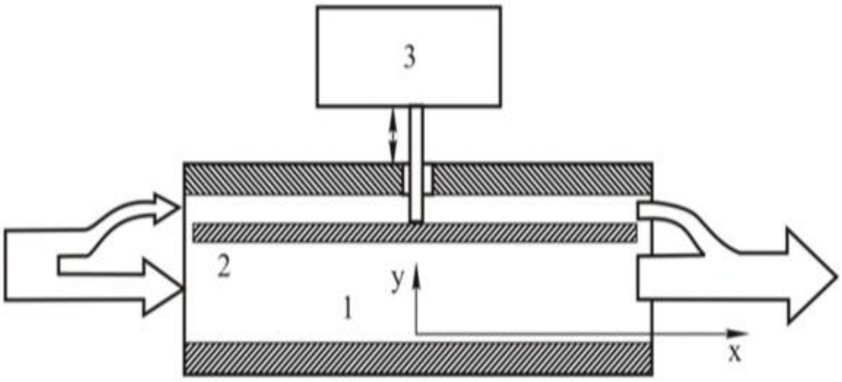

Fig. 3. Schematic diagram of the flow part of a single module with oscillating hydrodynamic flocculant activation
1 – flow channel; 2 – vibrating partition; 3 – electromagnetic vibrator

The essence of its operation is as follows. The fruit juice to be clarified, together with a strictly dosed amount of dissolved flocculant is pumped into the settling tank through a number of alternating sections of flow chambers containing several modules with variable flow area. The number of sections and modules in the flow chamber is determined empirically. The variation of the flow area was carried out by means of vibrations of the partition 2 connected to an electromagnetic vibrator 3. The amplitude of vibrations of the partition 2 (membrane) was controlled by a special device. As a result of reciprocating motion, the partition between the upper and lower walls draws or displaces liquid from the corresponding channel 1 (Fig. 3). In both cases, a longitudinal velocity gradient is realised near the vibrating surface, the magnitude of which can vary within wide limits.

To achieve the required temperatures fruit juice, utilized customized thermostatization [32–36]. The temperature stabilization was maintained at the specified level with precision up to ±0.1 °C.

Results and discussions.

One of the most significant properties of PEO macromolecules is their intrinsic anisotropy and the anisotropy of their shape. Therefore, using polarisation-optical flow visualisation and measuring ray refraction of aqueous solutions of PEO, it is possible to obtain information about the local deformation features of macromolecular tangles in the convergent flow. In [26], it was proved that in convergent flow at a regime above the critical, for the concentration area lying between very dilute and moderately concentrated solutions, a rather strong deformation influence of the hydrodynamic field on macromolecular chains occurs. The ratio of the measured double refraction to the maximum possible one when macromolecules are exposed to the hydrodynamic field generated by a freely convergent flow reaches 0.37 [26], and at the superposition of two oppositely directed convergent flows – 0.8–0.95 [29], which corresponds to the degree of unfolding of macromolecular tangles of ~63 % and 90–100 %, respectively.

The longitudinal velocity gradient is realised when the polymer solution flows through short capillaries or slits [27; 30]. Therefore, the presence of the impact effect of the longitudinal velocity gradient on the flocculation effect of macromolecules can be verified by a comparative experiment on the effect of the conditions of flowing a polymer solution through capillaries with different geometry of the entrance area – one with the angle of entrance of 180^0 (curve 1 of Fig. 4), and the other – a de Laval nozzle (curve 2 of Fig. 4).

From the data obtained in [26], it follows that for the first capillary at regimes of flow above the critical (when $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$), the degree of unfolding of the macromolecular chain can be ~ 63 %, and for the second – almost zero. Therefore, it could be expected that in the case when the polymer flocculant solution was introduced into the fruit juice through the first capillary at regimes above the critical, the flocculation intensity should be higher due to the increase in the size of molecular tangles under the influence of the hydrodynamic field than in the case of the second capillary. During the flow of the solution through the second capillary, a regime above the critical is not realised because the longitudinal velocity gradient depends not only on the flow velocity but also on the angle of entrance into the flow resistor (in our case, it is a short capillary).

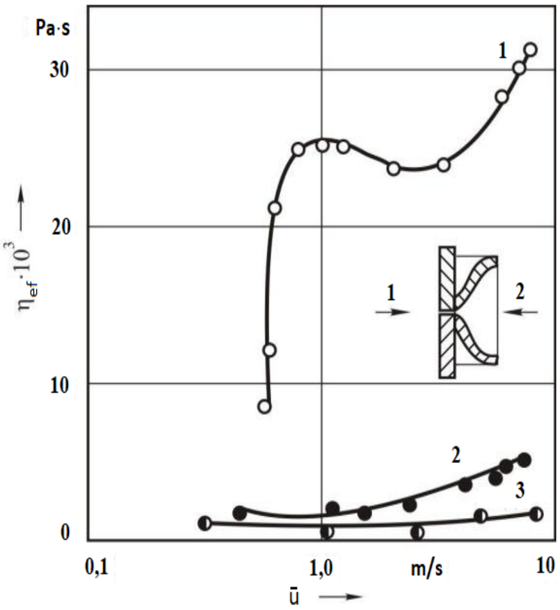

Fig. 4. Effect of capillary entry conditions and flow velocity on the effective viscosity of the PEO solution
$M_{PEO} = 7\cdot10^6$, $C_{PEO} = 0.05$ % –curve 1and 2, Water – curve 3. $d_{min} = 0.53\cdot10^{-3}$m

However, the experiment we conducted did not reveal any effect of the longitudinal velocity gradient on the flocculation effect of macromolecules. The negative result obtained in the case under consideration is primarily explained by the kinetics of the tangle-unfolded chain transition in the convergent flow of aqueous solutions of PEO. In the processes of flocculation by polymers of dispersed systems, such as unclarified fruit juices, the diffusion rate of macromolecules to the particle surface plays an important role, i.e. the time required for the interaction of macromolecules with the particles of the dispersed system. In our experiment, only a small number of particles had the opportunity to interact with macromolecular chains unfolded by the hydrodynamic field, while another larger number (due to the relatively short time for macromolecular chains to fold) was able to interact with macromolecules that had already assumed their original conformation.

In this connection, flow elements were developed, manufactured and tested, in which the flocculant macromolecules deployed by the hydrodynamic field could interact with the maximum number of colloid-dispersed particles (see Fig. 2 and Fig. 3). First of all, in these flocculators the influence of the hydrodynamic field was carried out on the system of fruit juice–flocculant, and not only on the flocculant solution injected into the fruit juice.

The study of the process of clarification of apple juice from Jonathan apples using a flocculator, the design of the flow chamber of which is shown in Fig. 2, showed that there was an increase in the flocculation ability of PEO molecular weight $7\cdot10^6$ and concentration of 0.004 % in apple juice up to 20–30 % in comparison with clarification without the influence of the longitudinal hydrodynamic field. But despite the rather high efficiency of flow channels with holes (see Fig. 2) for hydrodynamic activation of polymeric flocculants, due to a number of difficulties of technical character, first of all, due to clogging of holes with flocculates, which leads to the difficulty of maintaining a constant longitudinal velocity gradient in the inlet area of holes, we had to propose an alternative method of hydrodynamic activation of macromolecules of flocculants (see Fig. 3). In this case, a longitudinal velocity gradient is realised near the vibrating surface, the value of which can be calculated as follows.

Since the flow is symmetric, consider the problem when the fluid flow is forced out of the gap between two planes. Let the lower wall of the channel is fixed and the upper wall moves vertically, changing the gap y according to the law

$$y(t) = \left(a + \delta_g\right) + a\sin\omega' t, \qquad (2)$$

where a – amplitude of oscillations of the upper plane;

δ_g – minimum gap (during oscillations) between the upper and lower planes;

ω' – cyclic frequency of oscillations;

t – time.

The continuity equation for this problem has the form:

$$S_0 V_y(t) = S(t) V_x(t), \tag{3}$$

where S_0 – the area of the upper plane (cell wall);

$S_0 = b \cdot x$, here b and x – depth and length of the slot gap;

$V_y(t)$ – velocity of the upper wall movement;

$V_y(t) = \frac{dy(t)}{dt}$;

$S(t)$ – is the flow area of the slot gap, which varies as follows: $S(t) = by(t)$;

$V_x(t)$ – is the fluid velocity at the exit of the slot gap.

Taking into account the above, the continuity equation will have the form

$$xa\omega' \cos\omega' t = V_x(t)\left[(a + \delta_з) + a\sin\omega' t\right], \tag{4}$$

from where

$$V_x(t) = \frac{xa\omega' \cos\omega' t}{(a + \delta_з) + a\sin\omega' t} \tag{5}$$

Then the average longitudinal velocity gradient $\dot{\varepsilon}_x$ in the direction is found as

$$\dot{\varepsilon}_x = \frac{dV_x(t)}{dx} = \frac{a\omega' \cos\omega' t}{(a + \delta_з) + a\sin\omega' t}, \tag{6}$$

and the average longitudinal velocity gradient $\dot{\varepsilon}_y$ in the direction y as

$$\dot{\varepsilon}_y = \frac{dV_y(t)}{dy} = \frac{a\omega' \cos\omega' t}{(a + \delta_з) + a\sin\omega' t}. \tag{7}$$

Then the total longitudinal velocity gradient $\dot{\varepsilon}$ will be equal to

$$\dot{\varepsilon} = \sqrt{\dot{\varepsilon}_x^2 + \dot{\varepsilon}_y^2} = \dot{\varepsilon}_x\sqrt{2} = \frac{\sqrt{2}a\omega' \cos\omega' t}{(a + \delta_з) + a\sin\omega' t} \tag{8}$$

We find the maximum longitudinal velocity gradient from the condition that the first derivative of the function (8) is equal to zero. By simple transformations, we obtain that this condition is fulfilled at $\sin\omega' t = -\frac{a}{a + \delta_з}$. Then

$$\dot{\varepsilon}_{\max} = \frac{a\omega'\sqrt{2}}{\sqrt{2a\delta + \delta_з^2}}. \tag{9}$$

It follows from expression (9) that at oscillation frequency $\nu = 150$ Hz, oscillation amplitude $a = 2 \cdot 10^{-3} m$ and minimum gap $\delta_g = 10^{-3} m$, the maximum velocity gradient is obtained equal to $1.2 \cdot 10^3 s^{-1}$, i.e. $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$. At such values of $\dot{\varepsilon}$ flexible chain macromolecules can reach a degree of unfolding of 60–100 % [26,29].

The data characterising the effect of longitudinal velocity gradient when changing δ on the flocculation capacity of PEO in the apple juice-PEO system are shown in Fig. 5. The flow section contained five modules (a single module is shown in Fig. 3). The magnitude of the effect of the hydrodynamic field on the flocculation ability of macromolecules was estimated by formula (1). It can be seen that at the longitudinal velocity gradient below some critical value (when $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$) the influence of the velocity gradient on the flocculation action of polymer macromolecules is absent and only when the critical value $\dot{\varepsilon}_{cr}$ is reached the flocculation intensity begins to increase.

The evidence base for the intensification of the apple juice clarification process using PEO molecular weights of 4·10⁶ was also provided by the data presented in Table 1.

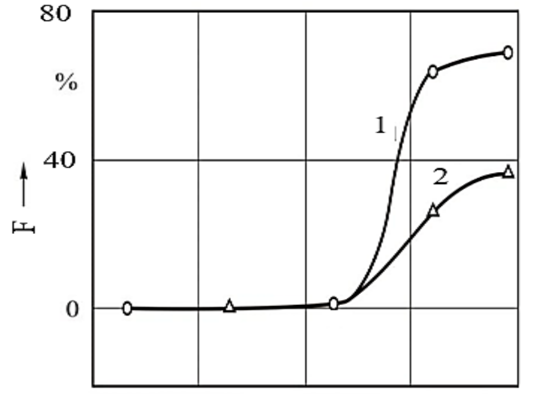

Fig. 5. Effect of longitudinal velocity gradient on the fluctuation capacity of PEO during clarification of apple juice from Jonathan apples. $M_{PEO} = 4 \cdot 10^6$, C_{PEO}: 1 – 0.004 %, 2 – 0.002 %

Table 1

Influence of flocculant-PEO concentration and longitudinal velocity gradient on the clarification speed of Jonathan apple juice

PEO concentration in the juice-PEO mixture, mg/L	Juice-PEO in a flow with $\dot{\varepsilon} < \dot{\varepsilon}_{cr}$; $l \cdot 10^{-4}$ m/$t \cdot 60$ s	Juice-PEO in a flow with $\dot{\varepsilon} = \dot{\varepsilon}_{cr}$; $l \cdot 10^{-4}$ m/$t \cdot 60$ s	Juice-PEO in a flow with $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$; $l \cdot 10^{-4}$ m/$t \cdot 60$ s
2	10	35	50
4	20	60	70

We see that the processing of the mixture of juice and flocculant-PEO in the flocculator (Fig. 3) with oscillating longitudinal velocity gradient, leads to an increase in velocity *l/t* ($l=51 \cdot 10^{-3}$m, *t* – time of movement of the front of settling floccules at a given site *l*) of clarification of apple juice and reduce the consumption of PEO only in the mode, when $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$. In this case, there is a limiting value of $\dot{\varepsilon}_{\lim}$, above which the effectiveness of the proposed method of increasing the flocculating ability of PEO decreases. Experiments were carried out with PEO of molecular weight $4 \cdot 10^6$ and its concentration in apple juice 0.002 % and 0.004 %.

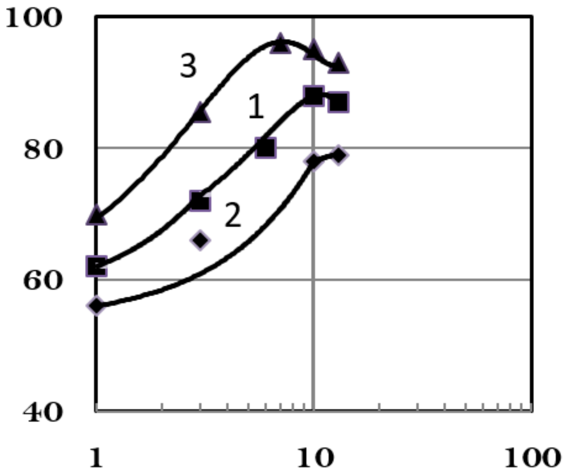

Fig. 6. Dependence of efficiency of flocculation action of PEO on its concentration in apple juice from Jonathan apples

M_{PEO}: 1 and 3 – $7 \cdot 10^6$, 2 – $4 \cdot 10^6$; 1 and 2 – $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$,

3 – $\dot{\varepsilon} > \dot{\varepsilon}_{cr}$

The influence of PEO concentration of molecular weights $4 \cdot 10^6$ and $7 \cdot 10^6$ on the flocculation effect in apple juice at 20 °C is shown in Fig. 6. It can be seen that the concentration dependence of the flocculating effect passes through a maximum in the area of concentrations of C^{op}_{PEO}=14 mg/L и 8 mg/L respectively to the considered molecular weights of PEO, and then the magnitude of the effect begins to decrease. Increasing the concentration of flocculant in apple juice leads to an increase in the viscosity of the juice-PEO system [37] due to the emerging intermolecular interactions of PEO molecules, and this in turn hinders the settling of the formed flocculates and, naturally, reduces the speed of clarification, i.e. flocculation effect.

The data presented in Figure 6 (curve 3) and Table 1 show that the effect of oscillating hydrodynamic field on the juice-PEO system increases the flocculation effect. This is reflected in the optimum flocculant concentration, which decreases and in the magnitude of the effect itself, which increases. If the longitudinal velocity gradient $\dot{\varepsilon}$ is increased significantly above $\dot{\varepsilon}_{cr}$, the speed of clarification of apple juice begins to decrease.

Thus, the experiments have confirmed the possibility of hydrodynamic control of the flocculation capacity of flocculant macromolecules, which is due to the rather strong deformation effect of the hydrodynamic field on macromolecular tangles in the flow with stretching of polymer solutions.

Intensive development in Ukraine of industry, transport, energy, wide urbanisation, chemicalisation of agriculture, as well as the consequences of today's war lead to pollution of the environment, in particular of fruit juices, by chemical elements and compounds of arsenic, cadmium, lead, mercury, nickel and other heavy metals [38]. Therefore, it is necessary to carry out the purification of fruit juices from heavy metals. Purification of apple juices from heavy metals using active hydrodynamic field PEO and GPAA was carried out simultaneously with the process of their clarification, which is economically favourable, as it does not require additional consumption of flocculant. The obtained values of heavy metal content in juice from Jonathan apples in comparison with the control (not treated with flocculant) and maximum allowable concentration (MAC) are shown in Table 2.

Table 2

Heavy metal content in apple juice from Jonathan apples clarified with activated PEO and GPAA

Chemical element	Concentration of heavy metals, mg/kg			
	MAC	With flocculant		Control without flocculant
		WSR-301	Praestol	
As	< 0.20	0.097	0.087	0.127
Cd (II)	< 0.03	0.018	0.008	0.023
Pb(II)	< 0.40	0.275	0.175	0.325
Hg (II)	< 0,02	0.009	trace	0.012
Ni	-	0.016	0.009	0.021

The results of the research allow us to conclude that polymeric flocculants PEO and GPAA are effective reagents that can be used not only for the intensification of the technological process of clarification of fruit juices but also for their deep purification from heavy metals. The obtained quantitative data characterising the content of heavy metals in apple juice meet the requirements of apple juice producers.

The results of the taste assessment of apple juice clarified and purified by activated PEO and GPAA in an oscillating hydrodynamic field by such characteristics as appearance, colour, smell, consistency and taste confirm the compliance of such juices with the requirements of the standard.

Conclusions

1. It has been shown that due to the influence of a hydrodynamic field on PEO and GPAA molecules, it is possible to dramatically increase the speed and degree of clarification of fruit juices on the example of apple juice, which is undoubtedly of both scientific and practical importance in solving problems related to food technology.
2. The experimentally confirmed fact of the influence of a longitudinal hydrodynamic field on the flocculation capacity of a polymeric flocculant opens up the possibility of developing devices that allow increasing the latter. An innovative method and equipment for the implementation of the method of hydrodynamic activation of polymeric flocculants are proposed.
3. The prospects of fruit juice purification using PEO and GPAA activated in an oscillating hydrodynamic field due to the reduction of the content of such hazardous elements as heavy metals (arsenic, cadmium, lead, mercury, nickel) are shown.

The prospects for further research in this area are to optimise the ratio between molecular weight, concentration, modes of hydrodynamic influence and methods of introducing a polymeric flocculant into fruit juices to significantly increase the speed and degree of their clarification, and, if they contain pollutants, the degree of their purification, with minimal flocculant consumption.

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