CAVITATION TECHNOLOGIES FOR THE FOOD INDUSTRY

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Abstract: The results are presented of the research, development and implementation of cavitation technologies and equipment for their application in the food industry. The action of the ultrasonic, hydrodynamic and/or bifrequency cavitation ensures preparation of finely dispersed homogeneous suspensions and emulsions of nanodimensional particles. The results confirm that the cavitation effects are promising for their wide practical application in the food production where the processes in the liquid - liquid and/or liquid - solid state systems are used.
Keywords: cavitation, food industry, dispergation, homogenization, cavitation treatment

The developments of food technologies were always closely linked with the progress in physics. In recent years a new scientific field has gained a growing interest – research in the field of nanomaterials. Their preparation can often be associated with the action of cavitation effects. A number of studies allowed to state that the cavitation effects are able to change the aggregate state of substances, facilitate preparation of dispersions and emulsions, to change the rate of diffusion, crystallization and dissolution, to activate chemical reactions and substantially intensify some specific technological processes.

The food industry experts worked much with the aim to widen the application of cavitation effects and to improve the cavitation equipment and technologies in various fields. The cavitation equipment working in a wide range of oscillation frequencies and intensities was developed and produced, which can be widely used in the food industry.

During the recent years, the phenomenon of cavitation and effects of its action have been studied in the Institute of Applied Physics of the Academy of Sciences of Moldova with the aim to intensify the technological processes. On the basis of the results obtained, various technological methods and equipment for multifaceted applications, including those for the food industry, were developed.

Cavitation Technology for Processing of Juices

In the production of natural fruit and berry juices with pulp it is very important to improve their organoleptic properties and retain such useful components as vitamins, fragrant and gustative substances, which improve the nutritive and commercial values of the end product. Homogenizers are used for fine disintegration of the pulp. But they cannot disintegrate the pulp so finely that it would not sediment in the juice. With the aim to increase their stability, juices are also repeatedly subjected to thermal treatments. This suppresses the microbial flora, especially yeasts, and increases the time of the suspended state of the pulp. However, the thermal treatment decreases the quality of juices.

Note, that the thermal treatments and addition of stabilizers do not ensure the necessary effect when the size of the pulp particles in the juice exceeds 100 μm. For the pulp suspension to be stable, the dimensions of the pulp particles should be in the range of

5–50 μm [1]. Therefore, the process of disintegration and homogenization of the pulp is one of the main and necessary operations in the production of natural juices.

We have studied the action of cavitation on the process of dispergation and homogenization of the pulp of apples and peaches with the aim to obtain sufficiently fine pulp particles, which do not sediment in the juice volume.

The data related to the influence of bifrequency cavitation on the physico-chemical properties of natural apple and peach juices are presented in Table 1.

Table 1. Physico-chemical parameters of the control and experimentally treated samples of apple and peach juices

No.	Parameter	Value	
		Control sample without cavitation treatment	Experimental sample after cavitation treatment
1.	Mass fraction of dry dissolved substances, %	12.2	13.4
2.	Mass fraction of citric acids (relative to the apple acid), %	0.28	0.31
3.	pH	3.3	3.27
4.	Mass fraction of the pulp, %	13.2	10.1
5.	Mass fraction of the pectin substances, %	0.14	0.24
6.	Viscosity, s	6.3	12.4
7.	Dimensions of the pulp particles, μm	20.0 – 400	5 – 80
8.	Mass fraction of the pulp particles with dimensions less than 50 μm, %	-	60 - 80

From the data presented in Table 1 we can conclude that the cavitation treatment allows one

- to perform the pulp disintegration to such a degree that the content of the particles with dimensions of 5 – 50 μm amounts to 60 – 80%, and this prevents the pulp sedimentation;
- to increase the mass fraction of pectin substances;
- to increase the juice viscosity due to the substantial pulp disintegration.

On the basis of the obtained results, we have developed a technology and installation for production of natural juices under the action of bifrequency cavitation, which were tested in the production line at the Chisinau canning factory (Fig. 1).

Fig. 1. Cavitation bifrequency installation in the production line at the Chisinau canning factory

Ultrasonic Cavitation Technology for Increasing the Yield of Grape Juice

The efficiency of the treatment of the grape pulp in the ultrasonic cavitation field before pressing with the aim to increase the yield of the grape juice and improve its coloration was studied in the laboratory and industrial conditions. It is known that the mechanical disintegration of grapes is not sufficient to ensure the high yield of the juice. Therefore, various methods of additional treatment of grapes before pressing were proposed (by application of cold, heat, electric current, etc.); however, they were not widely used in industry.

The proposed method of treatment of grape pulp was accomplished using a UZG-2-10 ultrasonic generator, which supplies a cavitation tubular magneto-strictive unit.

During the tests in the industrial conditions the mashed grapes passed through a cavitation unit where they were subjected to the ultrasonic treatment. The main increasing of the juice yield occurs during the first 20 – 30 min, then the juice yield dramatically decreases and then terminates (Fig. 2).

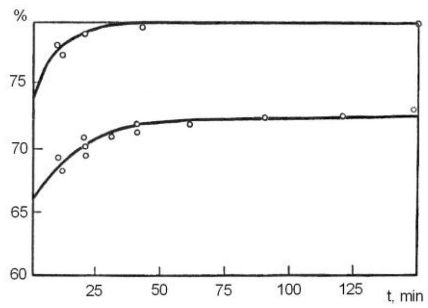


Fig. 2. Percentage of the grape juice yield versus the duration of the ultrasonic cavitation treatment

Birfequency Cavitation Technology for Bentonite Dispergation

Bentonite powders are widely used for clarification of wines owing to their high absorption ability. The powdered natural bentonite can trap the sedimented particles containing in the wine; this clarifies the wine and improves its quality.

Bentonite can be prepared as a suspension of the particles with submicronic dimensions; its contact surface with the wine material is by two or three orders of magnitude greater. This allows one to intensify substantially the process of adsorption of pectin substances and their flocculation. Taking this into account, we present in this work the results of the studies of the process of fine bentonite dispergation. Bentonite particles with initial dimensions of 200 – 300 μm were dispergated to submicronic dimensions using the proposed cavitation technology for preparation of homogeneous fine suspensions bentonite – water and/or bentonite – wine material.

The process of fine bentonite dispergation in distilled water under the action of ultrasonic cavitation was studied versus the sonication time and the amplitude of oscillations of the waveguide. The dimensions of the particles in suspension and the degree of bentonite dispergation were studied by virtue of the electron microscopy method [2].

The experimental data, which characterize how the dimensions of the bentonite particles depend on the duration of the ultrasonic cavitation treatment and the amplitude of oscillations are presented in Table 2. The results show that the particle dimensions decrease with the increasing of the amplitude and duration of the ultrasonic cavitation action (Fig. 3).

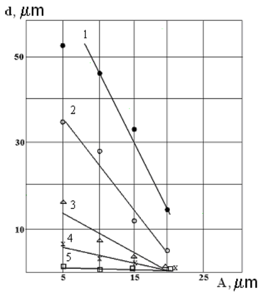
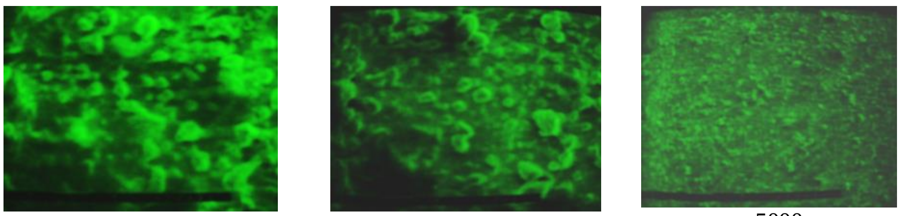


Fig. 3. Dimensions of the bentonite particles vs the amplitude of ultrasonic oscillations for various □, min: 1 – 4; 2 – 8; 3 – 12; 4 – 16; 5 – 20

The electron microscopy analysis gives evidence that the bentonite suspension consists of the particles with various dimensions. The average transversal and longitudinal dimensions of the particles before the ultrasonic treatment amounted to 200 - 300 µm. The microscopic pictures confirm the preparation of finely dispersed homogeneous suspension by virtue of the cavitation treatment (Fig. 4).

Table 2. Dimensions of the particles *d* versus the amplitude of oscillations A and the duration of the ultrasonic cavitation treatment τ

Amplitude of oscillations A, µm	Duration of the cavitation treatment τ, min					
	Control	4	8	12	16	20
	Dimensions of the particles *d*, µm					
5	200 - 300	52	35	17	7	3
10	“ – “	46	28	7	2	0,5
15	“ – “	31	11	4	1	0,4
20	“ – “	14	4	1	0,5	0,4



x 500
a

x 5000
b

x 5000
c

Fig. 4. Electron microscopy pictures of the dispersed bentonite particles: *a* – control sample (200 – 300 µm), *b* – A = 5 µm, τ = 4 min, *d* = 52 µm; *b* - A = 20 µm, τ = 20 min, *d* = 0,4 µm

On the basis of the obtained results we have developed a bifrequency cavitation installation and technology for fine bentonite dispergation, which were tested at the Stauceni winary (Fig. 5). The technology allows one to reduce the bentonite consumption by ten times and the duration of the clarification process by 6 – 8 times.

Fig. 5. Hydroacoustic cavitation installation in the department for clarification and stabilization of wines (Stauceni winery)

Technology of the Ultrasonic Presowing Treatment of Seeds

The agroindustrial complex is the main supplier of the raw materials for the food industry. The production of food products depend substantially on its successful development. Therefore, the accelerated and sustainable increasing of the production of agricultural products remains a key problem of the agroindustrial complex. Various physico-chemical methods are used to improve the quality of sowing seeds, and methods using ultrasonic field can occupy a definite place among them.

The treatment of seeds by high-frequency ultrasonic oscillations (18 – 22 kHz) in air without presoaking or other pretreatment can simplify substantially the standardization of the treatment conditions and to improve the repeatability of the results. This also allows one to choose the optimal conditions of the ultrasonic action on the seeds with the aim to increase the productivity of agricultural plants. With this aim in cooperation with the colleagues of the Institute of Solid State of the Russian Academy of Sciences a cavitation installation was developed.

The seeds were supplied into the zone of treatment by a ultrasonic radiator layer by layer. The thickness of the layer can be varied in the range of 1.0 – 10 cm. The treatment of the seeds continued during 0.1 – 1.0 min by ultrasound with the amplitude of oscillations in the range of 1 – 40 μm with the frequency of 18 – 20 kHz.

The seeds of wheat "Bezostaya 1", barley "Kristall", and oats "Mirnyi" were chosen as the main objects of our research in laboratory conditions. Tomato seeds were also subjected to the ultrasonic treatment.

The results obtained at the experimental fields have shown the acceleration of the development of plants, increasing of the quantity of spikelets from one seed, and the quantity of seeds in one spikelet. In total, these effects give a noticeable increasing of the productivity (from 10 to 30% for various plants and cultivars). The plants grown from the seeds treated by ultrasound were more resistant to lodging and fungus diseases. Tomato seeds before sprouting were treated by low-frequency ultrasonic oscillations (18.5 kHz, amplitude of 10 – 15 μm). The control and treated seeds were soaked in water. The germination ability, the harvest degree of maturity of tomatoes, and the structure of the yield formula (green weight and the quantity of tomatoes per plant) were taken as the parameters for characterization of the state of the plants. In general, the ultrasonic treatment accelerated the maturation by 7 – 10 days. The mean values exceeding 1.5 – 2.0 times the control values are highly significant both for the mass of plants and the productivity of tomatoes.

Thus, the ultrasonic pretreatment of seeds ensures the following:

- increases the growth rate and vegetation of plants, increases the productivity of cereals and vegetal cultivars;
- accelerates the maturation of plants (oats, barley, wheat);
- stimulates the growth and maturation, and increases the yield;
- damages the surface seed envelopes; this intensifies the mass transfer processes at the cellular level.

The obtained results give evidence that the method of ultrasonic pretreatment of seeds before sowing is promising for its wide application.

Conclusions

The cavitation treatment of materials in the food industry ensures the following:

- fine pulp dispergation and homogenization in apple and peach juices up to particle dimensions of 10 - 30 μm, stability of the pulp suspensions in juices during 5 – 6 months; reduction of the metal consumption by 30 – 40 times, electric and heat energy saving up to 35%;
- increasing of the yield of grape juice owing to the using of the ultrasonic cavitation method by 9 – 10 %; the intensity of the juice coloration increases by 70 %;
- dispergation and homogenization of bentonite up to particle dimensions of 0.1 - 2.0 μm; reduction of the bentonite consumption for treatment of wine materials up to 10 times, improvement of the quality of wine clarification; increases the productivity of the wine clarification up to 5 - 8 times;
- acceleration of the growth and vegetation of plants, stimulation of the growth and maturation, increasing of productivity, intensification of mass transfer processes at the cell level owing to the ultrasonic pretreatment of seeds.

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