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ЕЛЕКТРОГІДРАВЛІЧНЕ ОБРОБЛЕННЯ МОЛОЧНОЇ СИРОВАТКИ: ПЕРСПЕКТИВИ, МОЖЛИВОСТІ

Досліджено доцільність використання електрогідравлічного оброблення при переробленні молочної сироватки.

Статистичний розподіл розмірів частинок сироватки з-під сиру кисломолочного визначали на аналізаторі частинок Malvern Zetasizer Nano ZS (Malvern Instruments Ltd., Великобританія).

Доведено, що електрогідравлічне оброблення забезпечує підвищення дисперсності, седиментаційну стійкість сировини і готових продуктів, сприяє покращенню органолептичних, фізико-хімічних та мікробіологічних показників.

Встановлено залежність розміру білкових частинок від напруги і кількості розрядів. Найкращого результату було досягнуто за напруги 45 кВ і кількості імпульсів 20 і 25. За зазначених режимів система наближалась до монодисперсної, кількість частинок з розміром понад 500 нм прямувала до нуля.

В середовищі математичного пакету MathCad побудовано математичну модель, що описує залежність розмірів білкових частинок від основних параметрів електрогідравлічного оброблення. Визначено оптимальні параметри оброблення – напруга 45 кВ і кількість розрядів 20.

Встановлено позитивний вплив електрогідравлічного оброблення на мікробіологічні показники молочної сироватки.

Ключові слова: *сироватка, електрогідравлічне оброблення, дисперсність, розмір частинок, електрокінетичний потенціал, мікробіологічні показники.*

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ЭЛЕКТРОГИДРАВЛИЧЕСКАЯ ОБРАБОТКА МОЛОЧНОЙ СЫВОРОТКИ: ПЕРСПЕКТИВЫ, ВОЗМОЖНОСТИ

Исследована целесообразность применения электрогидравлической обработки при переработке молочной сыворотки.

Статистическое распределение размеров частиц творожной сыворотки определяли на анализаторе Malvern Zetasizer Nano ZS (Malvern Instruments Ltd., Великобритания).

Доказано, что электрогидравлическая обработка обеспечивает повышение дисперсности, седиментационную устойчивость сырья и готовых продуктов, способствует улучшению органолептических, физико-химических и микробиологических характеристик.

Установлена зависимость размера белковых частиц от напряжения и количества разрядов. Наилучшие результаты были достигнуты при напряжении 45 кВ и количестве импульсов 20 и 25. При указанных режимах система приближалась к монодисперсной, количество частиц с размером свыше 500 нм приближалась к нулю.

В среде математического пакета MathCad построена математическая модель, описывающая зависимость размеров белковых частиц от основных параметров электрогидравлической обработки. Определены оптимальные параметры обработки – напряжение 45 кВ и количество разрядов 20.

Установлено положительное влияние электрогидравлической обработки на микробиологические показатели молочной сыворотки.

Ключевые слова: *сыворотка, электрогидравлическая обработка, дисперсность, размер частиц, электрокинетический потенциал, микробиологические показатели*

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ELECTROHYDRAULIC TREATMENT OF WHEY: PROSPECTS, CAPABILITIES

The appropriateness of electrohydraulic processing in treatment of whey was researched.

The statistics of the distribution of curd whey particles' sizes was determined using Malvern Zetasizer Nano ZS analyzer (Malvern Instruments Ltd., UK).

It was established that electrohydraulic processing leads to increase in dispersion, sedimentation stability of raw material and end product, improves organoleptic, physical-chemical and microbiological indexes.

The protein particles size dependence on the voltage and charges quantity was established. The best results were achieved with 45 kV voltage and charges quantity of 20 – 25. At the mentioned modes the system was about to reach the monodisperse condition and the above 500 nm big particles quantity was approaching zero.

Within the MathCad mathematical package the mathematic model was created, which describes the dependence of the particle size of the protein on the basic parameters electrohydraulic treatment. The optimal processing parameters were established: 45 kV voltage and charges quantity of 20.

The positive impact electrohydraulic processing curd whey microbiological indexes has been determined.

Key words: *whey, electrohydraulic method, dispersion, particles size, electrokinetic potential, microbiological indexes*

Introduction. The sized up to 2 microns precipitated protein presence in the curd whey provides negative impact on its procession technology for the protein particles incline to be settled on the heat-transferring surfaces which not only results in the precious component loss, but decreases the heat treatment effectiveness, complicates the equipment washing process and makes the CIP-washing impossible, which is the compulsive condition of the modern production.

The different ways whey purification (separation, filtration, sedimentation, membrane methods etc) enables us to eliminate the adverse residue, but unfortunately, provides negative impact the products biological value.

Possible way of solving these problems is search of new means leading to particles size reduction and increase of sedimentation stability of whey.

One of the promising directions in developing methods of dispersion in food industry is exposure of the dispersion system to impulse electric disruption resulting in electrohydraulic effect (EH-effect). [1–3].

Dispersion effect of the electrohydraulic effect was researched in mid-20th century by Lev Yutkin and further developed in works of many researchers [3 – 8]. It is known that with the passage of electric charge, the integrity of the fluid layer is broken with the overcoming of molecular links in particles and creation of cavities inside their volume. With the end of electric charge influence the walls of the created cavity are closing with sonic or supersonic speeds. According to contemporary views the process itself is accompanied with same phenomena as the cavitation process. The impulse charge causes at least two hydraulic blows: first – in the moment of cavity creation, second – with its closure. This is conducive to dispersion of particles within the zones of cavity voids.

The authors investigated the possibility of using an electrohydraulic treatment during use of secondary raw milk aimed to intensify production and eliminate the adverse protein residue in the curd whey.

Objective the curd whey with the protein level of 1,0…1,5 % and fat level of 0,05…0,1 %, derived after fatless cottage cheese production was researched.

The curd whey was processed using the laboratory EH-facility, incorporating electric-discharge chamber with 2,7 cubic dm volume and generator, providing pulse discharges ГИТ 50-5?1/4С УХЛ4 [8-9]. During the exploration the voltage has been varied within 25…45 kV range and charges quantity within 5…25 range with the 5 pitch.

The size of the protein phase particles, conductivity and electrokinetic potential (ζ-potential) of the whey were determined using the *Malvern Zetasizer Nano ZS* (Malvern Instruments Ltd., UK) particles complex analysis system. All measurements in this research were conducted at 25 °C. At least five repeated measurements were conducted for each specimen. Distribution by size in intensity and volume units were derived from the analyses of correlation functions with the use of *General purpose* algorithm of *Zetasizer Software 6.20*.

Microbial growth in whey samples was studied Plate-Count methods.

In order to determine the optimal parameters of electrohydraulic treatment of whey the full-factor experiment using the MathCad software was conducted.

Discussion of results. Analysis of experimental data has shown that curves of volume dispersion of protein particles in curd whey prior and after electrohydraulic processing as a rule had extremes in following rows of numbers: first – up to 150 nm, second – 150–500 nm, third – above 500 nm. The size of protein particles in the input curd whey was beyond 500 nm, their overall volume constituted 89%. Most common size of the particle was about 2,2 mcm, which corresponds to reference book size for particles of deposited protein from whole curd whey.

While examining the dynamics of the whey disperse phase after an electrohydraulic treatment the dependence of the protein particles size on the voltage and charges quantity was established. While varying the mentioned parameters the presence of the larger particles in the samples processed with the 20…30 kV voltage was noticed with and their sizes decrease and peaks shifting down to 500 nm range while the voltage and charges quantity increased. With the increase of processing parameters, redistribution of particles of more than 500 nm between first and second change raws was observed.

The best results were achieved at the 45 kV voltage and 20, 25 charges quantity. At the mentioned modes the system was about to reach the monodisperse condition (i.e. very narrow width of distribution), and the above 500 nm big particles quantity was approaching zero.

After the processing, the average hydrodynamic diameter of particles decreased from 1697,5±82,38 nm to 221,34±10,3 nm at maximum voltage and number of discharges (table 1).

Table 1

The influence of electrohydraulic treatment on average particle diameter of curd whey

Indicator	Curd whey					
	prior to processing	after processing with 45 kV electric voltage and number of impulses:				
		5	10	15	20	25
Average hydrodynamic diameter (Z-average), nm	1697,5 ± 82,38	1474,8 ± 65,51	948,43 ± 41,12	654,3 ± 27,71	306,3 ± 13,78	221,34 ± 10,3
Polydispersity Index (PdI)	1,000 ± 0,000	1,000 ± 0,000	0,993 ± 0,011	0,550 ± 0,022	0,425 ± 0,021	0,403 ± 0,018

As shown by the PdI, input whey and electrohydraulically processed whey under 45 kV voltage with 5 and 10 discharges had a wide distribution in size and high level of polidispersion. With the increase of discharge number, the PdI significantly diminished and with 20 and 25 discharges equaled to (0,425±0,021)…(0,403±0,018). This charachterizes the system as close to a monodispersed one.

It was determined that the process temperature had no substantive impact on the particles dispersing level. Because of the productivity and in order to avoid excessive power consumption the electrohydraulic treatment of whey is to be conducted at (4±2) ^{o}C average storage temperature or immediately after the protein settlement and separation of the whey from the curd at (30±2) ^{o}C temperature.

Within the MathCad mathematical package the mathematic model was created, which describes the dependence of the particle size of the protein on the basic parameters of electrohydraulic treatment: voltage and charges quantity.

The optimal parameters of electrohydraulic treatment of whey were established using the full-factor test: 45 kV voltage and charges quantity of 20, which provides the system dispersivity enough to slow down the protein particles settlement.

An absence of the protein residue in the curd whey samples, processed at the 45 kV voltage and 20–25 charges quantity has been proved both visually and centrifugation method, providing particles' hindered settling.

The sedimentary stability of the whey prior and after the processing was established based on the speed of sediment settling and the volume of the sediment separated as a result of forced sedimentation within the gravity field. It was found that in the whey processed with the electrohydraulic method, visible sediment of protein was absent unlike the input whey. Protein particles remained in suspension during 2-3 days, on the forth day some sediment was found.

It was found that because of the decrease in protein particles size after electrohydraulic treatment, the speed of their sedimentation in accordance with the Stokes' law diminished greatly. The volume of the sediment in the processed whey decreased from 0,9…1,1 to 0,1…0,2 cm^3 at the voltage level of 45 kV and under 20…25 number of discherges.

The conductivity and ζ-potential testing results prove the system stabilization and protein settlement process slowdown due to the electrohydraulic treatment of curd whey. The testing data collected before and after the electrohydraulic treatment impact over the whey colloid system indicates the dependence of the mentioned indexes on the voltage and charges quantity.

By analyzing correlation functions with the use of *General purpose* algorithm by *Zetasizer Software 6.20* it was found that with the increase of the voltage and number of electrohydraulic treatment discharges, the absolute value of electro kinetic potential is increased. For instance under 45 kV voltage with the gradual increase of discharge number, the absolute value of Z-potential of the treated whey gradually increases from (-0,06±0,02) to (-4,02±0,26) mV.

The positive impact of the EH-effect over the processing whey microbiological indexes has been proved. It was determined that the electrohydraulic procession inactivating impact increases along with the charges quantity and voltage increase. After the procession at the 30…40 kV voltage and 5…10 charges quantity the insignificant decrease of the overall microorganisms quantity (at the average rate of 8…28 %) comparing to the unprocessed whey has been noticed (control). At the same time the electrohydraulic treatment at the 45 kV voltage and 15…25 charges quantity has provided the most effective inactivation of the whey microorganisms. Their total number has decreases by 47-58 % comparing to the control.

Molds and yeast has also appeared to be sensitive to the EH-effect. After the electrohydraulic treatment their number has decreased by 40…55 % depending the voltage and charges quantity.

Conclusions. The obtained results enable to suggest that the electrohydraulic treatment of curd whey at the 45 kV voltage and 20 charges quantity could be used for:

- production technology of the beverages made of the whole fermented and non-fermented whey in order to obtain the products with new features free from the adverse protein residue;
- curd whey preprocessing lines in order to decrease the total quantity of the microorganisms and its storage terms extension.

Prospects of further research. As long as ultra thin dispersion of raw material has a positive effect upon the intensification of drying process, further research will be directed at the study of prospects of electrohydraulic treatment use for dry whey production.

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