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RESEARCH OF RECONSTITUTED WHEY PARTICLE SIZE CHANGING DURING ITS STORAGE

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Abstract

Dry whey is widely used in different types of foodstuffs as a powder and as a liquid solution that must be reconstituted and has the properties, which should be the same as for natural whey. There are some methods that are used for whey reconstitution in food industry. Cavitational disintegration is one of the prospective and new method of stable solution making that can be implemented instead of traditional ones like mechanical homogenization. The goal of the research work was to study the different methods of the dry whey reconstituting and to determine their influence on average value of the hydrodynamic radius of the dry whey particles at its storage for 3 hours.

The three variants of reconstituted whey made on the different kind of activated water were used as objects of research. All samples had the same concentration of the dry whey which was equal to 15%. Sample 1 was made on the ordinary water by homogenization on the blender. Samples 2 and 3 were treated by cavitational disintegration (CD) and the sample 2 was made by the ordinary water and the sample 3 was obtained by the catholyte of electrochemically activated water. Method of photon correlation spectroscopy wasused for measuring the whey particles sizes (nm) by using of the spectrometer of the dynamic light scattering "PhotocorComplex". The scanning force microscope Ntegra was used for reconstituted samples study.

It was established that the traditional mechanical homogenization and ordinary water is not effective for dry whey reconstitution as there were no any desired condition for dissolving of dry whey and forming of the stable suspension. The sample 2 had more homogenized and fine system when the average value of the particles radius (34.63 nm) in 2.1 times less than the same particles in the sample that was made by mechanical homogenization (73.41 nm). The sample 3 had the least average value of the particles radius (22.59 nm) that was in 3.3times less than in the sample 1 and in 1.5 times less that in sample 2.

Reconstituted whey has more homogenized and stable structure and was less influenced to fractionation when this method was used. The results of research allow recommending the cavitational disintegration method usage for reconstitution of the whey made on the catholyte of the electrochemical activated.

Key Words: *Whey, Reconstituted whey, Storage, Cavitational disintegration, Catholyte or alkaline water, Suspension stability.*

1. Introduction

Whey is the valuable secondary product which is remains after curd and cheese making. Natural whey has the short shelf life that is why it is usually dried for reduction of its storage expenses and extending its shelf life.

Dry whey should be reconstituted by the water mixing before its using. The modern food industry uses the dry whey as well as its reconstituted form for wide values of foodstuffs including infant formula. There are some problems met at reconstitution process [1, 2, and 3]:the obtained solutions made from dry whey are not stable; the properties are not complied to the same ones for native whey; using of the chemical stabilizers and preservation agents in the food formulations; impossibility to obtain the solutions with the required physicochemical properties, which equivalent to the respective final products.

Traditional methods of dry whey reconstitution, based on the intensive mechanical mixing of the reconstituting systems do not solve the problemslisted above. It is necessary to find more effective and perspec-

tive methods based on the new and safe methods of the whey reconstitution like hydro-dynamical and sonochemical (acoustic) methods oriented on the developing of the whey solution quality and the process intensification [4]. According to that, the goal of the research was to study the different variants of the dry whey reconstituting and to determine their influence on average value of the hydrodynamic radius of the dry whey particles at its storage for 3 hours.

2. Materials and Methods

2.1 Materials

The reconstituted whey solutions (variants) were the objects of the research. Dry and demineralized about 50%-level whey was used (according Russian technical condition 9229-001-82062396-2012), [5]. Nutritional value according this technical condition is as follows: content in 100 g of product: fat 1 g, protein 8 g, carbohydrates 80.5 g, and energy value is 363 kcal / 1520 kJ. Used water had pH = 7 and catholyte at pH = 10.4 - 10.6 was used for dry whey reconstitution.

2.1.1 Whey solutions design and preparation

There are three kinds of the samples were made for particles study in the reconstituted whey. All samples had the same concentration of dry whey which was equal to 15%, but were made by the different ways. Sample 1 was made on the ordinary water by homogenization in blender Bosch, and samples 2 and 3 were made by the cavitational disintegration at the modes that were established in the previous research [6, 7, 8]: rate of treatment was 100 % ($3{,}6 \cdot 10^5$ W/m^2) at 50 s in ultrasound disperser Hielsher UP 400s. Sample 3 was made based on the catholyte of activated water (pH = 10.4 - 10.6) and sample 2 was made based on the ordinary water.

2.1.2 Storage time

The total storage time was set to 3 hours that is related to the maximal recommended time of reconstituted whey before its future using in technology of foodstuffs production [2, 3, and 9].

The measurements were carried out at the same temperature (20 ± 2 ^{0}C) in the following order:

- During the first 30 minutes, when the most significant structural changes occur, measurements were made at 5, 10, 15, 30 minutes;

- The rest period of whey storage the measurements were carried out after 1 hour. Thetotalstorage was 3 hours.

2.2. Methods

2.2.1 Particles measurement

Method of photon correlation spectroscopy was used for measuring the whey particles sizes by using of the spectrometer of the dynamic light scattering (DLS) “Photocor Complex” which allows determining the particles size measuring in automated mode as well as their dispersions. Method of dynamic light scattering fluctuation is based on the rate of light scattering measuring in the small volume of colloid solution [10]. DLS measuring includes the analyses of the temporal autocorrelation function of the light scattering made by the digital correlator [11, 12].

2.2.2 Scanning force microscopy

The scanning force microscope NT-MDT Ntegra Aurawas used for reconstituted samples studying by analyzing of the microscopic photos. The samples were placed on the glass conducting substrates by centrifugation and then were dried at the room temperature. The samples were studied by the semi-contact method [13].

3. Results and Discussion

Immediately after production the testedsample 1 had a polydisperse structure with two distinct peaks at 74.060 nm and 1.481 nm respectively. The average hydrodynamic radius was 73.41 nm. The obtained distribution of the particles sizes (Figure 1), shows that sample 1 has a disordered and non-homogeneous structure.

During the first two hours of storage the average hydrodynamic radius (AHR) of particles did not change significantly. After two hours of storage, the AHR increased by 22.5% and did not change significantly thereafter.

It should be noted that the storage for 3 hours led to visual fixed separation of the system into the layers. The general dynamics ofAHR changing during the entire storage period made it possible to establish that when ordinary water and mechanical homogenization are used for reconstruction, conditions for efficient dissolution of dry whey and formation of a stable suspension are not provided (Figure 2).

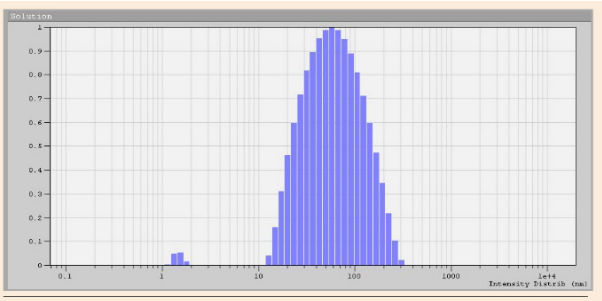
The same research was made for sample 2. It was established that the suspension formed by cavitational disintegration was as a monodispersed system which had the AHR in 2.1 times less than in the Sample made by mechanical homogenization (Figure 3).

It was shown that cavitational disintegration provided the homogeneous and fine dispersed structure of the reconstituted whey. During first 30 minutes of storage apparent increasing of the particles sizes in 1.85 times was noted (Figure 4). At the same time the system

saved its homogeneity without visible separation of the phases that could testify the intensive hydration and swelling of whey protein and it could lead to increasing of AHR. Further storage of the sample 2 led to some changes of AHR by 7-16 % at the slight visual layering till 3 hours of storage.

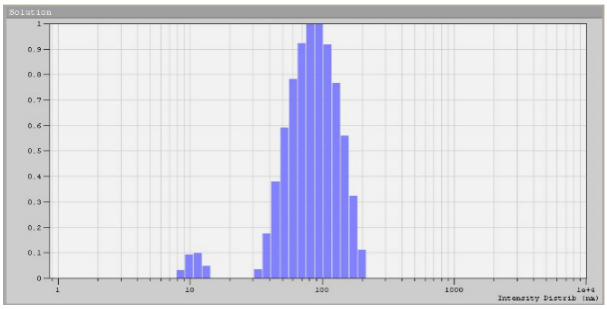
It was determined that the sample of reconstituted whey made by the cavitational disintegration on catholyte had the finest sizes and AHR immediately after its making. The average hydrodynamic radius of particles in the sample 3 is equal to 22.59 nm that is in 3.3 times less than in the sample 1 and in 1.5 times less than in the sample 2 (Figures 5 and 6).

It could be explained that the solubility of the catholyte is higher than for ordinary water, and cavitational disintegration provides more intensive dispersion of the solid phase of the system and its uniform distributing in suspension that as a result of intensification of a process of stable homogeneous system forming [2]. This fact is acknowledged by insignificant changing of



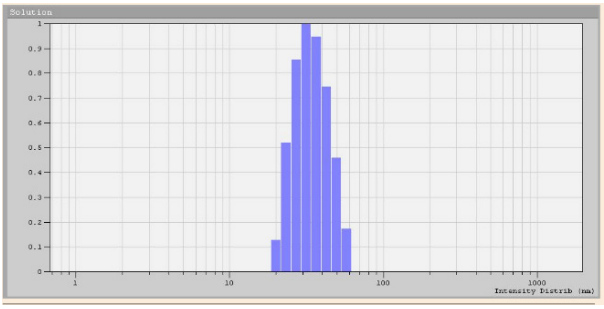
Peak Num	Area	Mean	Position	STD
1	0.009	1.481	1.533	0.170
2	0.991	74.06	57.81	52.07

Figure 1. Particle size distribution of sample 1 immediately after its making



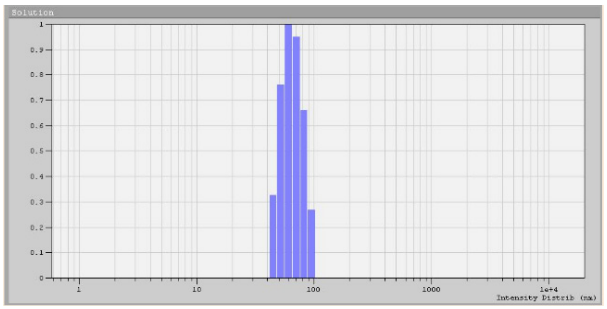
Peak Num	Area	Mean	Position	STD
1	0.034	10.77	11.35	1.552
2	0.966	92.76	81.10	37.18

Figure 2. Particle size distribution of sample 1 after two hours of storage



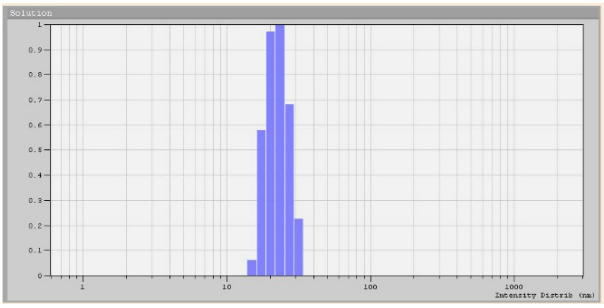
Peak Num	Area	Mean	Position	STD
1	1.000	34.63	31.42	9.526

Figure 3. Particle size distribution of sample 2 immediately after its making



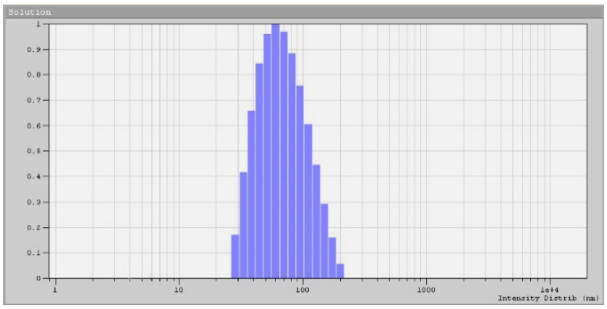
Peak Num	Area	Mean	Position	STD
1	1.000	65.59	60.28	13.92

Figure 4. Particle size distribution of a 15% solution of dry wheymade by CD treatment after three hours



Peak Num	Area	Mean	Position	STD
1	1.000	22.59	23.38	4.232

Figure 5. Particle size distribution of a 15% solution of dry whey made by CD treatment and catholyte immediately after making



Peak Num	Area	Mean	Position	STD
1	1.000	73.81	60.28	35.22

Figure 6. Particle size distribution of a 15% solution of dry whey made by CD treatment and catholyte after three hours after making

AHR for sample 3 during 30 minutes of whey storage. It was noted that there was highest rate (1.13 nm/min.) of AHR increasing from 30 to 60 minutes of storage, which could be explained by the intensive swelling of the whey protein. The succeeding period of storage provided the AHR increasing, but at lower rate which was about 0.18 nm/min. The system remained homogeneous after three hours of storage, without visible layering and fraction separating.

Particles radius changing depends on time of storage shown on Figure 7.

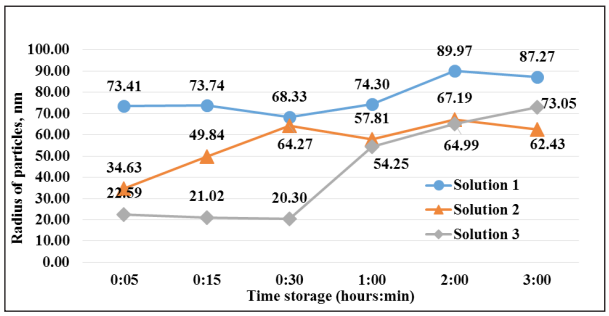


Figure 7. Consolidated graph of AHR particles changing in time of storage

It could be noted that hydrodynamic radius of particles increasing in time of storage. Sample 3 had more intensive dynamics of radius changing, which became in 3.23 times more at the third hour of storage. The same dynamics of AHR increasing was noted for sample 2 (in 1.8 times) and for sample 1 (in 1.18 times).

Microscopic pictures analysis allows determining the possible mechanism of the dry whey reconstitution. At the first stage, lactose and mineral elements are extracted from the dry piece of whey under the cavitational disintegration, which is explained by the average radius of particles reducing and it provides assess of the solvent molecules to the whey protein and its hydration and swelling as well as it will promote the carcass forming of the reconstituted system. The offered phenomenon could be approved by uniform protein carcass of suspension, which consists of the big and swelled molecules of the protein shown on the Figures 8 and 9.

There is uniform protein carcass of suspension on the Figure 9, which shows the large and swelled protein molecules. Microstructure of the sample 2 shown on Figure 8 represents the nonhomogeneous and disordered structure that consists of the large fragments with the maximal peaks created at the tight condition of the small fragments placed around of the protein. It could be explained by the partial dilution of lactose and mineral components which are limit the process of protein swelling. It is known that catholyte improves the system solubility and cavitational disintegration leads to intensive dispersion of the solids into liquid. Both of mentioned actions could develop the process of the stable homogeneous systems making.

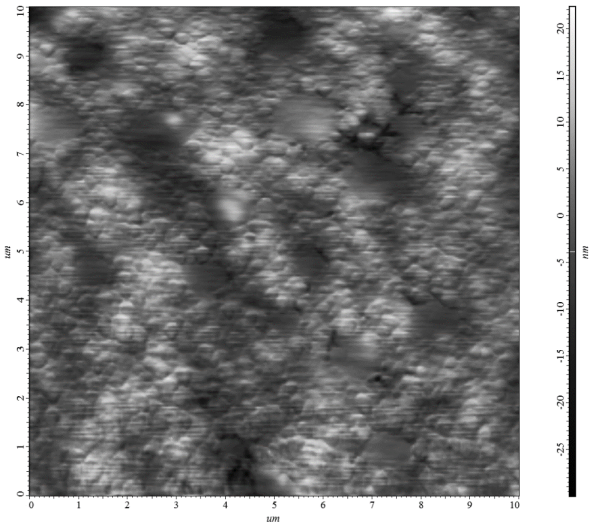


Figure 8. Microscopy of reconstituted whey made by CD use

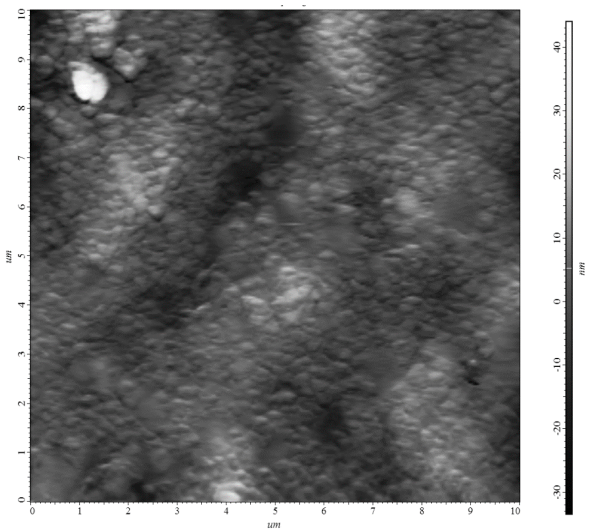


Figure 9. Microscopy of reconstituted whey made by CD and catholyte use

4. Conclusions

- The most appropriate properties of reconstituted dry whey could be obtained if the catholyte would be use instead of water. The reconstituted by cavitational disintegration dry whey made on the catholyte could be used for beverage and milk kinds of deserts production.

- Using of catholyte instead of water and cavitation disintegration for dry whey reconstitution improve the solubility of the treated systems and lead to intensive and uniform dispersing of solid particles of dry whey into solutions that have more stable condition.

- Complex analysis of the AHR changing in the studied systems could recommend using the cavitational disintegration as a method for effective reconstitution of the dry whey, the obtained suspensions would be more homogenous, and fine dispersed systems, which would be stable for 3 hours.

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