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ASSESSMENT OF THE EFFECT OF CHICKPEA PROTEIN CONCENTRATE ON KEFIR PROPERTIES

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Abstract. The object of the research is the technological process of kefir production using traditional dairy raw materials and alternative sources of vegetable protein. The problem to be solved is to increase the nutritional and biological value of a fermented milk beverage without compromising its organoleptic, physico-chemical and microbiological parameters during storage. The aim of the study is to identify the influence of various concentrations of chickpea protein concentrate on the formation of physico-chemical, microbiological and organoleptic properties of kefir. Chickpea protein concentrate in the amount of 1-3% was used for experimental samples. The effect on fermentation, structural and mechanical properties, and sensory characteristics of the product was evaluated. Physico-chemical, microbiological and sensory research methods were applied in accordance with the current DSTU and ISO standards. The study has found that the addition of 2% protein chickpea concentrate provides the best combination of structural, mechanical and sensory properties of the product. The developed kefir was characterized by increased viscosity (82±2 s vs. 71±2 s in the control), higher moisture retention capacity (95.0±0.5% vs. 75.0±0.5 %), as well as an increased titer of lactic acid bacteria ($8\cdot10^8$ CFU/cm3, which is 4 times higher than the control). Significant protein enrichment is reflected in the increase in nutritional value: the protein content has increased from 2.7 to 4.2 g/100 g of the product. The analysis of the amino acid composition has shown an increase in the rate of lysine to 168.4 %, isoleucine to 142.5% and phenylalanine+tyrosine to 145.0 %, which indicates an improvement in the biological usefulness of the protein fraction. It has been found that the developed product retains stable organoleptic and microbiological properties for 21 days, which meets the requirements for fermented beverages of increased nutritional value. The results are recommended for use in the manufacture of functional fermented dairy products, in particular for protein enrichment of the diet of children, athletes and people who adhere to a healthy diet. The proposed technology can be implemented at milk processing enterprises without significant modification of the main technological process.

Keywords: dairy product, vegetable raw materials, chickpeas, protein concentrate, high-protein product, combined drink, lactic acid fermentation, amino acid composition, sensory properties, microbiological safety.

Introduction. Formulation of the problem

The modern concept of nutrition is based on the introduction of functional products that can minimize the risks of metabolic disorders and chronic diseases [1]. One of the priority areas of the food industry is the manufacture of products with high biological value by integrating natural fortifiers into traditional matrices. Fermented dairy products occupy an important place in human nutrition, as they are a source of essential nutrients and perform a significant preventive function [2]. In this regard, fermented dairy products, in particular kefir, deserve special attention. Due to its probiotic potential and specific microflora composition, it plays an important role in maintaining the immune system and the balance of the gut microbiota [3].

Analysis of recent research and publications

The technology of kefir production is based on fermentation of milk by bacterial-yeast symbioses (kefir fungi or starter cultures of direct application) using thermostatic or reservoir methods [4]. The global consumer trend for high-protein products makes it necessary to increase the protein content in kefir from the traditional 3.2% to 4.5–6.0% [5]. This ensures that the product is competitive among people with an active lifestyle and consumers who need dietary correction [6]. The possibility of varying recipes and the use of flavoring fillers, processed products of vegetables and fruit increases its competitiveness [7].

Innovative approaches to kefir enrichment include the use of milk concentrates (whey proteins, caseinates) and enzymatic hydrolysis methods that improve the bioavailability of nutrients [8, 9]. However, modern studies show that the fermentation efficiency and rheological parameters of the clot significantly depend on the genetic profile of milk proteins, in particular, the impact of the genotype on the coagulation process of mesophilic lactic acid bacteria [10]. In addition, innovative approaches involve the use of plant extracts (for example, hops) to modulate the biotechnological properties of the beverage and extend its shelf life [4]. Kefir has enriched with whey proteins has been shown to have a high biological potential, which is manifested in significant antioxidant activity and the ability to inhibit angiotensin-converting enzyme at all stages of gastrointestinal digestion [11,12].

A promising direction is the use of plant protein concentrates, which are characterized by high nutritional value, the availability of biologically active components and the ability to exhibit functional properties in multicomponent food systems.

Despite the prevalence of soy and pea proteins, their use is limited due to their specific sensory profile and allergenicity. Chickpeas (Cicer arietinum L.) is one of the most consumed legumes in the world, which is due to its high nutritional status [13, 14]. Chickpea protein (*Cicer arietinum L.*) is characterized by a balanced amino acid composition (high content of lysine and tryptophan), low allergenicity and high technological properties: solubility, ability to hydrate and form a stable structure [15, 16]. In addition, chickpea oligosaccharides can act as a prebiotic substrate to stimulate the growth of lactic acid microflora.

Despite the significant potential, the effect of chickpea protein concentrate on the dynamics of fermentation of the dairy system and the formation of a three-dimensional network of protein gel remains insufficiently studied. There is a scientific lack of data on the interaction of plant globulins with the casein fraction of milk under conditions of acid coagulation, as well as on the stability of rheological parameters and organoleptic profile of such combined systems during storage.

The hypothesis of the study is based on the assumption that partial replacement or addition of the milk base with chickpea protein concentrate within critically justified limits will strengthen the structural and mechanical properties of kefir and increase its biological value without inhibiting the metabolic activity of the fermentation microflora.

Goal and objectives of the study. *The goal* of the study is to identify the influence of various concentrations of chickpea protein concentrate on the formation of physico-chemical, microbiological and organoleptic properties of kefir. The study is aimed at scientifically substantiating the optimal dose of vegetable protein fortifier, which ensures stable quality over a certain shelf life. This will expand the range of functional fermented dairy products, increase their competitiveness, and provide consumers with a valuable source of vegetable protein without changing traditional production technology.

To achieve this goal, the objectives to be sought have been set as follows:

1. to substantiate the feasibility of using chickpea protein concentrate as a vegetable fortifier in the technology of thermostatic kefir;
2. to develop kefir formulations with different concentrations of chickpea protein concentrate (1-3 %) and produce prototypes in the laboratory;
3. to study the effect of chickpea protein concentrate on the course of the fermentation process, the dynamics of acid formation and the formation of a fermented milk clot;
4. to evaluate the physical and chemical quality indicators of kefir (titrated and active acidity, conditional viscosity, moisture retention capacity) depending on the content of vegetable protein;
5. to analyze the organoleptic properties of prototypes by sensory profile analysis and establish the optimal concentration of chickpea protein concentrate based on a set of qualitative indicators;
6. to determine microbiological indicators of kefir quality and safety during the entire shelf life and evaluate the effect of vegetable protein on the viability of fermentation microflora;
7. to calculate the nutritional, energy and biological value of the developed product, including the integral speed and amino acid speed of the protein fraction;
8. to determine the optimal shelf life of kefir with chickpea protein concentrate based on a comprehensive assessment of organoleptic, physico-chemical and microbiological indicators;
9. to develop an improved technological scheme for the production of kefir with a high protein content

and evaluate the prospects for practical implementation of the product.

Research materials and methods

The object of the research is the technological process of kefir production using traditional dairy raw materials and alternative sources of vegetable protein.

Milk for research was obtained from cows kept at the SOE State Institute of Agriculture of the North-East of the National Academy of Agrarian Sciences of Ukraine (Sumy Region, Ukraine). Milk quality indicators corresponded to the “extra” category according to the State Standards of Ukraine (DSTU) 3662:2018: the mass fraction of protein was (3.2±0.2) %, fat – (3.9±0.3) %.

Chickpea protein concentrate produced by Desnaland LLC has been used as a protein fortifier (according to TU U 10.41-39224310-002:2021), which is a fine powder of light cream color with a protein content of at least 80%. Fermentation has been carried out using a lyophilized fermentation culture of direct application “KEFIR 2” (Chr. Hansen), which includes *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *cremoris*, *Lactococcus lactis* subsp. *lactis biovar. diacetylactis*, *Leuconostoc*, *Streptococcus thermophilus* and yeast *Debaryomyces hansenii*.

The name “Pro-Kefir” is used as a designation for the developed product and is not a registered commercial name.

Research methods. Analytical methods were used to comprehensively determine the chemical composition, physico-chemical parameters, microbiological characteristics, as well as to assess the safety indicators of the studied samples. The choice of methods was based on the principles of ensuring maximum accuracy and reliability of the obtained data, taking into account the specifics of each of the analyzed indicators.

Production of prototypes. In laboratory conditions, kefir prototypes were made using a standardized technological scheme. For the experiment, formulations with different mass fractions of chickpea protein concentrate were developed as follows: 1 % (sample K1), 2 % (sample K2) and 3 % (sample K3). For control (sample K0), the technology of production of thermostatic kefir based on normalized cow’s milk and sourdough culture without the use of vegetable additives is adopted.

At the initial stage, the calculated amount of prepared chickpea protein concentrate was added to normalized milk with a mass fraction of fat of 2.5%, preheated to a temperature of 40-45°C. The resulting mixture was kept for 20-30 minutes to swell the protein components and intensify the transition of biologically active substances to the milk phase.

Heat treatment of the mixture was carried out at a temperature of (92±1)°C without exposure, and then cooled to a temperature of (30±2)°C. The selected heat treatment mode ensures sufficient denaturation of whey proteins due to the high temperature of the process. This promotes their interaction with casein micelles through the formation of disulfide bonds, which is an important factor in the formation of a stable protein structure of the clot, even in the presence of plant protein. Inoculation was carried out by adding direct sourdough in an amount of 0.2%, followed by mixing for 5-10 minutes to evenly distribute the microflora.

The prepared mixture was poured into consumer containers and fermented by thermostatic method at a temperature of (30±2)°C for 12-14 hours until a clot was formed. Fermentation was stopped when the titrated acidity reached 85-130°T and the active acidity reached pH 4.6±0.1, after which the samples were immediately cooled to a temperature of (4±2)°C to stop fermentation processes. The finished samples were stored at a temperature of (4±2)°C until further analysis was performed. The appearance of the prototypes is shown in Fig. 1.

The assessment of organoleptic properties was carried out in accordance with the requirements of DSTU 4417:2005, supplemented by the recommendations of ISO 22935-2:2023. The sensory-profile method, which provided for a detailed description of such parameters as appearance, consistency, taste, aromatic properties and color of the product, was applied in the process of assessing.

Determination of physical and chemical quality indicators. The mass fraction of dry substances was determined using a gravimetric drying method in accordance with the requirements of DSTU 8552:2015.

K0 K1 K2 K3

Fig. 1. Appearance of kefir prototypes

The protein content in the samples was determined using the Kjeldahl method (DSTU 8063:2015).

The mass fraction of fat was analyzed using the Gerber acid method. The quantitative carbohydrate content was determined by the Bertrand method.

Titrated acidity was determined using the titrimetric method to ensure accurate quantitative measurement of the total acidity of the samples.

The active acidity was determined with the application of the potentiometric method using a pH meter, in accordance with the requirements of DSTU 8550:2015.

The conditional viscosity of the product was estimated by measuring the flow time. The method consisted of fixing the time required for 100 ml of the substance to flow out through a calibrated pipette with an outlet diameter of 5.0 mm at a stable temperature of 20 °C.

The microbiological indicators of sample quality and safety were determined in accordance with DSTU 7357:2013, DSTU 7999:2015, DSTU 8446:2015 and DSTU 8447:2015.

The calculation of the energy value of kefir with a high protein content was determined as the sum of the energy contributions of the main macronutrients – proteins, carbohydrates and fats. The calculation was based on the mass fractions of the corresponding components in 100 g of the product, taking into account the generally accepted coefficients of energy value: 4 kcal/g for protein and carbohydrates and 9 kcal/g for fat. The resulting value reflects the total energy value of the product, expressed in kilocalories.

Integral score is an indicator that reflects the ratio of the amount of essential substances contained in the product to the standard values determined in accordance with the formula of balanced nutrition. This indicator is usually expressed as a percentage and used to assess the nutritional value of the product. The integral speed has been calculated for 10 g of the finished product. Biological value is an important indicator that demonstrates how useful and balanced in terms of amino acid composition the protein contained in the product is.

Amino acid score (AS) is the ratio of the amount of essential amino acid contained in the test protein to its content in the “ideal protein”, which serves as a reference.

Sensory profile analysis was used to evaluate the taste and aroma characteristics of intermediate and final products in accordance with the requirements of DSTU ISO 6658:2005. The method provided a comprehensive study of the impact of technological factors on the qualitative parameters of the product and allowed comparing samples with similar sensory properties. It also made it possible to track quality changes during storage.

The formation of the expert commission began with the selection of five specialists who had received preliminary training. The preparatory stage included an assessment of the ability to distinguish odors, reproduce aromatic characteristics, determine the thresholds of sensory sensitivity and the level of sensory memory in accordance with the provisions of DSTU ISO 6658:2016. The experts had been also instructed on terminology and procedures, which ensured reproducibility of the results.

In the first phase of the study, the experts identified key sensory descriptors of taste and smell in the skin sample. Additionally, reference samples with comparable profile characteristics were formed to improve the accuracy of subsequent comparisons.

Another stage involved an individual assessment of the order of manifestation and intensity of descriptors. The intensity was determined on a 5-point scale:

0.0-0.9 – no sign;
1.0 - 1.9 – low intensity;
2.0 - 2.9 – low intensity;
3.0 – 3.9 – moderate intensity;
4.0-4.9 – pronounced intensity;
5.0 – a very strong manifestation of the sign.

Each sample was evaluated three times to improve the reliability of the results. The data were recorded in standardized tasting sheets.

Mathematical and statistical methods for processing the research outcomes. The obtained experimental data were processed using the standard Microsoft Excel software package using correlation and regression analysis methods. The generally accepted methods, in particular, determining the arithmetic mean (n=3) and standard deviation of individual results were used for data processing. The accuracy of the measurements was evaluated taking into account the level of reliability (confidence probability) P≥0,95.

Results of the research and their discussion

The organoleptic parameters and physico-chemical parameters were determined in the prepared samples. Titrated acidity, viscosity indicators, and moisture retention capacity were evaluated. The dynamics of acidity changes during fermentation is shown in Fig. 2.

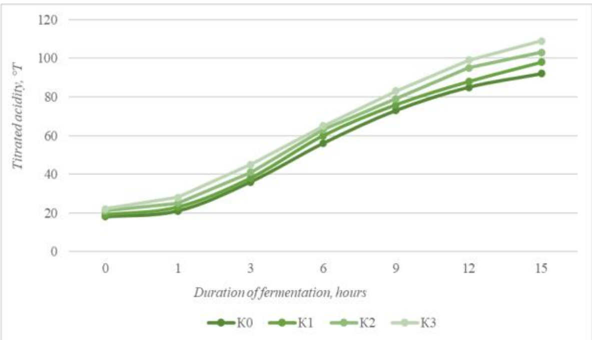

Fig. 2. Dynamics of acid formation of kefir prototypes

A slower increase in acidity during fermentation was established in the control sample K0. Experimental samples with the addition of chickpea protein concentrate were characterized by a more intense fermentation process. It only took them 12 hours to reach the titrated acidity of 100°T. This indicates an acceleration of clot formation and a potential reduction in energy consumption during production. The acceleration of acid formation in experimental samples containing 1-3% concentrate is consistent with the data of previous works, where fermentation of chickpea flour with the participation of kefir cultures has reduced phytic acid and accelerated the biochemical processes accompanying clot formation [17].

The results of the study of moisture retention capacity are shown in Fig. 3.

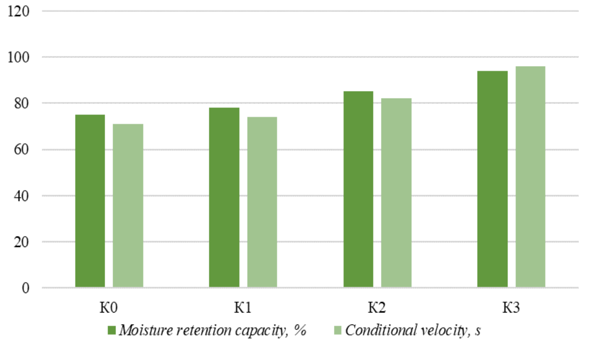

Fig. 3. Structural and mechanical properties of kefir prototypes

The data obtained show a decrease in the amount of isolated whey with an increase in the proportion of chickpea protein concentrate. An increase in the concentration of the protein component provides an increase in the moisture retention capacity of prototypes by 16-19%.

The addition of chickpea protein concentrate reduces the intensity of whey formation, which has a positive effect on the stability of the product during storage. At the same time, the viscosity of the samples increases, which contributes to the formation of a thicker consistency without the need for additional stabilizers. This is confirmed by the analysis of structural and mechanical properties shown in Fig. 3. Such changes partially correlate with the known effects of legume proteins on the structure of fermented milk systems and have been recorded in experimental studies of the enrichment of yoghurts and kefirs with plant ingredients [4, 18]. The improvement in structural and mechanical properties can be explained by protein-protein interactions occurring in the combined system. Chickpea proteins, represented mainly by globulins (legumin and vicillin fractions), are capable of hydration and partial unfolding of the structure during heat treatment. This promotes their interaction with casein micelles through the formation of hydrogen bonds, hydrophobic interactions, and possible disulfide bonds with denatured whey proteins. This has resulted in the formation of a more branched three-dimensional grid with increased moisture retention capacity, which leads to a decrease in syneresis and an increase in the viscosity of the product. At the same time, it should be noted that no direct microstructural (in particular microscopic) or electrophoretic studies have been conducted for the period of this study, so the proposed mechanism is based on indirect data and generalization of literature sources [4,18, 22].

It was found that the introduction of protein concentrate significantly affects the texture characteristics of kefir, so the choice of the optimal concentration of this component requires sensory evaluation of samples. According to the results of sensory analysis, control samples of thermostatic kefir (K0) fully comply with the current regulatory requirements. The sample is characterized by a thick and uniform texture without signs of violation of the clot structure. The taste is typical for a fermented milk product and characterized by purity and the absence of foreign tastes or odors.

The addition of chickpea protein concentrate leads to a gradual compaction of the consistency of the samples, which partially worsens their sensory parameters. At the same time, there is a modification of taste and aroma characteristics. The samples K1 and K2 have a sweet and sour-milk taste with a slight hint of chickpea component. An increase in the content of chickpea protein in the sample K3 forms intense “chickpea” shades of taste and aroma, which may be unacceptable for some consumers. This finding is consistent with other studies where the introduction of plant proteins has required optimization of concentrations or the use of pretreatment (e.g. germination, fermentation, thermal or enzyme modification) to reduce unpleasant taste notes and improve compatibility with milk microflora [18,19].

The results of sensory analysis indicate that the optimal dose of chickpea protein concentrate is 1-2%. The best organoleptic properties have been obtained for a sample with a content of 2%, which confirms the feasibility of using this particular concentration in the formulation of thermostatic kefir.

A recipe for kefir with a high protein content has been formed based on the results of the experimental studies (Table 1). The recipe composition provides for the use of normalized milk, chickpea protein concentrate and direct sourdough. The addition of 2% protein concentrate increases the nutritional value of the product without violating its structural and rheological characteristics.

The improved technological scheme provides for a set of standard operations with appropriate adjustment of heating, cooling and fermentation modes, which makes it possible to obtain a product with a high protein content. The technological process of Pro-Kefir production begins with the acceptance and input quality control of raw milk in accordance with the requirements of DSTU 3662:2018. Chickpea protein concentrate comes in a moisture-proof package and is stored at a temperature not exceeding 22 °C in dry conditions. After acceptance, milk pre-processing is carried out-purification and cooling to 4±2°C. The duration of temporary storage of raw milk does not exceed six hours, which prevents the occurrence of defects in taste, smell and consistency. After that, the milk is heated to 40-45 °C and normalized to a mass fraction of fat of 2.5%.

Table 1 – Recipe composition of kefir "Pro-Kefir"

Recipe components	Raw material consumption per 1000 kg of finished product	
	%	kg
Normalized milk (fat content = 2.5%)	98,00	993,50
Chickpea protein concentrate	2,00	20,30
Sourdough for kefir	0,20	2,03
Total	100,20	1015,83
Output	100,00	1000,00

At the stage of preparing the mixture for normalized milk, chickpea protein concentrate is put according to the recipe. The protein component dissolves at a temperature of 40-45 °C for 20-30 minutes. After that, homogenization is carried out, which ensures an even distribution of vegetable protein and the formation of a stable structure of the future product.

Then, the mixture is pasteurized at 92±1 °C without exposure – the high-temperature regime significantly reduces the microbial load and creates conditions for the formation of a dense, homogeneous clot. After pasteurization, cooling is carried out to 30±2°C, which is the optimal temperature for applying sourdough.

Fermentation is carried out using a culture of direct application of KEFIR 2 (Chr. Hansen, Denmark) in the amount of 0.2%. Mixing lasts 5-10 minutes until the bacterial composition is evenly distributed. The prepared mixture is poured into consumer containers and sent to a thermostat for fermentation. The fermentation process lasts 11-12 hours at a temperature of 30±2 °C until an acidity of 85-130 ° C and a pH of 4.0–4.8 is reached.

After fermentation is completed, the product is cooled to 20±2 °C, which ensures the cessation of active growth of lactic acid bacteria and stabilization of the formed structure. Further, labeling and packaging are performed in accordance with the requirements of current standards. The finished product is additionally cooled to 4±2 °C, after which it is stored.

Pro-Kefir is implemented at a temperature of 4±2 °C and a relative humidity of up to 75%. The shelf life is up to 21 days, of which the product can be stored on the production site for no more than two days.

When evaluating the quality indicators of the developed product, a comparison was made with traditional thermostatic kefir (Table 2).

Table 2 - Quality characteristics of kefir

Indicator name	Characteristic	
	Traditional kefir	Pro-Kefir
Titrated acidity, °T	93,0 ±1,0	103,0 ±1,0
Active acidity, un. pH	4,50±0,05	4,35±0,05
Conditional viscosity, c	71,0 ±2,0	82,0 ±2,0
Moisture retention capacity, %	75,0 ± 0,5	95,0 ±0,5

An increase in titrated acidity in the Pro-Kefir sample (+10°T) indicates an intensification of lactic acid fermentation processes. This is also confirmed by a decrease in the active acidity index to pH 4.35, which is typical for products with a higher metabolic activity of fermented microflora. This decrease in pH is probably due to the availability of additional nutrient substrates that provide chickpea protein concentrate, stimulating the vital activity of lactic acid bacteria.

The conditional viscosity index has increased by 15.5%, which confirms the tendency to compact the consistency. An increase in viscosity correlates with an increase in moisture retention capacity (+20%), which is a positive technological effect, since it reduces the risk of serum release and contributes to the stability of the clot structure during storage. This enables to predict better stability of the colloidal system and a long period of maintaining the correct texture.

According to the results of microbiological studies, it has been found that the content of lactic acid bacteria is $8 \cdot 10^8$ CFU/cm^3, which is four times higher than the traditional indicator ($2 \cdot 10^8$ CFU/cm^3). This effect is consistent with the literature, which indicates that legume ingredients can improve the growth of probiotic microflora due to the availability of available amino acids and oligosaccharides [20]. A similar trend can be traced for yeast, the number of which has increased from $1 \cdot 10^3$ to $5 \cdot 10^3$ CFU/cm3, which indicates a more active formation of kefir symbiosis. Bacteria of the Escherichia coli group (coliforms), *L. monocytogenes*, pathogenic microorganisms and mold fungi have not been detected in the samples, which confirms their microbiological safety and compliance with sanitary and hygienic requirements.

The results of calculating indicators of nutritional and energy value indicate a modification of the nutritional profile of the product. The defining change is an increase in the mass fraction of protein. In the developed product, this indicator has reached 4.2 g/100 g, which is 55.5% higher than the value of the control sample (2.7 g/100 g). This significant enrichment enables to position Pro-Kefir as a source of additional protein in the diet.

Changes in fat content are minimal (2.6 g vs. 2.5 g), which enables to maintain the dietary orientation of the product. The total amount of carbohydrates has increased by 0.4 g/100 g due to the natural carbohydrates of chickpeas. At the same time, the product contains trace amounts of dietary fiber (0.06 g/100 g), which are absent in traditional dairy raw materials.

The energy value of the product has increased moderately – from 48.5 kcal to 57.1 kcal (by 17.7 %). The increase in caloric content occurs mainly due to the protein fraction, which is a positive factor for a balanced diet.

The effectiveness of the developed product is largely determined by its ability to cover the physiological need of the body for basic nutrients. For men (18-29 years old), consuming one serving of Pro-Kefir provides 10.5% of the daily protein requirement, while the traditional product provides only 6.8 %. For women (18-29 years), the rate of satisfaction of daily needs increases to 13.8% (against 8.9% in the control). The obtained data confirm the feasibility of introducing the developed drink into the diet as an effective source of protein. An increased protein concentration can significantly improve the balance of nutrition without the need to increase the volume of food consumed, which is relevant for creating functional products.

Evaluation of the amino acid composition of traditional and developed kefir has shown that both products are characterized by a high biological value of the protein fraction. At the same time, the enrichment of kefir with chickpea protein concentrate has significantly affected the profile of essential amino acids (Table 3).

The amino acid score of all essential amino acids exceeds 100%, which indicates a high biological value of the developed product. In particular, the lysine score is 168.4%, which is an important indicator, since chickpeas are a valuable source of this amino acid. The score of sulfur-containing amino acids (methionine+cysteine), which are usually deficient in legumes, in the developed product remains at a high level (105.1%) due to compensation with milk protein.

Minor fluctuations are observed for threonine, valine, isoleucine, and the combination of phenylalanine and tyrosine, but amino acid scores in both samples exceeded the recommended FAO/WHO values. This indicates that the protein component of the developed product fully meets the body’s needs for these amino acids. In particular, the AS of isoleucine in Pro-Kefir is 142.5%, which is an indicator of the high availability of amino acids for synthetic processes. Thus, the consumption of 100 g of the product provides the body not only with an increased amount of protein, but also with a full range of essential amino acids in an easily digestible form.

To establish the optimal shelf life, kefir prototypes have been periodically monitored for organoleptic, physico-chemical and microbiological parameters for 30 days. At the initial stages of storage (1-9 days), both products are characterized by stable organoleptic properties – a homogeneous, viscous consistency, an undisturbed clot and permissible gas formation, which is typical for the active life of kefir microflora. In the developed sample, there is a slight chickpea tint in taste and color, which is a direct consequence of the introduction of vegetable protein concentrate. The dynamics of titrated acidity shows a gradual increase in acidity over the entire follow-up period.

Traditional kefir is characterized by rapid accumulation of acidity, which reached 131°T from 15 days, and 189°T at the end of the period. In the sample with the addition of chickpea protein concentrate, the increase in titrated acidity during storage was less intense compared to the control sample. This phenomenon is not associated with the suppression of the vital activity of microflora, but is due to the high buffer capacity of plant proteins. Chickpea protein molecules are able to bind free hydrogen ions, which eliminates a sharp increase in the active acidity of the system. Thus, enriching the product with chickpea protein helps to stabilize the pH during the shelf life, providing a milder taste profile of the finished drink.

Microbiological indicators clearly demonstrate the benefits of recipe enrichment. The content of lactic acid bacteria in Pro-Kefir remains high until the 21st day, while in the traditional sample their number begins to decrease after 6-9 days, which is a typical trend of depletion of the microbial consortium. This resistance of the microbiota in the enriched product may be due to the prebiotic effect of chickpea protein and availability of additional nitrogenous and mineral substrates for bacteria.

Table 4 – Biological value of kefir

Amino acid	Recommended FAO/WHO content, g/100 g protein	Content, g/100 g of protein/ amino acid score, %	
		Traditional kefir	Pro-Kefir
Lysine	5,5	8,00 / 145,5	9,26 / 168,4
Threonine	4,0	4,50 / 112,5	4,40 / 110,0
Valin	5,0	6,00 / 120,0	5,90 / 118,0
Methionine+cystine	3,5	3,10 / 88,6	3,68 / 105,1
Isoleucine	4,0	6,00 / 150,0	5,70 / 142,5
Leucine	7,0	9,50 / 135,7	9,10 / 130,0
Phenylalanine + tyrosine	6,0	8,50 / 141,7	8,70 / 145,0

Organoleptic characteristics have proven to be a key criterion for determining the optimal shelf life. For traditional kefir, consistency defects (significant separation of whey) were observed until the 21st day, and after 27 days the product completely lost its uniformity. For the developed sample, similar changes were detected on the 27th day, although the typical taste and smell remained until that time. After 30 days, both samples showed significant serum separation, which made it impossible for the product to be sold for organoleptic parameters. At the same time, during the entire storage period, coliform bacteria, pathogenic microorganisms and mold fungi have never been detected, which indicates the effectiveness of production control.

Based on a comprehensive assessment, it has been found that the developed kefir sample retains stable quality indicators on the 21st day at a temperature of (4±2) °C, which is due to a combination of active microflora and functional properties of the plant component. Similar results are observed in the works of other scientists, where the period of 14th-21st days is a typical interval during which physico-chemical, microbiological and sensory indicators remain acceptable [20, 21]. In particular, several sources demonstrate the preservation of probiotic titers and the stability of viscosity and acidity during the 21st day [22, 19].

The practical significance of the study is that the use of 2% chickpea protein concentrate can increase the nutritional and biological value of kefir without deterioration of organoleptic properties, as well as ensure stable quality of the product during the 21st day of storage. This is important for industrial producers who want to create functional products with an increased proportion of vegetable protein.

Conclusion

The expediency of using chickpea concentrate in the technology of thermostatic kefir is scientifically substantiated and experimentally confirmed. It has been found that the optimal concentration of protein fortifier is 2%. At this dose, the best balance is achieved between organoleptic parameters and technological properties of the product.

The positive effect of chickpea concentrate on the formation of structural and mechanical properties of a fermented milk clot is proved. The developed Pro-Kefir is characterized by increased viscosity and increased moisture retention capacity up to 95 % (against 75% in the control). This indicates the formation of a stable protein-polysaccharide matrix that prevents syneresis during storage.

It has been determined that the introduction of vegetable protein stimulates the development of fermentation microflora. In Pro-Kefir, the number of lactic acid bacteria and yeast increases by 3-4 times compared to traditional kefir, which significantly enhances the probiotic properties of the beverage.

The protein content of Pro-Kefir has increased by 55.5% and amounts to 4.2 g/100 g. The calculation of the amino acid score has shown that the combination of milk and chickpea proteins provides a complete amino acid profile (score of all essential amino acids >100%), leveling the nutrient deficiency, is inherent in certain types of raw materials.

It is calculated that the consumption of one serving (200 g) of developed kefir provides 10.5–13.8% of the body's daily protein requirement (for people aged 18-29). The results obtained enable to recommend Pro-Kefir for putting into production as a functional product for mass and health-improving nutrition.

Prospects for further research include determining the effect of different fractions of chickpea proteins on texture formation, evaluating changes in volatile aromatic components, optimizing heat and hydration treatment of concentrate, and developing new combined fermented milk drinks.

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ОЦІНКА ВПЛИВУ НУТОВОГО БІЛКОВОГО КОНЦЕНТРАТУ НА ВЛАСТИВОСТІ КЕФІРУ

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Анотація. Об'єктом дослідження є технологічний процес виробництва кефіру з використанням традиційної молочної сировини та альтернативних джерел білка рослинного походження. Проблема, яку вирішували, полягає у підвищенні харчової та біологічної цінності ферментованого молочного напою без погіршення його органолептичних, фізико-хімічних та мікробіологічних показників протягом зберігання. Метою дослідження є виявлення впливу різних концентрацій білкового нутового концентрату на формування фізико-хімічних, мікробіологічних та органолептичних властивостей кефіру.Для експериментальних зразків використано концентрат білка нуту в кількості 1–3 %. Було оцінено вплив на ферментацію, структурно-механічні властивості та сенсорні характеристики продукту. Застосовано фізико-хімічні, мікробіологічні та сенсорні методи дослідження відповідно до чинних стандартів ДСТУ та ISO. У ході дослідження встановлено, що додавання 2 % білкового нутового концентрату забезпечує найкраще поєднання структурно-механічних і сенсорних властивостей продукту. Розроблений кефір характеризувався підвищеною в'язкістю (82±2 с проти 71±2 с у контролі), вищою вологоутримувальною здатністю (95,0±0,5 % проти 75,0±0,5 %), а також збільшеним титром молочнокислих бактерій ($8 \cdot 10^8$ КУО/см³, що у 4 рази перевищує контроль). Значне збагачення білками відображено у зростанні харчової цінності: вміст білка підвищився з 2,7 до 4,2 г/100 г продукту. Аналіз амінокислотного складу показав збільшення скору лізину до 168,4 %, ізолейцину до 142,5 % та фенілаланіну+тирозину до 145,0 %, що свідчить про покращення біологічної повноцінності білкової фракції. Встановлено, що розроблений продукт зберігає стабільні органолептичні та мікробіологічні властивості протягом 21 доби, що відповідає вимогам до ферментованих напоїв підвищеної харчової цінності. Результати рекомендується використовувати у виробництві функціональних кисломолочних продуктів, зокрема для збагачення білком раціону дітей, спортсменів і людей, що дотримуються здорового харчування. Запропонована технологія може бути впроваджена на молокопереробних підприємствах без суттєвої модифікації основного технологічного процесу.

Ключові слова: молочний продукт, рослинна сировина, нут, білковий концентрат, високобілковий продукт, комбінований напій, молочнокисле бродіння, амінокислотний склад, сенсорні властивості, мікробіологічна безпека.

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