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A New Approach to Developing the Quality of Yoghurts with Functional Ingredients

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Abstract.
Only high-quality products are competitive, and competitive products have to meet all kinds of requirements, from regulatory documentation to consumer expectations. Functional foods, such as yogurt, are designed with targeted properties, which is a complex task that requires a methodologically universal approach. The research objective was to develop and test a new approach to developing the targeted properties in functional yoghurts.
The research featured a new technology and formulation of functional yogurt with sea buckthorn and cryopowdered germinated rye. The study involved qualimetric forecasting methodology, as well as standard quality assessment tools and analysis methods. The new approach included several stages: 1) identifying requirements for product quality and production processes, 2) analyzing data on inadequacy, 3) predicting the effect of quality-forming factors, and 4) developing universal solutions to ensure the required properties. The research resulted in a nomenclature of consumer expectation indicators and a comprehensive assessment formula. It revealed the reasons behind the poor quality of yogurt at different stages. The key requirements for yoghurt included: 1) high moisture-binding capacity, 2) natural functional ingredients that give the product high consumer properties and reduce the risk of microbiological spoilage. The article introduces a formulations and production technology for the new functional yogurt, which proved to have a high content of vitamin C, potassium, and β-carotene. The sensory evaluation demonstrated its high consumer properties.
The new approach to the development and production technology proved to be effective. It can be used in the design and quality control of yoghurts with functional ingredients.

Keywords. Product design, quality, formulation, functional products, sea buckthorn, healthy nutrition, qualimetry, technology

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Новый научный подход формирования качества йогуртов с функциональными ингредиентами

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Аннотация.
Для обеспечения конкурентоспособности необходимо быстро проектировать продукцию, отвечающую комплексу требований к ней: от нормативной документации и до ожиданий потребителей. Важно проектировать продукцию с заданными свойствами в сегменте функциональных продуктов питания, таких как йогурт. Целенаправленное формирование свойств продукции является многоаспектной задачей, требующей методологически универсального подхода. Цель работы заключалась в разработке и апробации нового подхода выявления и формирования требуемых свойств йогуртов с функциональными ингредиентами.
Объекты исследования – технология производства и рецептура йогурта с функциональными компонентами (соком облепихи прямого отжима и криопорошком пророщенного зерна ржи) и факторы, формирующие его качество. Применялась методология квалиметрического прогнозирования, а также общепринятые инструменты оценки качества и методы анализа.
Представлены результаты применения подхода формирования требуемых свойств йогурта с функциональными ингредиентами. Подход заключается в выявлении требований к качеству продукции и процессам ее производства, анализе данных о несоответствиях, изучении и прогнозировании влияния формирующих качество факторов, а также разработке универсальных решений обеспечения требуемых свойств. Установлена номенклатура показателей потребительских требований к качеству йогурта и предложена формула комплексной оценки. Установлены причины несоответствий йогурта на разных этапах товародвижения. Обоснованы ключевые требования при проектировании свойств и технологии йогурта: высокая влагосвязывающая способность и содержание полезных натуральных функциональных ингредиентов, придающих продукту высокие потребительские свойства и снижающих риск микробиологической порчи. Разработаны рецептуры йогурта с требуемыми свойствами и предложена технология производства нового продукта. Лабораторные исследования промышленных образцов продукта показали высокое содержание витамина С, калия и β-каротина. Проведенный органолептический анализ свидетельствует о высоких потребительских свойствах продукта.
Результаты говорят об успешной апробации предложенного подхода при разработке рецептуры и технологии производства йогурта с функциональными ингредиентами. Они могут быть использованы при проектировании и управлении качеством широкого ряда йогуртов с функциональными ингредиентами.

Ключевые слова. Проектирование, качество, рецептура, функциональные продукты, облепиха, здоровое питание, квалиметрия, технология

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Introduction

According to the World Health Organization, human health depends on lifestyle (50%), heredity (20%), environmental conditions (20%), and healthcare (10%). Diet is the most important component of lifestyle [1, 2]. A proper diet can reduce overall morbidity, improve resistance to adverse environment, and increase life expectancy [3].

The state strategy of food industry development usually depends on several key issues. In the Russian Federation, these issues stretch far beyond the simple task of providing the population with high-quality and safe food products. Food industry should provide people with functional foods that satisfy their physiological needs and are fortified with essential nutrients [3–9]. As a result, food products with functional ingredients are gaining popularity, often as part of therapeutic, preventive, and targeted diets [2]. Such foods attract patients with homeostasis problems or people subject to extra risk or stress, e.g., pregnant women, senior citizens, children, etc. [10]. Functional foods intended for these population groups have stricter safety and quality requirements [2, 3, 10]. These products require a compulsory field-to-fork strategy of quality and safety control [5, 11].

Together with economic efficiency, the theory and practice of food design usually follows one or two of the following goals:
– attractive consumer properties;
– new functional ingredients;
– broader product range;
– stable quality indicators;
– longer storage capacity at all distribution stages;
– lower production and sales risks related to faulty or unsafe products;
– predesigned technological characteristics of the product or production processes, e.g., particular viscosity, etc. [1, 3, 12, 13].

Product quality and safety of products require a whole complex of procedures [14]. In food systems, the mechanism of quality development is a multifactorial process. Finished products are the result of a complex interaction of technology, formulation, raw materials and other factors along the entire field-to-fork chain [11]. New universal solutions of food quality issues need a new scientific approach based on modern principles of quality modeling and nutrition science. In addition, customer satisfaction is one of the key factors that determine product quality [15, 16].

Qualimetry is a new promising direction based on the achievements of domestic science and world experience of quality management. Qualimetry is based on the principles of forecasting quality and food safety indicators as methods of assessing, planning, and quality formation [10, 11, 17].

This approach is especially relevant for structured dairy products, e.g., yogurt. This product can turn into a nutrient medium for unwanted microflora. As a result, its quality indicators are highly sensitive to the storage and transportation conditions, the sanitary profile of the enterprise, the quality of raw materials, etc. [18–20].

The present research objective was to develop a new scientific approach to product quality formation and test it on a new functional yogurt product.

Study objects and methods

This new yogurt production technology relied on a particular scientific approach to the food quality formation. The key elements of the new approach followed a sequence of steps:
– requirements for product quality and production processes, which were identified, structured, and ranked based on regulatory documentation and the intermediate and final consumer demands;
– formula for a complex product quality indicator that reflects the weight of each indicator;
– the main requirements for the target quality indicators of the finished product, including the functional ingredients and production processes;
– processing the data on faulty products, e.g., negative consumer reviews, batch reviews, and complaints, followed by a cause identification analysis;
– factors that make up product quality indicators and their effect on quality;
– information-matrix models for the formation of product quality affected by the factors identified at the previous stage [11];
– universal solutions, e.g., by selecting specific functional ingredients, that guarantee the required properties of the finished product, take into account the requirements for the target quality, and reduce production risks.

The method of qualimetric forecasting included the following steps:
– a sociological survey of 250 respondents in the Moscow region based on the questionnaire method with subsequent statistical processing (State Standard R 56087.2-2014);
– weight coefficients of indicators by pairwise comparison;
– a formula for a complex quality indicator based on a qualimetric assessment, i.e., an integrated method for assessing product quality as a weighted arithmetic mean;
– collecting data from distribution centers on faulty functional yoghurts in 2015–2019 using a control sheet (State Standard R ISO 13053-2-2013) and the SAP program;
– applying such intelligent expert techniques as the Delphi method (State Standard R 54147-2010) and expert qualimetry to the questionnaires, expert assessments, and data analysis;
– applying the profile method (State Standard ISO 13299-2015) and expert qualimetry to the sensory assessment of samples;
– information-matrix models based on qualimetric scaling of expert qualimetry methods with subsequent statistical concordance coefficient processing [11];

– a complete factorial experiment with regression equations: mass fraction of yogurt – 50–85%, mass fraction of germinated rye cryopowder – 1.0–3.0%; mass fraction of fat in yogurt – 0.5–5.0%;
– values of normalized quality and safety indicators as determined by conventional methods of laboratory analysis: mass fraction of fat – by State Standard 5867-90, mass fraction of protein – by State Standard 25179-2014; mass fraction of carbohydrates – by State Standard R 54667-2011; vitamin C – by State Standard 34151-2017; *β*-carotene – by State Standard EN 12823-2-2014; potassium – by State Standard ISO 8070/IDF 119-2014). The results were statistically processed using an Intel(R) Core (TM)i7 personal computer and Microsoft Excel software.

The research featured requirements for the quality of yogurts, the causes of product discrepancies, the production technology and formulation of yogurt with functional components (patent RU 2742146C1), and the sources of functional ingredients, i.e., directly expressed sea buckthorn juice and sprouted rye cryopowder (OS 25622234-001-2018).

Results and discussion

The first stage identified the quality and safety requirements for yogurts with functional ingredients. They were decided into three groups: safety indicators, identification indicators, and indicators of consumer requirements. The first two groups are to be found in such standards as Technical Regulations of the Customs Union TR CU 021/2011, 033/2013, and 022/2011, State Standard R 31981-2013, etc. These indicators are mandatory for all new products. The third group of indicators, however, has no mandatory requirements since they totally depend on the consumer needs, and the degree of customer satisfaction determines the demand for new products.

The sociological survey involved 250 respondents from the Moscow region. The survey established a range of indicators of consumer requirements for the quality of functional yoghurts, which were ranked by their importance for consumers. The resulting formula for a comprehensive quality assessment of functional yoghurts was as follows:

$$Q = 15.2 \cdot q_1 + 13.7 \cdot q_2 + 12.9 \cdot q_3 + 10.6 \cdot q_4 + 9.8 \cdot q_5 + 8.1 \cdot q_6 + 8.1 \cdot q_7 + 4.2 \cdot q_8 + 4.1 \cdot q_9 + 3.3 \cdot q_{10} + 3.1 \cdot q_{11} + 2.7 \cdot q_{12} + 2.3 \cdot q_{13} + 1.9 \cdot q_{14} \quad (1)$$

where Q is a complex quality indicator, and $q_1 \ldots q_{14}$ are relative quality indicators: 1 – pleasant taste, 2 – useful components, 3 – affordability, 4 – minimal amount of ingredients, 5 – maximal amount of flavor filler, 6 – low calorie content, 7 – uniform consistency, 8 – low fat, 9 – pleasant smell, 10 – no liquid fraction, 11 – uniform and pleasant color, 12 – expiration date, 13 – a large amount of protein, 14 – unusual filler.

The sociological survey revealed the following consumer expectations. A good yogurt with functional ingredients should be both beneficial to human health, i.e., contain functional ingredients, and natural, i.e., no artificial additives, dietary supplements, etc. Consumers wanted a product with functional flavors, vitamins, or mineral premixes. They saw no fundamental difference between a functional product and a product with functional ingredients.

The next stage analyzed five years of statistical data on product discrepancies registered at the distribution network or mentioned by consumers (Fig. 1). The most common discrepancies included mislabeling, blown or leaking packaging, and liquid separation.

Mislabeling included the differences between the information on the label and the established requirements or misinformation about the flavor. They can be prevented by involving highly qualified specialists in the label design, as well as a stricter control of the labeling process during packaging. Other discrepancies resulted from unwanted microbiological processes in the product and a decrease in the moisture-binding capacity of the curd. Therefore, the new yogurt with functional ingredients needs higher moisture-binding capacity, lower risks of unwanted microbiological processes during distribution, and also stricter control during storage and transportation from the producer to the shop.

The main requirements for the target quality indicators of the finished product included:
– fortifying the yogurt with functional ingredients by adding functional flavoring agents;
– selecting such flavoring fillers that need no food dyes, flavor enhancers, acidity regulators, etc.;
– reducing the risks of producing and selling yogurts with syneresis;
– selecting components with lower risks of microbiological spoilage.

The next stage established the main requirements for the production processes, as well as the product quality factors. The resulting factors were divided into three groups: technology, formulation, and raw materials.

The research revealed the weight and nature of the effect provided by each group. The technological factors included the sequence, as well as the type and modes of technological operations. The raw material factors included the type of raw materials and their quality and safety indicators. The formulation factors included the type of each ingredient and their ratio. The obtained results were processed and represented as an information-matrix quality predicting model for yogurts with functional ingredients.

The quality of yogurt with functional ingredients appeared to depend on the technological and formulation factors in the ratio of 42 to 38%, respectively.

The research also revealed the total expert assessment of the contribution of each factor on the quality and safety. The most important technological factors included milk pasteurization (259 points), fermentation (129 points), formulating (120 points), and packaging (113 points). The formulation factors with the greatest contribution included stabilizer (184 points), flavor filler (156 points), yogurt (145 points), and dye (103 points). Consumers appreciated yogurts with few components: the weight coefficient of the "minimal number of ingredients" indicator was 10.6%. Therefore, the number of functional ingredients should be minimal.

Functional ingredients increase the nutritional and biological value of the product. However, they should also provide the following additional target properties:
– be associated not with an artificial additive but with a healthy natural food product;
– high moisture-binding (≥ 32%) and structure-forming abilities;
– a pleasant taste and aroma;
– a pleasant rich color, i.e., act as a natural dye;
– inhibit unwanted microflora.

Sea buckthorn juice and germinated rye cryopowder were chosen from the database of food fillers and functional ingredients. Their functional properties were proved information-matrix models for predicting the effect of functional ingredients on structured dairy products. These models were developed at the Department of Quality Management and Commodity Research of the Moscow Timiryazev Agricultural Academy.

Adding 5–7% of sea buckthorn juice increases the taste characteristics and fortifies the product with vitamin C, minerals, and fatty acids. *β*-carotene improves the dietary properties of the product, as well as its quality characteristics. Sea buckthorn has a bright yellow color that mixes well with both fat and water fractions. Vitamin C possesses preservative properties, which reduce the risk of developing unwanted microflora.

Rye dietary fibers fortify the product with plant fiber and give it the desired rheological properties. They are a source of amino acids, vitamins C, E, PP, folic acid, copper, manganese, selenium, and silicon. They help to lose weight, increase hemoglobin, strengthen the immune and antioxidant system, improve eyesight, skin, hair, and nails. In addition, sprouted rye cryopowder has a high moisture-binding capacity and structure-forming properties.

A complete factorial experiment provides universal solutions that allow food producers to respond to the constantly changing product requirements and to develop competitive products. A regression equation for the effect of controlled factors on the moisture-binding capacity (Y) looks as follows:

$$Y = -21.336 + 1.341 \cdot j + 156.671 \cdot k + 0.038 \cdot f + 1.029 \cdot j \cdot k + 0.002 \cdot j \cdot f - 0.408 \cdot k \cdot f + 0.005 \cdot j \cdot k \cdot f \quad (2)$$

where j – mass share of yoghurt in the model environment, %; k – mass share of sprouted rye cryopowder in the model environment, %; f – mass share of fat in the yoghurt, %.

The resulting regression equation made it possible to develop a high moisture-binding yogurt formulation fortified with sea buckthorn juice and germinated rye cryopowder (Table 1).

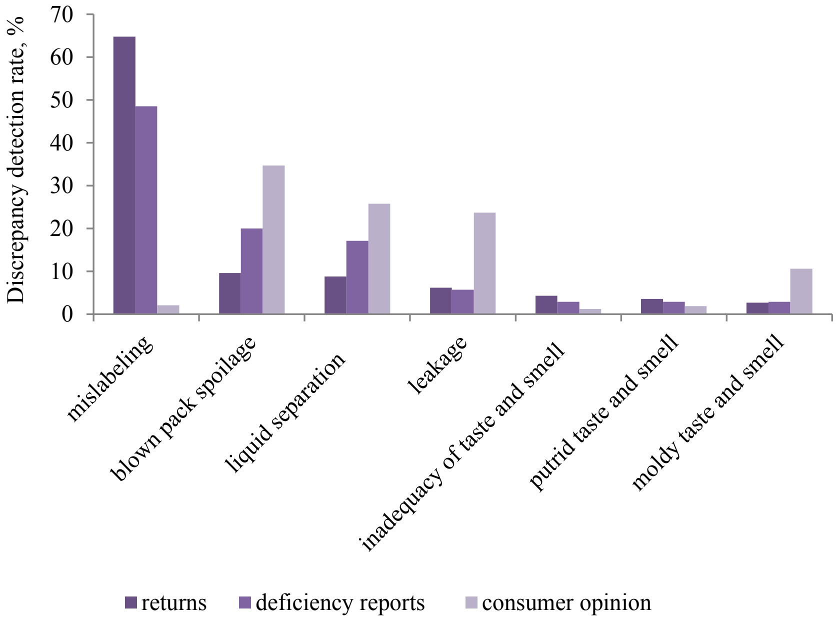

Figure 1. Discrepancies and their frequency over five years of product distribution: yoghurts with functional ingredients

Table 1. Formulations of yoghurts with functional ingredients

No.	Component	Weight of components, kg/1000 kg of finished product			
		Formulations			
		No. 1	No. 2	No. 3	No. 4
1	Yoghurt with 3.3% fat	750.0	650.0	700.0	630.0
2	Standardized milk with 3.3% fat	98.0	190.0	145.0	207.0
3	Sea buckthorn juice with sugar (1:1)	140.0	140.0	140.0	140.0
4	Germinated rye cryopowder	12.0	20.0	15.0	23.0
Total, kg		1000.0	1000.0	1000.0	1000.0

Table 2. Sensory evaluation of yoghurts with functional ingredients

No.	Sensory properties	Weight of components, kg/1000 kg of finished product			
		Formulations			
		No. 1	No. 2	No. 3	No. 4
1	Taste	4.9	4.9	4.9	4.8
2	Smell	4.7	4.7	4.7	4.7
3	Appearance	4.9	4.8	4.9	4.8
4	Texture	4.7	4.6	4.6	4.7
5	Color	5.0	5.0	5.0	5.0
Total score		24.2	24.0	24.1	24.0

The obtained data made it possible to develop a new production technology for yogurt fortified with sea buckthorn juice and germinated rye cryopowder.

The main stages of production included: raw material delivery and evaluation; milk standardization, homogenization, pasteurization, cooling; adding starter culture, fermentation, and curd mixing; adding a mix of sea buckthorn juice, skim milk, sugar, and sprouted rye cryopowder; mixing, bottling, packaging, and storage.

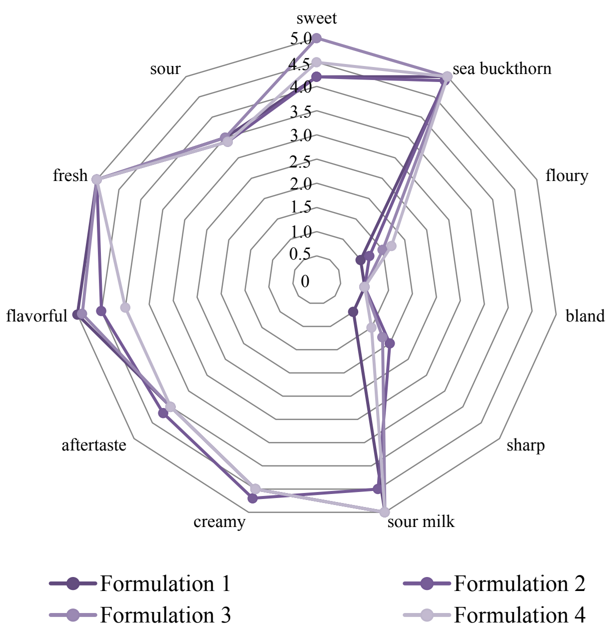

Figure 2. Sensory profile of yogurts with functional ingredients

Milk was standardized according to the mass fraction of fat (3.3%), heated to 60–65°C, homogenized at 1.5 ± 2.5 MPa, pasteurized at 88 ± 2°C for 8–10 min, and cooled until fermentation at 40 ± 2°C. After that, it was mixed with starter cultures *Lactobacillus bulgaricus* and *Lactobacillus thermophiles* (3–5%). The fermentation was complete when the acidity reached 90–100°T.

Cryopowder and sugar were dissolved in sea buckthorn juice in a separate container. The mix was cooled to 8–12°C, mixed with standardized milk, and stirred for 10 min. The resulting mix was added to the fermented curd and stirred for 10 min. Yoghurt with functional ingredients was cooled to 15–20°C, packed in containers, labeled, and cooled to 4°C.

The sensory analysis of commercial samples revealed their excellent consumer properties (Table 2). Figure 2 illustrates the flavor profile chart.

Conclusion

Qualimetric forecasting proved to be an effective approach to product quality formation. The obtained results made it possible to develop universal solutions that provide prompt adjustment of formulation and production technology. The approach guarantees properties important for yogurts with functional ingredients, stable quality and safety, lower risks of discrepancies, and better consumer attractiveness.

The proposed scientific approach revealed the key requirements for the quality indicators of yogurts with functional ingredients: high sensory properties, natural formulation components, and low risks of syneresis or microbiological spoilage. The research also substantiated the choice of sea buckthorn juice and germinated rye cryopowder as functional components. A set of experiments resulted in regression equations that can predict the effect of the content of germinated rye cryopowder and the mass fraction of fat in the milk base on the moisture-binding capacity. These equations produced new formulations and production technologies for yogurts with sea buckthorn juice and sprouted rye grain cryopowder.

Table 3. Nutritional and energy value of yogurts with functional ingredients

Formulation	Protein, g	Fat, g	Carbohydrates, g	Energy, kcal	Potassium, mg%	Vitamin C, mg%	β-carotene, mg%
Basic	3.80 ± 0.02	3.50 ± 0.10	9.70 ± 0.9	85.5	147.0 ± 1.1	0.61 ± 0.05	10.11 ± 0.05
No. 1	3.29 ± 0.02	3.25 ± 0.20	10.48 ± 0.8	83.9	150.0 ± 1.2	14.58 ± 0.04	114.03 ± 0.19
No. 2	3.27 ± 0.02	3.24 ± 0.10	10.57 ± 0.8	84.2	149.0 ± 1.3	14.32 ± 0.05	112.02 ± 0.18
No. 3	3.28 ± 0.02	3.23 ± 0.20	10.34 ± 0.7	83.3	151.0 ± 1.1	14.78 ± 0.05	114.31 ± 0.19
No. 4	3.26 ± 0.02	3.26 ± 0.10	10.15 ± 0.9	81.6	150.0 ± 1.1	14.02 ± 0.05	113.03 ± 0.19

The sensory assessment and the flavor profile chart revealed excellent consumer properties of all samples (24.0–24.2 points out of 25.0 points). The yoghurt was rich in vitamin C, β-carotene, and potassium. The content of vitamin C rose from 0.61 in the base sample to 14.02–14.78 mg% in the experimental samples. The content of β-carotene increased from 10.11 to 112.02–114.31 mg%, and that of potassium – from 147 to 149–151 mg% for. The high content of vitamin C and β-carotene makes the new yogurt a functional product.

Contribution

N. I. Dunchenko supervised the project; V.S. Yankovskaya performed the experiments.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this article.

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