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APPLE JUICE CLARIFIED BY THE POLYMERIC FLOCCULANTS

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Abstract. Based on the research, a innovative method for processing apple juice has been proposed, which consists in the use of safe polymeric flocculants – polyethylene oxide and hydrolyzed polyacrylamide, which can increase the speed and degree of transparency and purification of apple juice from heavy metals in conditions of its turbulent flow in channel, which is the gap between the stator with inlet and outlet pipes and the rotor kinematically connected to the electric motor. The mechanism of increasing the flocculating ability of flocculants under conditions of detected turbulent transparency of apple juice makes it possible to develop ways to improve the consumer properties of both the flocculant and apple juices during transparency. A comprehensive assessment of the quality of apple juice illuminated by hydrodynamically activated polyethylene oxide and hydrolyzed polyacrylamide was carried out, namely: the features of changes in mineral, vitamin, physical and chemical composition and safety, which together form the nutritional value and consumer properties of the product, were studied. The results of sensory and qualimetric analysis of apple juice clarified by activated flocculants indicate that when apple juices are illuminated with polyethylene oxide and hydrolyzed polyacrylamide, changes are observed primarily in transparency and color. The obtained quantitative data characterizing the physical and chemical composition of apple juice and the content of heavy metals in apple juice clarified with hydrodynamically activated polyethylene oxide and hydrolyzed polyacrylamide meet the requirements for apple juice producers. The research results allow us to conclude that polymeric flocculants polyethylene oxide and hydrolyzed polyacrylamide are effective reagents that can be used for deep purification of apple juices from heavy metals. Based on the obtained data characterizing the residual concentration of polyethylene oxide in apple juice treated with polyethylene oxide with hydrodynamic activation in a flocculator, it was concluded that the hydrodynamic activation of the flocculant reduces its residual concentration by more than 1.5–2 times.

Keywords: Apple Juice, Consumer Properties, Flocculation, Lighting, Purification, Product Safety, Hydrodynamic Activation

Introduction. Formulation of the problem

Used in practice methods of clarification of juices have their advantages: effective removal of colloidal compounds of juice, low reagent costs and disadvantages: limited use, high cost, lack of established production in Ukraine [1-9]. All this is a prerequisite for the search for more effective clarification agents that would technologically and economically meet the requirements of the production for increasing the transparency and stability, primarily of apple juice.

Analysis of recent research and publications

An analysis of the literature shows that an effective agent for the clarification of apple juice can be polymeric flocculants, which are widely used for purifying, for example, drinking water [10], drug solutions and cell suspensions in biotechnology [11-15], and for processing wine materials and wines [16-19]. 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 [20,21]. As a rule, with an increase in the molecular weight of the flocculant, their flocculating effect increases, which makes it possible to reduce its optimal concentration in the liquid to be clarified. This is due to the possibility of large macromolecules to bind a greater number of particles in a floccule with the help of polymeric bridges between the particles. Calculations show that a twofold increase in the size of macromolecules should cause an increase in the intensity of flocculation by one or two orders of magnitude. All this indicates that the flocculating effect of macromolecules of the same molecular weight is determined by the size of the surface of the macromolecular coil, i.e. its conformation, which is determined by the flexibility of the chain. Chain flexibility can be changed by temperature, solvent, and also by the action of a hydrodynamic field on a macromolecular coil.

The problem of the effect of a tensile (longitudinal) hydrodynamic field on the flocculating action of macromolecules is reduced to the following basic 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. Moreover, it does not matter which way β_{cr} is achieved, even an isolated macromolecule loses stability with respect to the distribution of rotational isomers and straightens out [22].

The foregoing allows us to state that under the action of a tensile hydrodynamic field, it is possible to increase the flocculating ability of macromolecules, i.e. without changing the molecular weight of the polymer flocculant, increase the intensity of flocculation and/or significantly reduce the optimal concentration.

In sources [20], the presence of a strong deformation effect of a hydrodynamic field on macromolecular coils under conditions of near-wall turbulence was experimentally proved. The study of polyethylene oxide (PEO) solutions showed that the ratio of the measured birefringence Δn to the maximum possible Δn_{∞} when exposed to a tensile hydrodynamic field on macromolecules under model conditions of near-wall turbulence reaches 0.35–0.46, which corresponds to ~ 60–70 % of the uncoiling degree of polymer chain [20,21]. The foregoing was decisive in order to propose innovative a method and device for hydrodynamic influence on the flocculating ability of macromolecules (Pat. 57600 Ukrayina, Byul. 5. 2011. Sposib osvitlennya kharchovykh ridyn polimernymy flokulyantamy).

The purpose of the research is to determine the physical and chemical characteristic, vitamins content and safety of apple juice processed with a hydrodynamically activated polymer flocculant.

To achieve this goal, the following **objectives** were formulated:

- prove the possibility of using the hydrodynamic activated polymer flocculants to increase speed and degree of transparency of apple juices;
- assess the toxicological safety of apple juice during the use of hydrodynamically activated flocculants for its purification from heavy metals.

Research materials and methods

In the workit is carried out the experimental studies of Natural freshly obtained apple juices from the following 4 varieties of apples, zoned in ecologically safe regions of Ukraine (Kherson region, v. Stanislav): Jonathan (winter variety), White Winter Calville (early winter variety), Malus domestica "Slava Peremozhtsiam" ("Glory to victorious") (autumn variety) and Malus pumila "Wealthy" (winter variety) 2009 harvest, as well as from Jonathan apples 2010 harvest from the most environmentally polluted environs of Gorlovka and Yenakiyevo (Donetsk region, Ukraine). Apples of the earth's maturity were used. Apples were stored in a chamber at a temperature of 18ºC for no more than 5 days. The control specimens were apple juices, brightened by bentonies concentration of 340 mg/100 g. Bentonies was used by «Bento Group Minerals», the characteristics of which are present in the course of works [23].

Polyethylene oxide (PEO) with a molecular weight of $4 \cdot 10^6$ (WSR-301, USA) and polyacrylamide (GPAA) with a molecular weight of $4.5 \cdot 10^6$ with a degree of hydrolysis of 5% (Stokopol, Germany) were chosen as the polymeric flocculant. The concentration of the flocculant in apple juice was chosen such that the inequality was fulfilled $C \cdot [\eta]_0 > 0,8$ (where $[\eta]_0$ is the intrinsic viscosity; C – concentration of the flocculant).

Physical and chemical parameters of apple juice were obtained using the following methods and techniques: dry matter content - refractometric method (GOST 28562-90); sugar content – by the Bertrand method (GOST 8756.13-87); the content of pectin substances (the sum of pectin substances) – by the calcium pectate method [24,25]; the content of ascorbic acid – by titrimetric methods (GOST 24556-89); vitamin B_1 content – by liquid chromatography (GOST 50929-96); the content of vitamin PP – by colorimetric method [25]; carbohydrates content – permanganate method (GOST 8756.12-91); iron content – by atomic absorption spectrometry (GOST 26928-86); the content of heavy metals was determined by spectral (STE-1 analyzer (in Ukrainian СТЕ-1)), atomic absorption (F115-PK (in Ukrainian Ф115-ПК) and AAS-1 spectrometer), spectrophotometric (SF-26 analyzer (in Ukrainian СФ-26) methods (GOST 51309-99), and mercury was determined using the RAF-1 analyzer (in Ukrainian РАФ-1) (GOST 26927-86). The error of determination did not exceed (in %) for dry substances – ± 0.33; total sugar – ±0.21; starch – ±0.016; titrated acidity – ±0.10; pectin substances – ± 0.06 and iron – ± 0.25 mg /100 g. The error in determining vitamins (in mg/100 g) was: for B_1 – ±0.002; for PP – ±0.01; for C – ±0.13. The PEO concentration was 8 mg/l. Molecular mass of PEO $4 \cdot 10^6$.

Definition of transparency and color. The transparency of apple juice was evaluated by optical density, which was determined by the photocolorimetric method on KFK-3 (in Ukrainian КФК-3) at $\lambda_{мах}$ = 540 nm. Before measuring the optical density, the juice was diluted with water 1:10. The color was evaluated by measuring the optical density using a blue light filter ($\lambda_{мах}$ = 410 nm.). The process of flocculation in apple juice by polymers was studied in cylindrical glass settling tanks, where clarified apple juice fell after hydrodynamic activation of the polymer in the flocculator.

The effect of the hydrodynamic field on the flocculating ability of macromolecules was estimated as

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

where n_{c0} и $n_{c\dot{\varepsilon}}$ – optical densities of apple juice with flocculant without exposure to hydrodynamic field and after hydrodynamic activation, respectively ($n_{c0} \equiv n_{c\dot{\varepsilon}}$ as the longitudinal velocity gradient $\dot{\varepsilon}$ tends to zero).

Flocculation with polymers in apple juice (without hydrodynamic influence) was studied in measuring glass cylinders with a volume of 0.2 l. The cylinder was filled with apple juice up to the mark of 200 ml, then the required amount of the flocculant solution was injected, the cylinder was closed, and it was overturned five times with an interval of about 2 s. After the fifth tipping, the stopwatch was turned on and the time was measured for which the boundary separating the clarified apple juice and the precipitating flocculi reached the mark of 140 ml. By the time of the front movement and the distance between the marks, equal to $51 \cdot 10^{-3}$m, the average clarification rate of apple juice was found. The clarification rate of apple juice was also determined by the change in the optical density of the juice over time (with an interval of 10 min).

Plant for clarification of apple juice. For hydrodynamic impact on the flocculation process, coaxial cylinders were used. The flocculator for implementing the proposed method (see Fig. 1) consists of a container 1 with clarified apple juice, a dispenser 2, a container with an aqueous solution of the flocculant 3, a flow channel 9, which is the gap between the stator 4 with the inlet 5 and outlet 6 pipes and the rotor 7 kinematically connected with the electric motor 8. Clarified apple juice with a flocculant, after processing it in the coaxial gap between the rotor and the stator, enters the tank 10, where the sediment is separated from the juice.

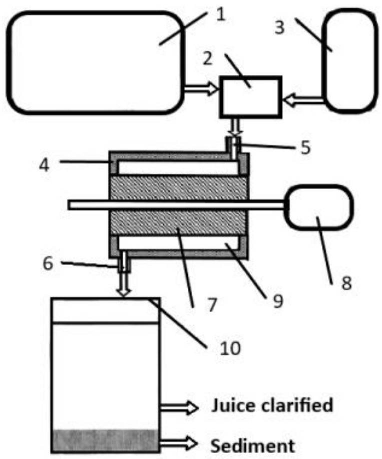

Fig. 1. Flocculator for clarification of apple juice

In order to have a clear idea of the possibility of clarification of apple juice with activated flocculants, we have determined the physical and chemical indicators of the quality and vitamin composition of apple juices. Activation of flocculants by a hydrodynamic field was carried out in the gap of coaxial cylinders at a Reynolds number equal to 7000, because it has been previously determined that, with higher Reynolds leap numbers, the efficiency of hydro-length activation of flocculant ability is reduced.

The small sample method was used for statistical data processing. Values are presented as the mean ± standard deviation of quadrutplicates or quintyplicates.

Results of the research and their discussion

Consumer properties of apple juices were evaluated by the vitamin, physical and chemical composition of freshly prepared juices. The main components that affect the organoleptic characteristics and determine the biological value of apple juice were selected. The results are shown in Tables 1 and 2.

The data given in Table 1 shows that carbohydrates such as sugar, starch and pectin make up the bulk of the dry matter in the studied juices. The content of soluble solids in juices varies, depending on the variety of apples, ranging from 14.09% (Wealthy) to 10.99% (Johnatan). The highest sugar content is observed in juice from Welsey apples (12.26%), and pectin substances are found in juices from White Winter Calville (0.67%). Starch ranges from 0.14% (Jonathan) to 0.28% (Welsea).

Table 1 – Physical and chemical composition of juices of different pomological varieties, which are illuminated with hydrodynamically activated PEO flocculant

Apple Variety	Content of Soluble Solids ±0.33*, %		Sugar ±0.21*, %		Titrated Acidity ±0.10, %		Pectin Substances ±0.06*, %		Starch ±0.016*, %	
	Control	Juice	Control	Juice	Control	Juice	Control	Juice	Control	Juice
Johnatan	11.54	10.99	10.16	9.33	0.79	0.55	0.70	0.61	0.15	0.14
White Winter Calville	15.47	13.89	12.04	11.03	0.53	0.45	0.88	0.67	0.28	0.25
Slava Peremozhtsiam	14.39	13.09	12.98	11.84	1.07	0.90	0.46	0.31	0.17	0.16
Weathy	14.95	14.09	13.40	12.26	0.88	0.77	0.71	0.51	0.32	0.28

*Values are presented as the mean ± standard deviation of quadrutplicates.

From Table 1 shows that the highest content of pectin substances 0.67% (among the studied juices) is observed in juices from White Winter Calville, and the lowest (almost twice) 0.31% in juices from Malus domestica "Slava Peremozhtsiam" apples.

The quantitative criterion of harmony of taste of juices can be considered sugar-acid index, which is determined by the ratio of the total amount of dissolved sugar and free organic acids. This indicator allows you to rank by taste characteristic apple juices. The sweetest taste has juice of apples Calville Snow (25.1). Almost half the value of the sugar-acid index will be the juice of the apple Slava Peremozhtsiam (13.23). This indicator almost coincides with the juices from Jonathan (17.01) and Welsey (17.12).

For the juices of the Jonathan, Calville Snow, Slava Peremozhtsiam and Wales apple varieties, iron content was also determined. The following iron content is found in the juices treated with activated PEO: 4.75, 5.01, 2.92 and 4.69 ±0.25mg/100g, and in juices (control) clarified with bentonite – 4.95, 5.21, 3.02 and 4.90 ±0.25mg/100g, respectively. Iron content reduction did not exceed 5%.

A comparative analysis of the vitamin composition of juices clarified with activated PEO and HPAA with varying their concentration in juice shows that the composition of vitamins B_1 and PP practically does not change with a change in PEO concentration (see Table 2). One can see a slight decrease in the content of vitamin C in the juice with an increase in the concentration of PEO and a sharper decrease in the content of vitamin C when using HPAA.

The composition of vitamins in juices depends on the variety of apples from which they are obtained. The highest total content of vitamins is observed in juices from White Winter Calville apples. In these juices, the iron content 5.01 mg/100g is also the highest. The lowest value of biologically active substances was obtained in juices from Wealthy apples. Considering the vitamin composition of juices (Table 2), it is appropriate to note that the juices illuminated by activated flocculants had differences in terms of the mass fraction of vitamins in the context of pomological varieties, and did not differ significantly from control samples in terms of the content of the main vitamins of apple juices (fluctuations were within 0.2–0.8 mg/l.

The research results presented in Tables 1 and 2 allow us to conclude that polymeric flocculants (PEO and HPAA) are effective reagents that can be used to clarify apple juices. The obtained quantitative data characterizing the physical and chemical composition of apple juice clarified with hydrodynamically activated PEO and HPAA meet the requirements for apple juice producers.

The results of sensory and qualimetric analysis of apple juice clarified by activated flocculants indicate that when apple juices are illuminated with PEO, changes are observed primarily in transparency and color (Table 3).

Table 2 – Vitamin content in apple juices clarified with activated PEO and HPAA

Apple juice		Vitamin C±0.13*, mg/100g	Vitamin B_1 ±0.002*, mg/100g	Vitamin PP±0.01*, mg/100g
Jonathan (control)		9.56	0.021	0.25
flocculant concentration, mg/l	C_{PEO}= 2	9.10	0.020	0.25
	C_{PEO} = 8	9.10	0.021	0.24
	C_{HPAA}= 1	8.81	0.018	0.22
White Winter Calville (control)		11.51	0.029	0.13
flocculant concentration, mg/l	C_{PEO} = 2	11.53	0.028	0.13
	C_{PEO} = 8	11.35	0.029	0.12
	C_{HPAA}= 1	10.87	0.027	0.12
Wealthy (control)		7.30	0.013	0.19
flocculant concentration, mg/l	C_{PEO} = 2	7.60	0.013	0.18
	C_{PEO} = 8	7.60	0.012	0.19
	C_{HPAA}= 1	7.60	0.011	0.18

*Values are presented as the mean ± standard deviation of quadrutplicates.

Table 3 – The average value of transparency and color of apple juice at different concentrations of PEO (from Weathy apples)

Indicator	Control	C_{PEO}, mg/l			
		4	6	8	15
Transparency, %	41.1	75.2	85.0	86.8	84.6
Chromaticity, units of optical density	0.611	0.278	0.125	0.071	0.125

The error of determination did not exceed for transparency – ±0,5* %;
chromaticity – ± 0,006* units of optical density
*Values are presented as the mean ± standard deviation of triplicates.

The sensory analysis of apple juice from different varieties of apples made it possible to evaluate consumer properties and state the high quality of the product. The average organoleptic evaluations of the quality of apple juices treated with activated PEO on a 5-point scale were determined, taking into account the coefficients of significance of indicators for apple juices Glory to the winners, Jonathan, Wealthy and White Winter Calville were the following values – 4.97; 4.95; 4.93 and 4.93 respectively.The content of pectin substances in juices (they interact with polyphenols and other substances of the cell, forming sediments, which leads to turbidity of juices) in the processed samples of apple juices was significantly less, as evidenced by the greater transparency of the juices: this indicator at C_{PEO} = 8 mg/l increases almost twice. (Table 3). This indicates the effectiveness of flocculation illumination. Control specimen is juice clarified with a bentonite concentration of 340 mg/100 g.

Intensive development in Ukraine of industry, transport, energy, widespread urbanization, chemicalization of agriculture, as well as the consequences of the Chernobyl disaster lead to environmental pollution, in particular apple juices, with chemical elements and compounds of arsenic, cobalt, lead, mercury, zinc, cadmium and others heavy metals [26]. Therefore, it is necessary to clean apple juices from heavy metals. Purification of apple juices from heavy metals using activated PEO and HPAA was carried out simultaneously from the process of their clarification, which is economically beneficial, because does not require additional flocculant consumption. The obtained values of the content of heavy metals in the juice from Jonathan apples in comparison with the control (not treated with flocculant) and maximum permissible concentrations (MPC) are shown in Table 4.

The research results allow us to conclude that polymeric flocculants PEO and GPAA are effective reagents that can be used for deep purification of apple juices from heavy metals. The obtained quantitative data characterizing the content of heavy metals in apple juice meet the requirements for apple juice producers.

A very important circumstance for the Donbass, Ukraine should be noted, this is the ability of polymeric flocculants to precipitate heavy metals from liquid, which can be used to remove heavy metals from heavily contaminated apple juices from apples grown in ecologically unfavorable areas with an excess of MPC by 5–10 times.

For example, if in the soils of the regions of Ukraine (Kherson region): no more than 0.024 mg/kg of mercury was found, while apple juices contained no more than 0.013 mg/kg, and lead 0.60 mg/kg and 0.31 mg/kg, respectively, then in the soils of horticultural cooperatives in the city of Gorlovka in the vicinity of the Nikitovsky mercury plant and the city of Yenakievo near the coke and metallurgical plants, these indicators reached 5 mg / kg (mercury) and 210 mg / kg (lead), and in some places up to 10 mg /kg (mercury, Gorlovka) and 673 mg/kg (lead, Enakievo). The content of mercury and lead in juices obtained from apples of these industrial regions of the Donetsk region exceeded the MPC by more than 10 times. The use of activated GPAA reduced the content of mercury and lead to 2–3 MPC, but for this the concentration of the flocculant had to be significantly (10–15 times) increased in comparison with the optimal one. A further increase in the concentration of HPAA in apple juice led to a deterioration in the effect of precipitating metals with flocculants, i.e. to reduce the degree of purification of juices.

Table 4 – Heavy metal content in Jonathan apple juice clarified with activated PEO and HPAA

Chemical element	Concentration of heavy metals, mg/kg			
	MPC	With flocculant		Control - without flocculant
		PEO	HPAA	
As	< 0.20	0.110 ±0.013*	0.100 ±0.013*	0.140 ±0.013*
Cd (II)	< 0.03	0.020 ±0.002*	0.010 ±0.002*	0.025 ±0.002*
Pb(II)	≤ 0.40	0.300 ±0.025*	0.200 ±0.025*	0.350 ±0.025*
Hg (II)	< 0.02	0.010 ±0.001*	trace	0.013 ±0.001*
Ni	–	0. 018 ±0.002*	0.011 ±0.002*	0.023 ±0.002*

*Values are presented as the mean ± standard deviation of triplicates.

Table 5 – Residual concentration of PEO in apple juice under different treatment modes and concentrations

C_{PEO}, mg/l	Re – Reynolds number	$C_{residual.\ PEO}$, mg/l
2.00	0	0.25 ±0.02*
	7000	0.11±0.02*
	20000	0.18 ±0.02*
8.00	0	0.70 ±0.02*
	7000	0.21 ±0.02*
	20000	0.60 ±0.02*
15.00	0	1.55±0.02*
	20000	1.10 ±0.02*

The residual concentration of the flocculant in apple juice after its lighting, despite the very low values (less than 0.2 mg/l for the optimal flocculation mode) is important and requires constant monitoring. Due to the fact that there were no simple and inexpensive express methods for measuring very low concentrations of a polymer flocculant in a solution, we proposed a method and developed equipment for estimating the residual concentration of a flocculant in apple juice, which made it possible to expand its measurement range by more than two order in comparison with known methods (Pat. 29362 Ukrayina, Byul. 1. 2008. Prystriy dlya vymiryuvannya kontsentratsiyi hidrodynamichno-aktyvovanykh polimeriv u rozchynakh). Based on the obtained data characterizing the residual concentration of PEO (Table 5) in apple juice treated with PEO with hydrodynamic activation in a flocculator (Fig. 1), it was concluded that the hydrodynamic activation of the flocculant reduces its residual concentration by more than 1.5–2 times.

Conclusions

1. A new phenomenon has been experimentally confirmed, which consists in an increase in the flocculating ability of PEO and GPAA macromolecules under conditions of turbulent flow of apple juice. The nature of this phenomenon is present in the strong deforming effect of turbulence on the macromolecular coils of the flocculant under the action of longitudinal velocity gradients, and this, in turn, leads to an increase in the flocculating efficiency due to an increase in the degree of unfolding (elongation) of the macromolecular chains of the flocculant.

2. Studies show that apple juices, lighting and purification from heavy metals using hydrodynamically activated PEO and GPAA, in terms of hydrodynamic treatment mode, residual concentration of flocculant, safety, physicochemical and vitamin composition, were distinguished by a stable physicochemical composition, as well as more high sensory performance and improved consumer properties.

3. The possibility of using hydrodynamically activated polymeric flocculants for clarification and removal of heavy metals from apple juices is shown. The promise of flocculants lies in their ability to improve their properties under the influence of turbulence and at the same time ensure high quality and safety of juices.

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ЯБЛУЧНИЙ СІК, ОСВІТЛЕНИЙ ПОЛІМЕРНИМИ ФЛОКУЛЯНТАМИ

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Анотація. На основі проведених досліджень запропоновано інноваційний спосіб оброброблення яблучного соку, який полягає у використанні безпечних полімерних флокулянтів поліетеленоксида і гідролізованого поліакриламіда, здатних збільшувати швидкість, ступінь освітлення і очищення від важких металів яблучного соку в умовах його турбулентної течії в проточному каналі. Проточним каналом є зазор між статором з вхідними і вихідними патрубками та ротором, кінематично пов'язаним з електродвигуном. Встановлений механізм підвищення флокулюючої здатності поліетеленоксида і гідролізованого поліакриламіда в умовах турбулентного освітлення яблучного соку, дозволив розробити спосіб поліпшення споживних властивостей як флокулянту, так і яблучних соків в процесі освітлення. Проведено комплексну оцінку якості яблучного соку, освітленого гідродинамічно-активованими поліетеленоксидом і гідролізованим поліакриламідом, а саме: досліджено особливості зміни мінерального, вітамінного, фізико-хімічного складу та безпеки, які у сукупності формують харчову цінність і споживні властивості продукту. Результати сенсорного і кваліметрічного аналізу освітленого гідродинамічно-активованими флокулянтами яблучного соку свідчать, що при освітленні яблучних соків поліетеленоксидом та гідролізованим поліакриламідом спостерігаються зміни в першу чергу прозорості і кольоровості. Отримані кількісні дані, що характеризують фізико-хімічний склад і вміст важких металів у яблучному соку, освітленого гідродинамічно-активними поліетеленоксидом та гідролізованим поліакриламідом, відповідають вимогам, які пред'являються виробникам яблучних соків. Доведено, що полімерні флокулянти поліетеленоксид і гідролізований поліакриламід, є ефективними реагентами, які можуть використовуватися для глибокого очищення яблучних соків від важких металів. На підставі одержаних даних, які характеризують залишкову концентрацію поліетеленоксида в яблучному соці, обробленому за допомогою поліетеленоксида з гідродинамічною активацією у флокуляторі, зроблено висновок, що гідродинамічна активація флокулянту знижує залишкову його концентрацію більш ніж в 1,5–2 рази.

Ключові слова: яблучний сік, споживні властивості, флокуляція, освітлення, очищеня, безпека продукту, гідродинамічна активація.