Review paper
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INFLUENCE OF CAVITATION DISINTEGRATION ON DAIRY FOODS PRODUCTION

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Abstract

One of the popular trends in dairy industry is final products making without chemical additives using like emulsifying and preserving agents. There are some electro-chemical, physical and acoustical methods that can be used for control and of properties of milk and final products. Cavitational disintegration is the method of acoustical treatment of liquids that can promote physicochemical and structural properties. This article provides an overview of using ultrasonic cavitation in dairy industry.

General task of raw materials processing is to save maximum nutritional value in final products. Currently, acoustic cavitation is used in the dairy industry to perform a large number of processes, which are: pasteurization, homogenization, inactivation of pathogenic microorganisms, emulsification, in the ultrafiltration processes, sonocrystallization. It is used for obtaining lactose-free milk, acceleration of exchange between cells and nutrient medium. At specific parameters of treatment it can reduce duration of enzyme hydrolysis and maintaining activity of certain ferments, which allow stimulating microorganism growth and increase of the biosynthesis rate of biologically active substances. Cavitation treatment is used in biotechnology for accelerating the cells adaptation to the new conditions, and increasing the efficiency of some fermentation processes. At the same time it was noted that modes of cavitation treatment, in which the processed product is exposed to short-term and high-intensity cavitation effects, were not considered and could be one of the aim of future research works as parameters of treatment could provide completely opposite results and effects.

Parameters of cavitation disintegration must be studied, systemized and scientific-based for the needed results providing and should be implemented into industrial scales. At the same time, results of the review can be used for new technology of safety dairy products development.

***Key words**: Ultrasonic cavitation, Milk, Whey, Inactivation of pathogenic microorganisms, Pasteurization, Sonocristallization.*

1. Introduction

At the present time the consumers demand grows for products made with low impact technology that based on the non-chemicals modification of quality and nutrition properties of raw materials and final foods. It is explained by the new knowledge that some traditional methods of raw materials processing can provide microorganism inactivation as well as nutrition reduction and undesired influence on the sensor characteristics of foods [10].

One of the methods of food processing is ultrasonic treatment, which is getting more popular with technologists. Ultrasonic treatment provides acoustic waves, which mechanical vibrations can be propagated at a higher frequency then the highest limit of human sense of hearing. There are cycles of extending and squeezing of medium under distribution of acoustic waves in it.

2. Influence of cavitation disintegration on dairy foods production

The ultrasonic waves of high intensity initiates the small barbules growing in liquid during extension cycle, and as soon as these barbules achieve the volume when the energy consumption is no longer going on, the collapse of burble initiates. This phenomenon is known as cavitation. Cavitation is an important ultrasonic phenomenon that initiates in liquids only [15]. When the barbules are collapsed there is extremely high temperature (around 4727 ^{0}C) and pressure (around 50.0 MPa) provides [10].

Cavitation process appears as initiation and extension of pulsed barbules that are filled by mixture of dissolved gases and solvent vapor at half periods of ultrasonic wave's rarefaction and barbules collapse after transferring to the high pressure area [2, 3].

Ultrasonic treatment is widely used in food industry for the next purposes:

- Pathogen microorganisms' inactivation.
- Milk pasteurization.
- Milk homogenization.
- Fine dispersed emulsions making.
- Membrane cleaning at ultra-filtration.
- Fermentation process stimulation.
- Dry milk products reconstitution.
- Milk protein supplementation in cottage cheese production.

It was established that mechanical and chemical effects that are initiated under low-frequency ultrasound at high intensity could be used for pathogen microorganism's inactivation in foods and improving emulsifying processes [1, 18, and 32]. It means that ultrasonic treatment at the respective parameters can be used instead of classical pasteurization processes without undesirable protein denaturation and nutrition value reduction [11].

Physicochemical action of ultrasound on biological objects connected with their surface morphology. Ultrasound intensifies permeability of the cell's membrane in tissues and changes the hydrogen ions concentration as well as initiates the high-molecular compounding segregation and metabolism acceleration. Effects of cavitation are practically non-expressed at the normal or low intensity and can be registered as natural barbules pulsation into biological liquids and enhancement of internal and external micro flows of liquids that usually stop at ultrasound source disabling.

Group of researchers established that combination of heating and acoustic treatment can inactivate intracellular lipase and protease more effective that traditional heat treatment [14, 26, and 31]. It was proved that inactivation of the mesophilic bacteria in raw milk much effective if thermo-ultrasonication is used instead of heat pasteurization [4, 5].

Garcia, Burgos, Sanz and Ordonez are studied combination of heat and ultrasound influence on viability of two strains of *Bacillus subtilis* in milk [12]. It was noted that using of heat (70 - 95 ^{0}C) and ultrasound (at 20 kHz and 150 Wt) was more effective for strains deactivation in comparison with heating and ultrasound separately. Viability of spores was reduced up to 70% and 99.9% after thermo-ultrasonication. However this method is not widely used in industrial scale as high intensity ultrasonic treatment of milk can promote undesired taste appearance [28].

There are some ideas about using of soft parameters of ultrasonic treatment for milk fermentation. Ultrasonic processing under low intensity increases mass transfer into fermentation chamber and hence fermentation rate is enhanced. It was proved that ultrasound accelerated lactose hydrolysis in milk at starter *Lactobacillus delbrueckii* presents and could promote the fermentation process [29]. Ultrasonic treatment at 20 kHz reduced ripening time for yogurt production [1, 19].

One of the most perspective directions is ultrasonic using for biochemical and fermenting reactions enhancing. It is known that ultrasonic can accelerate metabolism between cells and nutrient solutions, and decrease ferment hydrolysis duration and support activity of some enzymes that can stimulate microorganism growing and the listed benefits could make the ultrasonic treatment to be one of the effective methods for quality development and effectiveness enhancing for fermented milk products making.

Group of researchers have proved that fermentation time for milk can be significantly decreased because of enzyme activity enhancing under ultrasonic treatment. At the same time, the syneresis reduction as well as viscous increasing of yogurt was shown. All of the mentioned effects were justified by water binding capacity enhancing because of fat globe surface enlargement [1, 34].

It is known that increasing of some enzymes sustainability and acceleration of fermentation processes can be initiated by ultrasound influence. For example, ultrasonic processes are successfully used for fermented hydrolysis intensification in sugar solutions, and enzyme activation happened at pretreatment of the solutions and rate of sugar inversion can be increased by 7 - 8% [34].

Using of the shown method can be more effective in processes of fermented methods of lacto-lactulose

syrup production from whey as short pretreatment by ultrasound can significantly decrease reaction time, and high concentration of calcium ions in whey would be used as a sono-protector and could safe enzyme activity under high intensive treatment [9].

Permanent treatment by ultrasound at high capacity and low frequency (20 - 40 kHz) could reduce the lactose concentration in fermented milk products made with enzymes and thermophilic bacteria [24, 30] and could increase enzymatic activity of bacteria class *Lactobacillus* and different strains of *Bifidobacteria* in milk [25].

Group of scientists from South Ural University (Russia) studied the possibility of fucoidan using for functional properties development in yogurt making technology, when ultrasonic treatment was used for dry milk products reconstitution in raw milk processing. Object of study was yogurt products made on reconstituted milk with fucoidan powder adding before ripening process at stage of milk preparation. It was recommended to use ultrasonic treatment and fucoidan powder for high quality functional products manufacturing [35].

Ultrasonic processes and equipment are widely used for membrane clearing at ultrafiltration. Membrane stucking is one of the basic problems that has negative influence on cost and effectiveness of different technological processes. The particles are stuck on filtration membranes at milk filtration process that can provide membrane's stuck and reduction of its permeability [1, 20, and 32]. Ultrasound can significantly increase the membrane cleaning effectiveness. First of all, the convectional heat transfer coefficient getting higher that promotes decreasing of surface temperature and rate of stucking getting lower. Secondly, there is no particle's sticking on surface because of cleaning and acoustic effects at the surface at high temperature as well. Ultrasonic treatment is successfully used for press-form cleaning in cheese making processes [1]. At the same time, investments and maintenance costs should be taken into account for membrane cleaning processes implementation as they can be much higher than benefits of the mentioned method using instead of traditional ones.

Group of scientists from Croatia made the research to study the high intensity ultrasound influence on functional properties of some food proteins that were widely used at industrial scale. There were solubility, emulsifying and foam making properties of whey protein concentrate, and hydrolyzed protein of milk whey studied. It was found that solubility had significantly increased in all of the samples of whey protein concentrate that were treated at 20 kHz, 40 kHz and 500 kHz. Thermal treatment was not significantly changed zeta potential of particles and dimensions of them increased after heating due to swelling. Results of research shown that swelling of particles had an important role for heat stability and rheological properties forming. Structural changes in proteins were initiated by partial breaking of intermolecular hydrophobic interrelations promoted by ultrasonic treatment. Process carried out at 20 kHz provided significant reduction of molecular mass and fractioning of proteins, which were also noted at 40 kHz of ultrasonic treatment [27]. It was established that ultrasound could decrease opalescence of whey suspensions up to 90% that could be explained by reduction of particles size of insoluble component initiated by ultrasonic treatment. There was not the same effect if ultrasonic action made at higher frequencies (more than 200 kHz). The best results of opalescence decreasing were fixed when ultrasonic treatment made during 15 min. at 15 Wt of capacity at 60 ^{0}C [27].

Ultrasound is successfully used for lactose sono-crystallization that can increase the quality of lactose up to 92% [8], in comparison with traditional method of lactose making by drying (up to 80%) [1, 13, and 33]. Developed process consists of three general steps. It starts from oversaturation of solutions and continues by the followed crystal's appearance and grows. Ultrasonic cavitation can increase the rate of reaction and intensify mass transfer processes in liquid. There are four characteristics that are specific for sono- crystallization: rate of process that is higher of the initial nucleation; optimal conditions of crystallization; secondary crystallization initiation and smaller and more frequent crystals forming [1, 16]. Ultrasonic treatment used on the stage of crystal sowing and lactose crystal growing, forming and size control. It was supposed that spontaneous sono-crystallization led to crystal forming in a bar shape.

The same research works was made of scientists of Utah State (USA) and Minas Gerais State (Brazil) Universities who studied the fat globes behavior in milk systems. They proved the unique ability to make a balance of crystallized and non-crystallized milk fat for physico-chemical parameters of product changing. Influence of ultrasonic treatment at high intensity on fat crystallization process was studied. It was noted that ultrasound using could enhance crystal forming rate with smaller sizes of them. At the same time, crystallization at the listed condition led to viscous increasing [1, 17].

Nowadays the ultrasonic processes are used for lactose-free milk production. It was established that ultrasound could enhance reaction activity of cells and stimulate new actions inside of cells. Hydrolysis of lactose under ultrasonic treatment can be achieved at the level 55% that much higher than in traditional way by enzymes using the same parameter can be achieved at 36% [10].

Ultrasonic treatment is rapidly developing area of research that find wide application in food industry for treating, changing and saving the properties

influenced on the final quality of foods. Existed knowledge about processes that are carrying out under acoustic cavitation and their impact of the treated medium have the scientific and practical interest to use them in technological processes of milk and whey processing, intensification of some mass transfer processes, emulsion making [6, 7], and membrane cleaning [21, 22, 23]. Another special interest of cavitation using is in ability of ultrasound to inactivate the pathogenic microorganisms and enzymes at the respective parameters.

3. Conclusions

- Cavitation disintegration initiated by acoustic treatments is one of the processes that control is a very difficult task as it depends on many factors influenced on it, like structural properties of liquid, temperature, geometrical parameters of acoustic wave's generator.

- At the same time it has many positive effects that can be used instead of traditional processes. New technology and devises could be designed as soon as models of the process of cavitational disintegration would be described in details. It can be effectively done if existed parameters of cavitation disintegration would be systemized and models of process would be described by mathematical methods and neural network, for example, it could give the possibility to control the process depending on the effect that needed to be obtained.

- Listed results can be placed in a body of the mathematical models and can be used for new technology of safe dairy and other liquid products development.

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