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ОБОСНОВАНИЕ ВЫБОРА ОПТИМАЛЬНЫХ КОНЦЕНТРАЦИЙ ДЕЙСТВУЮЩИХ ВЕЩЕСТВ АНТИОКСИДАНТНОЙ КОМПОЗИЦИИ ДЛЯ ОБРАБОТКИ ПЛОДОВ ПЕРЕД ХРАНЕНИЕМ

Разработана антиоксидантная композиция на основе ионола, диметилсульфоксида и лецитина, применение которой будет способствовать продлению срока хранения плодов с минимальным уровнем ежесуточных потерь. Проведенной оптимизацией установлено, что при хранении плодов яблони и груши концентрация дистинола должна быть на уровне 0,041...0,042 %, концентрация лецитина – 2,9 %, при хранении плодов сливы соответственно: дистинола – 0,022 %, лецитина – 3,4 %.

Ключевые слова: обработка плодов антиоксидантным композицией, продления срока хранения, ежесуточные потери при хранении.

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DETERMINING QUALITY PARAMETERS OF ALCOHOL-FREE FUNCTIONAL BEVERAGE BY THE PROCEDURE THAT EMPLOYS AFFINE TRANSFORMATIONS

Проведені розрахунки якості безалкогольних напоїв функціонального призначення, згідно методики оцінки із застосуванням афінних перетворень, яка може бути застосована при будь-якому ідеальному значенні. Експериментальні дослідження виконувалися на прикладі процесів виробництва безалкогольних напоїв з м'якітною текстурою, застосовуючи розроблену методику, показники фізико-хімічних та органолептичних властивостей продукту, математичні методи обробки результатів вимірювань.

Ключові слова: *функціональні харчові продукти, управління якістю та безпечністю, середнє квадратичне відхилення.*

1. Introduction

Activities on the creation of a modern system of control over safety and quality of functional products, market surveillance, adapted to the requirements of the World Trade Organization (WTO) and the European Union (EU) have been intensified over recent years.

According to the law of Ukraine «On safety and quality of food products», quality of a food product is the combination of perfection of its properties and characteristic attributes that are able to satisfy the needs (requirements) and wishes those who consumes or uses this product. Among the variety of factors that affect the human health, one of the most essential is quality of nutrition [1].

Quality of the soft drinks with functional purpose is assessed by organoleptic and physical-chemical indicators. Among the physical-chemical indicators, most commonly determined are density (by saccharimeter), acidity, content of carbon dioxide and salts of heavy metals. Density and acidity are established by a standard for each particular beverage. Organoleptic assessment of drinks is conducted by a 100-point system by five indicators: transparence,

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saturation with carbonic acid, taste and aroma, color and physical design.

It is a relevant issue to apply a procedure to assess parameters of quality of functional soft drinks, which would make it possible to solve a number of practical tasks on the evaluation of processes that affect the overall standard of quality.

2. The object of research and its technological audit

In the present study we examined calculation of quality of alcohol-free beverage, by constructing a model using affine transformations, for the purpose of improving quality and safety of food products.

The value K_i obtained by authors [2] for the i indicator is recalculated along with other received values of the indicators. Generalized quality indicator K_o is calculated by formula:

$$K_o = \sqrt[m]{K_1 \cdot K_2 ... K_m}, \quad (1)$$

where m is the number of indicators of the parameters of comparison used for this system.

As a result of generalization, quality function K_o becomes the only parameter of optimization instead of many. The way of assigning this indicator is so that if even one quality K_i=0, then the generalized quality will be equal to zero. On the other hand, K_o=1 only when K_i=1. Generalized function is very sensitive to small values of indicators while the number of these indicators can be different for different systems. This makes it possible to compare generalized coefficients even when part of the parameters of comparison in different systems or their data are missing. The root of m power «smoothes out» arising deviations and the obtained result makes it possible to estimate the systems with a defined accuracy degree.

A generalized function of desirability proposed by author in [3] as a single comprehensive quality indicator:

$$d = \exp(-\exp(-Y)), \quad (2)$$

where Y is the coded value of partial parameter y, that is, its value in a conditional scale.

That is why, in order to determine the quality of the system, it is necessary to have weighted coefficients of parameters. It is proposed to assess the quality of the system using the geometric weighted mean with weights form formula:

$$K_o = \sqrt[\sum_i^m \alpha_i]{K_1^{\alpha_1} \cdot K_2^{\alpha_2} \cdots K_m^{\alpha_m}}, \quad (3)$$

where α_i are the weighted coefficients of the i-th indicator.

3. The aim and objectives of research

The aim of present research is to determine numerical characteristics of the generalized model of quality indicators of functional food products (FFP). Analysis of this model and comparison with previous estimates of quality. Construction of a procedure for FFP quality evaluation using affine transformations [2], which could be used at any perfect value. The application of this procedure would provide FFP with the most accurate quality indicators according to results of the sample.

To accomplish the set goal, the following tasks had to be solved:

1. To identify indicators of physical-chemical and organoleptic properties of alcohol-free functional beverage (AFB).
2. To propose to assess quality parameters of AFB in line with a mathematical model using affine transformations.
3. To calculate AFB quality according to a series of stages in the procedure for evaluation of quality indicator, and to present graphically the dependences of indicators from a group of physical-chemical and organoleptic properties.

4. Research of existing solutions of the problem

Application of comprehensive systems approach to quality management has been widely accepted, with significant contribution to its development from the scientists in articles [4–6]. The world's best known concepts are CWQC (Company Wide Quality Control) – quality management within a firm in Japan, and TQC (Total Quality Control) – general quality management in the USA [7, 8]. Paper [9] employed a procedure to assess product quality by using a desirability function. However, the existing mathematical models (desirability functions) make it possible to evaluate quality of products and processes of different nature, to apply their numerical characteristics that help obtain their interval quality indicators [10, 11]. In order to assess quality of the products, the Harrington desirability function is used. This very function has many advantages. Authors of paper [12] applied, as a function to convert multidimensional quality indicators into a dimensionless magnitude, a desirability function, which is known as the Harrington function. This function has a double exponential form and has a number of features that attracted researchers to practice its application [3]. It is obvious that the logistic desirability function of Harrington can be used as a sample, which had the largest values. That is why the assessment of quality of a product has to be low since the first type of asymptotic normalized allocation of maximum is employed [13–17].

Therefore, any functional soft drink has a number of indicators that are measured by different scales. All this results in difficulties when obtaining an overall qualitative assessment of the quality of the product. That is why, in order to receive the overall assessment of product quality, there is a need to normalize results of the experiment. Moreover, construction of a procedure for the assessment of AFB quality using affine transformations [15–17] allows us to determine indicators of quality and safety of food products in the substantiation of the system of food safety indicators.

5. Methods of research

When determining quality indicators of a group of organoleptic properties, collection and processing of expert data required for the calculation is carried out. According to existing recommendations, a group of experts should not exceed 20 persons [14]. The expert survey engaged four head of industrial production, four engineers-technologists and two specialists with extensive experience. The selection of experts was based on competence, lack of personal interest in the result of the examination, creativity (breadth of knowledge). After selecting the experts, they were asked to fill in a questionnaire, which provided the text part that explains the rules of the expertise of the provided model on the importance of quality indicators relative to the functionality of food products.

When determining indicators of physical-chemical properties of alcohol-free functional beverage, in the present work we applied procedures for the analysis of raw materials, semi-finished products and finished products that meet the purpose of the study:

1) modern standard physical and chemical;
2) physical-chemical;
3) biochemical;
4) organoleptic.

List of methods of analysis is given in Table 1. Selection and preparation of samples of the examined products for sensory, physical-chemical and bacteriological analyses was performed according to DSTU 4856. Determining the organoleptic parameters was carried out in line with DSTU 7099.

Table 1

Research methods for the assessment of quality and safety of food raw materials, semi-finished products and soft drinks with functional purpose

Indicators	Method title, features
Examination of chemical composition	
Mass fraction of dry substances	Determined in accordance with DSTU 4855 by using the refractometric method. The method is based on determining a share of dry substances by a refractometer scale at a temperature of 20 °C after conducting in the sample of a product at complete inversion
Ash mass fraction	Method of mineralization based on burning a batch followed by dry exposure in the muffle furnace at a temperature of 520…700 °C and quantitative account of the residual
Moisture mass fraction	Thermogravimetric method of drying a batch to constant weight at $t=103\pm2$ °C
Content of monosaccharides	By polarimetric method
Content of polysaccharides	By phenol-sulfur method
Content of fiber	By the method of Krushner and Gashek
Examination of functional-technological properties	
Dynamic viscosity	Viscosity of the finished beverages was examined on the constant voltage viscometer VZ-246P (Russia)

The research consisted of two interrelated parts that aligned various modern research methods with a single purpose. The first part is theoretical, applied for the development of methodological approaches to the design of new soft drinks with functional purpose through the systematic analysis of patent-information literature in this field. The theoretical stage defined a general direction of our own scientific research; it became a starting point for conducting the experiment using computer simulation.

The main part of experimental research and practical work was carried out in the laboratories at Kharkiv Trade-Economic Institute KNTEU (Ukraine), and Ukrainian Engineering and Technological Academy (Kharkiv, Ukraine).

6. Research results

Data on determining quality indicators of the group of physical-chemical properties and the group of organoleptic properties are given in Table 2.

Table 2

Comprehensive quality indicator of the group of physical-chemical and organoleptic properties

Comprehensive quality indicator of the group of organoleptic properties	
Consistency	4.87; 4.89; 4.915; 4.93; 4.954
Physical appearance	4.85; 4.91; 4.93; 4.945; 4.97
Aroma	4.86; 4.87; 4.89; 4.95; 4.9
Flavor	4.9; 4.95; 4.98; 4.99; 5.0
Color	4.78; 4.82; 4.825; 4.85; 4.871
Comprehensive quality indicator of the group of physical-chemical properties	
Mass fraction of dry substances	18.42; 18.45; 18.48; 18.75; 18.87
Mass fraction of sediment in the examined samples	0.6; 0.62; 0.64; 0.645; 0.66
Mass fraction of pulp in the examined samples, %	18.0; 19.0; 19.5; 20.0; 20.5
Mass fraction of titrated acids in the examined samples, %	1.38; 1.39; 1.41; 1.44; 1.47
Viscosity (dynamic) of beverages with the use of raw materials of plant origin in the examined samples, Pa·s	30.4; 38.4; 39.3; 41.3; 48.9
pH	30.4; 38.4; 39.3; 41.3; 48.9

Procedure for the assessment of beverage quality indicator, which includes a number of stages:

1. Determine a number n of conducted experiments on quality indicator, and record their values – x_i $(i=1,...,n)$.
2. Find numerical characteristics (4)–(7):

– random mean:

$$\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i; \quad (4)$$

– corrected variance:

$$S^2=\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2; \quad (5)$$

– empirical standard:

$$S=\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i-\bar{x})^2}; \quad (6)$$

– variance coefficient:

$$v=S/\bar{x}. \quad (7)$$

3. Write the values of maximum quality indicator x_0, permissible boundaries of quality indicator – lower a and upper – b.
4. Determine the absolute value of difference – $x_i'=|x_i-x_0|$.
5. Compile variation series from the obtained values $x_i'-x_{(i)}'$, that is, record the values of ordinal statistics $x_{(i)}'$.

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6. Determine permissible values for variation series $a' = a - x_0$ and $b' = b - x_0$.

7. Find numerical characteristics of the obtained variation series $x'_{(i)}$ ($i = 1,...,n$) – random mean $\bar{x}' = \frac{1}{n}\sum_{i=1}^{n} x'_{(i)}$, corrected variance $S'^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x'_{(i)} - \bar{x}')^2$, empirical standard $S' = \sqrt{S'^2}$ and the coefficient of variation $v' = S' / \bar{x}'$.

8. Find ratio λ of the point of division of the random mean $\bar{x}'$ along segment $[a'; b']$ using formula:

$$\lambda = (\bar{x}' - a') / (b' - \bar{x}'). \quad (8)$$

9. Determine the estimate of mathematical expectation $\bar{y}$ along segment $[-\gamma, \gamma]$ using formula:

$$\bar{y} = (-\gamma + \lambda \cdot \gamma) / (1 + \lambda). \quad (9)$$

10. Estimate of parameter $p - \tilde{p}$ of the model is determined from formula:

$$\tilde{p} = \frac{\bar{y} + \gamma}{2\gamma}. \quad (10)$$

11. Find the mean at affine transformation along segment $[-4{,}6; 4{,}6]$ using formula:

$$\bar{z} = (-4{,}6 + \lambda \cdot 4{,}6) / (1 + \lambda). \quad (11)$$

12. Determine the estimate of quality indicator using formula (12), substituting p with the obtained value $\tilde{p}$ and y with $\bar{z}$, that is we calculate magnitude:

$$K_j = [\tilde{p} \cdot \exp(-\exp(-\bar{z})) + (1 - \tilde{p}) \times \times (1 - \exp(-\exp(\bar{z})))] \cdot 100~\%. \quad (12)$$

The results received (Tables 3, 4) allow us to solve a number of practical tasks and are used in order to control indicators of quality and safety of soft drinks with functional purpose. Table 3 shows that the coefficient of variation v of random magnitudes X_1, X_2, X_3, X_4 and X_6 are lower than 0.1 (Fig. 1). This suggests a slight dispersion of these values. Only the random variable X_5 has a medium degree of dispersion, that is, valid for quality calculation (Fig. 1).

Fig. 1 shows that the models of quality indicator of random variables X_1, X_2, X_3, X_4, X_5 and X_6 have a mode in the ideal values of beverage quality indicator.

Table 3

Quality indicator of the group of physical-chemical properties

2.1. Mass fraction of dry substances,, %: X_1		2.2. Mass fraction of sediment in the examined samples, %: X_2		2.3. Mass fraction of pulp in the examined samples, %: X_3		2.4. Mass fraction of titrated acids in the examined samples, %: X_4		2.5. Viscosity (dynamic) of beverages with the use of raw materials of plant origin in the examined samples, Pa·s: X_5		2.6. Method of determining pH in the examined samples: X_6	
$\bar{x}_1$	18.590	$\bar{x}_2$	0.6330	$\bar{x}_3$	19.400	$\bar{x}_4$	1.418	$\bar{x}_5$	39.660	$\bar{x}_6$	3.906
S^2	0.2500	S^2	0.0006	S^2	0.9250	S^2	0.0079	S^2	43.8750	S^2	0.0008
S	0.5000	S	0.0250	S	0.9618	S	0.0887	S	6.6238	S	0.0274
v	0.0269	v	0.0395	v	0.0496	v	0.0626	v	0.1670	v	0.0070
x_0	18.45	x_0	0.2	x_0	18.00	x_0	1.390	x_0	39.00	x_0	3.00
a	0.3	a	0	a	5	a	1.2	a	20	a	2
b	25	b	1	b	25	b	1.6	b	50	b	5
$\bar{z}$	2.218	$\bar{z}$	1.224	$\bar{z}$	2.024	$\bar{z}$	1.242	$\bar{z}$	2.5576	$\bar{z}$	1.2451
$\tilde{p}$	0.7410	$\tilde{p}$	0.6330	$\tilde{p}$	0.7200	$\tilde{p}$	0.6350	$\tilde{p}$	0.7780	$\tilde{p}$	0.6353
K	92.36 %	K	82.65 %	K	91.07 %	K	82.93 %	K	94.20 %	K	82.97 %

Table 4

Quality indicator of the group of organoleptic properties

2.1. Taste (point), X_1		2.2. Aroma (point), X_2		2.3. Physical appearance (point), X_3		2.4. Consistency (point), X_4		2.5. Color (point), X_5	
$\bar{x}_1$	4.958	$\bar{x}_2$	4.894	$\bar{x}_3$	4.921	$\bar{x}_4$	4.912	$\bar{x}_5$	4.829
S^2	0.00125	S^2	0.00125	S^2	0.0020	S^2	0.0010	S^2	0.0010
S	0.035355	S	0.03536	S	0.04472	S	0.03162	S	0.03162
v	0.0071	v	0.0072	v	0.0091	v	0.0064	v	0.0065
x_0	0	x_0	0	x_0	0	x_0	0	x_0	0
a	3	a	3	a	3	a	3	a	3
b	5	b	5	b	5	b	5	b	5
$\bar{z}$	0.5530	$\bar{z}$	0.5160	$\bar{z}$	0.5316	$\bar{z}$	0.5263	$\bar{z}$	0.4786
$\tilde{p}$	0.979	$\tilde{p}$	0.947	$\tilde{p}$	0.9605	$\tilde{p}$	0.9559	$\tilde{p}$	0.9146
K	98.81%	K	98.46%	K	98.62%	K	98.57%	K	98.01%

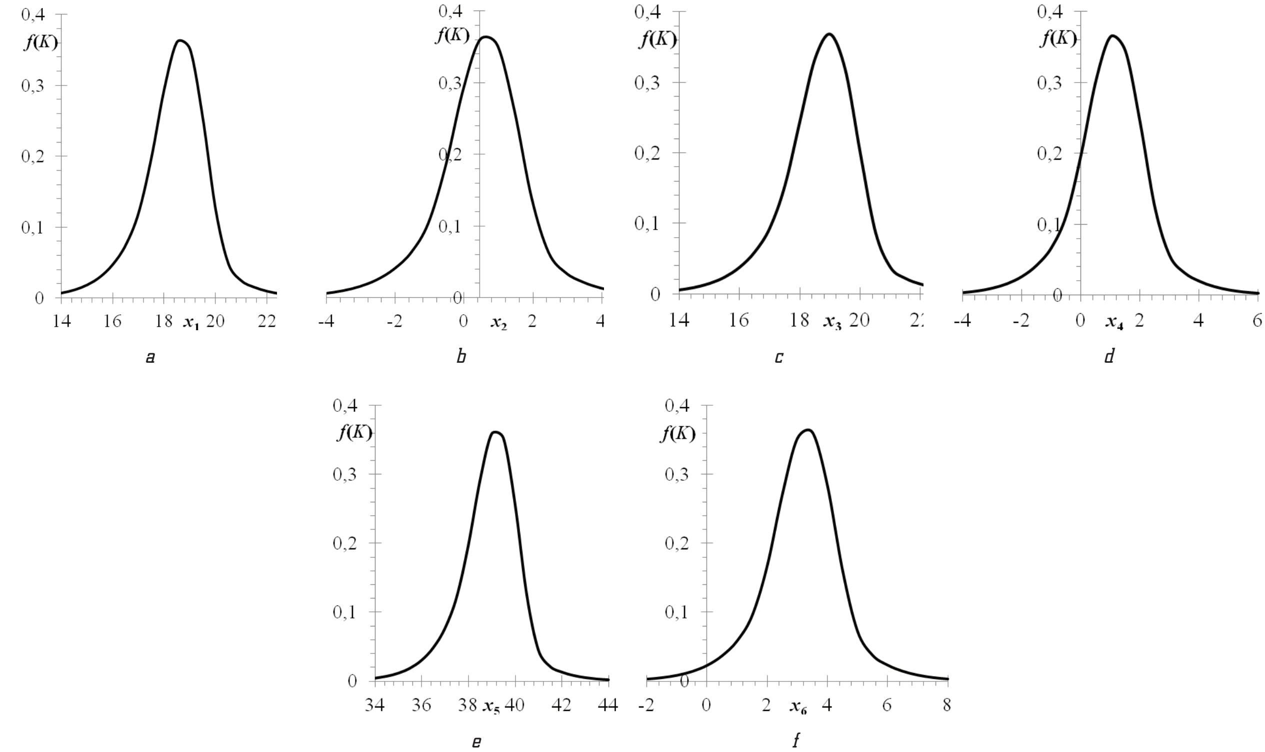

Fig. 1. Charts of the quality indicator model of random magnitudes: *a* – X_1; *b* – X_2; *c* – X_3; *d* – X_4; *e* – X_5; *f* – X_6

Charts of quality indicators of the group of organoleptic properties are given in Fig. 2.

Fig. 2 shows that charts of function of random magnitude quality X_1, X_2, X_3, X_4 and X_5 are practically the same. The mean values of these magnitudes are also close, which is why values of quality and value will also be close to each other. Quality of the group of organoleptic properties (Table 4) differs only by a few tenths of percent.

Implementation of the procedure of quality evaluation using affine transformations provides FFP with the most accurate quality indicators by results of the sample. An analysis of this model and comparison with the previous estimates of quality could be applied at any ideal value.

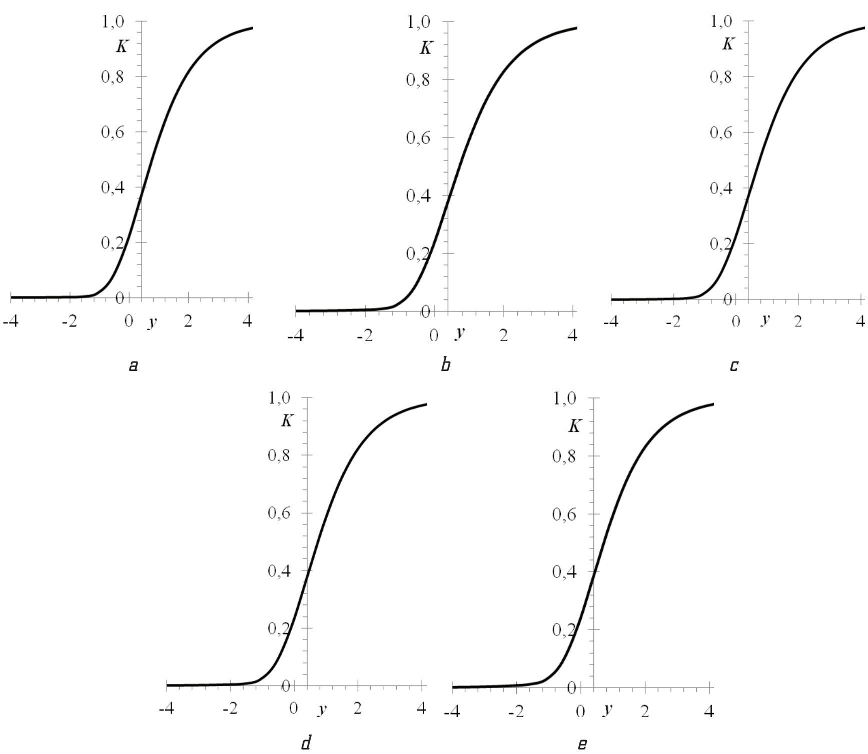

Fig. 2. Charts of function of random magnitude quality: *a* – X_1; *b* – X_2; *c* – X_3; *d* – X_4; *e* – X_5

7. SWOT analysis of research results

Strengths. Positive effect on the examined object in terms of internal factors is exerted by the calculation of quality of alcohol-free functional beverage, obtained using compiled programs in the software Maple. Developed procedure of calculation using derived formulas for a general product quality model employing a mixture of extreme values makes it possible to assess quality of any beverage. This is possible due to the improvement of a desirability function for the evaluation of quality indicators of AFB, varying in dimensionality, by applying coefficients that take into account the best value of quality, which will enable its unification in order to assess heterogeneous processes.

Weaknesses. Food manufactures and enterprises of restaurant business lack qualified professionals who might determine a comprehensive quality indicator of AFB using a pro-

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cedure that employs affine transformations. This procedure could be applied only for beverages with a delicate texture because we examined certain physical-chemical and organoleptic quality indicators. For other food product groups, it is required to improve number n of experiments.

Opportunities. Prospects of further research are in improving legal framework and norms that regulate the following:

– parameters of quality and safety of FFP;

– continuation of harmonization of international standards, especially a method to control indicators of quality and safety of products;

– ensuring compatibility between technical conditions and acting legislative norms and standards; consideration of indicators of quality and safety of food products when substantiating a system of indicators of food safety.

Threats. Solving a task on quality and safety of FFP has comprehensive character, it requires taking into account sectoral regularities that control quality at all stages of agricultural production, its processing, storing, transporting and selling the finished product. An important condition to ensure food safety is the intensification of implementation of management systems to control quality and safety of functional products and their certification at enterprises in the food industry.

8. Conclusions

1. We identified physical-chemical indicators of AFB: mass fraction of dry substances; mass fraction of sediment; mass fraction of pulp; mass fraction of titrated acids; viscosity (dynamic); pH. When determining quality indicators of the group of organoleptic properties, we carried out collection and processing of expert data required for the calculation of taste, aroma, physical appearance, consistency, color.

2. We proposed assessment of AFB quality indicators, according to a mathematical model using affine transformations, which is provided by authors in [2]. To assess quality of an alcohol-free beverage with functional purpose, it is proposed to use the beverage as a system consisting of subsystems and elements that it includes. Elements of the system are the indicator that characterizes beverage quality.

3. We calculated AFB quality, according to a number of stages in the procedure of evaluation of quality indicator and provided graphic dependences of indicators from the group of physical-chemical and organoleptic properties. In order to assess a beverage quality indicator, which includes an ideal value of indicator and its boundaries, assigned by a technologist, it is proposed to find absolute deviation of the values from the ideal and to consider this value as a random magnitude of the set. The application of this technique to assess quality, which is proposed for the subsystems of the system and the system itself as the smallest of the qualities of subsystems, makes it possible to assess quality of a beverage.

We determined estimates of quality indicators by the procedure using affine transformations, based on the results of the sample:

1) mass fraction of dry substances – 92.36 %;
2) mass fraction of sediment – 82.65 %;
3) mass fraction of pulp – 91.07 %;
4) mass fraction of titrated acids – 82.93 %;
5) viscosity (dynamic) – 94.20 %;
6) pH – 82.97 %.

Implementation of the procedure of quality evaluation using affine transformations provides FFP with the most accurate quality indicators by the results of the sample. An analysis of this model and comparison with the previous estimates of quality could be applied at any ideal value.

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ОПРЕДЕЛЕНИЕ ПАРАМЕТРОВ КАЧЕСТВА БЕЗАЛКОГОЛЬНОГО ФУНКЦИОНАЛЬНОГО НАПИТКА ПО МЕТОДИКЕ С ПРИМЕНЕНИЕМ АФФИННЫХ ПРЕОБРАЗОВАНИЙ

Проведенные расчеты качества безалкогольных напитков функционального назначения, согласно методики оценки с применением аффинных преобразований, которая может быть применена при любом идеальном значении. Экспериментальные исследования выполнялись на примере процессов производства безалкогольных напитков с мякотью, применяя разработанную методику, показатели физико-химических и органолептических свойств продукта, математические методы обработки результатов измерений.

Ключевые слова: функциональные пищевые продукты, управления качеством и безопасностью, среднее квадратичное отклонение.

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