

Отримано комплекс даних щодо зміни в'язкості, вологоутримувальної здатності, активної та титрованої кислотності йогуртів з використанням натуральних наповнювачів. Проаналізовано можливість використання в технології йогуртів овочевих наповнювачів з різними типами структури (порошкоподібної, твердої та пастоподібної). Проведені дослідження є актуальними, з огляду на підвищення якості йогуртів та надання їм статусу натуральних, завдяки вилученню з їх складу стабілізаторів, смакових та ароматичних добавок. Крім цього, введення до рецептури йогуртів наповнювачів, як правило, призводить до погіршення їх реологічних показників: зменшення в'язкості, відділення сироватки та погіршення смакових властивостей продукту. Це обумовлює збільшення кількості введених до їх складу смако-ароматичних речовин та стабілізаторів, що негативно відбивається на зменшенні популярності «живої мікрофлори», погіршенні біологічної цінності продукту. Встановлено, що всі наповнювачі (полуничний порошок, бурякові цукати та полуничний джем) не мали негативного впливу на процес сквашування. Досліджено вплив харчових волокон, що входять до складу наповнювачів (цукати з буряка, полуничний порошок та полуничне варення) на реологічні властивості продукту. Зміни в'язкості, утримування вологи, активної та титрованої кислотності йогуртів з різними типами наповнювачів визначали та аналізували відразу після виготовлення та під час зберігання. Експериментально показано позитивний вплив пектиновмісних наповнювачів на гідрофільні властивості йогуртів, які підвищують вологоутримувальну здатність продукту на 2–3 %. На підставі отриманих даних було доведено доцільність використання запропонованих видів наповнювачів, а саме полуничного порошку та бурякових цукатів, у виробництві йогуртів без використання стабілізаторів, ароматизаторів та інших харчових добавок. Встановлено ємність зберігання, розроблені йогурти та термін зберігання, визначений у нормативних документах

Ключові слова: натуральний йогурт, ефективна в'язкість, стабілізатори структури, полуничний порошок, бурякові цукати, полуничний джем

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INFLUENCE OF THE STRUCTURE OF SOME TYPES OF FILLERS INTRODUCED TO THE YOGURT RECIPE ON CHANGES IN ITS RHEOLOGICAL INDICATORS

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1. Introduction

Yogurt is a structured fermented milk drink, whose popularity among consumers is explained not only by its taste, but also by its functional properties. For the fermentation of yogurt, are used species cultures of *Lactobacillus delbrueckii subsp. bulgaricus*, *Streptococcus salivarius subsp. Thermophilus*.

Useful properties are inherent only in natural yogurts, for the production of which raw materials and ingredients (dyes, flavors, preservatives, stabilizers) of natural origin are used. The shelf life of yogurt is no more than 14 days [1].

For this reason, the urgent task of research on storage stability is to develop formulations of dairy products that would have no additives other than natural fillers with a balanced content of vital nutrients.

2. Literature review and problem statement

In the production of yoghurts, as a stabilization system, are most often used both starch and modified starch, alginate, carrageenan, locust bean gum, pectin, carboxymethyl

cellulose, gelatin, which increases the water-holding capacity of the product and improve the rheological properties of this type of product [1]. In addition, the microorganisms contained in stabilizers are able to break down pectin and starch, thereby reducing the stabilizing effect.

The introduction of fillers into the recipe for yoghurt, as a rule, leads to a deterioration in their rheological parameters: a decrease in viscosity, separation of whey and a deterioration in the taste of the product. This causes an increase in the amount of flavors and stabilizers introduced into their composition, which negatively affects the population of “living microflora”, the biological value of the product [2].

Their use is prohibited by the order of the ministry of Health No. 222 of 23.07.96 “On approval of the sanitary rules and regulations on the use of food additives”. However, they may get into the product together with fillers [3].

The content of preservatives in yogurts is regulated by DSTU 5050 [4]. This document does not cover the whole range of preservatives, especially those present in fillers, from overseas production, unlike the International Standard IDF 139-2008 in which they are standardized. That is why unscrupulous manufacturers abuse the possibility of introducing preservatives into the composition of yogurt, extending the shelf life up to 30 days, without specifying on the labels what additives this is due to [5].

In [6], the issues of rheology of food products, including fermented, are covered. Studies have shown the influence of some types of stabilizers, fillers and fermenting microflora on changes in the viscosity of fermented drinks (yogurt, kefir). It is proved that the introduction of flavoring substances and stabilizers into their composition negatively affects the populations of “living microflora” and contribute to the deterioration of the biological value of the product. However, there are no alternative ways of overcoming these disadvantages when introducing stabilizers and fillers into the yogurt formulation.

The work [7] is devoted to the principles of analysis of data processing obtained on viscometers of different types and application of these data in technological processes of yogurt production. It is proved that the viscosity index of products gives an idea of the behavior of liquids related to their rheological and physical properties and shelf life. This gives an opportunity to understand the behavior of yogurt structure when introducing different types of fillers. However, the totality of data on the behavior of yogurt structure, depending on the introduction of substances with different physical characteristics.

In the work [8] determining the viscosity of yoghurts with the addition of serum and a stabilizer of the structure of starch of sweet potato is investigated. It was found that the best viscosity of the product is provided by the introduction of 6 % starch and heat treatment of the product with a temperature of 90 °C for 5 minutes. The dependence of the structural and mechanical properties of yogurt on the amount of added starch has been established. But, the question remains unresolved regarding its effect on the water-holding capacity and acidity of yogurt.

Stocks of vegetable and fruit raw materials in Ukraine are sufficient. At the same time, beets and strawberries are of high biological value, contain micro- and macro-elements, vitamins, natural pigments, flavonoids and dietary fiber, including insoluble pectins. Beet production in Ukraine annually is about 12 million tons, strawberries – 40 thousand tons. But the question of expanding the spectrum of use

of these types of raw materials in the technologies of popular products such as yogurt has not been studied previously. Therefore, to enhance the nutritional and biological value of yogurt and its rheological properties, strawberry powder and candied beets were proposed and used in the experiment [9].

Almost all types of dairy products can be combined with different plant components. Many scientists are trying to solve the problem of creating healthy foods by considering natural vegetable and fruit components [10]. The possibility of producing yogurts and kefir with the use of kombucha was investigated. The produced sour milk drinks have high textural characteristics and can be used as health products [11]. The technology of yogurt with probiotic properties with the addition of pumpkin pulp was developed. [12] Five different yogurts with a filler such as carrots, green peas, zucchini and beans were studied [13]. The work [14] was aimed at studying the effect of kiwi puree (*Actinidia deliciosa*), which can be used as a natural alternative to synthetic additives in foods such as pudding, tea, sauces, and yoghurts to improve their taste. However, the use of vegetable components in their natural form has several disadvantages. This is primarily due to the high moisture content, which, when introduced into yogurt technology, imparts an unfavorable water-holding capacity and viscosity. Adding vegetable puree had a negative effect on the pH and titrated acidity.

Analyzing the results obtained, we can conclude that it is necessary to search for an alternative method of processing vegetable raw materials in order to increase the amount of solids in the original product. From the analyzed data of literary sources [1–14] it is clear that the question of studying the influence of fillers of various powdery, solid or pasty structures on changes in the rheological parameters of yogurt remained unresolved. Stabilization of structural-mechanical properties, water-holding capacity and acidity of yogurts is an open question in the production of natural yogurts using fruit and vegetable fillers.

3. The aim and objectives of the study

The aim of the study is to analyze the effect of the structure of some types of fillers introduced into the formulation of yogurt on changes in its rheological parameters.

To achieve the aim of the study, it was necessary to solve the following problems:

- to develop a recipe of yogurts with fillers having different powdered, solid (in the form of slices) or pasty structure, the formulations are given in the methods section;
- to analyze the dependence of the product acidity on the type of fillers;
- to investigate the water-holding capacity of yogurts and fillers included in their composition;
- to investigate the influence of structural and mechanical properties of fillers on the consistency of yogurts.

4. Materials and methods for the investigation of yogurt with fillers

The control and experimental batches of yogurt were made by the thermostatic method in semi-industrial conditions of the Department of milk and meat technology of the Sumy National Agrarian University, as required by the current regulatory-technical documentation.

In cow's milk pasteurized at 90–95 °C with a holding time of 3 minutes, the fillers (8.5 kg per 10 liters of milk): strawberry powder, candied beets, strawberry jam were introduced. The mixture was stirred for 5 min and cooled to a temperature of 40–45 °C.

Upon reaching the set temperature, leaven was introduced into it. For the preparation of yoghurts, bacterial sourdough “VIVO Yogurt” made according to TUU15.5-3060300036-001: 2009 at the Institute of Food Resources of the USEEBF (State Experimental Enterprise of Bacterial Ferments, Ukraine) was used.

Fermentation of the control sample without fillers (C) and experimental samples (E1, E2 and E3) was carried out in a thermostat at a temperature of 40–45 °C for 5 hours until the formation of a dense clot.

In appearance, all obtained, control and experimental samples had a homogeneous, dense clot.

The recipe of yogurts was selected according to the technological instruction for obtaining the finished product in accordance with the requirements of DSTU 4343: 2004 “Yogurts. General specifications” [1]. As a control sample, the yogurt recipe with a fat content of 3.2 % was chosen [15]. Three samples of yogurt with pasty, powder and solid fillers were prepared in parallel (Table 1).

Table 1

Formulations of yogurt with fillers with a fat content of 3.2 % (in kg per 1.000 kg of product excluding losses)

Ingredients	Control sample	Yogurts with fillers		
		strawberry powder	candied beets	strawberry jam
	C	E1	E2	E3
Whole milk with a fat content of 3.2 %	950	850	850	850
Ferment on skim milk	50	50	50	50
Amount of filler	0	100	100	100
STABMILK-P stabilizer	0.001	0	0	0
Total	1,000	1,000	1,000	1,000

The shear stress of the experimental samples was determined using a “Reotest-2” (Russia) rotary viscosimeter for 30 s with a shear gradient of 100 s^{-1} , using an S1 spindle. The determination temperature is 25 °C. The effective viscosity was calculated by the formula (Oswald de Valais equation):

$$\eta_{ef} = \frac{\theta}{\gamma}, \quad (1)$$

where η_{ef} is the effective viscosity, Pa·s; θ is the shear stress, Pa; γ is the shear rate, (s^{-1}).

The view of the “Reotest-2” viscometer for determining the shear stress in yogurts is shown in Fig. 1.

To assess the water-holding capacity of the clot, yogurt samples (10 cm³) were centrifuged for 60 min in 15 min increments and the volume of whey obtained was measured in ml.

The calculations were performed according to the formula:

$$\text{WHC} = (1 - \alpha/\beta) \times 100 \%, \quad (2)$$

where WHC is the water-holding capacity of yogurt, %; α is the volume of whey, ml; β is the volume of yogurt, ml.

Fig. 2 shows a laboratory centrifuge for separating whey from yogurt.



Fig. 1. “Reotest-2” viscometer



Fig. 2. Centrifuge

The active acidity of the products was determined by direct potentiometry (GOST 26781) using a “pH-500” pH-meter (Fig. 3), the titrated acidity – according to GOST 362492.



Fig. 3. “pH-500” pH-meter

Plotting and mathematical processing of the results were performed in MS Excel 2010.

5. Results of the study of yogurt with fillers

The essence of the study was to analyze the effect of the structure of fillers (powdered, solid and pasty) on the consistency of yogurts, their water-holding capacity, active and titrated acidity. The developed yogurts were made according to standard technology and the recipe developed. The result was achieved by replacing stabilizers and additives with natural fillers (strawberry powder, candied beets and strawberry jam).

5. 1. Analysis of the relation of product acidity on the properties of fillers

The active and titrated acidity of the control and experimental samples of yogurt was determined. The results of the study of active and titrated acidity are presented in Fig. 4.

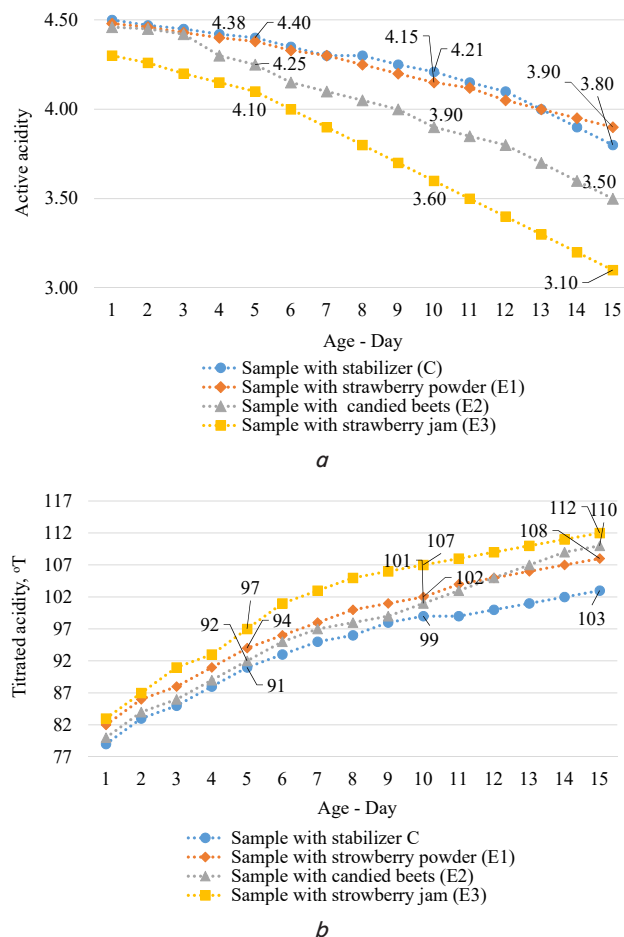


Fig. 4. Changes in the acidity of yogurts during storage: *a* – active, *b* – titrated

From the graph in Fig. 4, *a* it can be seen that the control (C), with the stabilizer filler and the experimental (E1) yogurt samples, with the filler of natural origin (strawberry powder), were characterized by almost the same high active acidity. On the 5th day of storage, the pH of the sample with the STABMILK-P (C) stabilizer was 4.4, and the sample with strawberry powder (E1) – 4.8. On the 10th day, the pH was observed at 4.21 (for sample E1) and 4.15 (for sample E1). On the 15th day of the study, the pH of the sample with the stabilizer was lower (3.8) compared to the sample with strawberry powder by 0.1 (3.9).

Slightly less active acidity was in the yogurt sample with candied beets, its level of active acidity pH was: on the 5th day – 4.25; on the 10th day – 3.9; on the 15th – 3.5.

The filler, which is strawberry jam, created the lowest active acidity pH=4.1; 3.6; 3.1 (on the 5th, 10th and 15th day of the study, respectively).

5. 2. Study of the water-holding capacity of yogurts and fillers included in their composition

The results of calculating the water-holding capacity (WHC) are presented in Fig. 5.

WHC was calculated on the 1st, 5th, 10th and 15th day of the experiment.

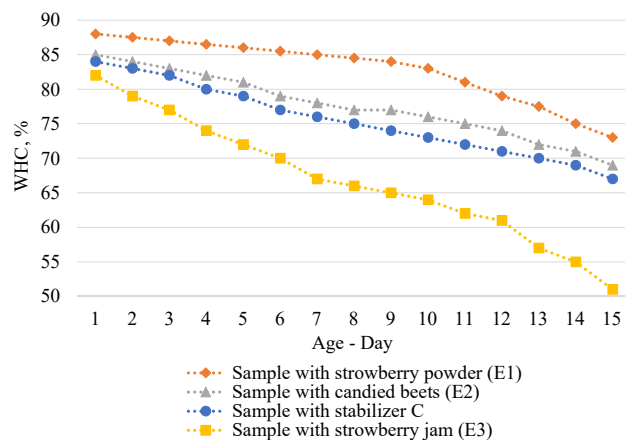


Fig. 5. Changes in water-holding capacity

From the graphs in Fig. 5 it can be seen that the WHC for the strawberry jam sample (E3) was 82 at the beginning of the study and dropped rapidly to the 7th day of storage and amounted to 66, with further storage the WHC also continued to decrease and on the 15th day of storage was 51. The WHC of samples with the stabilizer (C) and samples with candied beets (E2) had almost the same values during 15 days of storage. At the beginning of the study, the WHC for the sample (C) was 84, for the sample (E2) – 85. After 15 days of storage, the WHC for the sample (C) was 67, for the sample (E2) – 69. The best indicators of the WHC were in the sample with strawberry powder. For (E1) at the beginning of the study, the WHC was 88. After 15 days of storage, the WHC for the sample (E1) was 73.

5. 3. Study of the influence of structural and mechanical properties of fillers on the consistency of yogurts

Yogurts, like other fermented milk drinks, are pseudo-plastic liquids. Their viscosity depends not only on the shear stress, but also on the shear rate, temperature, mass fraction of fat and acidity.

The effective viscosity of the samples is presented in Fig. 6.

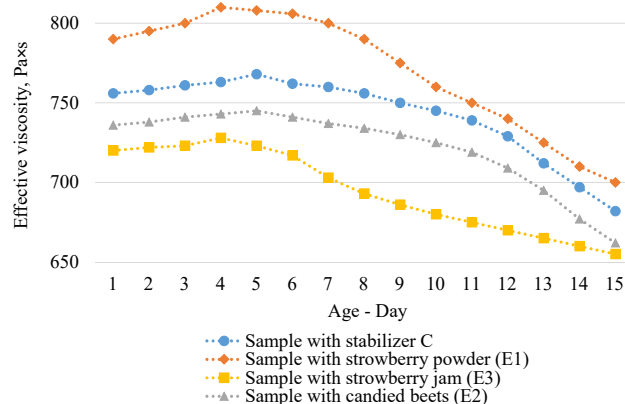


Fig. 6. Rheogram of the studied samples

From the rheogram in Fig. 6, it can be seen that the introduction of powder fillers to yogurt increases the viscosity and preserves the structure without the use of stabilization systems.

From the graphs in Fig. 6, it can be seen that the effective viscosity of the sample with strawberry jam (E3) was 720 Pa·s at the beginning of the study, and slightly increased to the 4th day of storage and amounted to 728 Pa·s, with further storage the effective viscosity decreased and on the 15th day of storage was 655 Pa·s. The effective viscosity of samples with the stabilizer (C) and candied beets (E2) had similar values during 15 days of storage. At the beginning of the study, the effective viscosity of the sample (C) was 756 Pa·s, for the sample (E2) – 747 Pa·s. After 15 days of storage, the effective viscosity of the sample (C) was 682, the sample (E2) – 678 Pa·s. The best indicators of effective viscosity were in the sample with strawberry powder. For (E1), at the beginning of the study, the effective viscosity was 790 Pa·s. After 4 days of storage, the effective viscosity increased to 810 Pa·s. And after the 4th day of storage, the effective viscosity tended to decrease and on the 15th day was 700 Pa·s.

6. Discussion of the results of the study of yogurt with fillers

From the graphs in Fig. 4, *a*, it can be seen that all the fillers (strawberry powder, candied beets and strawberry jam) had no negative effect on the fermentation process. The values of active (pH=4.8–4.0) and titrated acidity (80–140 °T) were within the limits of the standard throughout the study. This is because the fillers used in the experiment, like most of the ingredients of plant origin, have the ability to produce an alkaline reaction of the medium in the area of their action (high active titrated and low titrated acidity).

The highest titrated acidity (112 °T) was observed in the experimental sample (E3) on the 15th day of the study, which is 4 °T more than the similar indicator of the experimental sample (E1), 2 °T more than the acidity of the sample (E2) and 9 °T than the acidity of the control sample. The increased titrated acidity of the experimental sample of the product (E3) indicates its poorer organoleptic characteristics than similar indicators of the experimental E1, E2 and control samples.

In addition, beets contain about 3 % of pectin substances [16], strawberry powder about 5–6 % [17]. Pectin is a hydrocolloid that enhances the water-holding capacity, nutritional and biological value of the product [18].

From the graphs in Fig. 5, it can be seen that the study of the water-holding capacity of dairy clots without the influence of pressure applied to them and under the action of centrifugal forces showed that the greatest WHC was possessed by samples of the product with strawberry powder and candied beets, WHC indicators of which were 2–3 % higher than in the control sample. From the graphs in Fig. 5, shows that the study of the ability of sour milk clots to retain moisture without pressure and under the action of centrifugal forces showed that product samples with strawberry powder and candied fruit had the greatest water-holding capacity, whose WHC values were 2–3 % higher than in the control.

Samples of strawberry jam products were characterized by the worst water holding capacity. Its WHC was 6–17 % lower compared to the same indicator in the control sample.

The high water-holding capacity of experimental yogurt samples with strawberry powder and candied beet fillers is explained by the presence of macro- and micropo-

res capable of absorbing moisture in the composition of dry plant ingredients.

The analysis of rheological parameters (graph in Fig. 6) of experimental yogurt samples with such fillers as strawberry powder (E1), candied beets (E2) and strawberry jam (E3) showed changes in the effective viscosity that occurred on the last day of their storage at 8 °C in the household refrigerator.

It should be noted that the effective viscosity of all samples on the fifth day of storage has increased. The highest increase was observed in the sample with strawberry powder (from 790 to 810 Pa·s), and the lowest in the sample with strawberry jam (from 720 to 730 Pa·s).

On the 10th day of the study, the effective viscosity of the sample with strawberry powder (E1) was 1.5 % higher compared with the control sample. The viscosity of the sample with candied beets (E2) was 3 % lower than in the viscosity of the same sample.

This is due to the structure of the filler in powder form, which promotes a more uniform distribution of moisture among the particles of crushed vegetable raw materials.

It is found that all the fillers (strawberry powder, candied beets and strawberry jam) can be used for yogurt production. This is due to a number of reasons: the content of dietary fiber, the presence of natural pigments and aromatic substances, vitamin and mineral composition. In addition, it is proven that all the fillers did not impair the quality of the developed yogurt during storage.

However, there are some limitations to the use of fillers with a pasty structure. Because they have been found to have the worst effect on the viscosity and acidity of yogurts, compared to fillers with a powdered and solid structure. To eliminate this disadvantage, based on the results of the presented studies, it is proposed to use fillers containing at least 5–6 % of pectin substances.

Further studies may focus on the effect of the above-mentioned fillers on changes in the physical and chemical composition of yogurt, its nutritional and biological value.

7. Conclusions

1. The structure of the fillers (powder and solid) has the effect of improving the rheological indicators of the ready-to-sell product and stability of clots to destruction during storage. This is explained by the fact that table beet contains about 3 % of pectin substances, strawberry powder about 5–6 %. The recipe of yogurts with fillers having different structure (powdery, solid and pasty) was developed.

2. The dependence of the product acidity on the type of fillers is analyzed. The least active and, accordingly, the highest titrated acidity was created by the strawberry jam filler (E3). The active acidity of the sample (E3) was pH=4.1; 3.6; 3.1 (on the 5, 10 and 15 day of the study, respectively). Slightly less active acidity was in the yogurt sample with candied beets, its level of active acidity pH was: on the 5th day – 4.25; on the 10th day – 3.9; on the 15th – 3.5. Low active acidity and high titrated acidity of the experimental yogurt sample (E3) indicate its poorer organoleptic indicators than similar indicators of experimental E1, E2 and control samples. Therefore, yogurt with a paste-like filler – strawberry jam – has worse acidity than yogurt with a solid and powder-like filler.

3. Strawberry powder and candied beets increase the viscosity and WHC of yogurt samples. However, the filler of

the pasty structure does not have this property. It is worth noting that the effective viscosity of all samples on the fifth day of storage has increased. The largest increase was observed in the sample with strawberry powder (from 790 to 810 Pa·s) and the lowest in the sample with strawberry jam (from 720 to 730 Pa·s). Studies of the water-holding capacity of fermented milk clots showed that samples of the product with strawberry powder and with candied beets had the highest WHC, which were 2–3 % higher than in the control sample. The worst WHC was shown by the samples of the product with strawberry jam. Its WHC was 6–17 % lower than the same indicator in the control sample.

4. The possibility of producing yogurts without structure stabilizers using vegetable fillers is proved. The analysis of the rheological parameters of the experimental yogurt samples with such fillers as strawberry powder (E1), candied beets (E2) and strawberry jam (E3) showed changes in the effective viscosity that occurred on the last day of storage at a temperature of 8 °C in the household refrigerator. The highest increase was observed in the sample with strawberry powder (from 790 to 810 Pa·s) and the lowest in the sample with strawberry jam (from 720 to 730 Pa·s). This is due to the powder structure of the filler, which promotes a more uniform distribution of moisture among the particles of crushed vegetable raw materials.

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