Discourse of the form and concentration of surfactants to ensure the sustainability foam-emulsive products

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Abstract

Introduction. Development of dry mixes for making spumy and emulsion products are topical, because nowadays there is a tendency to minimize the time spent on the process of cooking, which is achieved by the use of semi finished products high degree of readiness.

Materials and methods. Foaming ability was determined by the method of multiplicity of the foam, the stability of unstable foam- by the half-life method of foam, highly resistant foam - as a ratio of the height of the column of foam after exposure for 24 hours.

Results. Was determined the influence of sunflower oil on the foaming ability and half-life foam of systems «sodium caseinate-oil». It was found that getting systems with high index of foaming capacity and foam stability in the presence of oil in the system is impossible without the use of low molecular weight surfactants. Substantiated recommendations regarding the feasibility of using two surfactants in systems «sodium caseinate-surfactants-oil», which provide the necessary kinship surfaces air, fat and water phases. it has been found that the use of 2,5...3,5% mono-and diglycerides of fatty acid sand Lecithin's 0.15...0.25% in the content of sodium caseinate about 0.5% allows to receive the stable foam-emulsive systems containing sunflower oil 7...8% and foaming ability about 640±1%.

Conclusions. It is established that for ensuring high indicators foaming capacity and stability of foam-emulsive systems required the use of low-molecular surfactants. The research results, is recommended to use when developing technology of foam-emulsive products.

Introduction

Given the specificity of functioning of the restaurant industry (fragmented dislocation within settlements, reducing the area of industrial facilities, specialization, etc) successful manufacture of food products with foam-emulsive structure, representatives of which are desserts, finishing semi-finished products (creams), layers of cakes and pastries, possibly on the basis of semi finished products high degree of availability, the use of which will provide stable quality parameters and safety of the finished product in the technological flow.

For existence on the food market of Ukraine is a wide assortment of multifunctional semi finished products and food concentrates in the form of dry and liquid mixtures [1], the volume of production and technological characteristics not satisfy fully the needs of institutions the restaurant industry. The main reasons are the unstable properties of prescription mixtures during foaming and storage of finished products; using as part of semi finished products hydrogenated vegetable oils - palm, palm kernel, soybean, which has a number of drawbacks, including the main - have transisomers of fatty acids; absence domestic production of semi-finished products.

Therefore development of dry fatty semi finished product for the production of food products with foam-emulsive structure is relevant, as it using will reduce the time and production areas providing the quality and safety of the finished product, create wide variety of desserts and pastry, able to satisfy the requirements of the modern consumer's by implementing business processes B2B and B2C.

With the implementation of the traditional method of making a dry fat-containing mixture limiting factor is the significant energy consumption in the production of semi finished products, which are produced by spray drying the emulsion pre-condensed product. The scientists of Kharkiv State University of Food Technology and Trade proposed a fundamentally new way of obtaining fat dry semi finished products (hereinafter - semi finished products) by spraying a mixture of fat based on sunflower oil on the powdered filler. This approach can reduce the energy consumption for the production of semi-finished products and provide high quality and stable indicators foam-emulsive products based on them.

Development of a new method for producing semi finished requires scientific substantiation prescription composition (form and concentration of surface-active substances (SAS) and technological parameters of its production (temperature and duration of recovery, churning, storage, etc.), for implementation of which he will meet the following requirements:

- have a commodity form of dry mixture with constant organoleptic, physicochemical and microbiological parameters during a specified period of storage;
- restoring by mixing with drinking water, followed by stirring to dissolve the ingredients, followed by the formation foam-emulsive system of its mechanical dispergation;
- foam-emulsive systems based on whipped semi finished should be technologically compatible with food ingredients and /or products in the form of fruit berry, chocolate and other fillers to create a wide range of culinary and confectionery.
- restored semi-finished product must have high performance foaming capacity and foam stability, ensuring its use in technology of dessert products and finishing semis.

The main and essential condition to obtain a foam emulsion products is the use of foaming agents, including traditionally used macromolecular compounds protein (egg white, milk), polysaccharide (methylcellulose, hydroxylpropylmethyl cellulose) nature and low molecular weight surfactants. In this important scientific and practical aspect of obtaining foam emulsion systems is to stabilize their structures in general, including the presence of a fatty phase, along with other factors affecting the formation of organoleptic and physic-chemical characteristics of products, such as textural homogeneity, shape stability, and others.

It is advisable to define the criteria for selecting surfactants dry fatty semi finished to obtain a foam emulsion systems:

- first, surfactants must ensure complete dissolution of the components during recovery of semi finished (the first stage) and emulsification fat phase (the second phase), which is in the dispersed state;
- secondly, by the reasonable using of surfactants high foaming ability and foam stability should provide initial indicators of foam systems throughout the period of storage and sales;
- thirdly, the foaming agent (or system foaming agent - stabilizer) should not alter their functional and technological properties of conditions for the introduction of fillers regardless of their chemical composition, colloidal state, allowing create a wide range of products from foam emulsion structure.

In the works of national and international scientists [2-5] is pointed out that one of the factors stabilizing stability of spumy systems is structural-mechanical, which is achieved by increasing the strength of interfacial adsorption layers (IAL). Providing strength IAL done by using macromolecular-surfactants (proteins). For the foam-emulsion systems it is necessary to regulate the strength IAL. In particular on stage whipping important is decrease in strength of IAL at the interface water-oil to form fat crystals capable of coalescence at the interface water-air and simultaneously increase the strength of IAL on the verge of water -air is realized by using a mixture of surfactants (proteins and low molecular weight surfactants) [6-8]. In studies noted that the above named course of the process achieved by adsorption surfactants at the phase interface - competitive, associative and layered.

During exploratory studies demonstrated that combined use of macromolecular (proteins) and surfactants with low molecular weight for rational ratio increases the mechanical strength of the foam systems by preventing thinning foam films and significantly prolongs duration of the existence of the foam. Also, use as part of semi-finished fat phase in the form of vegetable oil (sunflower), likely will improve the solubility of low molecular weight surfactants.

Given this, the aim of these studies is the justification for type and concentration surfactants by identifying patterns of change foaming capacity and stability of food foams systems that simulate the composition of dry fat-free cake mix for the production of foam-emulsion products.

Materials and methods

In order to study the rational content of the main prescription components studied foaming ability (FA), the half-life of foam (HLF) and the stability of foams (SF). Experimentally was found regularities FA, HLF and SF on the concentration of sodium caseinate, surfactants, sunflower oil in the systems.

Spumy systems were obtained by churning prescription mixtures of defined composition. The mixture was prepared by dissolving low molecular weight surfactants in sunflower oil at a temperature of 60 ... 70ºC and followed by mixing with an aqueous solution of sodium caseinate. Whipping was performed in 5×60^1s using a mixer at a speed of rotation of the working organ 29 s^{-1}.

Foaming ability of systems was determined by the method and calculated by the formula:

$$\Pi 3 = 100\frac{V_F}{V_S}$$

V_F - volume of foam cm^3;

V_S - volume of solution before churning, cm^3.

The stability of foams unstable systems expressed through a half-life of foam ($\tau^{1/2}$), that determined the time during which the foam column destroyed half of the original height of the foam. Persistence of stable foams was determined as the ratio of the height of the foam column after holding for 24 × 60^2s at a temperature of 20,0 ± 0,5 ºC to the total height of the sample, expressed as a percentage.

Results and discussion

In order to study the type and concentration surfactants consisting of semi-finished researched the patterns of change ability of foaming and half-life of foams food systems «sodium caseinate-oil», «sodium caseinate-surfactants», «sodium caseinate-surfactants-oil».

Based on previous studies as raw that contains protein was selected sodium caseinate at a concentration of 0.5...2.0% low molecular weight surfactants - E471, E473, E481, E322, E472e (Table 1). The content of sunflower oil in the systems was investigated varied in the concentration range 0...10%.

Table 1

Characterization of surfactants

Name of surfactants	The properties of surfactants
E471 Mono- and diglycerides of fatty acids	Nonionic surfactants, HLB = 3…4, iodine number – 80g I/100g
E471 Mono- and diglycerides of fatty acids	Nonionic surfactants, HLB = 3…4, iodine number – 3g I/100g
E473 Sucrose esters of fatty acids	Nonionic surfactants, HLB = 13…15
E481 Sodium stearoyl-2-lactylate	Anionactive surfactants, HLB = 16…18
E322 Lecithins	Amphoteric surfactants, HLB = 4
E472a Acetic acid esters of mono- and diglycerides of fatty acids	Nonionic surfactants, HLB = 2…3

In the first phase of research identified patterns of foaming «sodium caseinate-oil» (Fig. 1).

It is proved that aqueous solutions of sodium caseinate 1.0%, 1.5% and 2.0% due to the high surface-active properties form foam system FA indicators which constitute 580 ±1%, 550±1%, 500 ±1%, respectively but these systems are characterized by low stability of the foam, as HLF these systems is $28×60^1$s, $16×60^1$s, $15×60^1$s and 60cm respectively. Introduction to oil system leads to its emulsification and is accompanied by a decrease in the above parameters for all concentrations of sodium caseinate. This fact is probably due to the destruction of the foam when added to a system of sunflower oil, which is a consequence of the reorientation of the protein due to changes in its adsorption on the interface water-air boundary for adsorption at water-oil [9]. Systems with a concentration of sodium caseinate about 0.5% in the presence of oil are not capable of churning.

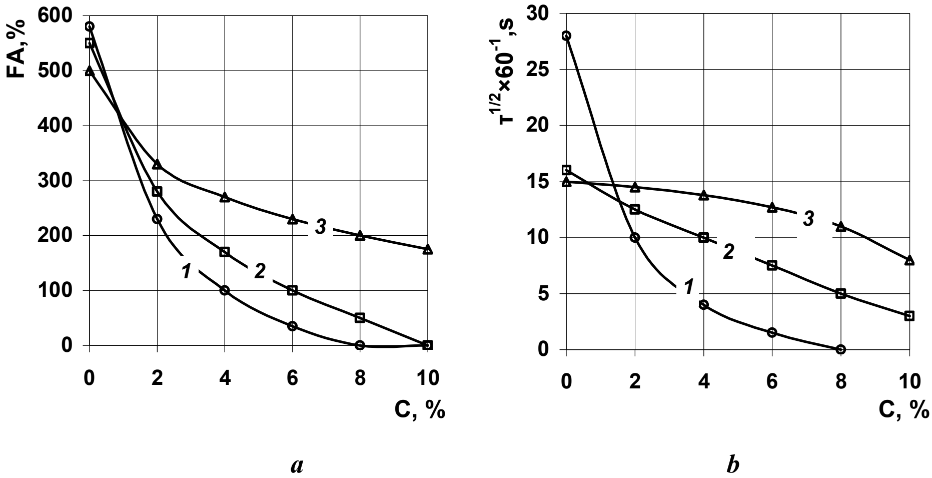


Fig. 1. Dependence of the FA (a) and HLF (b) of systems «sodium caseinate-oil» on the content of sodium caseinate concentration:
1(○) - 1,0; 2(□) - 1,5; 3(Δ) - 2,0

Experimental results show that the foam-emulsion system with high and stable indicators of foaming ability and stability of foam based on sodium caseinate, which serves as a foaming agent and emulsifier simultaneously receive impossible. Thus for maintain the set of indicators is necessary using of low molecular weight surfactants [10].

Formulated a working hypothesis that requires theoretical and experimental discourse and evidence that the mechanism of formation and stabilization of foam-emulsion systems based on the dry fatty semi finished product , comprising a fatty phase is emulsification of fat phase , followed by foaming , crystallization fat phase after recovery contributing to the stabilization of foams by absorption of fat crystals and their koalistsention the air bubbles and blocked Plateau- Gibbs channels , thereby preventing the drainage of fluid and form a plastic consistency.

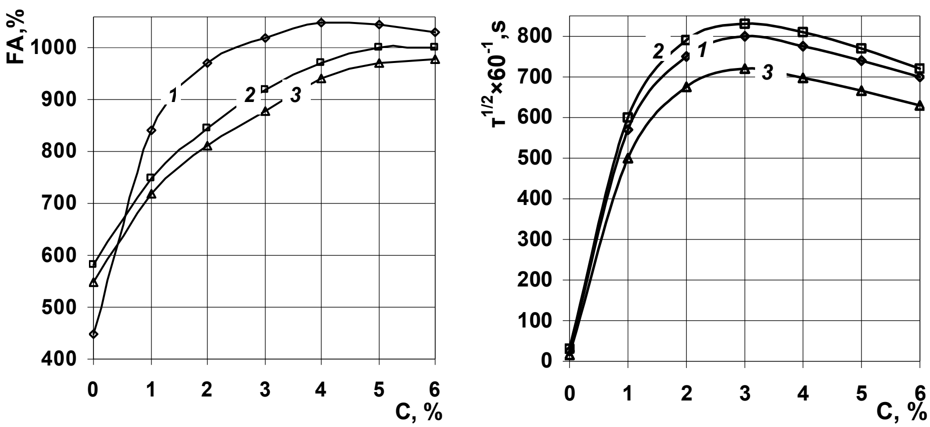
Was predicted that above named processes are achieved by using a mixture of macromolecular semi finished (in our case - sodium caseinate) and surfactants with low molecular weight , on the one hand, provides high indicators FA and HLF, and, on the other - crystallization of the fat phase of partial desorption of proteins from interfacial surface water-oil.

To substantiate form and concentration of low molecular weight surfactants to stabilize foam-emulsion products defined patterns of foaming «sodium caseinate-surfactants». The choice of surfactants based on securing the flow of processes allows obtaining stable over time foam-emulsion system. During the pilot study were used ionic, nonionic, amphoteric surfactants of different value of hydrophilic-lipophilic largest balance (HLB) (Table 1). Of all the surfactants which was used GRAS status (used without restrictions) having all except E481 and E473: their maximum permitted level shall not exceed 5 g/kg of finished product [11]. Given the properties of surfactants with low molecular weight (Table 1), the scientific interest is the use of E481 and E473 based on the high value of HLB and the ability to foaming.

In view of the aforecited was researched FA and HLF of systems «sodium caseinate-surfactants» (Figure 2-6). It was established that under the same concentrations of surfactants in systems «sodium caseinate-surfactants» foaming process is different.

Analysis of the data obtained suggests that the dependence of the FA and HLF are worn not linear character. With increasing concentration surfactants E471 (3g I/100g) at concentrations of sodium caseinate in the system of 0.5%, 1.0% and 2.0% of FA increases and reaches a maximum value for the concentration of sodium caseinate, 0.5% surfactants E471 – 3,5...4,5% constitutes 1050 ±1%. The biggest HLF system characterized protein concentration of 0.5 ... 1.0% and surfactants E471 (3g I/100g) 2.5...3.5%, which HLF is (720...830)×60^{-1}s. Extreme character of dependence systems "sodium caseinate-E471" is probably related to the fact that the protein begins to be associated with micelles surfactants in the aqueous phase and desorbed from the interfacial surface. This leads to a lack of a surfactant at the interface water-air to provide strength interfacial adsorption layers needed to stabilize foamy tapes.

By using surfactants E471 (80g I/100g) as opposed to SAS E471 (3g I/100g) with increasing concentrations FA and HLF are reduced. You can ascertain that surfactants E471 (80g I/100g) acts antifoam (Fig. 3) and is unable to stabilize spumy system.



a *b*

Fig. 2. Dependence of the FA (a) and HLF (b) systems "sodium caseinate - E471» from the content E471 (83g I/100g) sodium caseinate concentration, %:
1(◊) - 0,5; 2(□) - 1,0; 3(Δ) - 1,5

In systems «sodium caseinate-E481» with increasing concentration of sodium caseinate foaming capacity increases and reaches maximum values for the content of sodium caseinate 1.5% and 0.5% and the E481 800 ± 1%. The maximum concentration of surfactant E481 due to the requirements of maximum allowable concentrations [8], according to which the content of the surfactant in the dessert products are limited (Fig. 4).

In systems «sodiumcaseinate-E473» with increasing concentration of SAS E473 FA and HLF increased and reach maximum values of FA that is 620 ±1% by E473 content of 0.5% and 1.0% of sodium caseinate. The maximum value of the HLF system is characterized by the content of sodium caseinate 1.5% and 0.5% of E473 is (340±1)×60^{-1}s. The maximum concentration of surfactants E473 requirements stipulated maximum permissible concentrations [8], according to which the content of the surfactant in dessert products limited (Fig. 5).

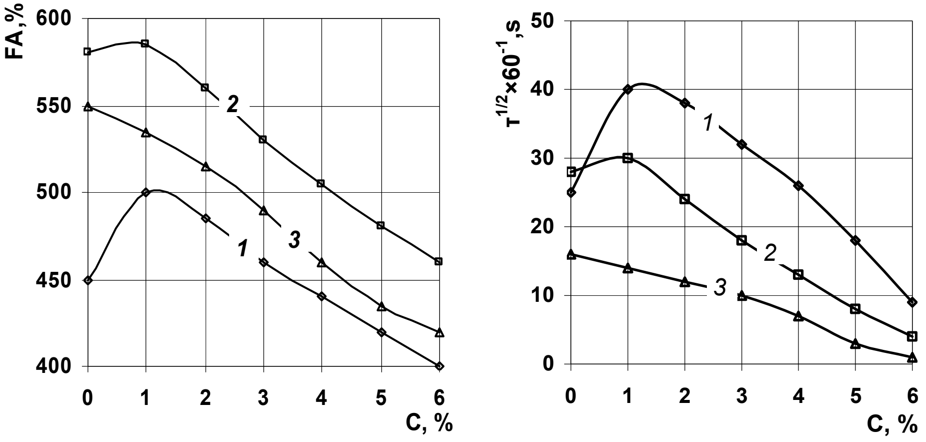


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Fig. 3. Dependence FA (a) and HLF (b) of systems «sodium caseinate - E471» content -E471 (80g I/100g) at concentrations of sodium caseinate, %:
◊ - 0,5; □ - 1,0; Δ - 1,5

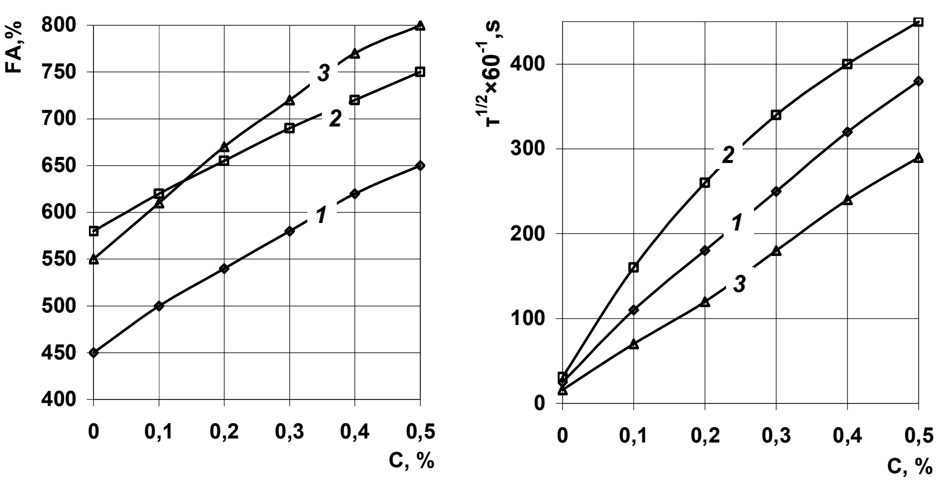

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Fig. 4. Dependence of the FA (a) and HLF (b) of system «sodium caseinate-E481» for the content of E481 sodium caseinate concentration,%:
◊ - 0,5; □ - 1,0; Δ - 1,5

Analyzing the data presented in Fig. 1 found that the increase in the content of sodium caseinate and surfactants E472a improves FA; under certain conditions HLF increases and reaches maximum values of 750 ±1%, 900 ±1% and 900 ±1% for the concentration of protein in the system of 0.5%, 1.0% and 2.0% respectively and surfactants E472e 4...5% (Fig. 6).

Systems «sodium caseinate-E322» is not able to churning. Perhaps SAS E322 leads to extrusion of protein from interphase water-air that E322 serves defoamers.

Based on the data obtained by foaming ability of «sodium caseinate-surfactants» surfactants can be arranged in series: E481 > E471 (3g I/100п) > E472e > E473 > E471 (80g I/100п) > E322, but this does not correlate with the value of HLB and is probably due to the low molecular weight surfactant packing parameters in the interfacial layers. That surfactants occupy different space, which in turn is likely to determine the conditions of compatible adsorption with sodium caseinate.

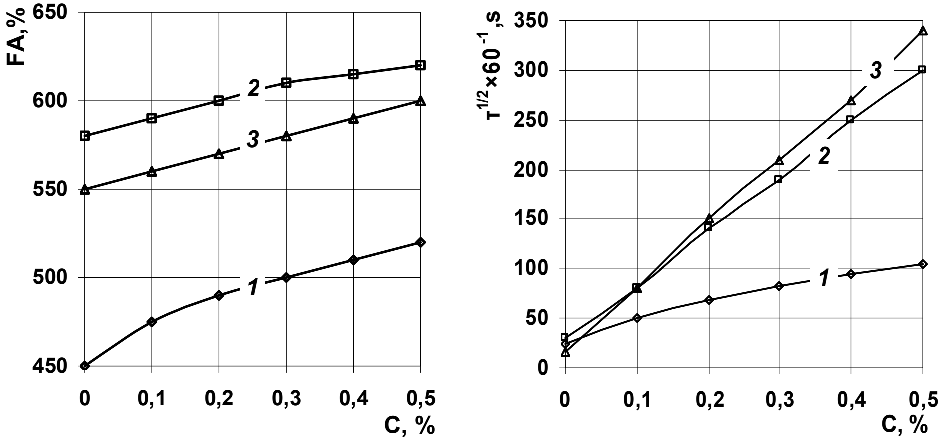

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Fig. 5 - Dependence of the FA (a) and HLF (b) of system «sodium caseinate-E473» for the content of E473 sodium caseinate concentration,%:
1(◊) - 0,5; 2(□) - 1,0; 3(Δ) - 1,5

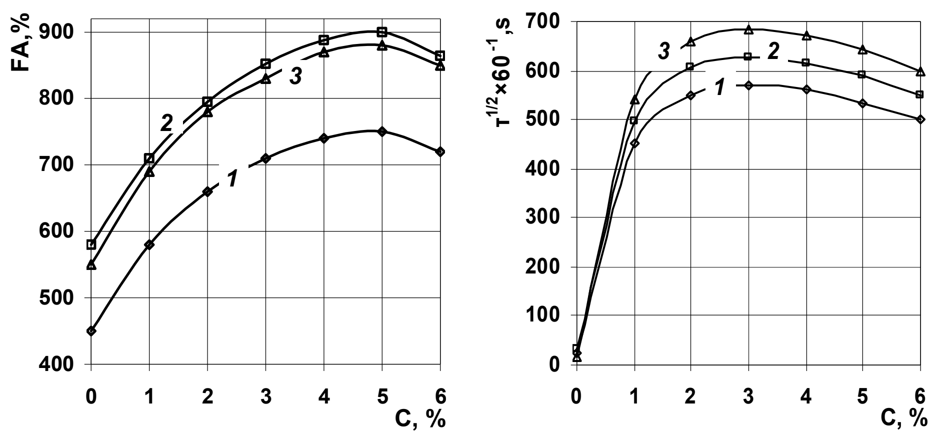

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Fig. 6 - Dependence of the FA (a) and HLF (b) of system «sodium caseinate-E472a» for the content of E472a sodium caseinate concentration,%:
1(◊) - 0,5; 2(□) - 1,0; 3(Δ) - 1,5

Determined that the most rational use of SAS E471 (3g I/100g) at concentrations of 3,0...4,0% and sodium caseinate 0,5...1,0%, which has advantages to other SAS in magnitude of FA and HLF besides E471 has the status of GRAS.

Based on the fact that a part of semi-finished product is supposed to use sunflower oil, it is necessary to determine the patterns of FA and SF of systems «sodium caseinate-surfactants - oil» in order to establish reasonable concentrations of the three-component system (Fig. 7).

It was established that the dependence of foaming ability of system «sodium caseinate-E471-oil» (Fig. 7a) is extreme in nature with a maximum at a concentration of sodium caseinate 0.5% and SAS E471 is 2.5...3.5% oil content is 7.5% (650±1%). Comparing the findings with the research FA and HLF systems «sodium caseinate-oil» shows that using of E471 can significantly improve the stability of foams in the presence of oil. The stability of foams (Fig. 7b) with increasing concentrations of E471 increases, however, with increasing oil content SF decreases.

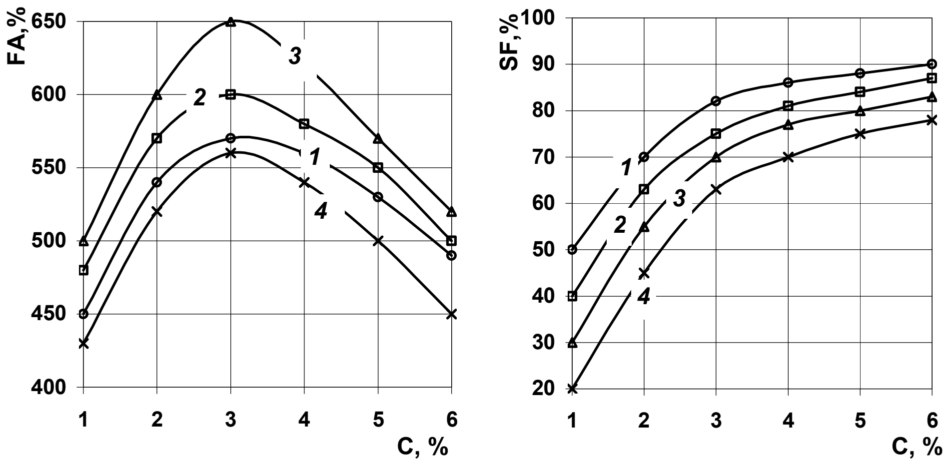

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Fig. 7. Dependence FA (a) and SF (b) of systems "sodium caseinate - E471 – oil" content -E471 (3g I/100g) for oil content:
1(○) - 2,5; 2(□) - 5,0; 3(Δ) - 7,5; 4(×) - 10, 0

So systems which containing surfactants E471 have most foaming ability – 2.5...3.5% oil 8…7% sodium caseinate – 0.5%. Using E471 (3g I/100g) in these concentrations provides foaming, emulsification and crystallization of fat, which helps stabilize the foam is probably due to the absorption of fat crystals in air bubbles and blocked Plato-Gibbs channels, thereby preventing the drainage of fluid.

In order to increase the stability and plasticity of foam-emulsion systems additionally introduced E322 (Fig. 8). Based on the working hypothesis and previous research FA of systems «sodium caseinate-E322» surfactants E322 provides desorption of protein from the interfacial surface. However, please note that the E322 should ensure desorption of protein with only from interphase water-oil because its concentration should be negligible. In this case, the use of SAS E322 will provide coalescence of fat phase on the air bubbles, resulting in increased stability and plasticity of foam and simultaneously high foaming ability.

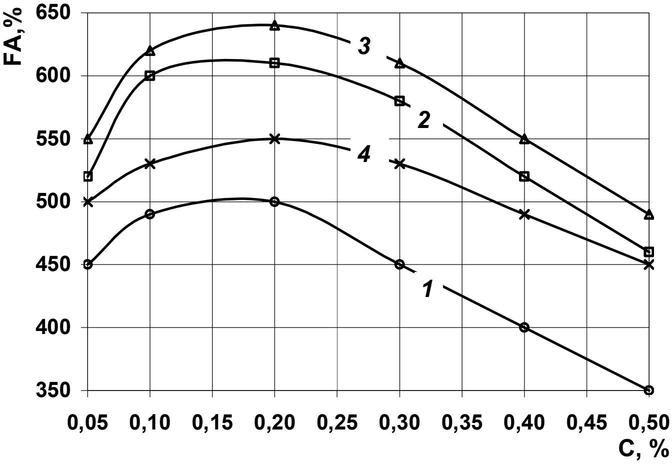

Fig. 8. Dependence FA (a) of systems «sodium caseinate-E471-E322-oil» content – E322 for oil content:
1(○) - 2,5; 2(□) - 5,0; 3(Δ) - 7,5; 4(×) - 10,0

In the systems which were research the content of SAS E471 (3g I/100g) is constant and is 3.0%.

Was established that dependence FA from the content E322 systems «sodium caseinate-E471-E322-oil» wear nonlinear character. Determined that the most foaming ability (640±1%) have a systems which containing oil 7.5% by content surfactants E322 – 0.2%. With increasing protein concentration FA is decreases. This behavior can be explained by competitive adsorption of surfactants and proteins in the system. Despite the fact that FA of systems using two surfactants (E471 and E322) is lower than using one – E471, this system is characterized by a 100% resistance during 24×60^2s.

Conclusions

1. Given the latest trends of food market Ukraine was proved expediency of developing dry lipid semi finished product for the production of food products with foam-emulsion structure and use of a fundamentally new method for producing dry and fat semi-finished from sunflower oil by spraying of fat mixture in powdered filler.
2. Experimentally confirmed working hypothesis which is the formation and stabilization of foam-emulsion systems is achieved by using a mixture of of sodium caseinate and surfactants with low molecular weight on the one hand, provides high indicators of FA and SF, and the other – the crystallization of the fat phase partial by desorption of proteins from interphase water-oil.
3. Determined that the introduction of sunflower oil in the system reduces foaming ability and foam stability at all concentrations of sodium caseinate in the system and leads to the destruction of the foam, which determines the need for the introduction of surfactants.
4. Investigated Influence of six surfactants with different HLB on foaming ability and stability of foams in systems «sodium caseinate-surfactants». Established that the use of surfactants can improve the foaming ability and stability of foams in system

"sodium caseinate-surfactants» and placed in in a series of descending of FA: E481 > E471 (3g I/100g) > E472e > E473 > E471 (80g I/100g) systems «sodium caseinate-E322» are unable to foaming.

5. Experimentally proved that the most rational use of SAS E471 (3g I/100g) at concentrations of 3,0... 4,0% and the content of sodium caseinate 0,5...1,0%, which has advantages compared with other surfactants. SAS E471 provides crystallisation of fat phase, increases foaming ability and stability of foams in the presence of oil.
6. To ensure 100% foam stability of emulsion systems during 24×60^2s proven the expediency of using a mixture of surfactants – E471 and E322. With the simultaneous use of E471 and E322 achieving by crystallization of a fatty phase, desorption of protein from interphase water-oil to form a product with spumy plastic consistency.
7. Substantiated content of main prescription components in fat dry semi-finished that must be provided in an aquatic environment after recovery dry and fat semi-finished products, such as: sodium caseinate – 0.5%, oil 7...8%, SAS E471 – 2,5…3,5%, surfactants -E322 – 0,15…0,25%.

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