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STRUCTURED DRINK BASED ON BUTTERMILK

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The article discusses preparing and adding a stabilizing system to butterfat-based beverages, including sodium alginate (E401) and marigold and rosehip extracts. The optimal concentration of the stabilizer to ensure the desired consistency was determined, and the effect of the extracts on the color, taste, and aroma of the product was studied. The influence of the amount of sodium alginate on the structural properties of the product, as well as its effect on rheological parameters, in particular, the viscosity and stability of the drink, was investigated.

Particular attention is paid to the evaluation of the organoleptic characteristics of beverages with the addition of extracts, in particular their effect on taste, color, and aroma. A profilogram was constructed, which made it possible to quantify the change in organoleptic properties depending on the concentration of extracts. The dynamics of changes in pH during storage, which affects the texture and stability of the beverage, were analyzed.

The paper presents the methods of preparation of model samples of structured beverages and investigates the effect of the mass fraction of extracts on physicochemical and organoleptic parameters. Viscometers of the VZ-246 and Hepler types (balls No. 5 and No. 6), as well as areometric methods, were used to determine the dynamic viscosity and density of the samples. The dynamic viscosity was calculated using the formula taking into account the bulk weight of the ball, the density of the liquid, and the time of the ball's passage.

The results obtained allowed us to determine the effective concentration of sodium alginate and plant extracts, which ensures optimal organoleptic and rheological properties of the product, as well as the stability of the drink during storage. This gives grounds for further implementation of such stabilizing systems in functional dairy beverage formulations.

Key words: *sodium alginate, empetrum extract, marigold extract, structured drink, model sample (MS), dynamic viscosity, rheological properties, organoleptic properties, pH, antioxidants, functional components, profilogram, stability, physicochemical properties.*

Шиманюк І. В. Структурований напій на основі маслянки

У статті детально розглядаються процеси підготовки та внесення стабілізуючої системи в напої на основі маслянки, зокрема використання альгінату натрію (Е401) та екстрактів чорнобривців і шикши. Визначено оптимальну концентрацію стабілізатора для забезпечення бажаної консистенції, а також вивчено вплив екстрактів на колір, смак і аромат продукту. Досліджено вплив кількості альгінату натрію на структурні властивості продукту, а також його вплив на реологічні показники, зокрема в'язкість і стабільність напою.

Окрему увагу приділено оцінці органолептичних характеристик напоїв із додаванням екстрактів,в кількості 0,1–0,5 % у вигляді водного розчину, що дало змогу дослідити концентрації зокрема їх впливу на смак, колір і аромат. Оптимальною концентрацією було обрано зразок з вмістом – 0,2 % екстракту чорнобривців та 0,3 % екстракту шишки, при яких профілограма органолептичної оцінки набула максимально збалансованого вигляду, що дозволило візуально оцінити зміну органолептичних властивостей залежно від концентрації екстрактів. Проаналізовано динаміку змін pH у процесі зберігання, що впливає на текстуру та стабільність напою.

У роботі наведено методику приготування модельних зразків структурованих напоїв та досліджено вплив масової частки екстрактів на фізико-хімічні та органолептичні показники. Використано віскозиметри типу ВЗ-246 та Геплера (кульки № 5 і № 6), а також ареометричні методи для визначення динамічної в'язкості та щільності зразків. Розраховано динамічну в'язкість за формулою з урахуванням об'ємної ваги кульки, густини рідини та часу проходження кульки.

Отримані результати дозволили визначити ефективну концентрацію альгінату натрію та рослинних екстрактів, що забезпечує оптимальні органолептичні та реологічні властивості продукту, а також стабільність напою протягом зберігання. Це дає *підстави для подальшого впровадження таких стабілізуючих систем у рецептури функціональних молочних напоїв.*

Ключові слова: *альгінат натрію (Е401), екстракт шикши, чорнобривці, екстракт, структурований напій, модельний зразок (МК), динамічна в'язкість, реологічні властивості, органолептичні показники, pH, антиоксиданти, функціональні компоненти, профілограма, стабільність, фізико-хімічні властивості.*

Introduction. On the basis of experimental and theoretical studies, the technology of a structured drink based on butter with the addition of plant extracts was proposed.

According to DSTU 2212:2003 [1], we used buttercup, which is a raw material obtained from butter production. It is characterized by high biological value, as it contains proteins rich in essential amino acids (cystine, lysine, methionine), as well as lactose, milk fat, and trace elements.

The physicochemical composition of butter is dominated by protein content of 2.9–3.2 %, lactose – about 4.8 %, solids – 8.3–9.5 %, acidity – 20–21 °T, density – within 1,027–1,029 kg/m^3. The buttercream is characterized by stable colloidal properties that ensure uniform dispersion of the components in the finished product. In systems of this type, the buttercream acts as a dispersion medium, contributing to the formation of a stable texture and homogeneity [2].

Sodium alginate is the sodium salt of alginic acid, obtained from various types of brown seaweed, and is a safe and non-toxic ingredient that has multiple uses. It is soluble in water and forms a viscous solution that can be further modified to adjust its viscosity and is stable under various processing conditions [3].

According to the study by Tkachenko N. A. et al [4], Tagetes patula flowers (French marigold) are a promising plant material for the production of biologically active substances with hepatoprotective, antioxidant, and immunomodulatory properties. Biologically active components, including flavonoids, essential oils, carotenoids, and catechins contained in marigold flowers, exhibit phytoncidal, antiviral, and antimicrobial activity, and can improve the organoleptic properties of the product due to its pronounced floral and spicy aroma. In addition, the flowers contain leucine (0.95 %), glutamic (1.1 %), and aspartic (0.83 %) amino acids, as well as ascorbic acid (1.78 %), tocopherols (0.6 %) and carotenoids (0.005 %). The mineral part of the plant material is represented by macro- (47.0 %) and microelements (7.28 %) in terms of ash mass. The flowers also contain pectin substances (11.87 %), water-soluble polysaccharides (16.26 %), hemicellulose A (0.91 %), and hemicellulose B (0.55 %), which together form a complex with pronounced sorption properties. Currently, there are no official recommendations for the use of marigold extracts in the production of dairy products, which makes further research in this area relevant.

Empetrum, also known as watercress, is known abroad by the Latin name Empetrum. It belongs to the genus Empetrum and the family Empetraceae, and the variety Empetrum nigrum var. Japonicum is distinguished by red or purple-black fruits. The antioxidant activity of wild berries, in particular rose hips, is significantly higher than that of cultivated species. Due to the high content of flavonoids and phenolic compounds 73.9 and 74.8 mg/g, respectively, the fruits of this plant have great potential as an effective antioxidant and can be used in the production of functional foods [5].

Section 1. Determination of the Effect of Sodium Alginate on the Structuring Viscosity Characteristics of Buttercup.

Model samples of structured beverages based on buttercup were prepared in accordance with the developed technological schemes and the mass fraction of the recipe components with the addition of sodium alginate, marigold, and empetrum extracts, which is given in Table 1.

In the first stage of the study, sodium alginate was prepared as the main thickener. The solubility of alginate in aqueous medium at temperatures of 40, 45, 50, 55, 60, and 65 °C was previously studied to determine the optimal conditions for its hydration.

The results showed that the best dissolution and swelling of sodium alginate occurs at a temperature of 60 °C. Accordingly, the oil that met the requirements of DSTU was preheated to this temperature. After that, sodium alginate was added to it in the amount of 0.7 g per 100 ml of product with gradual intensive stirring until it was completely dissolved.

The mixture was kept at this temperature for 30 minutes to ensure complete swelling of the structured agent. After the hydration process was completed, the product was cooled to 20 °C, and extracts, such as marigold or empetrum extract, were added at the specified concentrations using a measuring pipette [3].

Table 1

Mass fraction of formulation components in model beverage compositions

Formulation component	**Mass fraction of formulation components in model beverage compositions, g.**											
	Control 1	**MS 1**	**MS 2**	**MS 3**	**MS 4**	**MS 5**	**Control 2**	**MS 6**	**MS 7**	**MS 8**	**MS 9**	**MS 10**
Buttermilk	200	100	100	100	100	100	200	100	100	100	100	100
Starch	10	–	–	–	–	–	10	–	–	–	–	–
Sodium alginate	–	0,5	0,6	0,7	0,8	0,9	–	0,55	0,65	0,75	0,85	0,95
Marigold extract	–	0,1	0,2	0,3	0,4	0,5	–	–	–	–	–	–
Empetrum extract	–	–	–	–	–	–	–	0,1	0,2	0,3	0,4	0,5

The experimental samples with a sodium alginate content of more than 0.8 g required periodic stirring before consumption.

The organoleptic and physicochemical parameters of each sample were determined by standard methods for beverages [6].

The use of dry marigold or rosehip powder led to the stratification of the mixture, so we used ready-made water-based extracts by TU-U-15.8-02010741 - 044:2005.

The study of the physicochemical parameters of the drink was carried out to observe the dynamics of changes during the storage of the finished product. The results obtained during the study are presented in Table 2.

Table 2

Results of the study of physicochemical parameters of the drink

Indicators	**(Control)**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
Density kg/m^3	1091	1101	1160	1284	1327	1394
Active acidity (pH)	5,63	5,35	5,47	5,88	6,36	6,53
Dynamic viscosity 10^{-3} mPa-s, Ball No. 5	48221,92	31915,44	45804,0	58890,24	67459,08	75375,44
Dynamic viscosity 10^{-3} mPa-s, Ball No. 6	1619,08	1072,94	1537,55	1975,27	2261,50	2527,82
conditional viscosity (seconds)	18,0 sec	11,9 sec	17.3 sec	22,6 sec	26,0 sec	29,4 sec

To determine the viscosity of the samples, a Hepler viscometer was used, the principle of which is based on measuring the time it takes for a ball to pass through a narrow capillary under the influence of gravity. The device was first filled with the test liquid to the set mark and thermostated to a stable temperature of 20 °C. After reaching the required temperature, the ball was launched, and when it crossed the mark, the stopwatch was turned on and the time taken for the ball to pass between the control marks was recorded.

The dynamic viscosity was calculated based on the duration of the ball's fall using the formula:

$$\eta = t \cdot (q_1 - q_2) \cdot K,$$

where: t – time of falling of the ball (experimentally determined on a Hepler viscometer)
q_1 – is the volume weight of the ball (calculated by the formula)
q_2 – is the volume weight of the liquid (density index kg/m^3)
K – is the ball constant (40 for No. 5, 10.5 for No. 6) [7].

The obtained values of dynamic viscosity made it possible to quantify the viscosity properties of the experimental samples and to establish the optimal concentration of stabilizing components to obtain the desired density of the beverage.

Section 2. Determination of the effect of marigold and rosehip extracts on the organoleptic characteristics of structured beverages.

To determine the effect of marigold extract concentration on the acidity of the beverage, a series of studies were conducted with a gradual addition of the extract in the range of 0.1–0.5 g per 100 g of product. The active acidity (pH) was determined immediately after preparation and after storage at 4 °C for 24 hours, 7 days, and 14 days.

According to the results obtained, the initial pH values show an upward trend with increasing concentration of the extract, which is probably due to the natural alkaline properties of some components of plant material. After storage, a slight decrease in pH was observed (by 0.1–0.2 units).

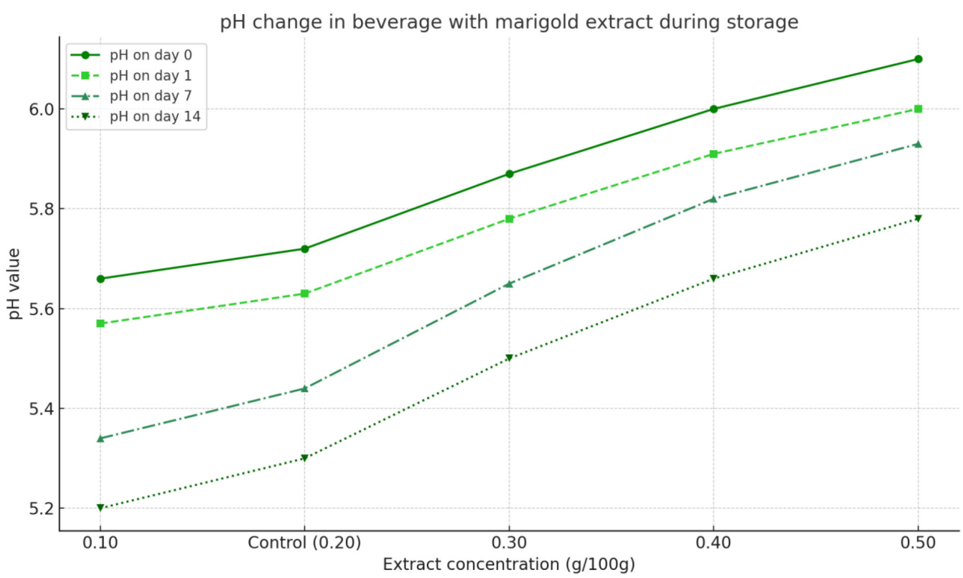

Fig. 1. Changes in pH of the drink with marigold extract during storage

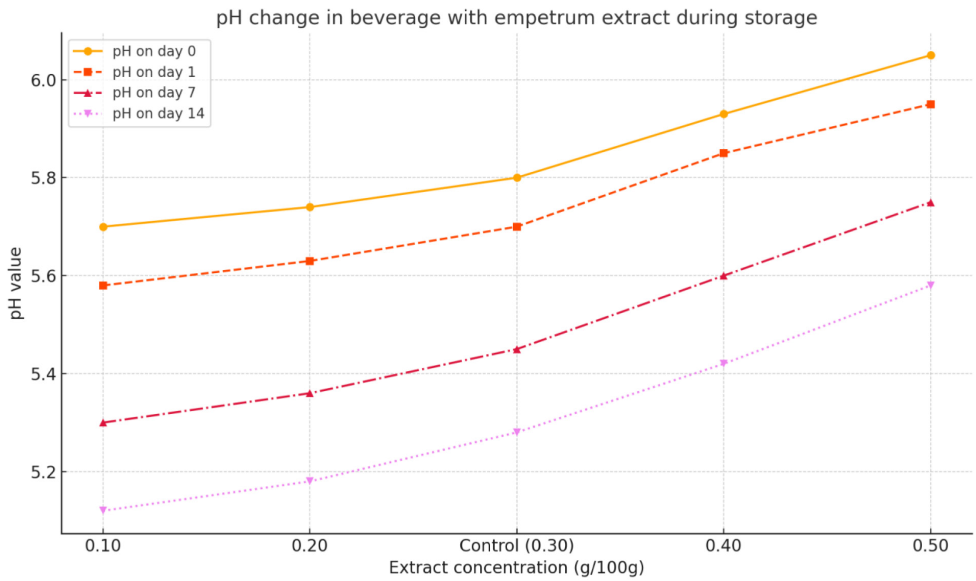

Fig. 2. Changes in pH of a drink with empetrum extract during storage

The study of the effect of marigold and rosehip extracts on the change in the active acidity of stabilized butterbur-based beverages revealed a clear dependence of pH values on the concentration of extracts and the duration of product storage.

Immediately after preparation, samples with a higher content of extracts showed higher initial pH values, which is explained by the natural alkaline reaction of active substances of plant origin. However, during 14 days of storage at +4 °C, a natural decrease in pH by 0.4–0.6 units was observed, indicating the development of a lactic acid process typical for this type of product.

For the samples with marigold extract, the dosage of 0.20 g/100 g was found to be optimal, which was taken as a control, since this variant combined the best pH stability and pleasant organoleptic properties. During the storage period, the pH in this sample decreased from 5.72 to 5.30, remaining within the regulatory limits.

In the series of samples with empetrum extract, the best sample was the one with a concentration of 0.30 g/100 g, in which the pH decreased from 5.80 to 5.28, which also corresponds to the permissible acidity for dairy drinks.

Samples with higher concentrations (0.40–0.50 g/100 g) in both series of studies showed less intense acidification, which indicates a possible bacteriostatic effect of the biologically active components of the extracts, which can slow down the development of lactic acid microflora. This allows us to consider such extracts as potentially stabilizing ingredients.

Thus, the introduction of extracts in doses of 0.2–0.3 g/100 g is optimal both in terms of taste characteristics and to ensure controlled acidity during storage. The obtained results confirm the feasibility of using rosehip and marigold extracts in the development of structured beverages.

The organoleptic properties of the samples were evaluated by a tasting panel on a five-point scale by standard sensory methods. Taste, smell, color, consistency, and appearance were evaluated. Based on the average scores, profilograms were created to visually and quantitatively compare the differences between the control and test samples.

For a comprehensive quality analysis, a generalized criterion of the «quality polygon» was used, which reflects the relationship between individual organoleptic indicators and allows you to select a sample with the best sensory characteristics [8].

The results of the assessment are presented in Fig. 3 and Fig. 4. The best was sample MS2 – the ratio of sodium alginate 0.7 g and marigold extract 0.2 mg. In the samples with empetrum, the best was sample MS8 with a ratio of sodium alginate of 0.75 g and empetrum extract of 0.3 mg. The finished product is characterized by a homogeneous consistency, pleasant taste, and aroma.

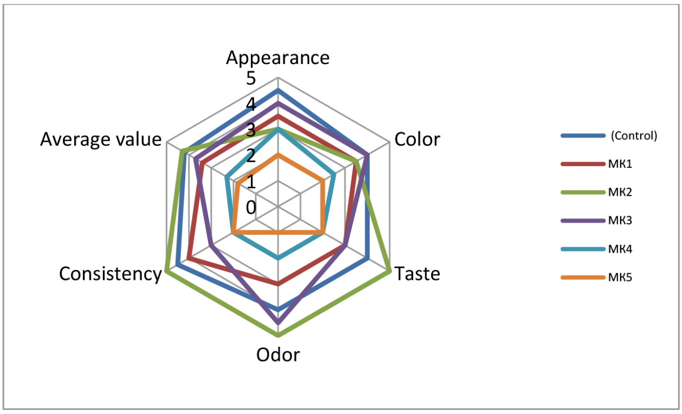

Fig. 3. Profilogram of organoleptic characteristics of structured drink with marigold extract

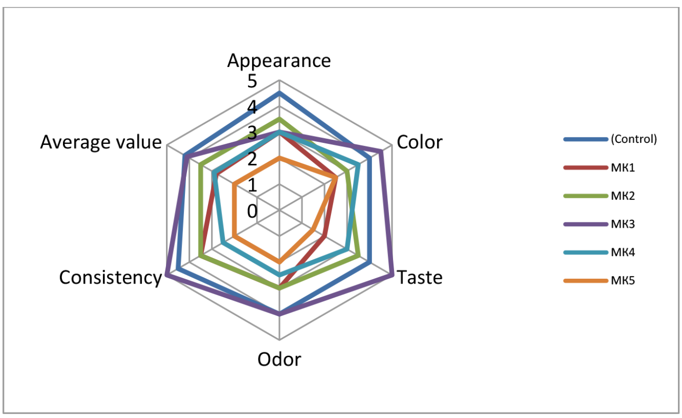

Fig. 4. Profilogram of organoleptic characteristics of structured drink with Empetrum extract

Organoleptic parameters: taste and odor – were determined organoleptically using aroma and taste sensors; consistency, appearance, and color – visually. To obtain the general organoleptic characteristics of the reconstituted product, a comprehensive assessment on a five-point scale was used [9].

Based on the scores of the organoleptic control, a profilogram was prepared to visualize the sensory characteristics of the samples and determine the advantages of formulations with the addition of plant extracts.

Table 3

Scoring of the organoleptic properties of the control samples of the drink with marigold extract

Organoleptic control indicators	Samples					
	(Control)	MS 1	MS 2	MS 3	MS 4	MS 5
Appearance	4,5	3,5	3	4	3	2
Color	4	3,5	3,5	4	2,5	2
Taste	4	3	5	3	2	2
Odor	4	3	5	4,5	2	1
Consistency	4,5	4	5	3	2	2
Average value	4,2	3,4	4,3	3,7	2,3	1,8

Table 4

Scoring of the organoleptic properties of control samples of the beverage with empetrum extract

Organoleptic control indicators	Samples					
	(Control)	МК1	МК2	МК3	МК4	МК5
Appearance	4,5	3	3,5	3	3	2
Color	4	2,5	3	4,5	3,5	2,5
Taste	4	2	3,5	5	3	1,5
Odor	4	3	3	4	2,5	2
Consistency	4,5	3,5	3,5	5	2,5	2
Average value	4,2	2,8	3,5	4,3	2,9	2,0

To determine the best option with the highest value of the complex quality criterion, the criterion formula was used:

$$F = f_1 f_2 + f_2 f_3 + \dots + f_{N-1} f_N + f_N f_1; \text{ ball}$$

The criterion F of the "quality polygon" is a nonlinear generalized quality indicator. For each sample, it is necessary to calculate the value of the generalized criterion F. The best sample is the one for which the value of F is greater [7].

Calculation of the complex quality criterion for the control sample of the beverage:

$$F_{K.} = 4.5 \cdot 4 + 4 \cdot 4 + 4 \cdot 4 + 4 \cdot 4.5 + 4.5 \cdot 4.5 = 88{,}25 \text{ ball.}$$

Calculation of a comprehensive quality criterion for a stabilized beverage based on buttermilk with marigold extract:

$$F_{MK2} = 3 \cdot 3.5 + 3.5 \cdot 5 + 5 \cdot 5 + 5 \cdot 5 + 5 \cdot 3 = 93{,}0 \text{ ball.}$$

Calculation of a comprehensive quality criterion for a stabilized beverage based on buttermilk with empetrum extract:

$$F_{MK8} = 3 \cdot 4.5 + 4.5 \cdot 5 + 5 \cdot 4 + 4 \cdot 5 + 5 \cdot 3 = 91{,}0 \text{ ball.}$$

In the course of the study of the organoleptic properties of stabilized beverages based on butterbur with the addition of marigold and rosehip extracts, a comprehensive quality criterion (CQC) was calculated using the «quality polygon» method. This approach made it possible to quantify the combined effect of innovative components on the overall quality of the product.

The calculations showed that:

– The model control scored 88.25 points, which is 4.75 points less than the model control with marigold extract and 2.75 points less than the sample with rosehip extract, indicating a significant improvement in organoleptic properties when the stabilizing system and plant extracts were introduced into the drink.

– For the MS2 sample with marigold extract (0.2 mg) and sodium alginate content of 0.7 g, the CAC was 93.0 points, which is the highest value among all the samples tested.

– In the group with empetrum extract, the best sample was MS8 with content of empetrum extract of 0.3 mg and sodium alginate of 0.75 g, which reached a QCS value of 91.0 points.

Conclusions. The study investigated the effect of a structure-forming agent (sodium alginate) and extracts of medicinal plants (marigold and rosehip) on the formation of physicochemical and organoleptic characteristics of butterbur-based beverages. Prototypes were made taking into account variations in the amount of extracts and thickener.

Several methods were used to evaluate the quality: determination of density by an areometer, viscosity using a Hepler viscometer (with balls No. 5, and No. 6), active acidity (pH), and changes in pH during storage.

The results showed that the density of the test samples varied from 1,091–1,394 kg/m^3, the dynamic viscosity varied from 167.1 to 53,752.3 · 10^{-3} mPa-s (depending on the amount of nasturtium alginate, the type of extract, and the balloon used for measurements), and the pH level varied from 5.35-6.36. During the storage of the beverages for 14 days at 4 °C, a gradual decrease in pH was recorded with a maximum decrease of 0.32 units.

The evaluations confirmed that the best organoleptic characteristics were demonstrated by samples with marigold extract at a concentration of 0.2 g/100 ml (F = 93.0 points^2) and empetrum – 0.3 g/100 ml (F = 91.0 points^2). The use of sodium alginate at a dose of 0.7 g/100 ml ensures a stable consistency and allows the formation of a homogeneous dispersion system with the desired viscosity.

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