Досліджено вплив технологічних чинників (концентрація та співвідношення, площа сорбції, характер та температура сорбції, етапність процесу) на сорбцію альгінатом натрію іонізованого кальцію з молока знежиреного та систем на його основі. Встановлено, що зниження вмісту кальцію у молоці знежиреному призводить до підвищення термостабільності та кислотостійкості харчових систем на його основі. Застосування даного способу декальцинування забезпечує підвищення ресурсного потенціалу молока знежиреного як сировини. Це вирішує проблему його комплексної переробки і дозволяє розробити інноваційні технології десертної продукції на основі молочної та плодово-ягідної сировини з регульованими показниками якості і новими споживчими властивостями

Ключові слова: молоко знежирене, комплексоутворювач, альгінат натрію, іонізований кальцій, сорбція

Исследовано влияние технологических факторов (концентрация и соотношение, площадь сорбции, характер и температура сорбции, этапность процесса) на сорбцию альгинатом натрия ионизированного кальция из молока обезжиренного и систем на его основе. Установлено, что снижение содержания кальция в молоке обезжиренном приводит к повышению термостабильности и кислотостабильности пищевых систем на его основе. Применение данного способа декальцинирования обеспечивает повышение ресурсного потенциала молока обезжиренного как сырья. Это решает проблему его комплексной переработки и позволяет разработать инновационные технологии десертной продукции на основе молочного и плодово-ягодного сырья с регулируемыми показателями качества и новыми потребительскими свойствами

Ключевые слова: молоко коровье обезжиренное, комплексообразователь, альгинат натрия, ионизированный кальций, сорбция

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STUDY OF INFLUENCE OF TECHNOLOGICAL FACTORS ON THE SORPTION OF IONIZED CALCIUM FROM SKIMMED MILK BY SODIUM ALGINATE

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1. Introduction

At present, development of the food industry directly depends on the implementation of resource potential of the raw materials used in the composition of food products. Thus, the formation of final nutritious properties, on the one hand, is the basis for the development of a range of food products, and, on the other hand, is possible only under conditions of using technological properties of raw ingredients.

Among a wide variety of food raw materials, milk and products of its processing are the most valuable due to their nutritional properties. Industrial processing of milk into cream, cheese, butter, casein in traditional ways is associated with receiving skimmed milk, which, given its volumes of production and chemical composition, has been for a long time regarded as a secondary byproduct.

The technological properties of milk imply the properties, which define the course of certain technological processes: solubility, moisture-retaining, foam-forming and emulgation capacities, heat resistance, the capability for rennin and acid coagulation, gel-formation, and concentrating, which are determined by properties of the protein substances of milk.

Coagulation of milk proteins (mostly of casein) is one of the important physical and chemical processes, which underlies industrial technologies of cottage cheese, cheese desserts, and fermented milk drinks. Fundamentalization of existing concepts of the role of calcium and the regularities of coagulation of milk proteins, understanding the relationship between the composition, structure and functional and technological properties of casein allow predicting the possibility of its structural modifications. The most important of them are the increase in hydrophilicity, the ability to dissociate, the uniformity of distribution of the surface charge and, accordingly, the correction of functional and technological properties.

The important technological properties of milk are thermo- and acid resistance, the regulation of which will extend the range and create new food products. This direction of technological studies is relevant and requires scientific substantiation.

2. Literature review and problem statement

At present, the problem of the joint use of skimmed milk and fruit and berries raw materials is interesting, given the creation of food products with new consumer properties. However, this food system is not stable over time and during thermal treatment because of the functional and technological properties of proteins of casein fraction. According to the literature data [1–3], during the decrease in active acidity (pH), as a result of the introduction of acid containing raw materials, there is a shift in equilibrium of the colloidal system and the loss of stability, accompanied by delamination of the system. As a result of the studies, scientists [3, 4–7] found that an important factor under conditions of decreasing pH is the accumulation of ionized calcium that is freed from the calcium–containing acids of colloidal phase and takes part in the coagulation of milk proteins during thermal treatment. In literature [8, 9], there is a reference to the fact that the transition of calcium from the ionized condition to calcium containing compounds by using sodium alginate leads to the increased acid- and thermal stability of skimmed milk.

At present, scientists [8–11] have proposed chemical and physical methods of regulating composition of the salt system of cow milk, which contributes to the physical and chemical stability of its colloidal phase during action of technological factors (active acidity, temperature). One of the promising methods of increrasing stability is the ion exchange, which in practice is implemented both by using ion-exchange materials (ionites) and by introducing the salts of stabilizers. In addition, the regulation of composition of the salt system due to the introduction of the salts of phosphates and citrates (salts of stabilizers) contributes to the stabilization of the system in terms of active acidity [9, 10], but is not justified, given the creation of food products with prolonged terms: the system is stable for some time, and then the uncontrolled growth of acidity is observed and, consequently, a loss of stability. The use of ionites [8] allows creating the systems, which are more stable to the decrease in active acidity and thermal processing; however, there is accumulation of by-substances of synthetic materials, which are used as ionites during sorption. The above mentioned facts form the background for the search for and implementation of more effective ways of the ion exchange, which, on the one hand, will be safe for the health of consumers, and, on the other hand, will contribute to obtaining systems with high thermo- and acid resistance. This will create technologies of food products based on dairy (skimmed milk) and acid containing (fruit and berry) raw materials.

Conducted studies revealed the expediency of using sodium alginate, a complexing agent [11], which is able to bind calcium ions [12, 13] (and in this case – ionized calcium of skimmed milk) with the formation of gel, which can be extracted from skimmed milk or from the systems based on it.

As of today, the information on technological principles of using sodium alginate as an ion exchanger, used in order to increase the colloidal stability of skimmed milk, has not been found in literary sources. Instead, scientists [14] made attempts to introduce the technologies that imply the use of salts of alginic acid for decontamination of milk from radionuclides of strontium. However, the expediency of using the salts of alginic acid was determined by scientists in terms of using them as a sorbent in relation to compounds of heavy metals, rather than in the context of the studied problem. These facts explain the feasibility of studies on the use of sodium alginate as a sorbent of ionized calcium of milk.

Scientific substantiation of parameters of regulating the technological properties of milk by sorption of ionized calcium by the complexing agent sodium alginate is an important task, the solution of which will significantly enhance the resource potential of milk as raw material, increase efficiency of the technological process, develop a wide range of competitive products of high consumer properties for different groups of population of Ukraine.

3. Aim and tasks of the study

The aim of the work is the study of influence of technological factors on the sorption of ionized calcium (Ca^{2+}) of milk, slimmed by the complexing agent sodium alginate (AlgNa) in the framework of enhancing its thermo- and acid stability.

To accomplish the set goal, the following tasks were solved:

– to determine the impact of the concentration AlgNa and the amount of the introduction of its solutions at various ratios of milk: solution AlgNa on the degree of decalcination;

– to explore influence of conditions of sorption (area of sorbent, character and temperature of sorption, active acidity of milk) on the amount of the extracted ionized calcium from milk;

– to define impact of the content of ionized calcium on the thermal stability of milk;

– to explore conditions of the course of reaction of ion exchange with regard to the content of calcium in milk in different forms.

4. Materials and methods of studying the influence of technological factors on the sorption of calcium by complexing agent sodium alginate from skimmed milk

The subjects of the study were:

– drinking skimmed cow milk;

– sodium alginate (manufactured by Danisco company, mark FD 127, Denmark), which is allowed to be used by the Central body of the executive power in the sphere of health protection of Ukraine;

– skimmed milk, the regulation of the composition of the salt system of which was carried out by the sorption of ionized calcium by AlgNa solution.

It is possible to get acquainted in more detail with the methods of research into the influence of technological factors on the sorption of calcium from skimmed milk by the complexing agent sodium alginate in paper [15].

5. Results of study of influence of technological factors on the sorption of calcium from skimmed milk by the complexing agent sodium alginate

It was predicted that the process of sorption of Ca^{2+} by the complexing agent AlgNa will be affected by a variety of technological factors, the boundary values of which were defined in analytical way and are listed in Table 1.

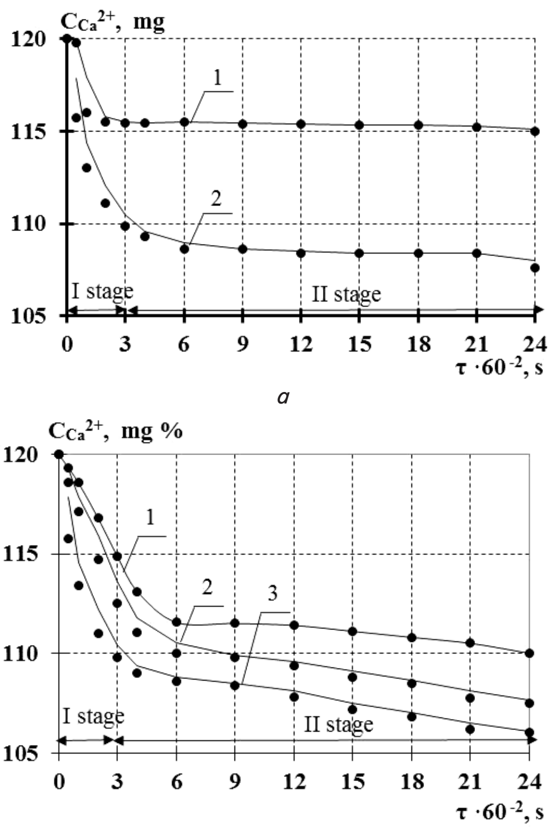
Table 1

Technological factors and their boundary values that were examined in order to substantiate technological parameters of sorption of Ca^{2+}

Name of technological factor	Unit of measurement	Boundary values
AlgNa concentration in the solution	%	1,0...2,0
Ratio milk:complexing agent	–	(100:10)...(100:50)
Sorption area	m^2	$(3\cdot10^{-3})...(15\cdot10^{-3})$
Sorption temperature	°C	2...40
pH of skimmed milk	unit	5,0...5,5
Character of sorption	–	Static or dynamic (stirring)
Stages of process with introduction of complexing agent	–	1...3
Duration of process	s	$(0,5\cdot60^2)...(24\cdot60^2)$

Among the above mentioned technological factors, at the first stage of the study we explored the process of sorption with stable parameters: temperature (t=21,0±0,5 °C), frequency of stirring (every 5·60 s) for $24\cdot60^2$ s, pH of milk – 6.6±0,1.

Results of the study of kinetics of sorption of Ca^{2+} from milk by the solution of AlgNa with concentration of 1,0 % and 2,0 % at different ratio of milk:solution AlgNa can be seen in Fig. 1.



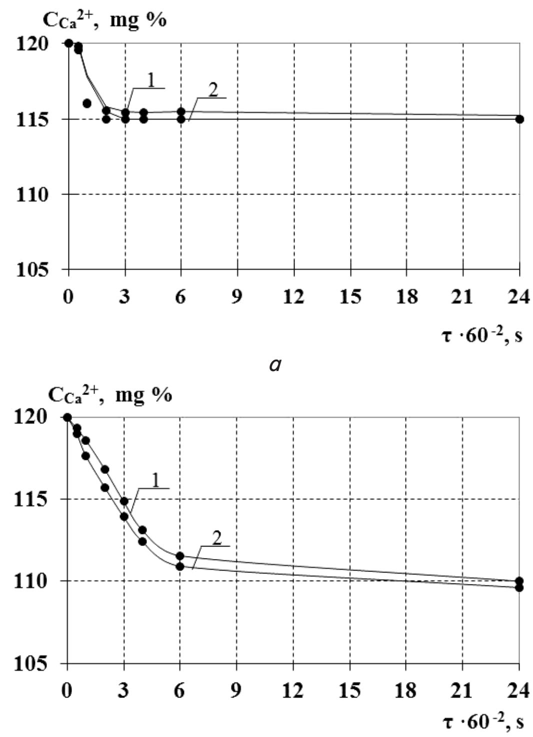
a

b

Fig. 1. Kinetics of sorption of Ca^{2+} from milk by the solution of AlgNa at ratio milk:solution AlgNa: 1 — 100:10; 2 — 100:20; 3 — 100:30: *a* — at 1,0% concentration of AlgNa; *b* — at 2,0% concentration of AlgNa

The data of Fig. 1 demonstrate that the introduction of solutions of AlgNa to milk and curing over a certain period of time leads to a decrease in the content of Ca^{2+} in its composition. It was established that under conditions of using the solution AlgNa of 1,0 % concentration, the maximum amount of sorbed calcium is 10.3±0,1 % of the total (Fig. 1, *a*, curve 2) at the concentration of 2,0 % – 11.7± ±0.1 % (Fig. 1, *b*, curve 3). An increase in the total content of complexing agent leads to an increase in Ca^{2+} which is sorbed, The introduction of the 1,0 % solution of AlgNa at the ratio milk: solution AlgNa as 100:10 causes the sorption of 4.17±0,1 % Ca^{2+} (Fig. 1, *a*, curve 1), and at the ratio of 100:20 – 10.3±0,1 % (Fig. 1, *a*, curve 2) that indicates the expedience of using AlgNa in a larger amount.

Experimental data on the influence of the sorption area, the different values of which were achieved with the introduction by droplets of the solution of AlgNa and as a layer of certain mass at the ratio of 100:10, on the kinetics of sorption of Ca^{2+} from milk by the solution of AlgNa, revealed an insignificant difference regarding the residual calcium content for various sorption areas (Fig. 2).



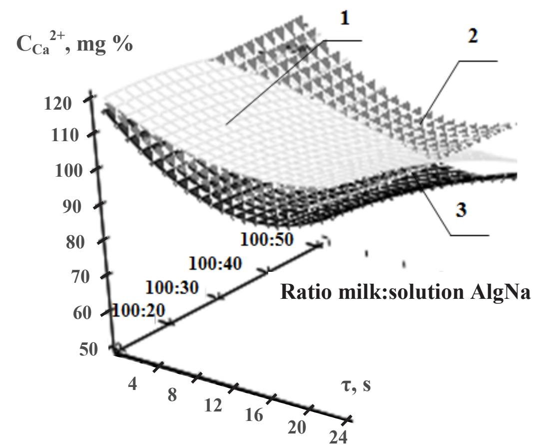
a

b

Fig. 2. Kinetics of sorption of Ca^{2+} from milk by the solution of AlgNa depending on the sorption area, 10^{-3} m^2: 1 — 3,0; 2 — 15,0: *a* — at 1,0 % concentration of AlgNa; *b* — at 2.0 % concentration of AlgNa

The data presented in Fig. 2 display that the content of calcium under conditions when the sorption area is $3,0\cdot10^{-3}$ m^2 and $15,0\cdot10^{-3}$ m^2 after curing it for $6\cdot60^2$ s is: using the solution of AlgNa of 1,0% concentration – 115,5±1,0 mg % and 115,0±1,0 mg %, 2,0 % concentration (Fig. 2, *b*) – 111,5±1,0 mg % and 110,9±1,0 mg %, respectively. Taking into account the resulting data, the complexing agent was consequently introduced to the skimmed milk by droplets.

The kinetics of sorption of Ca^{2+} from milk by the solution of AlgNa of 1,0 % and 2,0 % concentration at different values of pH was established (Fig. 3).



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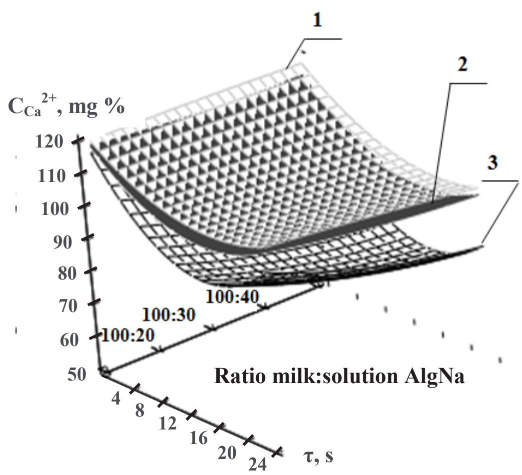


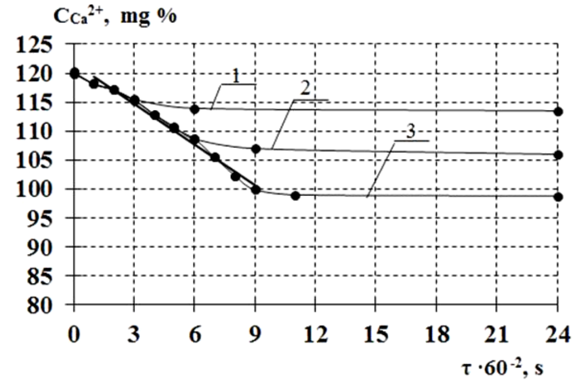
b

Fig. 3. Kinetics of sorption of Ca^{2+} from milk by the solution of AlgNa at pH 6,0 (1) 5,5 (2), 5,0 (3): *a* – at 1,0 % concentration of AlgNa; *b* – at 2,0 % concentration of AlgNa

An analysis of the obtained data (Fig. 3, *a, b*) shows that the nature of change in the content of Ca^{2+} in milk at pH 5,0≤pH≤6,0 is similar. At pH 6.6: we observed a decrease in the content of Ca^{2+}, the concentration of AlgNa in the solution and the sorption duration under conditions of increasing the mass of the introduced complexing agent (ratio).

With regard to the process of sorption, accompanied by a decrease in the content of Ca^{2+} in milk and the formation of «AlgNa–Ca^{2+}», the uniformed distribution of complexing agent in the system is important. Conducted experimental studies suggest the feasibility of stirring every (15...20)× ×60 s, which provides for the progress of the sorption process with the formation of «AlgNa–Ca^{2+}» systems, and from the physical point of view – AlgSa granules that have the same structural and mechanical properties in all the volume of reacting mixture.

Removal of Ca^{2+} from skimmed milk is a dynamic process, the development of which depends on many factors. However, the existence of two stages (Fig. 1), which are characterized by different sorption speed, allows determining the expediency of the phased introduction of complexing agent (Fig. 4).



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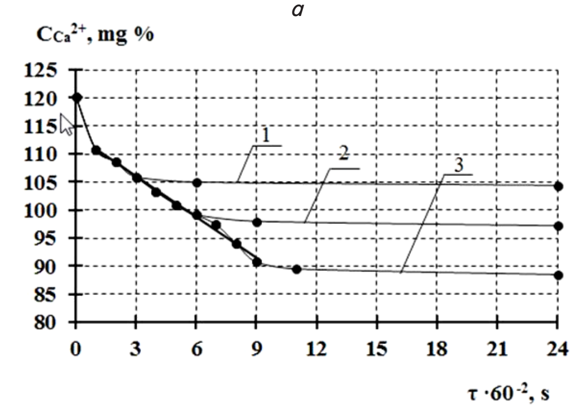

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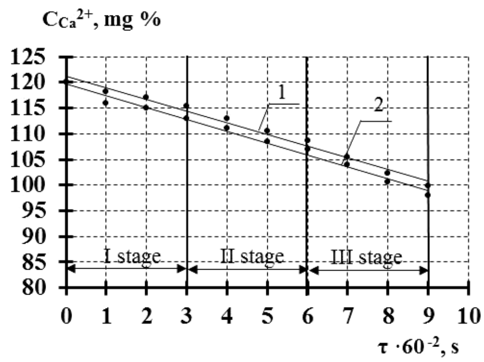
Fig. 4. Kinetics of sorption of Ca^{2+} from milk under conditions of staged introduction of the solution of AlgNa: 1 – I stage (ratio of milk:solution of AlgNa – 100:10); 2 – II stage (ratio of milk:solution of AlgNa – 100:(10+10)); 3 – III stage (ratio of milk:solution AlgNa – 100: (10+10+10)): *a* – at pH of milk – 6.6; *b* – at pH of milk – 5.5

An analysis of experimental data (Fig. 4) enables us to point out that regardless of pH of milk, a staged introduction of the solution of AlgNa leads to a general decrease in the content of calcium in milk with the same speed, which at pH 6,6 and pH 5,5 is $(0,4...0,5)\cdot 10^{-3}$ %/s and $(0,8...1,0)\cdot 10^{-3}$ %/s.

Along with the study of kinetics of sorption of Ca^{2+} from milk under conditions of a staged introduction of the solution of AlgNa, we carried out studies of the staged introduction of acid containing raw material (Fig. 5). The obtained results suggest a more intensive decrease in Ca^{2+} in milk under conditions of a staged introduction of the solution of AlgNa and acid containing raw materials along with the stage introduction of only a complexing agent to the system.

It was established (Fig. 5) that under conditions of sorption ($\tau = 9\cdot 60^2$ s, pH 5,5), the total content of calcium during the phased introduction of the solution of AlgNa decreases to 90,7±0.1 mg %. A phased introduction of the solution of AlgNa and of correctors of solubility to the system contributes to a decrease in calcium to 88,0±0,1 mg %.

Taking into consideration the process of regulation of composition of the salt system of milk, it is important to determine the sorption capacity of solutions of AlgNa depending on temperature (Fig. 6). While substantiating the value of pH of skimmed milk (pH 5.5), we considered the amount of Ca^{2+}, where an increase in pH up to 6.6 leads to a decrease in the content of Ca^{2+}. Decreasing pH to 5.0 in the process of curing at temperatures 30...40 °C contributes to destabilization of the colloidal system of milk, resulting in its delamination with the formation of whey and casein in the form of agglomerates. The starting content of calcium in milk was 120,0±1,0 mg %.



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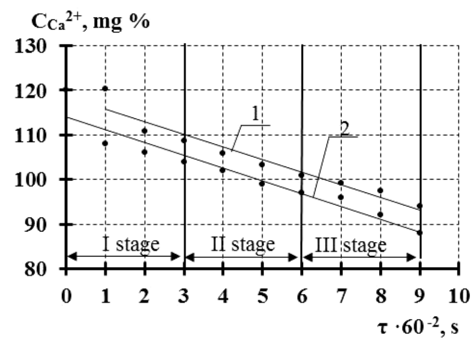

b

Fig. 5. Kinetics of sorption of calcium Ca^{2+} from milk under conditions of a staged introduction: 1 — solution of AlgNa; 2 — solution of AlgNa and acid containing raw materials: *a* — pH of milk — 6.6; *b* — pH of milk — 5,5

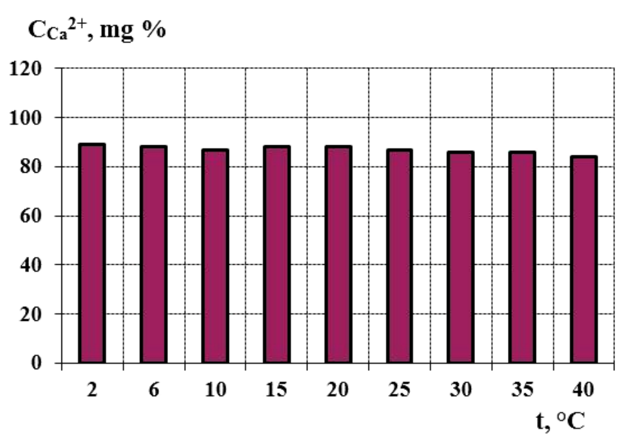

Fig. 6. Content of calcium in milk (pH 5,5) depending on the sorption temperature

The study of influence of temperature on the change in calcium content in milk under conditions of a staged introduction of the AlgNa solution enables us to state that a slight decrease in the studied index is observed along with an increase in temperature (Fig. 6). Thus, at temperature 2 °C and 40 °C, the content of calcium in milk (pH 5,5) decreased to 89,0±0,1 mg % and to 86,0±0,1 mg %, respectively.

Results of the study of thermal stability of milk with the regulated composition of salt system are presented in Table 2.

Table 2

Thermostability of milk with regulated composition of salt system depending on the amount of sorbed Ca^{2+}

Alcohol concentration, %	Thermostability of milk depending on the amount of sorbed Ca^{2+},%									
	0	10	11	13	15	18	19	20	23	26
68	–	+	+	+	+	+	+	+	+	+
70	–	–	–	–	+	+	+	+	+	+
72	–	–	–	–	–	–	–	+	+	+
75	–	–	–	–	–	–	–	–	–	–

To determine the composition and the patterns of change in the existence of the states of calcium, we studied its quantitative content in milk (pH 5.5), in true solution and in colloid phase; in particular, calcium bound with caseins (Fig. 7).

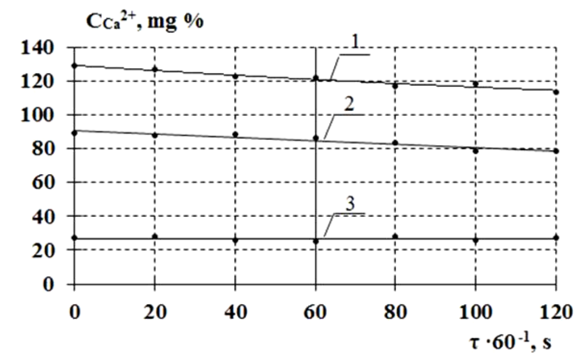

Fig. 7. Change in content of Ca^{2+}: 1 — milk (pH 5.5); 2 — true solution (pH 4,6); 3 — calcium caseinate (pH 4,6)

The data in Fig. 7 demonstrate that under conditions of sorption of Ca^{2+} by a complexing agent, we observed a decrease in Ca^{2+} in milk from 120,0±1,0 mg % to 110,5± ±1,0 mg % and changes in calcium content in true solution from 94,0±0,9 mg % to 78,5±0,7 mg %. In this case, the content of calcium, which is bound with casein, in the process of regulation of the salt system composition remains practically unchanged regardless of the duration of the process

6. Discussion of results of studying the influence of technological factors on the sorption of calcium sodium by the complexing agent sodium alginate from skimmed milk

During the stoichiometric interaction of AlgNa and ionized calcium, calcium alginate (AlgCa) is formed – a new phase of the system "solution AlgNa – milk", which is characterized by low chemical potential and can be removed from the system. Reaching the stoichiometric balance is an inertial process, that is why under conditions of formation and development, the system "solution AlgNa–Ca^{2+} of milk" polymer is being in several states. At the initial stages of the process, at any ratio of reacting components, there is a thickened system that contains [AlgNa]>>[AlgCa], which is possible under conditions [AlgNa]>>[Ca^{2+}]; in the course of the process of ion exchange, there happens the formation of the ionotropic gel with pronounced plastic properties, that is, "soft" gel, which is possible under conditions [AlgNa]>>[Ca^{2+}]. The measure of plasticity and elasticity of this system will depend on the proportion of AlgCa in AlgNa, and with the sufficient content of Ca^{2+}, the elasticity will increase and the plasticity will decrease for the AlgNa solutions of different concentrations. As the progress of chemical reaction of substitution of Na^{+} with Ca^{2+} will be accompanied by an increase in hydrophobicity, we observe the separation of the water phase, and under conditions of great excess of Ca^{2+}, xerogels appear as a result of competition for water.

It is important to understand that the occurrence in the system, which is common by a solvent, of a new (by the colloid state) phase and its development in the direction of AlgNa→AlgCa will be accompanied by the mass transfer. Taking into account the fact that the molecular weight of AlgNa is 542300 Da [13], and that of ions of calcium is 40, according to the Einstein equation, which describes the diffusion movement of particles of low- and high molecular substances in a liquid, the only possible development of the system is the diffusion of calcium ions to the solution of AlgNa. Under these conditions, milk will be depleted in the content of Ca^{2+}, and the AlgNa solution, on the contrary, will be enriched due to its sorption.

The result of the ion exchange will be the occurrence of a new phase, and its further transformation from the state "gel AlgNa–Ca^{2+}" to "gel AlgCa". Understanding the above mentioned processes allows defining the prospects of creating new technological systems on the basis of substantiation and determination of rational parameters of the sorption of Ca^{2+} by the complexing agent AlgNa.

Conducted studies confirmed theoretical research into the possibilities of using sodium alginate for bonding and removing ionized calcium from milk. According to Fig. 1, we established an increase in the total content of calcium in milk, where it is possible to predict that the process of sorption occurs due to ionized calcium as a single reactive form that is contained in its composition. The amount of the sorbed Ca^{2+} will be proportional to the product of the concentration by the mass of the introduced solution of AlgNa. It was established that an increase in the concentration of AlgNa by 2 times leads to the 13,6 % increase in calcium, which was sorbed, which enables us to draw a conclusion about the inertial character of the salt balance in milk.

The experimental data (Fig. 1) show that the introduction of the same amount of AlgNa (0,2 g) to milk in solutions of 1,0 % concentration with the ratio of 100:20 (Fig. 1, *a*, curve 2) and of 2,0 % concentration with the ratio of 100:10 (Fig. 1, *b*, curve 1) leads to the sorption of relatively less amount of Ca^{2+}, which is 10 % and 8 %, respectively. The latter is probably explained by viscosity and the ratio of milk: solution of AlgNa. An increase in viscosity helps to slow down the process of sorption, and an increase in the ratio, vice versa, accelerates the process by increasing the contact of AlgNa with Ca^{2+}, which allows using it with less concentration, but in larger quantity. It should be noted, that the conducted analysis [16] and experimental research (Fig. 1) indicate that the ratio of AlgNa and Ca^{2+} of milk does not attain the stoichiometric values, regardless of the conditions of sorption.

Based on the determination of influence of the sorption area, we defined the feasibility of introducing a solution of sodium alginate by droplets, and although a slight difference in the process of sorption by the amount of sorbed ionized calcium was observed according to the results of the study, it was not decisive. However, it should be noted that the study of the process of granules formation was covered in the paper of scientists [13]. Under these conditions, the processes of stirring are important during the course of sorption, when with a decrease in the duration we observed obtaining granules with different properties, which complicates their further use in the food products technology; the increase in duration does not lead to improving the properties of the obtained granules.

One of the important factors of influence on the system is the introduction to its composition of fruit and berries along with milk. This will result in the disruption of colloidal stability and an increase in the solubility of calcium containing salts and, consequently, the accumulation of ionized calcium that is immediately sorbed by the solution of sodium alginate. It was established that the speed of sorption in the course of decreasing pH from 6,0 to 5,0 increases by 2,5 times: at pH 6,0 and 5,0 (Fig. 3, *a*) the sorption speed is $0{,}4{\cdot}10^{-3}$ %/s and $1{,}0 \cdot 10^{-3}$ %/s, respectively, and the total amount of calcium, sorbed for $6{\cdot}60^{2}$ s is 9,3 % and 21,5 % of the starting content, respectively. The obtained results are fully consistent with theoretical research.

It should be additionally noted that the decrease in active acidity to pH 5,0 leads to obtaining unstable systems, in particular, the existence of casein particles. On completion of the process of sorption, they are not likely to be visually observed as a result of bonding ionized calcium.

The inertia of the process of bonding ionized calcium under the defined conditions (Fig. 1) does not make it possible to intensify the process of sorption. Effective solution (Fig. 3, 4) is a phased introduction to the system of a complexing agent and acid containing raw materials. Thus, a comparison of the results (Fig. 3, 4) makes it possible to define that a staged process allows for a more efficient use of the complexing agent.

Conducted analytical studies of the temperature effect indicate an increase in the solubility of calcium containing salts during the rise in temperatures, however, the salt balance in milk forms other patterns, in particular, an increase in temperature promotes the transition of salts of calcium to a colloidal form. On the one hand, during heating, the equilibrium in the salt system is shifted towards the formation of colloidal components and, on the other hand, an increase in temperature leads to the intensification of mass transfer processes as a result of a more rapid movement of ions. Of course, temperature under conditions of lowering pH of milk is an important factor that initiates the process of Ca^{2+} deposition on casein micelles (thermo-calcium coagulation). Considering the obtained results (Fig. 6), where, depending on temperature, the amount of sorbed calcium changes slightly, and taking into account the stability of the system and the inexpediency of complication in the technology, it is a priority to conduct the process of sorption of Ca^{2+} at temperatures 2...6 °C.

The process of regulating the composition of the salt system of milk leads to increasing its colloidal stability, which in turn contributes to the more thermostable systems. Taking into the consideration the conducted studies regarding the phased introduction of complexing agent and acid containing raw materials, the research into thermal stability of milk by alcohol trial (Table 2) makes it possible to state that the process of regulation of the composition of the salt system of milk leads to an increase in its thermal stability. The established regularities are fully consistent with the research of scientists [3], which indicate the relationship between the content of ionized calcium and thermal stability of milk. However, of not less importance is the buffer capacity of milk, which in this case is a deterrent to the increase in acidity in the system. We should also point out that an increase in pH is characteristic for all of the studied systems, the results of the thermal stability of which are presented in Table 2, which is explained by the ion exchange reaction and accumulation of sodium ions in the system.

Not less important is to determine a change in the content of calcium in different forms contained in milk. The sorption of ionized calcium will cause the release of the latter from calcium containing salts in terms of systems tending to restore the balance, which is undesirable in view of the transition of bio-accessible calcium, which is contained in compounds with caseins, to ionized state. An analysis of the obtained experimental data presented in Fig. 7 makes it possible to determine that the regulation of the composition of the salt system of milk leads to a decrease in calcium content, mainly due to ionized calcium. The establishment of a new equilibrium under condition of the introduction of complexing agent causes the release of Ca^{2+}, which is likely to be found in the composition of calcium containing salts (phosphates and calcium citrates), with the exception of calcium bound with casein.

7. Conclusions

1. Introduction of the complexing agent sodium alginate leads to a decrease in calcium content in skimmed milk. It was established that a determining factor of sorption is the concentration of sodium alginate and the ratio of milk: solution of AlgNa.

2. The sorption area and its character, as well as temperature of the process, are not determining factors with regard to bonding and removal of calcium. With this in mind, it is expedient to set the modes of sorption based on the requirements of the course of technological process of production of certain food products.

3. During the process of sorption of ionized calcium from skimmed milk, it is advisable to use a staged introduction of the sorbent and acid containing raw material, which leads to obtaining the same speed of the process and contributes to a relatively larger amount of sorbed calcium.

4. The sorption of ionized calcium from skimmed milk with well grounded parameters allows obtaining food systems with high indices of thermal and acid resistance, which opens up the prospects for the creation of new food products – dairy drinks, cocktails, etc., the formulation of which includes milk and fruit and berry raw materials.

5. The course of reaction of ion exchange in milk depending on the form of calcium (ionized or as a part of casein-calciumphosphate complex) proceeds in different ways. In addition, the maximum intensity of the process is observed under condition of existence of free ionized calcium.

References

1. Singh, H. Heat stability of milk [Text] / H. Singh // International Journal of Dairy Technology. – 2004. – Vol. 57, Issue 2-3. – P. 111–119. doi: 10.1111/j.1471-0307.2004.00143.x
2. Marianthi, F. The effect of free Ca2+ on the heat stability and other characteristics of low-heat skim milk powder [Text] / F. Marianthi, L. Mike J., G. Alistair S., D. Hilton // International Dairy Journal. – 2009. – Vol. 19, Issue 6-7. – P. 386–392. doi: 10.1016/j.idairyj.2008.12.006
3. Tepel, A. Chemistry and physics of milk [Text] / A. Tepel. – Saint Petersburg: Profession, 2012. – 824 p.
4. Philippe, M. The effects of different cations on the physicochemical characteristics of casein micelles [Text] / M. Philippe, Y. Legraet, F. Gaucheron // Food Chemistry. – 2005. – Vol. 90, Issue 4. – P. 673–683. doi: 10.1016/j.foodchem.2004.06.001
5. Auty, M. A. E. The application of microscopy and rheology to study the effect of milk salt concentration on the structure of acidified micellar casein systems [Text] / M. A. E. Auty, B. T. O'Kennedy, P. Allan-Wojtas, D. M. Mulvihill // Food Hydrocolloids. – 2005. – Vol. 19, Issue 1. – P. 101–109. doi: 10.1016/j.foodhyd.2004.04.019
6. Xu, Y. Effect of calcium sequestration by ion-exchange treatment on the dissociation of casein micelles in model milk protein concentrates [Text] / Y. Xu, D. Liu, H. Yang, J. Zhang, X. Liu, J. M. Regenstein et. al. // Food Hydrocolloids. – 2016. – Vol. 60. – P. 59–66. doi: 10.1016/j.foodhyd.2016.03.026
7. Post, A. E. Effect of temperature and pH on the solubility of caseins: environmental influences on the dissociation of αS-and β-casein [Text] / A. E. Post, B. Arnold, J. Weiss, J. Hinrichs // Journal of Dairy Science. – 2012. – Vol. 95, Issue 4. – P. 1603–1616. doi: 10.3168/jds.2011-4641
8. Tanashuk, S. Zastosuvaniya ionoobmennuh smol [Text] / S. Tanashuk, O. Savchenko, A. NIkolaych // Harchova i pererobna promuslovist. – 2006. – Vol. 2. – P. 23–25.
9. Sokolova, L. I. Application of ion exchange processes for improving the thermal stability of milk [Text] / L. I. Sokolova. – Moscow, USSR: Moscow Technological Institute of Meat and Dairy Industry, 1975. – 21 p.
10. Fedushnov, P. A. Ispolzovanie sistemu Budal 935 [Text] / P. A. Fedushnov // Produktu i ingredientu. – 2007. – P. 63–67.
11. Pyvovarova, O. Analytic study of the system «AlgNa – CaSO4 – water» and scientific prognostication of its structure-forming regularity [Text] / O. Pyvovarova, O. Grinchenko, Y. Pyvovarov // Formular de evaluare. 33 Congres Ara : a lucrarilor din cadrul Celui, 2009. – P. 101–113.
12. Pivovarov, P. P. Innovatsionnyie tehnologii proizvodstva kapsulirovannyih produktov [Text] / P. P. Pivovarov, O. P. Neklesa, A. Yu. Nagornyiy // Produktyi & ingredientyi. – 2013. – Vol. 3. – P. 24.
13. Moroz, O. V. Doslidzhennya vplivu kaltsiyu na strukturno-mehanichnI vlastivosti algInovih dragliv z metoyu vikoristannya v tehnologiyi produktsiyi z zheleynoyu strukturoyu [Text] / O. V. Moroz, V. O. Protsik, P. P. Pivovarov // Visnik Kharkivskogo

natsionalnogo tehnichnogo universytetu silskogo gospodarstva Im. P. Vasilenka. Suchasni napryamki tehnologiyi ta mehanIzatsiyi protsesiv pererobnih i harchovih virobnitstv. – 2012. – Vol. 131. – P. 271 278.

14. Donskaya, G. V. Izbiratelnue sorbentu rastitelnogo proishogdeniya dlya ochistki moloka ot stronziya [Text] / G. V. Donskaya, V. M. Drozhzhin, A. I. Grivkova // Molochnaya promushlennost. – 1998. – Vol. 1. – P. 31–32.
15. Plotnikova, R. The study of sorption of the milk ionized calcium by sodium alginate [Text] / R. Plotnikova, N. Grynchenko, P. Pyvovarov // EUREKA: Life Sciences. – 2016. – Vol. 4 (4). – P. 45–48. doi: 10.21303/2504-5695.2016.00191
16. Pyvovarova, O. P. Tehnologiya polufabrikatov restrukturirovannuh na osnove shampinonov [Text] / O. P. Pyvovarova. – Kharkiv State University of Food and Trade, 2009. – 19 p.

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EXPLORING THE EFFECT OF DRY PROTEIN-CARBOHYDRATE SEMI-FINISHED PRODUCT ON THE STRUCTURAL-MECHANICAL PROPERTIES OF YEAST DOUGH OBTAINED BY THE ACCELERATED TECHNIQUE

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Доведена перспективність використання сухого білково-вуглеводного напівфабрикату (СБВН) у технології дріжджового тіста, отриманого прискореним способом. Досліджено структурно-механічні, пружньо-еластичні та реологічні властивості тіста в залежності від концентрації СБВН. Встановлено, що використання СБВН в технологічному процесі виробництва дріжджового тіста надає можливість корегувати силу борошна та цілеспрямовано впливати на реологічні властивості тіста

Ключові слова: сухий білково-вуглеводний напівфабрикат, суха картопляна добавка, дріжджове тісто, структурно-механічні властивості, реологічні властивості

Доказана перспективность использования сухого белково-углеводного полуфабриката (СБУП) в технологии дрожжевого теста, полученного ускоренным способом. Исследованы структурно-механические, упруго-эластичные и реологические свойства теста в зависимости от концентрации СБУП. Установлено, что использование СБУП в технологическом процессе производства дрожжевого теста дает возможность корригировать силу муки и целенаправленно влиять на реологические свойства теста

Ключевые слова: сухая белково-углеводная смесь, сухая картофельная добавка, дрожжевое тесто, структурно-механические свойства, реологические свойства

1. Introduction

Significant changes in the conditions of life and labour of society caused imbalance between consumer demand and proposals in the market of bread and bakery products, which necessitates extending their product range for the production of new products with improved consumer properties [1].

Bread and bakery products have very large physiological importance in human nutrition as they are related to the products of mass consumption and possess digestibility that does not decrease over the course of daily use. Bread is characterized by favorable consistence and structure that provides the most efficient work of the digestive system and contributes to the fuller assimilation of other products by the human organism. Bread provides about 50 % of the daily