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Technological Properties of Sonochemical Treated Reconstituted Milk

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Abstract

The aim of this study was to examine the character of the sonochemical effects of treatment on technological and microbiological parameters of water and reconstituted milk.

Sonochemical processing performed in a reactor ultrasonic cavitation (RUC) with a piezoceramic ultrasonic transducer with power level at 45, 60, 80, 100% from capacity (1000 W) and temperature (20 ± 2), (40 ± 2) and (50 ± 2)°C.

We reported on the effect of ultrasound for water pretreatment in the technology of reconstituted milk product. We showed that ultrasound (US) treatment of water is changing its dissolving ability, due to destruction of water hydrogen-bonded network.

It was experimentally confirmed that the sonochemical treatment poses an inactivating effect on the total microorganisms and fungi, and that the impact effect depends on the processing parameters-power and temperature.

Overall, we showed that the sonochemical reactor reported here used for ultrasound water pretreatment can be successfully implemented in food industry and have positive effect on quality of reconstituted milk as well as extend shelf life of the final product.

Keywords: Sonochemical treatment; Reconstituted milk; Dissolving ability; Microbiological properties

Introduction

Unconventional treatment methods enhancing the processing efficiency, shelf-life, safety and functional properties of dairy products and other processed foods and food ingredients play an increasing role in modern industrial technologies. Among various “emerging technologies” such as ultra-high pressure processing, pulsed electric fields, supercritical fluid extraction, microfluidization and ultraviolet light treatment, ultrasonication has been identified as a particularly promising technology for processing specific food materials, including dairy products [1].

The main idea of introduction of ultrasound technologies and sonochemical treatment in food industry lays in the fact that ultrasound treatment causes changes in functional and technological properties of liquid food systems (chemical, technological, physical, organoleptic etc.) thus contributing to a certain technological effect [2,3].

Many helpful reactions initiated by the ultrasound in food systems solutes, according to one of the leading experts in food sonochemistry M Ashokkumar (Australia), are based on the cavity treatment mechanisms during the denaturation of biopolymers in their colloidal solutes, restructuring of hydrated membranes of ions in true solutes, and even dispersion of sols phases, in other words in any process where the object of treatment is connections created by dipole-dipole and ion-dipole relations [1,4].

Technology of the sonochemical water treatment can be implemented in the technology of dairy products from reconstituted and recombined dairy material, as well as in production of dairy, combined and milk constituting products [5-7].

Majority of phenomena, caused by ultrasound treatment were studied in batch mode, on small amounts of model systems with the use of laboratory installations and modules. Nonetheless, during the last decade continuous flow ultrasound systems, able to accomplish industry sized volumes if treatment, become more and more available.

So, as an acoustic source of elastic fluctuations can be used German-made *Hielscher Systems GmbH* ultrasound industrial processors. Six such processors (500 W each) assembled together in one block can provide the needed water treatment for the material at room temperature for up to 2.5 m^3/hour.

Russian scientists have suggested to use a reactor ultrasonic cavitation (RUC) with a piezoceramic ultrasonic transducer (certificate C–RU–TM05.B.00020 TP 1002178, Russia) as an alternative to mentioned ultrasound systems. Productivity of the system is 0.36 m^3/hour, which is able to satisfy industrial needs of enterprises with small amounts of produced goods.

This work presents technological and microbiological indexes of water and dairy materials processed with the RUC.

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Materials and Methods

The sonochemical reactor for water pretreatment is shown in Figure 1 Its technical characteristics in Table 1

RUC unit structurally consists of an electronic unit and the process with a fixed volume of the ultrasonic vibrating system, a centrifugal pump, assembled in a protective stainless steel casing.

The electronic unit is an electronic generator - a source of electrical oscillations with working purity 20 kHz for excitation of mechanical vibrations of a piezoelectric transducer located in the ultrasonic vibrating system.

It is important to note that reactor underwent “Federal Service for Supervision of Consumer Rights and Human Welfare” and “State Standards of Russia” inspections and were permitted for food processing use.

Examinations of water after the sonochemical treatment was performed, as well as examinations of milk and milk formulas reconstituted on the treated water.

Only drinking (bottled) water was used for the experiments. Ultrasound treatment of water was carried at operating frequency of 20 kHz.

Figure 1: The reactor ultrasonic cavitation with a piezoceramic ultrasonic transducer.

Sonochemical treatment was performed at capacities of 45, 60, 80% from the RUC capacity (1000 W) and with water temperatures of (20 ± 2), (40 ± 2) и (50 ± 2) °C.

Solubility index powder milk was determined according to ISO 8156:2005(en). Drinking and sonochemical reactor treated water was used to dissolve the dry milk products. This research presents average results of solvability index assessment (samples deviations ± 0.03 cm^3).

The comparative dissolution speed is expressed as a percentage and appears to be a ratio of a dry product materials caught in a solution to a product sample weight. The concurrent specifications within-run precision was ±1.5%.

Microbial growth in water samples was studied by Plate-Count methods.

The storability forecast of drinking milk samples generated from the dry milk using sonochemical water treatment, has been conducted according to the specific conductivity (SC) index and determined correspondence connecting SC trend and microorganisms quantity changing rate.

The АНИОН-7051 conductometer was programmed to measure SC (σj) and upload the results j=1, 2… 100 of these measurements into computer memory every 12 minutes. The vectors σ1, σ2, σ3, σ4 presenting amounts of SC time trends (mCm/cm) point sets became available for the reconstructed milk samples, being processed using the traditional technologies (control) and sonochemical water treatment.

The total microbial flora growth rates using every hour inoculation within 16-hours period has been examined for the reconstructed milk test samples, stored at +8 и+22°C temperature.

First the logarithms of the correspondences being obtained from the point sets have been taken and then they’ve been brought into proximity with the well-known least squares method.

The approximation function N (t) of total microbial flora unit/cm3 containment is as follows:

$$N(t) = 1807 \cdot 10^{0,203\,t}$$

After functions form determination Nn (t) (formula 1) out of formula:

$$\varepsilon n = 10^{\pm\alpha\, 0{,}005 \sqrt{\frac{1}{81}\sum_{k=0}^{80}[\lg N(t_k) - \lg N_n(\sigma_k)]^2}},$$

Where: a0.005– Student’s reciprocal distribution, the deviance confidence ranges have been calculated with the significance level at 99.5%. The Table 1 presents their rates 1 (Table 2).

Deviance	ε_1	ε_2	ε_3	ε_4
Rate, unit/см^3	10 ± 0.187	10 ± 0.192	10 ± 0.115	10 ± 0.141

Table 1: Student’s reciprocal distribution, the deviance confidence ranges.

Title characteristics	**Measurement unit**	**Index**
AC power supply	V	220 ± 10
Mechanical frequency	kHz	20 ± 1.5
Consumed power (min)	W	1200
power Control band	%	30…100
Running time (max)	M	90
Following break time (min)	M	3…5

Table 2: Technical specifications of the RUC with a crystal pick-up.

The functions confidence intervals $N_n^{<0,995>}(t)$ of the microorganism’s growth within the tested reconstructed milk samples, prepared at different level of sonochemical water treatment have been determined according to the following formula: $N_n^{<0,995>}(t) = N_n(t) \cdot \varepsilon n$

The water biological testing has been assessed according to the water toxicity express-determination method using “Ecolum”

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luminescent bacterial test based upon the changes of the microorganisms luminous intensity, emerged during their lifetime.

The luminous intensity has been registered by the "Biotox-7" device. The microorganisms vitality index has been assessed in accordance to the luminous intensity during the fixed-time exposition of the tested solution with the test-object and control (distilled water) [8].

Results and Discussion

We suggest that pulses of pressure occurring due to oscillating cavitation bubble growth shift water self-organization equilibrium $(H_2O)_n$=n(H_2O) to the right, thus, destroying three-dimensional hydrogen-bonded network (Figure 2a). Released in such a way so-called "free molecules" of water have higher possibility to be trapped by proteins present, for example, in a powdered milk (Figure 2b).

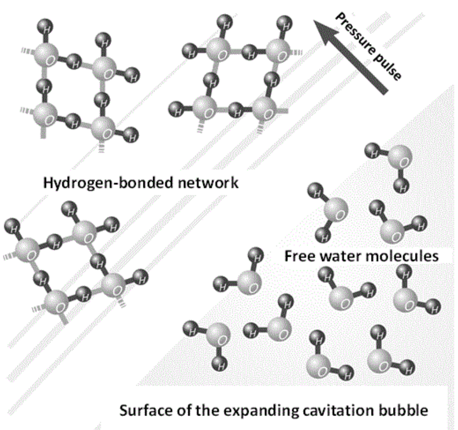

Figure 2a: Schematic representation of hydrogen-bonded network destruction due to cavitation effect of ultrasound.

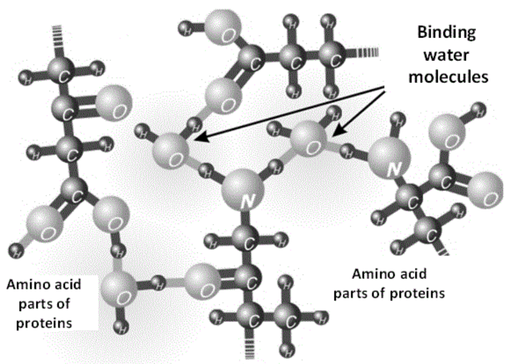

Figure 2b: Released free water molecules incorporation into proteins.

Increasing dissolving ability of water by the action of cavitation can effectively compensate natural water which was artificially removed for the purpose of prolonged storage of milk in the dried form. Figure 3 shows how US treatment can improve dissolving ability of water. Equal amounts of dry milk whey were added to regular water (Figure 3a) and to the water which was preliminary sonicated (Figure 3b). It can be clearly seen that US treatment of water significantly enhances whey dissolving.

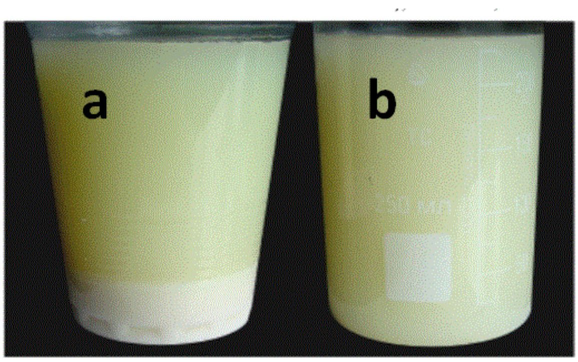

Figure 3: Solubility of powdered whey in regular (a) and sonochemical treated water (b).

During the approbation of RUC it was found that solubility index of dry milk and solutes, reconstituted on the treated water was lower by 0.1…0.2 cm^3 than control, which signifies higher level of solubility of dry substances.

Intensification of the renewal processes with a sonochemical water treatment is also proved by the results of the relative dissolution speed determination. Its increase is 18.0-45.0 in accordance with the processing power and dry milk products type.

In the samples of reconstituted material with the use of sonochemical water treatment a low level increase in mass portion of dry elements was found, including proteins, as well as increases in density and dynamic viscosity indexes.

The study of structural-mechanical features showed positive changes of dynamic viscosity humectants ability of the milk clot in the samples created with the use of acoustic cavitation method, which can be considered an indirect sign of increase of the hydratable level of the protein and its amount.

It was experimentally proved that sonochemical treatment has a certain inactivation influence upon microorganisms. In which connection decrease in the overall population of microorganisms and moldy fungi was influenced by the intensity of the treatment and temperature of the treated water (Figures 4a and 4b). It was established that practically complete inactivation of microorganisms was observed in treatment when the capacity of the installation was 80% from the RUC capacity and temperature of (50 ± 2°C). Similar results were obtained in sonochemical treatment of the whole cow milk, maximal bacteriostatic effect was observed at 100 and 80% capacity levels.

It should be mentioned that *E. coli* bacteria was absent in all samples of water treated in the reactor.

We revealed that cavitation effects on water caused by acoustic wave could also influence the microbial growth. (Figure 5) shows the total microbial content of the milk samples which were prepared by dissolving of powdered milk in regular and sonicated in different regimes (variable acoustic energy) water. Picture 6 shows that

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sonomechanical water treatment increases products' storing term compared to the traditional technology.

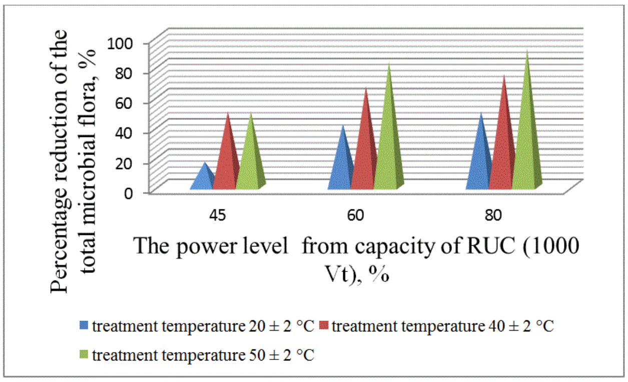

Figure 4a: Dependence of total microbial flora and the colony count of fungi

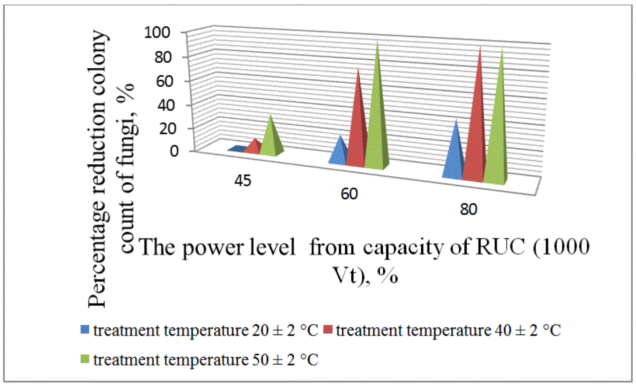

Figure 4b: Dependence of total microbial flora of processing parameters sonochemical.

In which connection, it was established that the speed of growing number of microorganisms was dependent on the durability of the sonochemical water treatment in other words on the number of acoustic energy received by the water

We can assume that the sonochemical processing water causes damage to the molecular structure of cells and cell membranes, which in turn causes the morphological changes and destruction of cells and their partial or complete loss of viability.

Clearly, US treatment of water used for milk drink preparation significantly slows the bacterial growth, which gives the possibility to store the product for a longer time without reducing its quality.

By means of mathematic processing of the received data was developed method of total microbial floracontainment control in milk drinks by the index of specific electrical conductivity, which allows predicting shelf-life of these products depending on the level of use of sonochemical treatments.

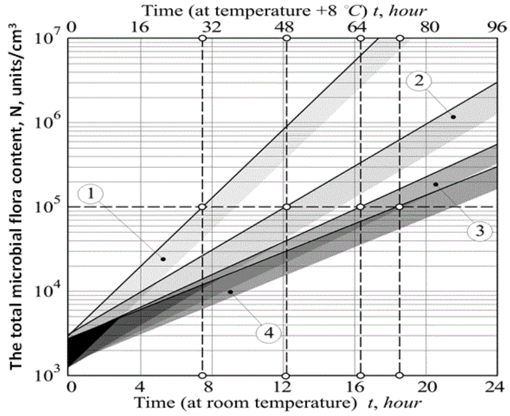

Figure 5: Development of microflora in milk drinks obtained by sonochemical processing with amplitude of sound pressure in the reactor of 2.5 *bar* and acoustic energy: 1-0 *kJ*, 2-30 *kJ*, 3-60 *kJ*, 4-90 *kJ*.

Besides, according to the the RAMC A.N.Sysin Human Ecology and Environment Hygiene Institute researches of cavitating water treatment on its state the sonochemical reactor treated water bacteriostatic specifications have been officially registered (Table 3).

Besides 5 min sonochemical treatment	**"Ecolum" microorganisms test lifetime rate**
Untreated water (control)	1,760
2 hour	0,630
24 hours	0,849

Table 3: In-water microorganisms lifetime range before and after sonochemical treatment.

Therefore, optimization of the duration of water US treatment makes it possible to control the quality and the shelf life of the final product, as well as opens the opportunity to use sonochemistry on industrial level.

Conclusions

We reported on the effect of ultrasound for water pretreatment. We showed that US treatment of water is changing its dissolving ability, due to destruction of water hydrogen-bonded network. Importantly, bacteriological properties of sonicated water has significantly improved, leading to much slower bacterial growth, which as it was found can be controlled by duration of US water treatment at fixed intensity.

The obtained results allow us to recommend sonochemical treatment at a temperature of (50±2) °C and 80% power as an alternative for the raw milk and dairy products thermization in order to inhibit microbial processes, improve the quality and extend the shelf life of both the raw materials and the end-product. Overall, we showed that the sonochemical reactor reported here used for ultrasound water pretreatment can be successfully implemented in food industry and have positive effect on quality powdered milk as well as extend shelf life of the final product.

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