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СЕРИЯ ГЕОЛОГИИ И ТЕХНИЧЕСКИХ НАУК

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НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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BASE MATRICES – INVARIANT DIGITAL IDENTIFIERS OF FOOD PRODUCTS

Abstract. The work shows the prospects of developing a single basic product matrix (basic food semi-finished product) for the subsequent design of technologies for a group of homogeneous products. Implementation of this principle of technology engineering allows to unify many stages of production and, as a result, to stabilize the quality of products, as well as to rationalize the system of identification and control. Accordingly, the mathematical model is developed for the latter, matrices of product markers from genuine to falsified are proposed. Variants of poor-quality, and also surrogate products as possible intermediate links are considered for completeness of the information. The integration of additional thermodynamic and functional-technological indicators into the system of evaluation criteria of technology rationality and product quality is substantiated.

Keywords: food products, technologies, terms, evaluation criteria, matrices, construction.

Modern levels of technology development, including the speed of information flows, interbranch and interdisciplinary integration of scientific and practical solutions, the loyalty of the legislative framework to the organization of production and a number of other objective and subjective factors have created prerequisites for reviewing the principles of construction technology and expanding the traditional area of evaluation criteria for quality and safety of food products [1-4].

It should be noted that at present the development of food products with specified properties, including functional purpose, has become quite an ordinary process due to the applied development of the basic principles of food combinatorics [5-8]. In addition, in recent years, along with the term "food development", the notion of "food construction" has become widely used. Both concepts are legitimate in terms of the logical-conceptual essence, but require some detail and concretization. The main difference in terms is that when "constructing" a priori, the main emphasis is on creating or improving technology and/or processes, and when "developing" - on the recipe of the product being created. Undoubtedly, the technological process and the recipe of the product are interrelated, these terms complement each other and, therefore, when using them, the main thrust of the work should be taken into account. At the same time, "construction" a priori assumes the existence of a more systematic approach [9-11].

An analysis of the development of the food industry shows that over the last 15-20 years, a reorientation of production is taking place all over the world - alternative technologies are developing that involve the use of new types of raw materials and fundamentally different technological solutions [12-15]. In general, for the industry, this trend is positive, as it is aimed at increasing production volumes and expanding product lines. However, the production of alternative technologies, most of which have been obtained empirically, has been insufficiently investigated, including, in some cases, due to the lack of appropriate analysis methods and the blurring of identification features within a homogeneous group of goods [3, 12, 14]. In this perspective, a significant potential is noted in studies of thermodynamic characteristics, functional and technological indicators and further implementation of the data obtained as system criteria for determining the rationality of technological operations, the validity of production schemes, and the evaluation of product quality. The data obtained over the last decades on the indicator "water activity", inhibition of abiogenic and biogenic degradation of micro- and macro components, "barrier" conservation technologies, scientific and applied methods of designing products of functional purpose and many other directions in various food systems allow to assume the possibility of indirect adaptation most methodological approaches to various food systems and processes [14, 16-18].

The development of a new product, and to some extent, the improvement of products from the traditional range, is the result of the efforts of a large group of specialists, including dieticians, food technologists, ingredients and equipment specialists, marketers, etc., which create the basic model of a new product. This model can be described by the matrix $C_p(P, Q, O)$, where P – composition matrix, Q – matrix of physico-chemical parameters, O – matrix of organoleptic characteristics. Suppose, that the matrix C_p has dimension $m \times n$, where m – number of the rows, n – number of the columns. The matrix P includes the values of the composition components - carbohydrates, proteins, fats, amino acids, vitamins and other; the matrix Q includes the values of physical characteristics - pH, viscosity, density, solids content and other, and the matrix O – the values of the characteristics of the organoleptic profile in accordance with regulatory documentation and/or additional characteristics, arising from the task of developing a new food product with a specified property.

These matrices P, Q, O can have differentiated dimension: suppose, that the matrix P has dimension $m_1 \times n$, the matrix Q – dimention $m_2 \times n$, and the matrix O – dimention $m_3 \times n$, equality should be strictly observed:

$$m_1 + m_2 + m_3 = m. \quad (1)$$

The requirement (1) is valid in the case when the number of columns of n is the same for all matrices. The condition n = const for all matrices P, Q, O is easily realized by adding columns with zero elements.

The development of food products requires the introduction of some changes in existing production schemes and, as a consequence, the design of the technology itself. This relationship is especially clearly traced when creating not a single product, but a group of products having a significant similarity of composition (the presence of a base matrix C_p^0) and technological solutions. In this case, we can talk about the development (construction) of a food products number on the basis of a single "semi", which has a base composition of the matrix C_p^0.

To further detail the universal approach to the development of a basic semi-finished product, it seems reasonable to clarify a number of terminological definitions, which will make it possible to eliminate the discrepancies in the future.

The Basic Food Semi-Finished Product – a semi-finished product, on the basis of which a homogeneous group of food products is manufactured under industrial conditions.

The Basic Matrix of Food Semi-Finished Product – matrix of the composition of the semi-finished product, the components of which are generally preserved in the production of homogeneous products.

Homogeneous Group of Food Products – a number of food products, derived from the basic food component by changing organoleptic or other indicators (characteristics) at the last stage of technological production.

Construction of Homogeneous Goods Technology – the development of a technology that includes the production of a food semi-finished product followed by a sequential or parallel release of a homogeneous group of food products.

Taking into account the introduced terminological definitions, let us consider the problems of constructing basic food semi-finished products technologies (BFSPT). It should be noted that some examples of the use of BFSPT are known, but they are extremely rare, and the lack of proper scientific and methodological coverage in the relevant technical literature does not allow to reveal all the exceptional possibilities of the proposed method.

The overwhelming majority of food technologies are based on a sequence of operations (linear or sequential scheme) and practically no feedback schemes are widely used in instrumentation, automatic control and other industries. It is necessary to clearly distinguish the technology of food production from the devices used at certain stages of the technology. These devices themselves can have different structural schemes, but they are not objects of this article.

A generalized model of food production technology can be represented in the form of a sequence of performing a number of technological steps (figure 1). For each stage, it is assumed that there is an appropriate hardware-technological design for the production process.

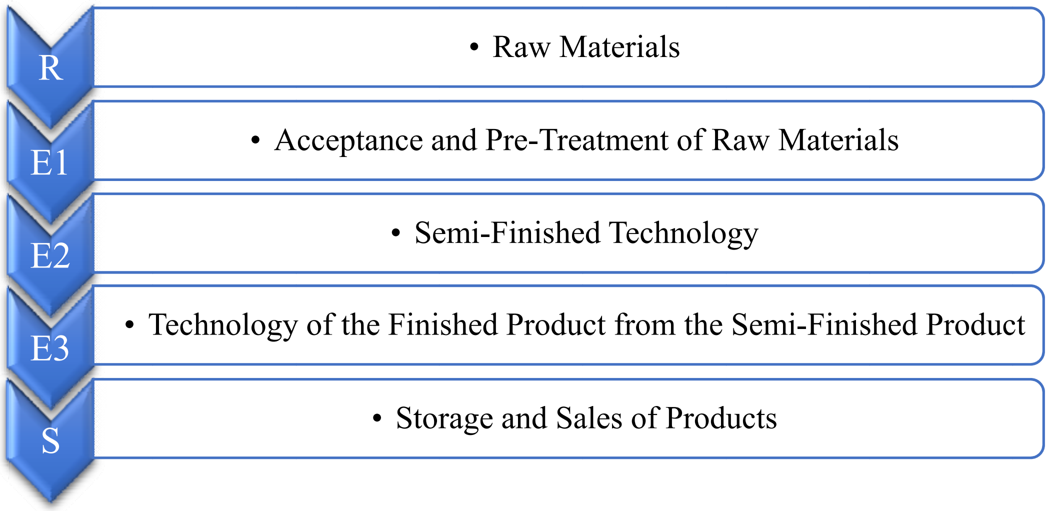

Figure 1 – Principal technology of food production according to the scheme with BFSPT

It should be noted, that the presented generalized technology is far from real production realizations. First of all, this refers to the availability of a specific semi-finished product – often in production it looks conditionally. But the high degree of generalization used in the generalized model of production technology makes it easy to formulate and explain the goals and ways of creating BFSPT. A generalized production model can be described with the help of operators:

$$C_p\left(P,Q,O\right)=W_3\cdot W_2\cdot W_1C^0, \quad (2)$$

where W_1, W_2, W_3 – conversion operators of the corresponding stages; C^0 – generalized matrix of raw materials.

It should be noted, that the operators W_i represent the sequence of operators of all equipment used at each stage [17]. For example, if the first step (E1) uses the sequence k equipment, the operator W_1 will have the form:

$$W_1=W_{1,k}\cdot W_{1,k-1}\cdot W_{1,1}. \quad (3)$$

In the process of developing a homogeneous product group C_p^b, it is possible to define a certain matrix of the semi-finished product, which is the same for the entire group of homogeneous products C_p^b, where b = 1,2,...,s. In this case, the generalized production technology of a group of homogeneous products C_p^b when implementing the BFSPT method, it can be represented as follows figure 2.

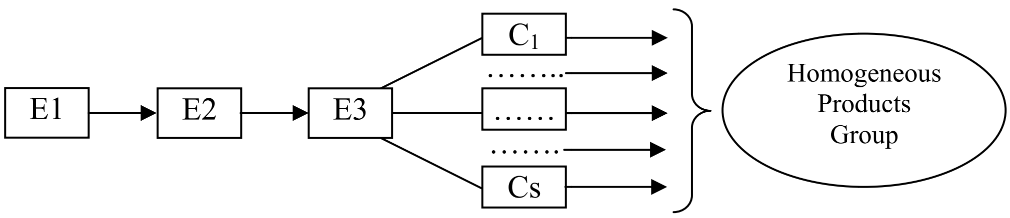

Figure 2 – Generalized Technology for the Production of a Homogeneous Food Products Group

The group of homogeneous products (figure 2), by total number s is characterized by the corresponding matrices $C_p^1, C_p^2, ..., C_p^s$. It should be noted that figure 2 shows a scheme with parallel output of homogeneous products. This scheme is preferable for large-capacity production with a sufficient production resource for the production of semi-finished products. In other cases, the parallel output scheme is replaced by a sequential-temporary scheme in accordance with the production plan.

Trends in the development of the soft drinks industry have shown that it is possible to create a new range of beverages C_p^b with distinctive organoleptics while maintaining the basic (majority) values of matrix elements P and Q.

In the practice of the Russian food industry, flour from triticale has been widely used in recent years. Studies have shown that a high-quality concentrated wort can be obtained from triticale, which can be used as a basis for obtaining a large range of new beverages. Analysis of the technological chain from the final product made it possible to determine the semi-finished product with the base matrix-concentrated wort. On the basis of the concentrated wort produced as soft drinks and kvass.

BFSPT principle is applicable in various fields of food industry, for example in dairy, when fruit yoghurt product line is formed around the base matrix – classic yogurt; glazed curds and cottage cheese mass- cottage cheese and stuff.

Today, there are quite clearly formulated points of view on possible ways to improve the quality of food products, including prolonging the shelf life and developing methods to combat falsification [19-24]. Theoretical and practical bases of physical, chemical, and biological changes that occur in food products during storage have been developed [12, 13, 17].

The level of modern knowledge, including interdisciplinary, allows us to predict the effectiveness of expanding the field of food quality assessment criteria and the rationality of technological schemes by integrating additional characteristics and predicting the economic, social and strategic effectiveness of developments, and accordingly declare the relevance of the direction [1, 12, 14, 18].

The analysis of the material made it possible to develop a mathematical model and to propose a product marker matrix from the point of quality loss from genuine to falsified. The proposed refinements and terminological definitions will eliminate the ambiguity of terminological definitions in the process of developing a set of documentation for identification of the adulterated foods.

Figure 3 shows the matrix of the genuine product.

Genuine product matrix is invariant with respect to adding null rows – y_k (dummy additionally introduced component in the product recipe) and null columns – x_l (dummy ingredients). The vector of ingredients x consists of components significant to determination of the authenticity of a particular product, and the recipe component y_j is the product sum of mass fractions a_{ij} by the corresponding ingredients x_i. The final column vector of the recipe y is equal to the mathematical product of the characteristic matrix A on the column-vector of ingredients x.

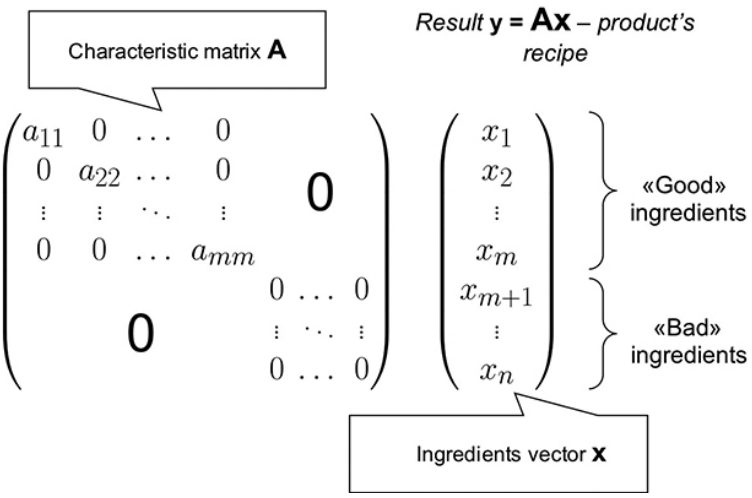

Figure 3 – Genuine Product Matrix

At the same time, it is possible to transform the original matrix into interval matrix and compare its reference range values with the actual results obtained during the analysis and presented as a numerical matrix of measurements.

Figure 4 presents a modified matrix, intrinsic to a substandard product (with violations of the mass fraction values of the components).

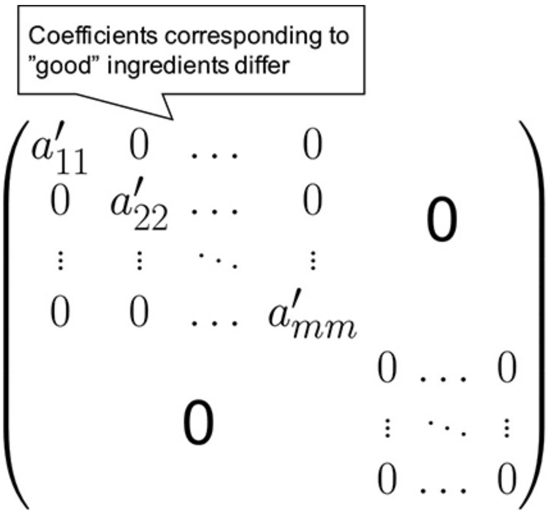

Figure 4 – Modified Product Matrix

Modified matrix { $a'_{i,j}$ }, intrinsic to a substandard product, differs from the original matrix { $a_{i,j}$ }, and while if $a'_{i,j} \neq a_{i,j}$, then with necessity $a_{i,j} \neq 0$, that is, in the modified matrix, the mass fractions of the ingredients may vary, but new ingredients can not be added to the components of the formulation.

Figure 5 shows the pseudomatrix.

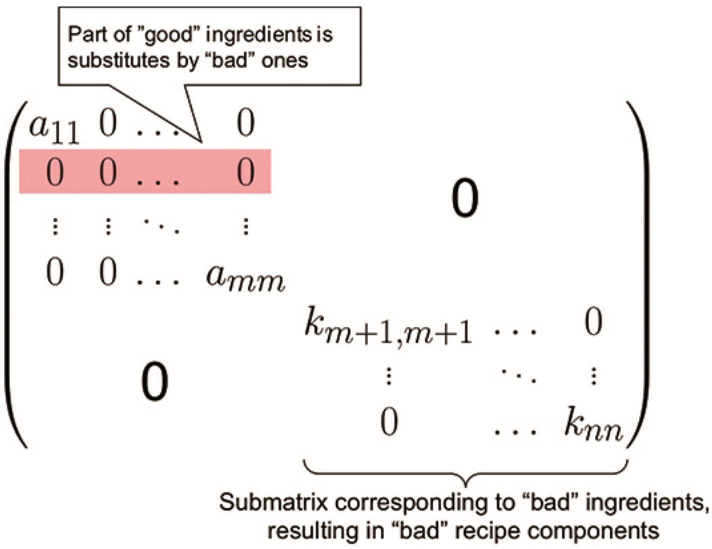

Figure 5 – Pseudomatrix

The pseudo matrix, characteristic of surrogate products, is distinguished by replacement or addition x_i ingredients, as well as by replacing or adding y_i of the recipe components, while the presence of the above components and ingredients is not hidden by the manufacturer. In this case, the added components x_i do not participate in the composition of the components of the formulation of genuine reference product.

Figure 6 shows a false matrix. A false matrix, characteristic of a falsified product, is a combination of a pseudomatrix and a modified matrix and can carry the properties of both a surrogate and a substandard

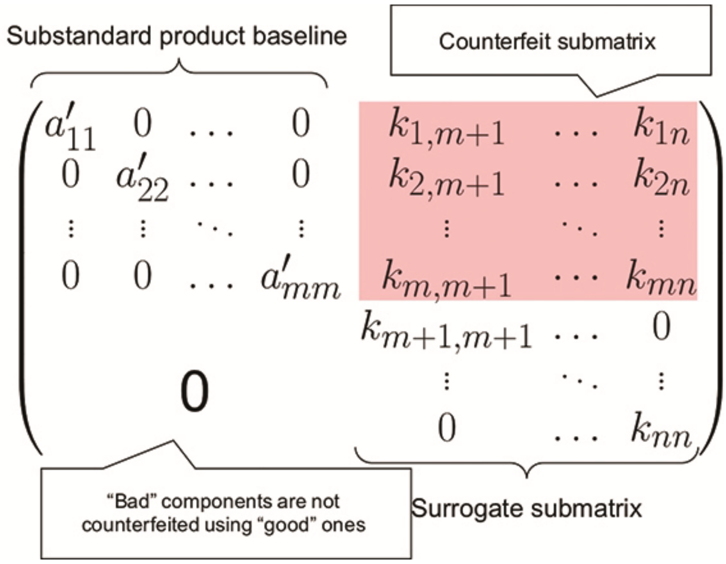

Figure 6 – False Matrix of Counterfeit

product and their various variations in terms of changing the mass fractions of the ingredients and adding additional ingredients and components. In this case, for a false matrix, the condition of the need to change only the non-zero mass fractions $a_{i,j}$ of the original matrix is not fulfilled, as in the modified version, the component of the formulation can consist of completely different ingredients and their combinations.

The resulting generalized form of the product characteristic matrix is shown in figure 7. In the case of counterfeit, the manufacturer generally does not report the relevant substitutions of the ingredients and/or their mass fractions.

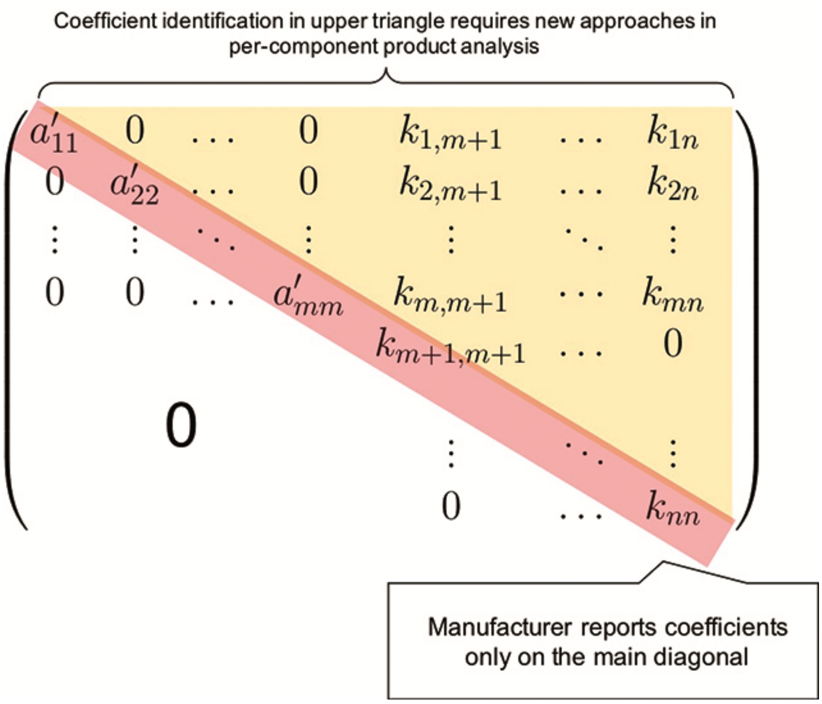

Figure 7 – Generalized Form of the Characteristic Matrix

To optimize the work with matrices, software was created – figure 8.

The operator introduces the indicators of the original matrix (standardized indicators of the product in accordance with the technical documentation) and the errors of the relevant research methods to obtain the

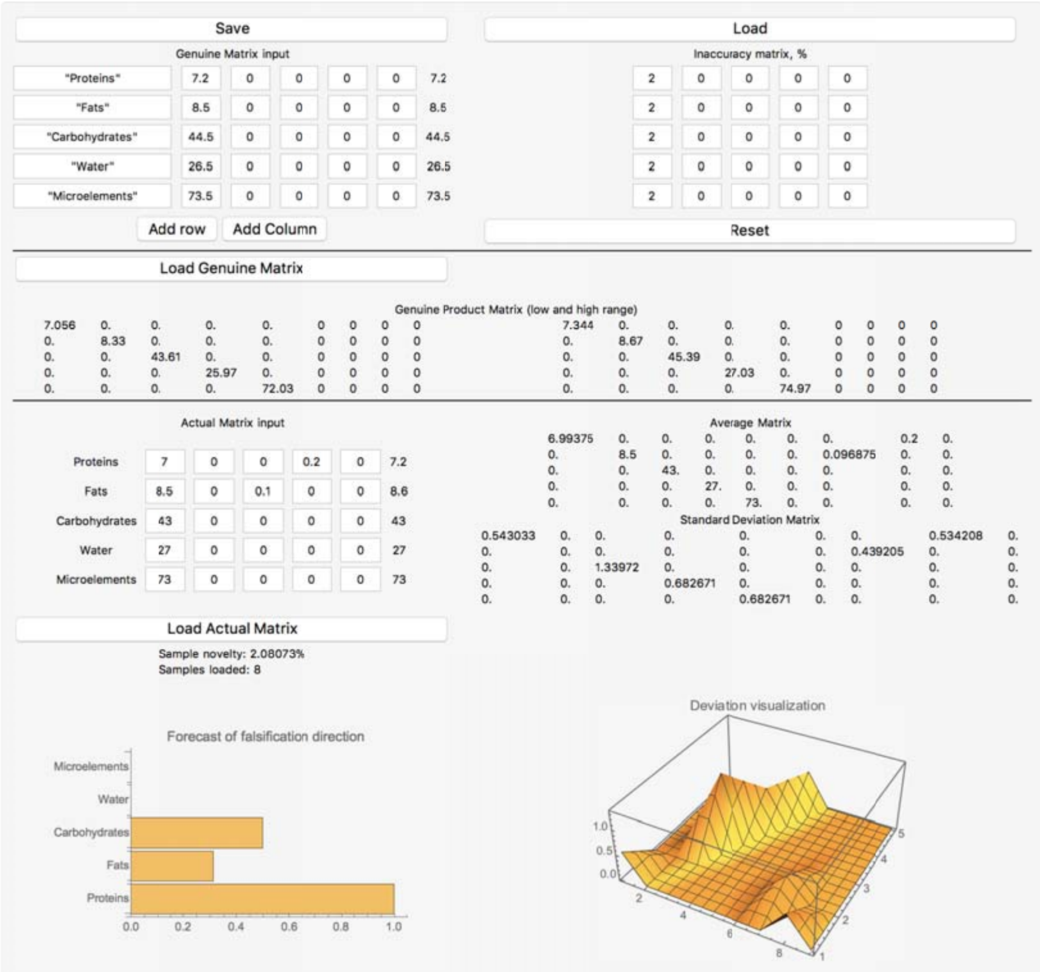

Figure 8 – Matrix Software Interface

interval characteristic matrix. The operator sequentially downloads the results of examining similar samples into the actual matrix. The program considers the average matrix of samples actually provided, as well as the matrix of standard deviations, presenting the received material in digital and graphical form. Deviations from the original matrix are determined by peaks on the surface deviation graph. In parallel, the program provides data on the relative novelty of the product compared to the reference product, which is in fact a new approach to assessing the novelty of technological solutions. A separate algorithm for predicting the direction of falsification has been introduced, which actually determines the quantitative ratio of samples with different deviations.

Shown the possibility of constructing a technology for the production of a group of homogeneous products based on the availability of semi-finished products from a single base matrix. The implementation of the principle of BFSPT allows us to unify two of the three stages of production, stabilize the quality of products and streamline the control system. Thus, a mathematical model has been developed, matrices of product markers and basic principles for integrating additional thermodynamic and functional-technological indicators, including water, into the system of evaluation criteria for the rationality of technologies and product quality have been proposed.

It can be assumed that the design of technologies for a complex of homogeneous food products based on BFSPT will develop taking into account the technological and economic advantages provided by BFSPT.

To identify and control the quality of products and the rationality of technological schemes, it is advisable to expand the scope of evaluation criteria. At the same time, the proposed grades of product matrices from genuine to falsified allow to fix any changes with a high degree of accuracy. Designed for ease of use with the matrix software allows you to speed up the evaluation process, create a database and identify falsification trends.

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БАЗАЛЫҚ МАТРИЦАЛАР – ТАҒАМ ӨНІМДЕРІНІҢ ИНВАРИАНТТЫ САНДЫҚ ИДЕНТИФИКАТОРЫ

Аннотация. Жұмыста тағам өнімдерінің бірыңғай негізгі базалық матрицасын жасаудың (негізгі азық-түлік жартылай фабрикаттарының) біртекті тағам өнімдерінің тобына арналған технологияларды кейіннен жобалау үшін келешегі көрсетілген. Құрастыру технологиясының осы принципін іске асыру өндірістің көптеген сатыларын біріктіруге және соның салдарынан өнім сапасын тұрақтандыруға, сәйкестендіру және бақылау жүйесін рационализациялауға мүмкіндік береді. Тиісінше, соңғы үшін математикалық модель әзірленді, түпнұсқалық маркерлердің матрицалары түпнұсқадан бұрмалаушылыққа дейін ұсынылады. Ақпараттың толықтығы үшін төмен сапалы, сонымен қатар суррогат өнімдердің нұсқалары аралық байланыстар ретінде қарастырылады. Қосымша термодинамикалық және функционалдық-технологиялық көрсеткіштерді технологиялар мен өнімнің сапасын бағалау критерийлеріне интеграциялау негізделген.

Түйін сөздер: тағам өнімі, технология, терминдер, бағалау критерийлері, матрицалар, құрастыру.

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БАЗОВЫЕ МАТРИЦЫ – ИНВАРИАНТНЫЕ ЦИФРОВЫЕ ИДЕНТИФИКАТОРЫ ПИЩЕВЫХ ПРОДУКТОВ

Аннотация. В работе показана перспективность разработки единой базовой матрицы продукта (базового пищевого полуфабриката) для последующего проектирования технологий группы однородной продукции. Реализация данного принципа конструирования технологий позволяет унифицировать множество этапов производства и, как следствие, стабилизировать качество продуктов, а также рационализировать систему идентификации и контроля. Соответственно для последнего разработана математическая модель, предложены матрицы маркеров продукта от подлинного до фальсифицированного. Для полноты информации рассмотрены варианты некачественного, а также суррогатного продуктов как возможных промежуточных звеньев. Обоснована интеграция дополнительных термодинамических и функционально-технологических показателей в систему оценочных критериев рациональности технологий и качества продукции.

Ключевые слова: продукты питания, технологии, термины, оценочные критерии, матрицы, конструирование.

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