

Study of the consistency of defrosted aerated fermented milk desserts by rheological methods

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Abstract. The aim of the research was to quantify the consistency of defrosted aerated fermented milk desserts. The objects of research were samples of desserts with a mass fraction of fat of 2.5%, in one of the samples whey protein concentrate was used (WPC). Rotational viscometry, penetrometric and thermostatic methods were used. It has been established that the use of WPC allows increasing dynamic viscosity by 4.5 times, mixture overrun by 1.4 times, dimensional stability (less shrinkage degree) by 1.26 times, adhesion by 1.65 times and stickiness by 1.93 times. Also, the hardness decreases by 1.6 times and the elastic modulus by 1.65 times. The results obtained are of practical importance in substantiating the composition, parameters of the production process and the sale of defrosted aerated fermented milk desserts.

1 Introduction

The increase in demand for fermented milk products in recent years is due not only to its benefits for the human body, but also to high organoleptic characteristics [1]. This fully applies to defrosted fermented milk desserts produced using the ice cream technology. The special organoleptic properties of desserts after defrosting are characterized by the consistency – airy and foamy, typical of mousses. Depending on the components used, the consistency may vary. In this regard, it is important to evaluate it by objective methods.

Defrosted fermented milk dessert is a structured product, the strength of the structure of which largely determines the state of the air phase. The inclusion of components that have a significant impact on the state of the air phase can significantly affect the consistency of the entire product. The whey protein concentrate (WPC) may be referred to such components. WPC is obtained from a by-product of cheese production. In the production of ice cream, it is used to improve the quality of the finished product [2]. WPC binds moisture and thereby increases the viscosity of the mixture, affects the surface of the air and fat phases, participates in the partial destabilization and agglomeration of fat particles, and also affects the formation of the consistency and structure of frozen desserts [3].

Rheological research methods are used to quantify the state of consistency. They are widely used in assessing the quality indicators of yogurt [4, 5], ice cream [6, 7], curds [8], ricotta cheese [9], sauces [10], chocolate [11], stabilizers - gelling agents [12], etc. Rheological methods are based on the study of the behavior of objects of research, including food products, under conditions of applied stress or deformation that affect the flow properties. Rheological properties are essential for evaluating product quality as they

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change during mechanical and thermal processing [13]. Rheological indicators also affect the organoleptic perception of food products, therefore, when assessing their texture, the taste and consistency of the product are evaluated. For an objective assessment of the consistency, methods of rotational viscometry and penetrometry are used. Viscometry makes it possible to evaluate the rheological properties of the mixture during the manufacturing and maturation process and when using various components. Penetrometric methods make it possible to evaluate the important components of the texture profile: hardness, stickiness, adhesive strength, etc. Despite the fact that due to the complex structure of the dessert, it is difficult to conduct penetrometric studies, the data obtained allow to evaluate the consistency and structure of these products [14].

Thus, the purpose of this work was to study the consistency of fermented dessert by objective (rheological) methods and to evaluate the effect of WPC, as a component that influences the formation of the air phase, on the consistency of defrosted fermented aerated dessert.

2 Materials and Methods

2.1 Objects of research

Samples of fermented aerated defrosted desserts, the characteristics of which are presented in the Table 1, were the objects of research.

Table 1. Characteristics of the dessert samples under study

Name of components	Sample ^a	
	№ 1 (%)	№ 2 (%)
Milk fat	2,5	2,5
DDMR ^b	11,0	11,0
Sugars	10,0	10,0
Composition of gelling agent and emulsifier	1,3	1,3
WPC	-	3,0
Dietary fiber and starch products	8,0	8,0
^a № 1 – sample without WPC, № 2 – sample with WPC		
^b DDMR – dry defatted milk residue		

2.2 Methods of research

The dynamic viscosity of mixtures for fermented structured desserts was determined in line with [15]. Consistency and flow indices were determined according to the Herschel–Bulkley equation {1}.

$$\tau = \tau^{\circ} + k \times D^n \quad \{1\}$$

where τ – shear stress, Pa;
 D – shear rate, s^{-1} ;
 k – consistency index;
 n – flow index;
 τ° – yield stress, Pa.

Dessert overrun (Ov, %) was calculated by the formula {2} according to [15].

$$Ov, \% = \frac{M_2 - M_3}{M_3 - M_1} \times 100 \quad \{2\}$$

where M_2 – mass of a glass filled with dessert mixture, g;

M_3 – mass of a glass filled with dessert, g;

M_1 – glass weight, g;

100 – percentage conversion factor, %.

The dimensional stability of the samples was determined visually and by the degree of shrinkage. To determine the latter, a cylinder was cut out from the dessert sample, which was then thermostated at a temperature of 4 °C. The height of the cylinder was measured before and during thermostating, after which the shrinkage (%) of the samples was calculated.

Texture indicators were determined on a LFRA Texture Analyzer BrookField. A TA10 sensor with a cylinder diameter of 12.7 mm was used. The prepared sample was placed on the instrument table, after which the measurement program was switched on. Measurements were carried out at a temperature of +4 °C, in 10 repetitions, after 4 hours of defrosting. The hardness, adhesion, stickiness and elasticity of the samples were determined.

The results were processed in the program Past 4.03. One-way analysis of variance was used (one-way ANOVA) (=95%).

3 Results and discussion

It has been established that the use of WPC allows increasing dynamic viscosity by 4.5 times and, in conditions without regulated air supply to the freezer, mixture overrun by 1.4 times (Figure 1). The increase in the viscosity of the mixture is due to the increased water-holding capacity of the WPC due to the formation of a network structure and the retention of moisture in it. The increase in overrun when using WPC is probably due to the high foaming ability of proteins [16, 17], the increase of which is also affected by the process of pasteurization of the mixture [18].

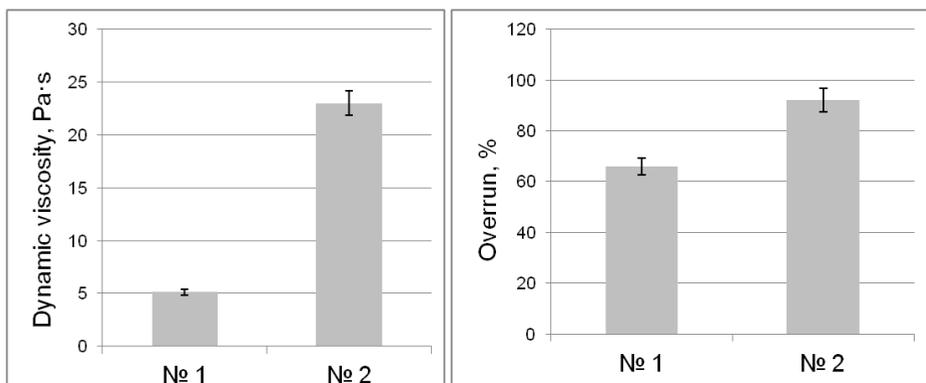


Fig. 1. Indicators of the dynamic viscosity of the mixture and overrun of dessert samples:
№ 1 – without WPC; № 2 – with WPC

In addition, in samples of mixtures for desserts, the values of the consistency and flow indices (Table 2) were established, which also indicate a positive effect of the WPC on their rheological properties. With the additional introduction of WPC into the product, an increase in these indicators was noted.

Table 2. Rheological characteristics of the mixture

Indicator	Sample № 1	Sample № 2
Consistency index	681	1166
Flow index	0,66	0,72

It was found that the shape of dessert samples in a defrosted state did not undergo noticeable changes during 4 hours of keeping at a temperature of 4 ± 2 °C (Figure 2). However, when quantifying dimensional stability in dessert sample № 2, despite the higher overrun (lower density), portion shrinkage occurred to a lesser extent (Table 3). The degree of shrinkage of sample № 2 after 48 hours of exposure was 1.26 times less.

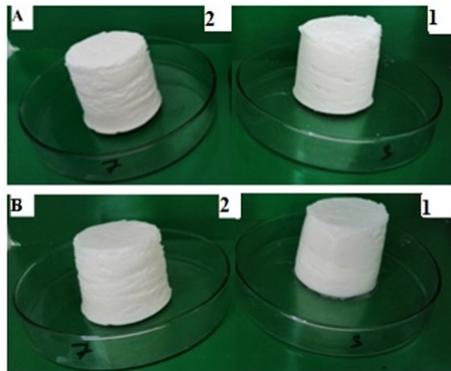


Fig. 2. Dessert samples: A – before thermostating; B – after 4 hours of thermostating, № 1 – without WPC; № 2 – with WPC

Table 3. Degree of shrinkage of dessert samples

Time of exposure, hours	Degree of shrinkage, %	
	Sample № 1	Sample № 2
0	0	0
4	20	16
24	24	19
48	24	19

When conducting penetrometric studies, it was found that in sample № 2, in comparison with sample № 1, hardness and elastic modulus are 1.6 times lower, adhesion is 1.65 times higher and stickiness is 1.93 times higher, which indicates a softer structure of the product, typical of mousses (Table 4).

Table 4. Dessert structure penetrometric indicators

Parameter	Sample № 1	Sample № 2
Hardness, g	95,6±14,3	59,0±12,6
Adhesion, g	-24,4±4,5	-14,4±2,9
Stickiness, gs	-34,7±14,1	-17,9±5,6
Elastic modulus, g/s	9,9±2,1	6,1±1,5
Recovered deformation, mm	2,5±0,4	2,3±0,4

The results obtained are quite natural. The hardness of a dessert is an indicator of the strength of its structure when exposed to a load (with external pressure) [19]. A significant change in hardness was established when adding WPC ($P < 0.05$). The hardness of an aerated dessert, like ice cream, is influenced by the total solids content, overrun, amount and type of stabilizer [20]. Considering the composition of the desserts, it is obvious that overrun has the greatest impact on this indicator.

The “stickiness” indicator is felt when eating dessert, when it is sandwiched between the teeth. The introduction of WPC led to a significant ($P < 0.05$) increase in this indicator.

Adhesion is the interfacial connection of the surfaces of two different bodies [21]. When studying this indicator, significant ($P < 0.05$) differences between the samples were established. The introduction of WPC led to an increase of adhesion.

Elastic modulus is defined as the ratio of stress to strain within the range of elasticity [22]. Significant differences ($P < 0.05$) in the elastic modulus between the samples were found. The introduction of protein reduces this indicator. This can be explained by the lower density (high overrun) of the dessert.

Recovery after stress characterizes the elasticity of the product. Defrosted dessert recovers about 50 % of its shape after the applied force by the sensor. There was no significant effect of WPC on this indicator ($P > 0.05$).

4 Conclusions

As a result of research on the example of 2 samples of defrosted fermented milk desserts (one of them with WPC), the possibility of quantifying their consistency was shown. It has been established that the use of WPC leads to an increase in the dynamic viscosity of the mixture, its ability to saturate with air and form stability. Dessert overrun (lower density) in a sample with WPC compared to a sample without its use contributes to a decrease in hardness and elastic modulus, an increase in adhesion and stickiness, which indicates a softer product structure, typical of mousses.

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