The evaluation of structural-mechanical properties of the functional fermented milk product

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Abstract. In the conditions of high competition on the market of food products producers have to carry out a search for new kinds of raw materials in order to diversify the assortment of produced products. Adding raw materials and ingredients of different origin of the composition of dairy products irrevocably leads to the change of quality parameters. One of such parameters is consistence. To control the consistence, it is necessary to check it organoleptically and study the structural-mechanical properties of the product under development. In the work, consistence of the samples of a newly developed fundamental fermented dairy product with wheat brans was studied by an organoleptic method and a method of rotational viscometry. The necessity of the conducted studies is conditioned by the fact that using only organoleptic method for the evaluation of the consistence is not always objective as it depends on the skills and qualifications of a specialist who carries out a study. The appliance of the method of rotational viscometry allows describing a model of body flow mathematically, defining effective viscosity and other characteristics. Rheological characteristic were identified with the help of the rotation viscometer Rheotest. The samples of a fermented dairy product with wheat brans were the objects of the study. Their amount in the product was from 0 to 10 %. As the result of the conducted organoleptic and rheological studies of consistence of the samples of the functional fermented dairy product with wheat brans, it was concluded that the new product, depending from mass fraction of wheat brans in the composition, could be referred to a drinkable or eaten by a spoon types. It was found out that according to the flow character the functional fermented dairy product could be referred to pseudoplastic bodies.

1. Introduction
In the last few years the use of vegetable raw materials in formulas of dairy products has become very popular. It is connected with the fact that vegetable ingredients have a significant quantity of functional components. Grain cultures are mostly rich for protein and fiber. The works for using back-wheat, flax, rice, corn flour or their mixes in production of dairy products are known [1-3].

As a functional ingredient by developing the new fermented dairy product, wheat brans were chosen. The choice was determined by the fact that brans contained a considerable amount of protein, fiber, vitamins of the B group and mineral matters such as ferrum, magnesium, manganese, cuprum and others. Besides, wheat brans are energy-restricted, it will allow producing a low-calorie product [4].

Taking into account that brans contain a big amount of protein (16 g/ 100g) and fiber (43 g/100 g) [2], it can be assumed that adding them into the composition of a fermented dairy product will...
influence such quality parameter as consistence significantly.

The necessity of the conducted studies is conditioned by the fact that using only the organoleptic method for the evaluation of the consistence is not always objective as it depends on the skills and qualifications of a specialist who carries a study out. The appliance of the method of rotational viscometry allows describing a model of body flow mathematically, defining effective viscosity and other characteristics. Moreover, currently the work is being done to create a data bank of ingredients with the aim of future development of legal requirements on organization of control of consistence by methods of engineering rheology [6-8].

Thus, the purpose of the work is the study of the influence of mass fraction of added into the composition of the fermented dairy product on structural-mechanical properties, on the consistence of the ready product; identifying a type of product’s flow and referring it to one of the kinds of rheological bodies; determining the most rational dose of brans based on the received results.

2. Materials and methods

The studies were carried out in several stages: development of the variants of the product composition, production of the product samples, study of their organoleptic characteristics, a study of structural-mechanical properties of the samples made by different composition variants, identifying a type of product flow and referring it to one of the kinds of rheological bodies; determining the most rational dose of wheat brans based on rheological and sensorial evaluation of the ready product.

The objects of the study were the samples of the fermented dairy product with wheat brans, produced in half-industrial conditions in the “Laboratory of production and study of milk and dairy products” of FSBEI HI Vologda SDFA. As a milk basis, defatted milk was used, wheat brans were added into the product samples from 0 (control sample) to 10 % in increments of 2.5 %. The highest limit of added doses of wheat brans in the product content came from the recommendations on their consumption: not more than 20 g of brans was recommended per day. It made 10 % from one-time portion of a fermented dairy product weighing 200 g. Fermentation of all samples were carried out by cultures of lactic microorganisms up to the fixed value of titrated acidity and pH.

The methods of composition development included the selection of ingredients, theoretical grounding of the added dose of the components, organoleptic evaluation of the received product samples. Such properties as appearance and consistence, taste and smell, color were evaluated.

Structural-mechanical properties of the product were studied with the help of rotation viscosimetry on the equipment Rheotest 2.1. The following properties were defined: shear stress, effective viscosity, viscosity loss coefficient, mechanical stability and structure recovery. The calculation of terminate shear stress and effective viscosity were envisaged by the methodology of the study [3] according to the following formulas:

\[
\tau = Z \cdot \alpha \quad (1)
\]

\[
\eta_{ef} = \frac{\tau}{\gamma_k} \cdot 100 \quad (2)
\]

where \( \tau \) – shear stress, Pa; \( Z \) – constant of measuring device Pa / scale division; \( \alpha \) – instrument data (number of scale division); \( \eta_{ef} \) – effective viscosity, mPa·s; \( \gamma_k \) – shear speed, corrected taking into account current frequency, s\(^{-1}\).

The processing of the study results was made with the help of Microsoft Excel and Statistica.

3. Study results

Based on the data received during degustation of the product, a summery profilogram of consistence of the studied samples was build. It is shown in figure 1.
Based on the conducted organoleptic studies it was defined that the samples of the functional fermented dairy product with 2.5 и 5 % of added wheat brans had the best organoleptic characteristics.

The analysis of rheological characteristics showed that in the studied product samples shear stress and effective viscosity changed by the shear speed variation. Diagrams of dependence of shear stress on shear speed are shown in figure 2.

**Figure 1.** Profilogram of consistence of the samples of the functional fermented dairy product, containing different amount of wheat brans

**Figure 2.** The influence of shear speed on shear stress in the sample of yoghurt by 20° C by dependence on the portion of added brans: 1 – 0 %, 2 – 2.5 %, 3 – 5 %, 4 – 7.5 %, 5 – 10 %.
All rheological bodies are characterized by different dependences of shear flow-curves, which comply with the certain mathematical laws. The most common is Herschel-Bulkley equation, describing the flow of non-Newtonian systems to which the most of fermented dairy products refer [4]:

$$\tau = \tau_0 + k \cdot \gamma^m,$$

(3)

where $\tau$ - shear stress between the layers of the product, Pa; $\tau_0$ – yield value, that is stress, by reaching which permanent deformations start to develop in the system, Pa; $k$ – consistency index, proportional to viscosity, Pa⋅s; $m$ – power coefficient, index of liquid flow; $\gamma$ – velocity gradient or shear velocity, s$^{-1}$.

For pseudo-plastic fluid $\tau_0=0$, $m < 1$, for suspension $m > 1$.

The change of shear stress in the samples of the fermented dairy product is described by the exponential equations presented in table 1. Coefficients of determination of received regressions have the value higher than 0.9, it proves the high level of their adequateness.

| Sample No. | Portion of added brans, % | Regression | Coefficient of determination |
|------------|---------------------------|------------|-----------------------------|
| 1 (control) | 0                         | $\tau = 1.93 \cdot \gamma^{0.437}$ | 0.9794 |
| 2          | 2.5                       | $\tau = 2.47 \cdot \gamma^{0.563}$ | 0.9580 |
| 3          | 5.0                       | $\tau = 3.16 \cdot \gamma^{0.596}$ | 0.9839 |
| 4          | 7.5                       | $\tau = 16.35 \cdot \gamma^{0.401}$ | 0.9418 |
| 5          | 10.0                      | $\tau = 17.66 \cdot \gamma^{0.438}$ | 0.9571 |

Based on the regression analysis presented in Table 1, a conclusion can be made that all samples behave as anomalously viscous fluids by the shear speeds less than 243 s$^{-1}$. By increasing the shear speed above the mentioned value all samples also show the properties, which are typical of pseudo-plastic fluid as evidenced by the absence of initial viscosity and index of fluid flow with the number, value less than 1.

Based on the received data, it can be concluded that the strongest viscosity has one of the studied samples, with the maximal highest content of wheat brans, i.e. sample No. 5. The weakest viscosity is registered in the control sample (No.1). Thus, the viscosity value is in the direct dependence from mass fraction of wheat brans in the composition of the fermented dairy product.

Now therefore, the results received by the organoleptic and instrumental study methods have showed referential results. The samples with added wheat brans in the amount of 2.5 and 5 % have more fluidal consistence comparing to the samples, which contain 7.5 and 10 %. This allows referring the products produced according to different formulas to drinkable and eaten by a spoon respectively.

In figure 3, a response surface for change of effective viscosity of the fermented dairy product is shown by dependence on the shear speed and mass fraction of the added functional ingredient.
Figure 3. Response surface for change of effective viscosity of the fermented dairy product by dependence on the shear speed and mass fraction of wheat brans

The mathematic model of effective viscosity dependence of the studied product on the shear speed and mass fraction of the added component for a quadratic response surface is presented below:

$$\eta_{ef} = 64.5815 + 19.4082 \cdot x - 0.5394 \cdot \tau + 2.1989 \cdot x^2 - 0.0434 \cdot x \cdot \tau + 0.0005 \cdot \tau^2.$$ 

Regression dependence is adequate since the approximation coefficient of this model makes 0.996.

4. Conclusions
The influence of mass fraction of wheat brans added into the composition of the fermented dairy product on the structural-mechanical characteristics of the product was studied. It was found out that by increasing mass fraction of wheat brans in the product composition its viscosity increased.

The mathematical models of the product flow were received based on the analysis of which, the functional fermented dairy product with wheat brans was refereed to pseudo-plastic fluid.

Based on the received results, the most reasonable dose of added wheat into the composition of the fermented dairy product was defined in the amount of 2.5 and 5 %.

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