ISSN: 0974-8369

Biology and Medicine

International, Open Access

Available online at: www.biolmedonline.com

Biology and Medicine

Ershova *et al*., Biol Med (Aligarh) 2015, 7:4
http://www.biolmedonline.com

Research Article Open Access

The Investigation of the Rheological Properties of Emulsion Products Based on Vegetable Oil

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Abstract

This report is devoted to the study of the rheological characteristics of a range of dessert creams. Data about the changes in the effective viscosity and shear rate, the effective viscosity of torque, and shear and torque of the emulsion products during storage were discussed. The technology of production of emulsion creams provides a stable emulsion based on vegetable oil. In the manufacturing process of creams, a mixture of refined sunflower and linseed oils was chosen as the fat base. Sodium alginate complex stabilizer was used as a stabilizer. The emulsifier function was performed by dry milk whey, and its emulsifying effect was determined by the contents of lecithin and other phosphatides, as well as membrane-forming lipoproteins. This study was undertaken at the Food Products Laboratory of the School of Biomedicine, Far Eastern Federal University. Traditional methods were applied. The effective viscosity of dessert creams with various stabilizers and fillers differed markedly and increased depending on the duration of storage.

Keywords

Emulsion rheology; Emulsion products; Creams; Stabilizer; Effective viscosity; Torsional moment

Introduction

The growing internationalization of tastes and the consumer demand for healthy food define new requirements for innovation in food products [1-3]. This is especially true for technology products with textured emulsion (cream), which when expressed in terms of health effects must satisfy new ethnic gastronomic tastes and textures [4].

The consumption of these products is not a curative technique for the treatment of diseases, which is typical for health food, but helps to prevent certain diseases and aging in terms of ecological problems [5,6].

The structure of emulsion creams allows us to enrich them with all kinds of functional ingredients, such as dietary fibers, vitamins, minerals, polyunsaturated ω-3 and ω-6 fatty acids, and fat-soluble antioxidants [7-13]. In addition, these creams are versatile products that allow us to reduce our calorie intake by replacing some of the ingredients with ingredients that are lower in calories [14-16].

Modern studies show a steady increase in the production and consumption of low-energy foods with increased biological value [17-22].

The technology of emulsion-type products is designed and scientifically justified with new consumer properties, which are produced by the use of systems consisting of a blend of vegetable oil (30%) and a stabilized aqueous fraction with various stabilizers such as sodium alginate and integrated stabilizer MSC 7146 (a complex polysaccharide obtained from the ground endosperms of *Cyamopsis tetragonolobus*) [23,24].

Based on rheological characteristics, emulsion creams are difficult, finely divided, direct-type stable oil–water emulsion (oil in water) consisting of absolutely uniformly distributed components and formulations [25,26]. Since 1936, which is the period of organization of industrial emulsion product production, the scientific and practical works of scientists such as N.I. Kozina, P.A Rebinder, and D.L. Talmud have contributed to its development [27,28].

The essence of thixotropy action inherent in the emulsion cream is that the links that have been destroyed by mechanical action can be restored as a result of collisions of particles of oil in Brownian motion [29-32]. This progressive restoration of the structure and hence the increase in strength occur during the flow system at a rate less than that which led to the given degree of destruction of the original structure [33,34]. In the transition from one flow mode to another, faster speed which usually causes an additional destruction of the structure reduces its strength and toughness [33-35].

Materials and Methods

The technology of production of emulsion creams provides a stable emulsion based on vegetable oil. When designing fat-based recipes, the fatty acid composition, physicochemical properties, and organoleptic characteristics of various oils are taken into account. In the manufacturing process of creams, a mixture of refined sunflower and linseed oils was chosen as the fat base. Sodium alginate and integrated stabilizer MSC 7146 were used as stabilizers. The emulsifier function was performed by dry milk whey, and its emulsifying effect was determined by the contents of lecithin and other phosphatides, as well as membrane-forming lipoproteins.

The following fillers were selected: pumpkin carrot, pumpkin banana, and apple sauce.

Objects of study were samples of emulsion creams with high organoleptic properties with various fillers and stabilizers: Sample B – with integrated stabilizer MSC 7146 and pumpkin carrot puree; Sample C – with sodium alginate and pumpkin mashed banana; and Sample H – with sodium alginate and apple sauce.

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Received: September 14, 2015; **Accepted:** October 24, 2015; **Published:** Nov 19, 2015

Citation: Ershova TA, Bozhko SD, Chernyshova AN, Situn NV, Pugachenko SA (2015) The Investigation of the Rheological Properties of Emulsion Products Based on Vegetable Oil. Biol Med (Aligarh) 7(4): BM-126-15, 4 pages.

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Thixotropic properties of emulsion creams were examined using a Programmable Brookfield Viscometer DV-II + PRO at 20°C. Samples were taken daily as creams after long-term storage and samples were taken weekly as creams for shelf-life validation.

Based on the readings taken on the Viscometer DV-II + PRO, graphs of changes in the viscosity of low-calorie dessert creams are drawn. The viscosity of the samples of emulsion creams was determined using a Viscometer DV-II + PRO in accordance with the policies and procedures attached to the instrument. When measurements of viscosity below the lower limit are taken into account, the viscosity measurement becomes acceptable if the torque ranges from 10% to 100%; the viscosity measurement should be carried out under conditions of laminar flow. The first limitation relates to the measurement accuracy. The relative accuracy of the viscometer is always ±1% in any combination of the spindle/speed of rotation. A second limitation allows for fluid flow mechanics when all the elements of the fluid move in layers parallel to the direction of shear stress.

The investigation results are processed using the program Microsoft Office Excel 2013.

Results

The effective viscosity of daily storage creams at 20°C varied from 1,500 to 90,000 mPa s and the shear rate of daily storage creams varied from 0.025 to 50 s^{-1}.

These results can be explained by the fact that the structure of creams is defined by the presence of the spatial grid that allows interaction of dispersed particles of fat and water. The strength of the system depends on the binding energies between particles. The the effective viscosity of creams versus the shear rate of creams for a weekly storage period is shown in Figure 1.

As shown in Figure 1, the effective viscosity of the weekly storage creams of different groups at 20°C varied from 1,800 to 513,003 mPa s and the shear rate of the weekly storage creams of different groups varied from 0.025 to 50 s^{-1}.

These results can be explained by the structural formation of the cream with the stabilizer that occurs after the first day of preparation.

Based on the proximity of rheograms, one can note some similarities based on the effective viscosity versus the shear rate of study creams. All of the samples retain the rheological properties with increasing shear rate at 20°C, indicating the the strength of the frame systems with different stabilizers. Analyzing the order of rheograms, creams can be arranged in a series of values of the effective viscosity: pumpkin and carrot, pumpkin and banana, and apple sauce.

The effective viscosity of emulsion creams versus the torsional moment of creams with a week shelf-life is shown in Figure 2.

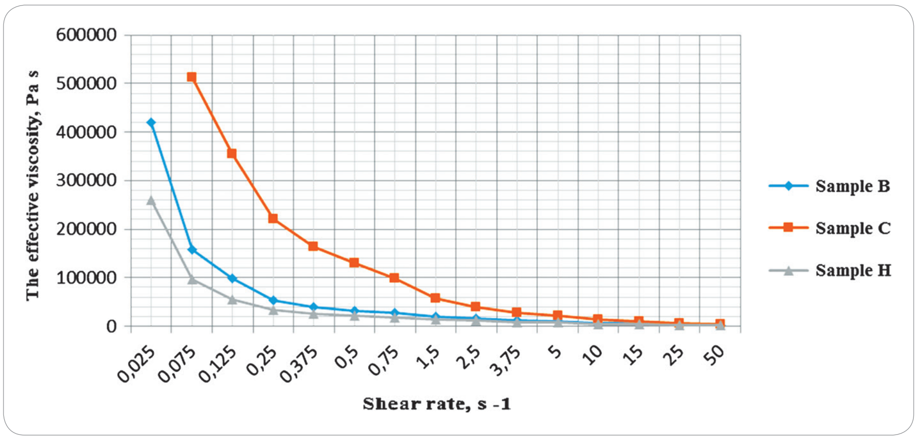

Figure 1: The effective viscosity versus the shear rate of weekly storage creams

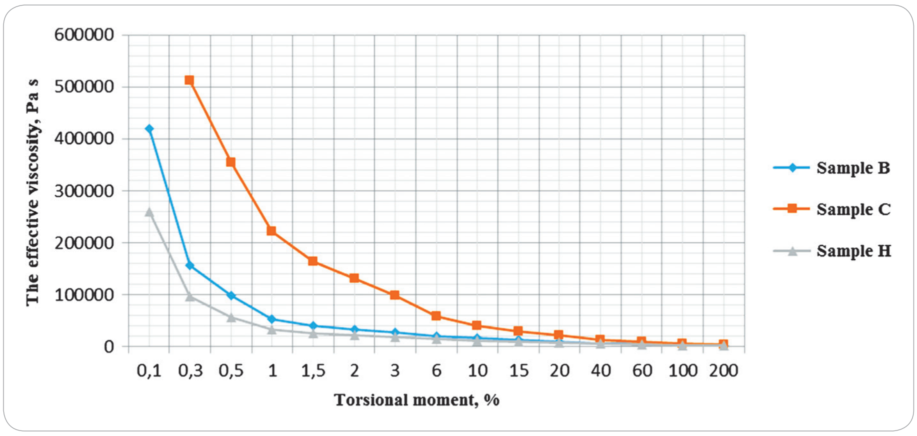

Figure 2: The effective viscosity of creams versus the torsional moment of weekly storage creams

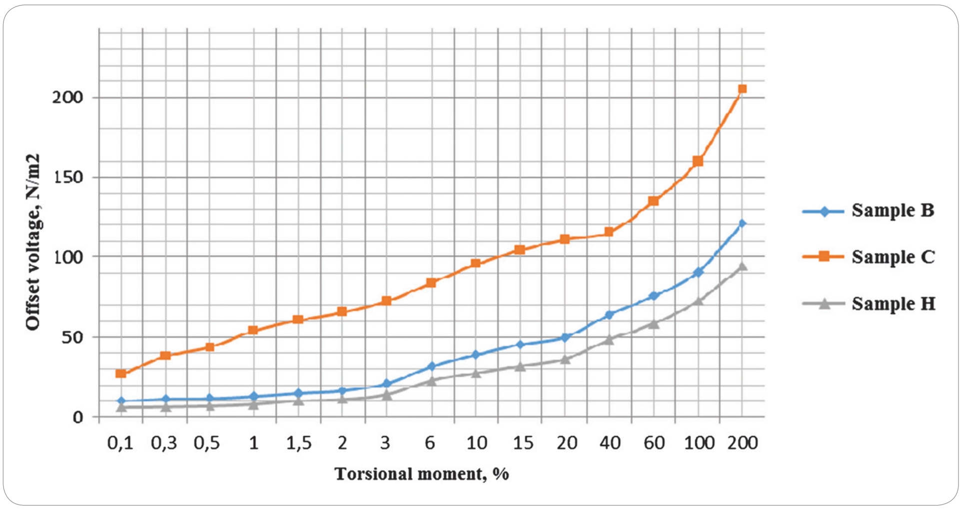

Figure 3: The offset voltage of creams versus the torsional moment of weekly storage creams

Analysis of data showed that the maximum value of the effective viscosity of creams was observed at low torsional moment.

When you change the rate of torsion from 0.3% to 6.0%, the viscosity decreases sharply, and then there is a smooth fall.

When comparing the daily and weekly charts of storage, there is a significant change in viscosity. For a more complete picture of the rheological properties of creams studied, the offset voltage of creams versus the torsional moment of creams with a week shelf-life is shown in Figure 3.

As shown in Figure 3, the offset voltage gradually increases with the increase of torsional moment; for a cream with a week shelf-life, the offset voltage appears to have doubled. High numerical values of shear stresses indicate heavily structured creams.

Conclusion

The experiment investigated the rheological properties of a range of dessert creams based on vegetable oils. The effective viscosity of dessert creams with various stabilizers and fillers differed markedly and increased depending on the duration of storage. The data presented in the study of the rheological characteristics of dessert creams should be used in the calculations of the process equipment, which also let us expand the use of dessert creams in the production of food products when exposed to different temperature regimes.

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