

Improving the quality of apple juice by using hydrodynamically activated polymer flocculants in the coagulation process

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Abstract

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Introduction. Improving the quality of apple juice by clarifying and purifying it using hydrodynamically activated polymer flocculants has been carried out.

Materials and methods. Apple juices from the following four varieties of apples: Jonathan, Snow Calville, Glory to the Winners, Wealthy. Polyethylene oxide and hydrolyzed polyacrylamide were chosen as the polymeric flocculants. A flocculator was used to activate the flocculant through turbulence in a circular tube that was rolled into a spiral coil without a frame. Evaluation of apple juice transparency was carried out via optical density measurements.

Results and discussions. It was found that treating a mixture of juice and polymeric flocculants polyethylene oxide and polyacrylamide during flow in a circular tube results in increased clarification rate of apple juice and reduced flocculant consumption only in turbulent mode. Experiments on apple juice clarification using activated flocculants demonstrated the high efficacy of the triple injection method.

The optimum concentration of polyethylene oxide was 1.5 and 1.5 mg/l (2 and 3 portions), and bentonite 340 mg/l (1 portion). On the basis of the established effect of turbulence on the flocculation process by varying the molecular concentration characteristics of polyethylene oxide solutions injected into the juice and the methods of their injection, rational parameters of apple juice clarification were obtained. The sensory analysis of apple juices made from different varieties of apples allowed to juice properties (appearance, color, consistency, smell, and taste) and proved the high quality of the products. The determined sensory assessments of the quality of apple juices processed using activated polyethylene oxide on a 5-point scale, taking into account the weighting coefficients of indicators (appearance, color, consistency, smell, and taste) for juices from apples of Glory to the Winners, Jonathan, Wealthy, and Snow Calville varieties were as follows: 4.97, 4.95, 4.93 and 4.93, respectively.

Conclusions. An innovative technological solution for the use of polymeric flocculants has been proposed, consisting in the processing of juice products using hydrodynamically activated polyethylene oxide and hydrolyzed polyacrylamide that has significantly increased the speed and degree of apple juice clarification, as well as improved their quality.

Introduction

A steady upward trend in the production and consumption of fruit and berry juices and other beverages is observed globally. To enable mass production of apple juice, it is necessary to address quality, stability, and safety of the final product. The resolution of this problem is primarily linked to how the apple juice clarification process affects its consumer properties. Fruit and berry juice clarification techniques commonly involve physical methods such as straining, settling, and separation, as well as biochemical methods that utilize enzymes. Treatment with enzyme preparations provides clarification of juices, particularly apple juice, which has a persistent colloidal system. Purified enzyme preparations authorized by health authorities for use in juice production are used for juice clarification: pectofectidase, amylorisin, and glucavamorin. These methods are based on the process of adsorption of colloidal particles by the surface of clarifying agents: gelatin or a combination of tannin and gelatin, as well as the addition of solutions of colloids with opposite charge to the juice (Diblan et al., 2021; Heshmati et al., 2020; Polidori et al., 2018; Ricci et al., 2021). If physical and biochemical methods for enhancing the quality of apple juice through the clarification process have been adequately investigated (Abdullah et al., 2023; Urošević et al., 2017), further research is still required for physical and chemical methods.

The process of separating the colloidal system of apple juice into sediment and clear juice is called clarification when using the flocculation method. Juices immediately after receiving them can be clarified using organic and inorganic substances such as bentonite, flocculants like gelatin, polyvinylpyrrolidone, polyacrylamide, or polyethylene oxide (Kawaguchi and Hasegawa, 2014). Methods for clarifying apple juice in practice have both advantages and disadvantages. Advantages include the effective removal of colloidal compounds present in apple 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 Aluko et al. (2023), Sachko et al. (2020) and Wongmaneepratip et al. (2023). 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. Polymeric flocculants are extensively used for the purification of drinking water (Way and McLellan, 2012), the concentration of cell suspensions in biotechnology (Marbelia et al., 2016; Nones et al., 2015), and the treatment of wine materials and wines (Dordoni et al., 2015; Ghanem et al., 2017; Ren et al., 2020; Romanini et al., 2020).

Polymeric flocculants are effective reagents that can purify liquids from heavy metals. The ability of polymeric flocculants to precipitate heavy metals from the liquid can be used for deep purification of apple juice from heavy metals, i.e. to improve its safety (Pogrebnyak et al., 2022).

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. As the molecular weight of the flocculant increases, its flocculating effect generally increases, too (Kawaguchi and Hasegawa, 2014; Pogrebnyak et al., 2022). This allows for a reduction in the value of 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 temperature, solvents, and the influence of a hydrodynamic field on a macromolecular coil (Latinwo et al., 2014).

The impact of a longitudinal hydrodynamic field on the flocculating behavior 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 (Pogrebnyak A. et al., 2022, 2020).

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 reducing the value of optimal concentration. The foregoing was decisive in order to propose innovative a method and device for hydrodynamic influence on the flocculating ability of macromolecules (Pat. 57600 Ukraine (2011). Clarification method for food liquids with polymeric flocculants; Pat. 51689 Ukraine, (2010). A device for clarifying liquid food products using flocculants).

Therefore, the consumable properties of apple juice during the clarification process can be improved by utilizing flexible-chain water-soluble polymers, which demonstrate an increase in flocculation action when exposed to a tensile hydrodynamic field (Pogrebnyak A. et al., 2022).

The aim of the present study – on the basis of experimental studies to establish rational parameters of flocculation process of clarification of apple juice, which provide a significant increase in the speed and degree of juice clarification, as well as an increase in its quality.

Materials and methods

Materials

The experiment conducted in this study examines the freshly obtained apple juices from four different apple varieties grown in ecologically safe regions of Ukraine (Kherson region, v. Stanislav): Jonathan (winter variety), Snow Calville (early winter variety), Glory to the Winners (autumn variety), and Wealthy (winter variety). The apples used for this study were harvested at their peak maturity. Apples were stored in a chamber at a temperature of 18°C for up to 5 days. Juice clarified with bentonite at a concentration of 340 mg/L was used as control juice samples. Juices clarified with flocculants without hydrodynamic influence were also used as control juice samples. Polymeric flocculants chosen include polyethylene oxide with molecular weights of $3 \cdot 10^6$, $4 \cdot 10^6$, and $6 \cdot 10^6$ (POLYOX WSR), hydrolyzed polyacrylamide (HPA) with a molecular weight of $4.5 \cdot 10^6$ and 5% degree of hydrolysis (Stokopol), and polyacrylamide 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 is a concentration of the flocculant).

Experimental research methods

Definition of transparency and color. The apple juice's transparency was assessed using the photocolometric method at $\lambda_{\max} = 540$ nm. Optical density was used to determine this. Before the optical density measurement, the juice was diluted with a water ratio of 1:10. The color was measured using a blue light filter ($\lambda_{\max} = 410$ nm.) via optical density evaluation. The process of flocculation in apple juice by polymers was studied in cylindrical glass settling tanks, where clarified apple juice goes after hydrodynamic activation of the polymer in the flocculator.

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

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

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

Flocculation with polymers in apple juice (without hydrodynamic influence) was studied in measuring glass cylinders with a volume of 200 ml. 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 $l = 51 \cdot 10^{-3}$ m, the average clarification velocity 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).

Experimental bench for clarification of apple juice. The experiments were conducted using a basic yet highly efficient flocculator that activated flocculants through turbulence within a circular tube, depicted in Figure 1.

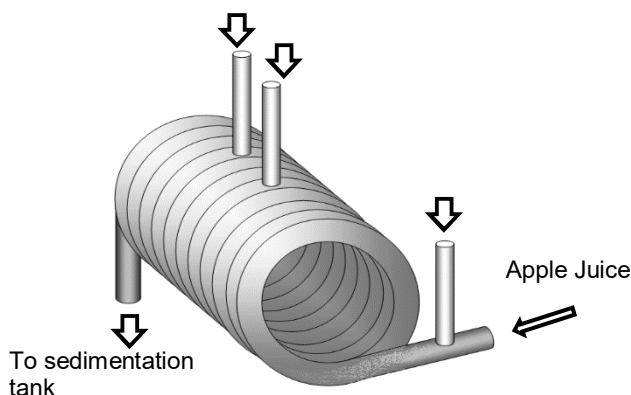


Figure 1. Tube flocculator with turbulence activation of flocculant in apple juice:
 1 – inlet for bentonite (1st portion);
 2 and 3 – inlets for polyethylene oxide (2nd and 3rd portions).

The essence of its operation is as follows. The clarification process involves pumping a precisely measured amount of flocculant together with apple juice, which is clarified, through a smooth pipe that is coiled in a frameless spiral configuration with one or more layers of winding prior to entering the sedimentation tank. By varying the flow rate and the length (number of turns) of the flocculator pipe, the processing time of the apple juice can be modified. The study determined the number of turns and diameter of the spiral, along with flow velocity of apple juice (based on Reynolds number) via empirical means. The assessment of the tubular flocculator (with consistent channel diameter) showed inferior efficiency compared to the flocculator assembled on coaxial cylinders (Pogrebnyak et al., 2022). However, its cost and maintenance expenses are significantly lower. In order to achieve the required temperatures for the juice, utilized thermostabilization system (Pashchenko et al., 2021; Pogrebnyak et al., 2021). The temperature stabilization was maintained at the specified level with precision up to 0.1 °C.

Evaluation of the quality of clarified juice

A comprehensive evaluation of the quality of apple juice that underwent clarification with hydrodynamically activated flocculants was conducted using the principle of qualimetry. Comprehensive evaluation of juice quality included several stages: determining the quality indicators, by which the quality of products was evaluated; ranking the quality indicators (appearance, color, consistency, smell, taste); evaluating the juice quality by selected indicators; calculating the indexes of improvement of properties; evaluating the juice quality by selected indicators, taking into account the weighting coefficients. In a comprehensive assessment of the quality of juices clarified by turbulence-activated polyethylene oxide, the content of vitamins was not taken into account, because their change in the composition of the evaluated samples in comparison with control samples is insignificant (Pogrebnyak et al., 2022).

Statistical analysis

The statistical data were processed using the small sample method. The values are reported as the mean \pm standard deviation of quadruplicate or quintuplicate samples.

Results and discussion

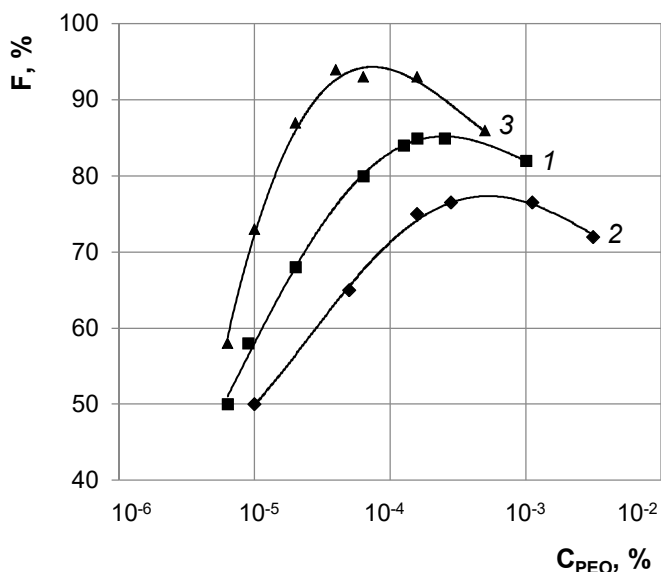
The data presented in Table 1 provide evidence for enhancing the apple juice clarification process using polyethylene oxide. By processing the mixture of juice and flocculant – polyethylene oxide in a circular tube, there is a notable increase in the speed l/t (where $l = 51 \cdot 10^{-3}$ m, t is the settling time of flocculi on a given section of l) resulting in improvement in apple juice clarification and a decrease in the amount of polyethylene oxide consumption, exclusively in turbulent mode. There is a limiting value of Reynolds number – 7000, beyond which the effectiveness of the proposed method for increasing polyethylene oxide flocculation ability decreases. Experiments utilizing polyethylene oxide of molecular weight $4 \cdot 10^6$ were conducted with concentrations of 0.0002% and 0.0004% in apple juice.

Table 1
Effect of flocculant- polyethylene oxide (PEO) concentration and Reynolds number on clarification rate of juice from Jonathan apples

PEO concentration in juice-PEO mixture, mg/L	Juice-PEO Re=0; $l \cdot 10^{-4} / t \cdot 60$ s	Juice-PEO in flow with Re=2000; $l \cdot 10^{-4} m / t \cdot 60$ s	Juice-PEO in flow with Re=4000; $l \cdot 10^{-4} m / t \cdot 60$ s	Juice-PEO in flow with Re=7000; $l \cdot 10^{-4} m / t \cdot 60$ s	Juice-PEO in flow with Re=10000; $l \cdot 10^{-4} / t \cdot 60$ s
2	10	10	35	50	20
4	20	20	60	70	50

The effect of polyethylene oxide concentration with molecular weights $3 \cdot 10^6$ and $6 \cdot 10^6$ on apple juice flocculation at 20°C is illustrated in Figure 2. It is apparent that the dependence of the flocculation effect on concentration reaches a maximum at $C_{\text{PEO}} = 20$ mg/L and 10 mg/L concentrations, respectively, conforming to the polyethylene oxide molecular weights analyzed. Afterward, the effect magnitude decreases. Increasing the concentration of flocculant in apple juice leads to a higher viscosity of the juice- polyethylene oxide system. This is caused by emerging intermolecular interactions of polyethylene oxide molecules (Almásy et al., 2022; Dimitrova et al., (2002); Yang et al., 2005). Because of this, it hinders the settling of the formed flocculates, ultimately reducing the clarification rate, or the flocculation effect.

The data presented in Figure 2 (curve 3) and Tables 1 and 2 show that the effect of turbulent hydrodynamic field on the juice- polyethylene oxide and juice- polyacrylamide systems increases the flocculation effect. This is reflected in the optimum flocculant concentration, which decreases and the magnitude of the effect itself, which increases. If Reynolds is increased above $7 \cdot 10^3$, the clarification rate of apple juice begins to decrease.



M_{PEO} : 1 and 3 – $6 \cdot 10^6$, 2 – $3 \cdot 10^6$; 1 and 2 – $\text{Re} < 2000$; 3 – $\text{Re} = 7000$

Figure 2. The relationship between the efficiency of polyethylene oxide (PEO) flocculation and its concentration in apple juice from Jonathan variety apples

Table 2
Optimal concentrations of polyethylene oxide (PEO) and hydrolyzed polyacrylamide (HPA) for the flocculant-apple juice system with and without hydrodynamic treatment (HT) for f apple juice from Jonathan variety

M _{PEO}	C _{opt} , mg/L					
	Without HT	With HT, Re = 7000	M _{GPAA}	Hydrolysis rate, %	Without HT	With HT, Re = 7000
6·10 ⁶	10	4.5	10 ⁷	14	0,5	0.35
4·10 ⁶	15	6.5				
3·10 ⁶	20	10	4.5·10 ⁶	5	1	0.75

Analysis of the experimental data reveals the expressions that demonstrate the correlation between molecular weight and optimal flocculant concentration. These expressions are obtained for cases where there is no hydrodynamic field impact on the apple juice- polyethylene oxide system (1) and with turbulent hydrodynamic field impact (2) at a Reynolds number of 7000.

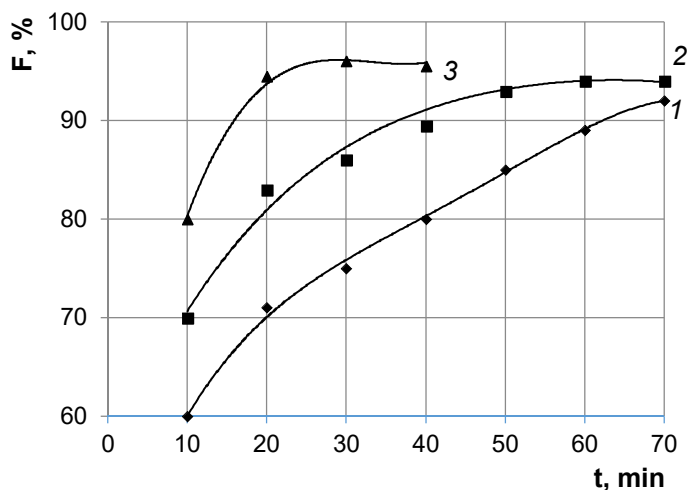
$$\frac{C_{opt} M_{PEO}}{100\%} = 60 \quad (1); \quad \frac{C_{opt} M_{PEO}}{100\%} = 26. \quad (2)$$

Consequently, the experiments support the predicted phenomenon described (Pat. 57600, Ukraine, 2011). Clarification method for food liquids with polymeric flocculants), in which macromolecules gain increased flocculation ability when exposed to a turbulent hydrodynamic field. This increase is due to the macromolecular tangles' ability to alter their conformational state under tensile flow conditions at subcritical regimes, potentially resulting in complete unfolding (Latinwo et al., 2014).

This finding is further supported by studies from Pogrebnyak et al. (2019) and Pogrebnyak et al. (1991). The distribution of the strain factor, as obtained in the study conducted by Pogrebnyak et al. (2019) under conditions of tensile flow, indicates that macromolecules could transition to a highly unfolded state. The study of polyethylene oxide 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.

To ensure a presentable appearance, apple juice should possess a maximum degree of clarification. However, the duration of the clarification process also plays a significant role in shaping the consumer properties. This is because a swift reduction in clarification time can halt many enzymatic reactions and oxidation processes (Alongi et al., 2019; Nehmé et al., 2019; Tong et al., 2022). Excluding or significantly reducing such reactions results in higher preservation of the valuable properties of apple juice, including organoleptic parameters, physical and chemical composition. Consequently, our study investigated the time-dependent change in transparency of the apple juice- polyethylene oxide system at the optimal flocculant concentration.

Figure 3 displays the results depicting the progression of flocculation effect in the apple juice- polyethylene oxide system over time at 20 °C, while Figures 4 and 5 illustrate the efficiency of clarifying apple juice based on the flocculant concentration at varying modes of turbulent impact on the juice- polyethylene oxide system. These figures pertain to apple juice extracted from the Jonathan apple variety.



$M_{PEO} = 6 \cdot 10^6$; 1 – without HT; 2 – with HT; 3 – with HT + 340 mg/L bentonite

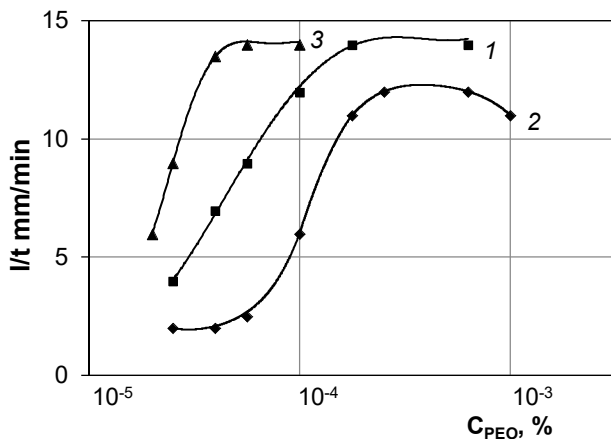
Figure 3. Variation of clarification degree of apple juice- polyethylene oxide (PEO) system at optimum flocculant concentration over time

The process of flocculation in apple juice using hydrodynamically activated flocculants was studied. Cylindrical glass sedimentation tanks were used, and clarified apple juice was delivered after polyethylene oxide was hydrodynamically activated in the flocculator. The transparency of the apple juice was measured at 10-minute intervals.

Figures 3, 4, and 5 demonstrate that using a turbulent hydrodynamic field to process the juice- polyethylene oxide system enhances the clarification rate of apple juice and reduces polyethylene oxide consumption, but only in turbulent mode. Table 1 and Figure 5 indicate that the flocculation efficiency of polyethylene oxide macromolecules decreases when the Reynolds number exceeds 7000, which sets a limit. The slight hydrodynamic impact unfolds macromolecular tangles, increasing macromolecule-particle contacts, leading to larger floccules. Conversely, intense hydrodynamic action worsens flocculation by destroying flocculi. Hydrodynamic activation of polyethylene oxide via turbulent flow allows for a reduced optimal concentration of 4 mg/L or lower, leading to apple juice with up to 85% transparency. The settling time for the juice was less than one hour.

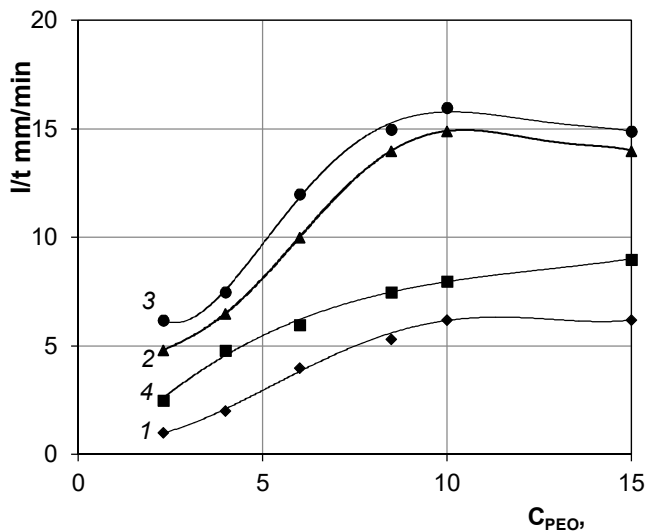
Flocculants Praestol and Stokopol were found to have a higher flocculating effect on apple juice compared to other flocculants, resulting in greater transparency. Transparency measured up to 93% with Praestol and 86% with Shtokopol. In addition, it was observed that the hydrodynamic activation of polyacrylamide was much less compared to polyethylene oxide, likely due to homonymous charges on polyacrylamide chains, which led to an increase in macromolecular clubs without the influence of a hydrodynamic field Qin et al., 2024).

Experiments utilizing activated flocculants to clarify apple juice demonstrated the triple injection method's efficiency, depicted in Figure 1. The best polyethylene oxide concentration was (1.5+1.5) mg/L (with bentonite concentration at 340 mg/L), leading to apple juice transparency of 95% (curve 3, Figure 2) at Reynolds $7 \cdot 10^3$ under turbulent flow from Jonathan apples. A ~5-minute interval elapsed between reagent portions (injection). The utilization of polyethylene oxide flocculant and bentonite in the combined clarification process of apple juice in turbulent flow resulted in a noteworthy reduction of sediment exposure time (3-5 times), leading to decreased production costs.



M_{PEO} : 1 – $6 \cdot 10^6$ (without HT); 2 – $3 \cdot 10^6$ (without HT); 3 – $6 \cdot 10^6$ (with HT)

Figure 4. The relationship between the clarification rate of apple juice from Jonathan variety apples and polyethylene oxide (PEO) concentration



$M_{PEO} = 4 \cdot 10^6$; Re: 1 – 0; 2 – $4 \cdot 10^3$; 3 – $7 \cdot 10^3$; 4 – 10^4

Figure 5. Impact of polyethylene oxide (PEO) concentration on the clarity of apple juice from Jonathan apples treated hydrodynamically at varying modes

The results in Figure 6 reveal the impact of polyacrylamide's molecular weight, concentration, and degree of hydrolysis on apple juice flocculation at 20 °C.

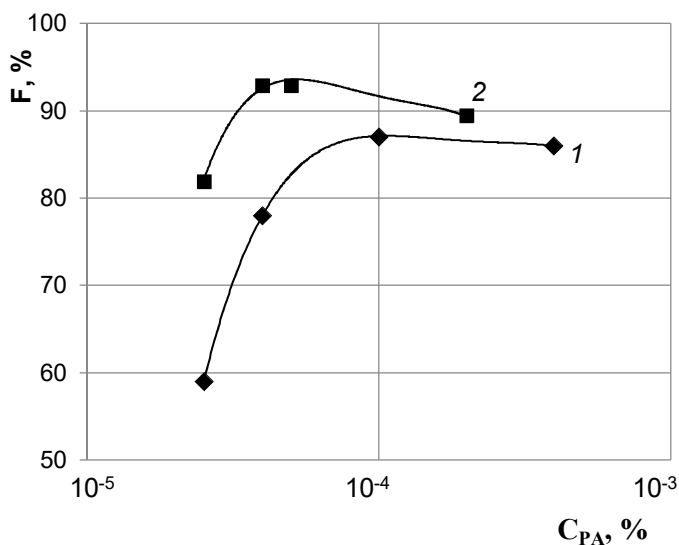


Figure 6. Dependence of flocculation efficiency of Praestol and Stokopol on concentrations of polyacrylamide in Jonathan apple juice
1 – Stokopol; 2 – Praestol

The substantial enhancement in the efficiency of clarifying apple juice via the combined utilization of bentonite and activated polyethylene oxide with turbulence is due to the rapid coagulation of positively-charged colloidal particles immediately following the introduction of bentonite. The particles then amalgamate into primary flocs directly after the initial dose of polyethylene oxide, which are then further enlarged into secondary flocs by the flocculant's macromolecules introduced with the second dose. The secondary flocs are larger than the primary flocs, enabling them to settle much more quickly (Kawaguchi and Hasegawa, 2014).

The last step of juice clarification involves filtering out aggregatively stabilized fine colloidal substances and residual turbidity. Obtaining a denser sludge will decrease the stress on filters and extend their service time. Our experiments showed a clear correlation between the effectiveness of polymer flocculation and sludge density. The density of the sludge was determined by measuring its volume in settling beakers intended for apple juice. A rise in the molecular weight of flocculant while under hydrodynamic influence in the apple juice-polyethylene oxide system (at $Re=7 \cdot 10^3$) results in a reduction of the optimal polyethylene oxide concentration in the juice, and an increase in sludge density. This outcome gives rise to the expected possibility of extending the life span of devices used for filtering apple juice.

To gain a better understanding of the potential application of hydrodynamically activated flocculants in apple juice production, a dual approach of technological and commodity science was used. The technological aspect encompasses not only the acceleration of the juice clarification process, but also an increase in juice clarification efficiency. This fosters another aspect of the study – commodity science – which centers on enhancing consumer properties and promoting juice stability.

The results of the sensory and qualimetric analysis of apple juice, clarified using activated flocculants, as well as toxicological studies, demonstrate that the use of flocculants leads to an enhancement in the transparency and color of apple juice (Table 3).

The sensory analysis of apple juices made from different varieties of apples allowed to evaluate consumer properties (appearance, color, consistency, smell, and taste) and proved the high quality of the products. The determined organoleptic assessments of the quality of apple juices processed using activated polyethylene oxide on a 5-point scale, taking into account the weighting coefficients of indicators (appearance, color, consistency, smell, taste) for juices from apples of Glory to the Winners, Jonathan, Wealthy and Snow Calville varieties were as follows: 4.97, 4.95, 4.93 and 4.93, respectively.

Table 3
Transparency and color measurements of apple juice (from Welsey apples) with varying concentrations of polyethylene oxide (PEO) molecular weight 3·10⁶

Indicator	Control C _{PEO} =0, mg/L	C _{PEO} , mg/L			
		4	6	8	15
Transparency, %	41.1	75.2	85.0	86.8	84.6
Color, optical density units	0.611	0.278	0.125	0.071	0.125

The evaluation of apple juices treated with activated polyethylene oxide and Praestol for toxicological indicators (Pogrebnyak A. et al., 2022) suggests that such juices meet the standard requirements. A thorough commodity assessment of apple juice clarified with hydrodynamically activated flocculants under rational flocculation parameters in a turbulent flow indicates at least a 10% increase in the quality indicator value compared to juice treated with optimal concentration bentonite.

New regularities in the process of clarifying apple juice using hydrodynamic-activated flocculants, specifically polyethylene oxide and hydrolyzed polyacrylamide, have been identified. With this understanding, it is now possible to scientifically control the process to optimize the consumer properties of the clarified juice.

Conclusions

1. A phenomenon has been experimentally confirmed, which consists in an increase in the flocculating ability of polyethylene oxide and hydrolyzed polyacrylamide 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. Based on the established impact of turbulence on the flocculation process when considering variations in molecular-concentration characteristics of polyethylene oxide solutions that are injected into juice along with the methods of injection, reasonable parameters (Reynolds number, flocculant concentration and its molecular weight, input methods) for apple juice clarification have been derived. By adhering to these parameters, the clarification process can be accelerated by over fivefold and the value

of the optimal concentration of flocculant can be decreased by 700 times or more in comparison to bentonite clarification methods.

3. On the basis of conducted research the possibility of using hydrodynamically activated polymeric flocculants for clarification of apple juices is shown. This method involves the treatment of juice products with hydrodynamically activated flocculants such as polyethylene oxide, Praestol and Shtokopol. This method significantly increases the speed and degree of clarification of apple juices, while improving their quality. 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 of juices.

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