FOOD SCIENCE AND FOOD TECHNOLOGY
RECEIVED 09.08.2014 ACCEPTED 10.09.2014 PUBLISHED 15.09.2014
DOI: 10.15550/ASJ.2014.10.037

THE STUDY OF SURFACE-ACTIVE AGENTS' IMPACT ON THE STRENGTH OF INTERFACIAL ADSORPTION LAYERS

O. Kotlyar, A. Goralchuk, O. Grinchenko

Kharkiv State University of Food Technology and Trade,
333, Klochkivska Str., Kharkiv 61051 Ukraine
ovkot@mail.ru

Abstract. The analytical study determined that the production technology of dry fats for food having foam and emulsion structure is to develop towards new approach allowing their absorption by spraying a fat mixture and transforming it into powdered filler. To justify the technology of obtaining dry fats for foamed desserts manufactures with the use of surfactants, we need to determine the rational contents of the main ingredients.

The purpose of these studies is to examine the influence of sodium caseinate and surfactants on the process of the interfacial adsorption layers formation. We found how surfactants impact interfacial adsorption layers and marginal interfacial shear strength on the edge of the oil and air. It allows the study of processes occurring during recovery of dry fats and foam and emulsion system.

We studies the impact of the sodium caseinate and surfactants on the marginal interfacial shear strength being on the edge of the oil and air at the temperature t = 20 ± 1 and 60 ± 1ºC. It has been found that the use of surfactants E471 provides systems with high interfacial shear strength on the edge of the oil and air at all analyzed The application of surfactants E322 provides a system with high interfacial shear strength on the edge of the oil at both high and low temperatures, which allows us to obtain a stable emulsion in the first stage of the restoration of dry fat.

Note that in case of properly selected surfactant mixture, while weakening interfacial adsorption layers at the water/oil interface, interfacial shear strength of adsorption layers at the water/air interface increases.
Keywords: dry fat, foam structure, emulsion structure, absorption, powdered filler, ingredient, food.

Introduction

Of late, the production volume for the dessert culinary products increases due to the introduction of the resource-saving technology. Because of the deficit of nutrients, we confront the need of developing recipes of dessert products with variable combinations of components. Among the wide range of food products, desserts are intensively demanded due to high nutritional value, organoleptic characteristics, recipes and possible combinations of components for their production.

The group of products having foam structure is highly demanded too. However, companies do not meet the consumer demand for these products. To provide consumers with products of foam structure, we should develop technologies for production of semi-finished products by restaurants.

The modern confectionery industry has accumulated rich experience in the use of mixtures for performing various technological functions, which would ensure a stable production process without technological problems and reduce the likelihood of uncontrolled changes in the product.

Therefore, manufacturing dry fat for the food products of foam structure is a topical point because it will reduce production time and capacity, ensure the quality and safety of finished products and create a wide range of desserts and types of pastry to meet the demand of consumers by implementing business processes of B2B and B2C.

The traditional method of making dry fat-containing mixtures is limited with significant energy costs of the production of semi-finished products while spray-like drying the pre-condensed emulsion product. The scientists of Kharkiv State University of Food and Trade proposed a fundamentally new method for producing dry fat (hereinafter - unfinished) by spraying a mixture of sunflower oil fat and transforming it into powder filler. This approach can reduce the energy consumption for the production of semi-finished products and provide high quality of foamed products made of them.

The new method for producing semi-finished products requires scientific substantiation of the recipe composition (type and concentration of surfactants and production parameters (temperature and duration of recovery, whipping, storage, etc.), for which it will meet the following requirements:

– It is expected to be dry mixture with constant organoleptic, physical and chemical and microbiological parameters for a specified period of storage;

– It should be renewed by mixing with drinking water and stirring until dissolved ingredients followed by the formation of the foam and emulsion system through its mechanical dispersion;

– The restored semi-finished product must have high foaming ability and stability of foam that will ensure its use in technology of dessert and decorating products;

– Foam and emulsion systems based on whipped semi-finished products should be technologically compatible with food ingredients and fruits, chocolate and other fillers to create a wide range of culinary and confectionery.

The resulting dry fat is mixed with water at the ratio of 1: 3 at 60 ° C and whipped towards 9 ... 10 times volume increase. While whipping, the system is cooled to 20 ° C to form stable, plastic foam. Previously, we found the type and content of basic rational prescription components, namely sunflower oil, sodium caseinate, E471 (GMS), E322 (soy lecithin), kappa-carrageenan. The sugar content (filler) was determined by subtracting the sum of all components.

Local and foreign scientists noted that one of the factors stabilizing emulsions and foams is a structural and mechanical factor introduced by P. Rebinder, which is achieved by increasing the strength of interfacial adsorption layers preventing disperse systems from destruction through the use of high-surface-active substances (proteins). However, foam and emulsion systems require the strength of interfacial adsorption layers to be regulated, which would provide formation and stabilization of emulsions with strong layers, inversion of emulsion phases, systems' foaming and adhesion of fat crystals at the water / air interface with the formation of plastic consistency. Providing these processes is not possible without the use of low molecular surfactants along with proteins. The use of surfactants allows for the above described processes and combining two stabilizing mechanisms: structural and mechanical and Marangoni-Gibbs effects.

Since each group of surfactants has a unique level of pH, ionic strength of solutions, temperature, properties of the dispersed phase, the ratio of surfactants which allow them to demonstrate surface-active properties in the most effective way, it is necessary to determine their behavior at the interface by finding the mechanical strength of interfacial adsorption layers to help identify the processes behind obtaining foam and emulsion products based on dry fats.

By studying phenomena at the liquid interface allows us to substantiate the parameters of stable foam and emulsion systems and the role of various surfactants. Achieving equilibrium values of adsorption leads to the formation of interfacial adsorption layers characterized by specific structural and mechanical properties.

The interfacial structure formation is objectively determined by the marginal interfacial shear strength, as the measure for interfacial adsorption layers.

Method

In order to study the impact of sodium caseinate and surfactants on the interfacial adsorption layers, we found the impact of surfactants on the marginal interfacial shear strength at the oil / air interface at the temperature t = 20 ± 1 and 60 ± 1ºC. It implies studying the processes that occur during recovery of dry fats and formation of the foam and emulsion system. Shear strength of interfacial adsorption layers was determined in 3600 s, which ensures diffusion of proteins and the formation of adsorption layers.

Interfacial shear strength of adsorption layers was determined by means of the device we specially constructed in accordance to the principle of the device by P. Rebinder and A. Trapeznikov (Fig. 1).

The interfacial shear strength of adsorption layers (P_s) was found through:

$$P_s = \frac{C_0 \cdot S_0}{360^0 \cdot R_0^2 \cdot n}$$

where P_s – marginal interfacial shear strength, Н/м;

C_0 – module of wire rotating, (Н×m)/grad;

S_0 – deviation of the photocell of the self-writing device until the maximum glass disc shift, m;

R_0 – radius of glass disc, m;

n – the ratio of transforming rotating degrees in the meters of scale.

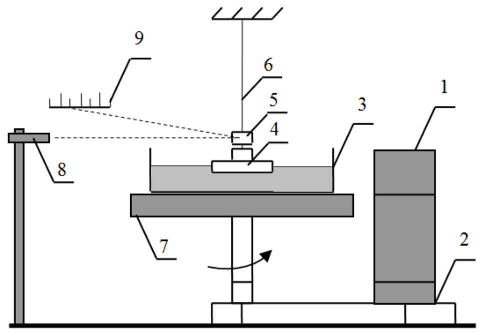


Fig.1 Schematic diagram of surface viscometer: 1 - electric motor; 2 – reduction element; 3 – crystalizing mold; 4 - glass disc; 5 - mirror; 6 – elastic nichrome wire; 7 - rotating table; 8 - laser; 9 - photocell of the self-writing device

To investigate the interfacial shear strength of adsorption layers in the foam and emulsion systems, we proposed a method of examining layers at the water / air and water / oil interfaces. The method implies the use of two connected with the pipe crystalizing molds being poured with the solution of protein; and the surface of one of the crystallizing mold is injected with oil. The system is maintained 3600 s. Then, we determined interfacial shear strength of adsorption layers at the water / air interface. Thus, we simulated foaming process while emulsification.

Results

The influence of sodium caseinate on the interfacial shear strength of adsorption layers at the oil / air interface and at temperature t = 20 ± 1 and 60 ± 1ºC is shown on the Figures 2-3. The strength at the oil interface increases with increasing content of sodium caseinate under isothermal conditions. With decreasing temperature from 60 to 20 ° C, the strength also increases. The strength at the air interface cannot be found by means of our laboratory equipment because of the low Ps due to the low average molecular weight of sodium caseinate, which is 2 kDa [9]. In addition, the strength at the water / oil interface is 10 times greater than at the water / air interface. The results are confirmed by the low resistance of foam based on sodium caseinate in the specified concentration range, which is (15 ... 28) × 60 s. The content of the sodium caseinate in the prescription of recovered fat semi-finished product is 0.5%. Therefore, further studies of “sodium caseinate-surfactant” mixtures were performed with these concentrations.

s

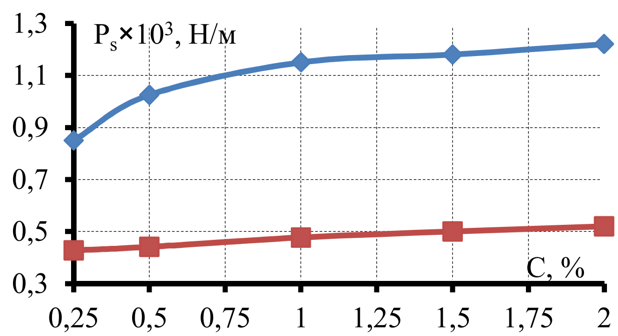


Fig.2 Relationship between interfacial shear strength of interfacial adsorption layers and sodium caseinate concentration at the oil interface at the temperature, °C: ◊ - 20; □ – 60

During the study of the interfacial shear strength of adsorption layers at the oil surface, emulsifiers (E471, E322) were dissolved in the oil; water contained 0.05% sodium caseinate – that is concentration of substances was reduced 10 times during the study of “sodium caseinate-E322”, “sodium caseinate-E471” and “sodium caseinate-E471-E322”. It will provide prescription ratio of components while preserving liquid interfaces of phases. The introduction of E471, E322 provides increases strength of interfacial adsorption layers (Fig. 3, 4).

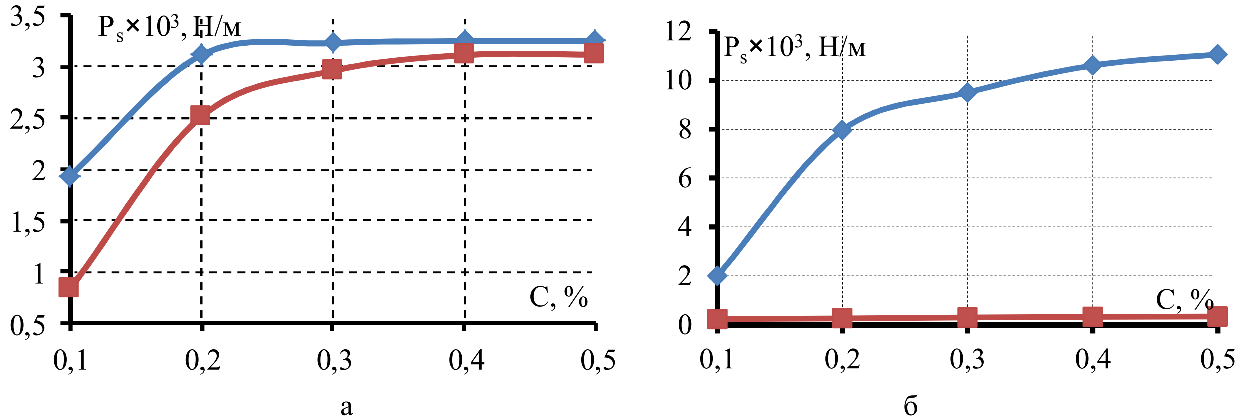


Fig.3 Relationship between interfacial shear strength of interfacial adsorption layers and E 471 concentration in the “sodium caseinate-E471” at the air (a) and oil (b) interfaces at the temperature: ◊ - 20°C; □ – 60°C

The injection of E471 significantly increases the stability of the foam. However, shear strength of adsorption layers at the water / oil interface at 60 ° C shows that the injection of E471 has virtually no effect on the stability of the emulsion. But, with decreasing temperature, this strength in the “sodium caseinate-E471” system at the interface increases 6.7 ... 36.7 times. The shear strength of adsorption layers at the water / air and water / oil interfaces at 60 ° C shows that the strength at the water / air interface is higher 8.3 ... 10.3 times. Therefore, the process of adsorption of proteins and surfactants at the water / air interface is more energetically advantageous and formation of foam at 60 ° C is more rational since 20 ° C cannot provide the foaming process. It is evidenced by the significantly higher strength of layers at the water / oil interface than water / air one. Rational relationship between sodium caseinate and E471 ranges from 1: 4 to 1: 8. In this case, the system has high strength of layers at the air interface with stable systems of “sodium caseinate-E471” during (720 ... 830) × 60 s.

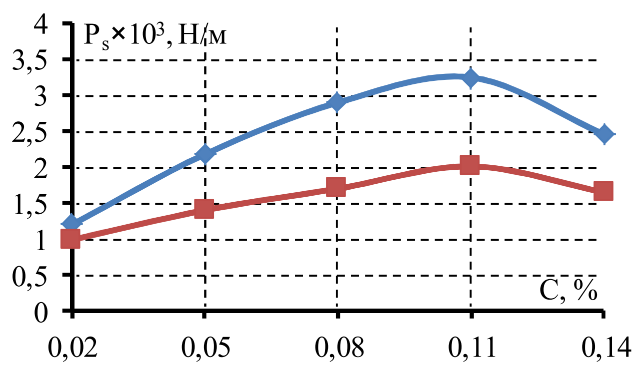
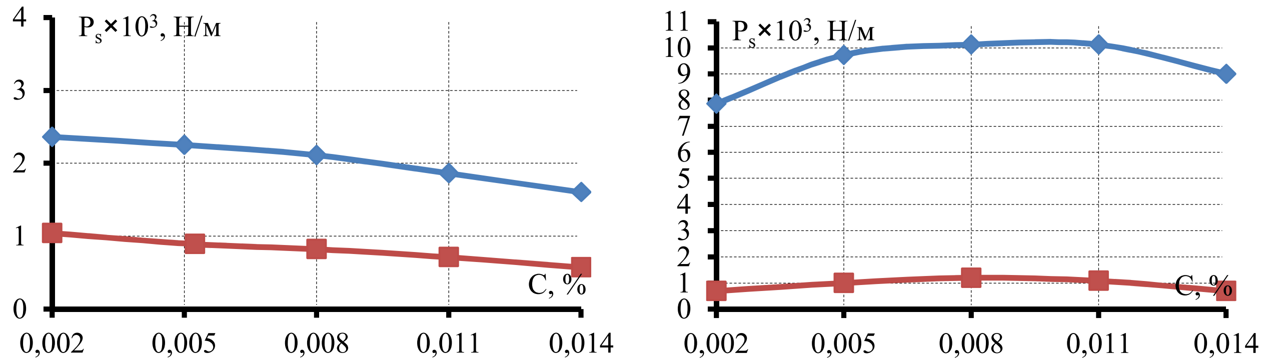


Fig.4 Relationship between interfacial shear strength of interfacial adsorption layers and E 322 concentration in the “sodium caseinate-E322” at the oil interface at the temperature: ◊ - 20°C; □ – 60°C

The strength of adsorption layers dependent on the E 322 concentration at the oil interface at the taken range of temperatures (Fig. 4) is extreme in nature. It is seen that Ps increases with increasing concentration to 0.11% and reaches a value of (3.2 ± 0.2) × 10-3 H / m at 20 ° C and (2.0 ± 0.2) × 10- 3 H / m at 60 ° C.

At the air interface, the strength is virtually absent and cannot be determined. The studies of foaming confirm the absence of foam formation. According to the literature, we found that the injection of surfactant E322 into systems based on skim milk reduces the strength of adsorption layers at the air interface.

In order to make foam and emulsion products based on dry fats have plastic consistency, it is necessary to ensure the partial destruction of the emulsion. Fat crystals adsorbed on air bubbles provide plastic consistency. This will require the use of a mixture of surfactants (E471 and E322) to regulate the interfacial shear strength of interfacial adsorption layers (Fig. 5).



а б

Fig. 5 Relationship between interfacial shear strength of interfacial adsorption layers and E 322 concentration in the "sodium caseinate-E471-E322" at the air (a) and oil (b) interfaces at the temperature: ◊ - 20°C; □ – 60°C

The study of the "sodium caseinate-E471-E322" showed that increasing concentrations of surfactants E322 leads to a 1.5 ... 2 times decrease in the strength of adsorption layers at the air interface compared with a the "sodium caseinate-E471" system, which is probably connected with the desorption of proteins and E471 and in the presence of E322. At the oil interface, injection of the E322 provides 5 times increase at 60 ° C. Probably, the injection of E322 into the prescription mixture will promote better emulsification of fat phase during the recovery of dry fat semi-finished product, which, in turn, increases the stability of the foam. The use of two surfactants provides 100% foam stability for 24 h. Comparing the strength of layers at 60 ° C at the air and oil interfaces shows that they are almost identical. Therefore, this system at this temperature may provide simultaneously two processes - foaming and emulsification. We found that in case of E471 and E322 content, the sunflower oil while being whipped and cooled forms fat crystals, which confirms our assumption.

Discussion

Given the current trends of food market in Ukraine, the production of dry fat semi-finished products of foam and emulsion materials due to fundamentally new approach to obtaining dry fats based on sunflower oil by spraying a mixture of fat in powdered filler is expedient.

Experiments confirmed that the use of surfactants E471 provides a system with high strength of adsorption layers at the air interface at all taken temperatures, ensuring conditions for obtaining foam structures.

The application of surfactants E322 gives a system with high strength at the oil interface at both high and low temperatures, which allows obtaining a stable emulsion in the first stage of the restoration of dry fat semi-finished products.

The range of effective ratios between sodium caseinate and surfactant E471 is from 1: 4 to 1: 8 and the ratio of E322 and E471 is from 1:25 to 1:30 respectively.

Note that for properly selected surfactant mixture along with the weakening of strength of adsorption layers at the water-oil interface increased the strength at the water-air interface and vice versa.

This approach allows us to obtain stable emulsions in the recovery of dry fat semi-finished product in the first stage followed by whipping and cooling. After it, the protein is desorbed with further obtaining stable foam products of high foaming ability and shape stability.

References

MakKenna, B. M.(2008) *Struktura i tekstura pishhevyh produktov. Produkty jemul'sionnoj prirody*. SPb.: Professija.

Izmajlova, V.N. and Rebinder, P.A. (1974) *Strukturoobrazovanie v belkovyh sistemah*. M.: Nauka.

Dickinson, E., Rolfe, S.E. and Dalgleish, D.G. (1990) Surface Shear Viscometry as a Probe of Protein-Protein Interactions in Mixed Milk Protein Films Adsorbed at the Oil-Water Interface. *International Journal of Biological Macromolecules,* №3, pp. 189–194.

Kelley, D., McClements, D.J. (2003) Interactions of bovine serum albumin with ionic surfacatants in aqueous solutions. *Food Hydrocolloids,* №17, pp. 73-85.

Dickinson, E. and Matia Merino, L. (2002) Effect of sugars on the rheological properties of acid caseinate-stabilized emulsion gels. *Food Hydrocolloids,* № 16, pp. 321-331.

Murray, B.S. (2002) Interfacial rheology of food emulsifiers and proteins. *Current Opinion in Colloid &Interface Science*, №5–6, pp. 426–431.

Martin, A.H., Grolle, K., Bos, M.A., Stuart, M.C. and van Vliet T. (2002) Network forming properties of various proteins adsorbed at the air/water interface in relation to foam stability. *Journal of Colloid and Interface Science*, №1, pp. 175–183.

Martin, A.H., Bos, M.A., Stuart, M.C. and van Vliet, T. (2002) Stress-strain curves of adsorbed protein layers at the air/water interface measured with surface shear rheology. *Langmuir,* №4, pp. 1238–1243.