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PROSPECTS FOR THE DIALECTIC SYNTHESIS OF AGRICULTURAL AND PROCESSING TECHNOLOGIES IN THE AGROINDUSTRIAL COMPLEX OF THE SIXTH WAVE OF INNOVATION

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ABSTRACT

The article is devoted to the peculiarities of designing multipurpose low-tonnage complex food technological systems in the agro-industrial complex. The focus is on solving the problem of food security in Russia by creating industrial agro-complexes that implement technologies for the production of agricultural products, their storage and processing. The range of discussed issues includes the structural complexity of the technologies for the agro-industrial complex, along with their functional simplification, due to the stabilization of the major processes of the agricultural resources conversion into food. Particular attention is paid to the fluctuations of the "large" technological systems processes that make up the system complex, under the influence of internal and external disturbing factors. These fluctuations are considered as a necessary condition for the development of complex technological systems. The data on the condition of the system technological complexes self-organization and their main characteristics: openness, nonlinearity and instability are summarized. The principles of designing such complexes in the agro-industrial complex and the dialectics of mutual reinforcement of the technologies, combined into a complex, are outlined. The necessity of the agricultural technologies industrialization as the dialectical inevitability of the industrial agro-complexes creation, that implements the new wave of innovation revolution in the agro-industrial complex, has been substantiated. The main provisions of the development paradigm of the agro-industrial complex technologies are formulated. It was proposed to accept the forecasting of trends and prospects for the development of research on the basis of data at its current state, taking into account the depth of forecast, as the main way to identify priorities. The conclusion was made about the priority steps in the implementation of engineering for complex technological systems in research organizations and universities.

INTRODUCTION

The concept of "technology" is now becoming more capacious and relevant. The technology from the purely industrial field is already constantly considered in the scientific field and has become the subject of independent theoretical research. In real conditions, the interaction of the three systems - technology, external raw materials and external consumer systems determines the quality of products. But their consideration is integrated, that is to say, in a complex, taking into account their joint essence. This gives the opportunity to optimize production and bring it to a completely new level. Without knowing the essence of phenomena, it is impossible to create a new whole.

Analyzing the quality of technologies in various industries, it is necessary to note one characteristic feature in the development of any technology. From one innovation wave to another, the structural complexity of the technology increases, also increasing the stability, sustainability, accuracy, manageability and reliability of major processes. It is in these technologies that dialectical methods of the nature development of are realized: the complexity of the structure and the simplification of the objects functioning, including anthropogenic ones. That is why modern scientific and engineering activities in the agro-industrial complex (AIC) are needed to be already realized in line with the sixth wave of innovation. In this work, fundamental research in the field of agriculture and processing technologies comes to the foreground, which should ensure high quality links throughout the technological chain of food production. At the same time, it is important to correctly select key areas of research and allocate resources. From here comes the understanding of the whole complexity of the task for the Russian agro-industrial complex science, which is to become one of the states with the sixth wave of innovation in the production of food products over the next decade.

The purpose of this article is to analyze and state a possible forecast of engineering and scientific features for the design of an agro-industrial complex, based on systematical information support of technologies that reveal the essence of phenomena, processes, the state of raw materials and semi-finished products, taking into account the physicochemical, mechano chemical, biophysical, biochemical patterns and vague cause-effect relationships. The solution of the food problem in the developed countries of the world is indivisibly linked with the goals and objectives of the sixth wave of innovation, which period is approximately 2025-2080. This wave will be characterized by the use of high-tech or, as they say, “high technologies” associated with the use of bio- and nanotechnologies, genetic engineering, membrane and quantum technologies, micromechanics and robotics with an artificial intelligence system.

MATERIALS AND METHODS

The dialectic development of food technology has not been the subject of research so far. The tasks of improving technology, equipment, controls and automation were solving and each time some internal contradiction of technology was resolved, for example, the interrelation - “productivity – quality”. Since ancient times, philosophers have been debating about the relationship between quantity and quality and today, the philosophy law about the transformation of quantity into quality, stating that the sum of the "systematic meanings" of the subsystems properties is not equal to the meaning of the system. This has become a dogma that does not cause any doubt. So, for example, in nuclear physics, the law of synergy is expressed in such a concept as “mass defect”.

As noted, by the founder of the concept of synergetics, G. Haken, [2,4], "every stage of evolution is associated with the processes of self-organization, self-regulation, self-structuring, self-reproduction of complex systems of different nature". The essence of the approach lies in the fact that the concept of “order parameter” is introduced, which describes a small possible number of essential types of the subsystems motion with a significant number of freedom degrees. Subsystem-modules are part of complex systems and are in complex interactions with each other. All types of possible motion-interaction of processors in subsystems also turn out to be “subordinate” (the principle of subordination) and can be predictably expressed through order parameters, using a hierarchy of simplified models of both process systems and processes themselves, including a small number of the most essential freedom degrees.

In modern conditions of the population urbanization and mixing of national cuisines, when studying the development of food technology, it is necessary to operate with methods of system ology and analyze the processes of the non-equilibrium open systems self-organization that interact with the external environment. Without this, considering our production as closed systems, we risk staying at the level of outdated, obviously erroneous ideas about development, understanding it only as a result of resolving the internal contradictions of this technological system in the form of improvements in individual processes and modernization of individual machines and devices.

Let’s consider the evolutionary development of the various food technologies organizations: technologies of flour, bread, confectionery, wine, vodka, sugar, vegetable oil, sausages and smoked meats, milk and dairy products, etc. from the past to modern food technologies and try to look forward. How can they be organized? And what will these technologies represent in the future [10]. This is necessary in order to consciously start moving forward, towards highly organized technologies that do not require active human participation.

Today we already have an example of highly developed automated and robotic enterprises, where human participation in the formation of a product is minimized. Under these conditions, at the enterprise the technologist performs completely different functions. The primary role is assigned to robots, machines, devices, computer equipment and their service technicians. There are completely new requirements for individual training of specialists for such industries. At such enterprises, as a rule, there are no problems with the quality of raw materials (large production volumes force suppliers to compete for the consumer due to competition in the market), quality stability is ensured by the stability of production technological parameters, the human factor in shaping quality is reduced to a minimum.

There are other enterprises where quality is formed in the interaction of production systems - raw materials (agricultural, livestock, etc.), technological and marketing, as well as in the creation of new systems, for example, agricultural-technological-marketing (this is, mainly, network campaigns), poultry-technological, etc.

We are talking about industrial technologies, which will allow us to create machine technologies of crop products, starting with precision seeding of agricultural products, and technologies of livestock products with factory features [18]. Such industrial production of agricultural products makes it possible to obtain it in a very narrow range of technological properties necessary for the organization of automatic processes systems in processing technologies, including rotary lines, using rotor technologies [15].

At the same time, the most important prerequisite should be in-depth specialization and concentration of agricultural production as the basis of industrial technologies in plant growing and animal husbandry. Such re-industrialization of food production can and should be conducted on the basis of a new Russian technological and technical base, rich in automation and electronics, which meets the conditions for the implementation of the sixth wave of innovation.

The basic principle of the sixth wave of innovation in the agro-industrial complex is that man doesn’t serve hectares of the field and individual animals, but automation equipment. This principle is the basis of the industrial production of crop and livestock products for processing and food enterprises, which guarantees sufficiently stable indicators of the raw materials quality for the organization of automatic technologies for their processing.

If we consider the problem formally, then the development of any technology, including food one, represents the passage from the area of summative systems to the area of integral systems.

This can be accomplished by structural simplification of the technology or stabilization of processes. Moreover, the simplification of production technology is possible due to changes in, for example, agrarian technology.

As an example, we can introduce mineral complexes into the plant nutrition together with bacteria, which convert mineral complex into a water-soluble form, granulated together with seeds. Due to this, the saturation of plants with microelements allows us to provide new properties to mineral complexes, ensuring their synergistic interaction with other plant components, helping us to bypass the "transparency" of the human body in assimilating these mineral components.

The development of biotechnology will receive its implementation in the agricultural sectors and in processing industries. Mankind has not yet had time to fully master the possibilities of the fifth wave of innovation, and the applied era of the sixth wave is already beginning. In the agro-industrial complex, it is a transition in crop production to mobile bridge systems (a mobile agricultural plant that processes tens of thousands of hectares) and in animal production to farms-plants with tens of thousands of animals [7]. The technologies of growing fruits, berries, mushrooms and vegetables, in physiological solutions, with given quality indicators, as well as micro propagation of highly productive varieties will be widely practiced.

The entry of the production process flow of any product into the field of highly organized systems requires robotization, both for the modules of production processes and for the process in general. This will lead the organization of the technology to the ideal state, which ensures the minimum entropy of the technological system state with given tolerances on the parameters of the technological properties of semi-finished products. The concept of "system" in recent years has been significantly enriched by deeper meaning from the angle of information and management, as well as recognition of self-organization processes possibility, both, in inorganic and biological systems [5,8,14] and even more in anthropogenic systems with human participation.

In the control circuits for self-organizing machine technology systems (automatized and automatic lines), in which a human is included, the control subsystem can be a mechanical, electronic or other technical device. In mechanized lines, the control subsystem is a human. The developing subsystem can be either a human or a technical device with a thesaurus, that is to say, full software and a systematized data bank allowing the robotic system to navigate in it, including distinguishing objects of the external world and acting independently (third generation robots).

By development is meant not just changes in general, which is inherent in every movement, but are changes related to the display processes of external disturbances, in which the ordering of connections, accumulation of information, the emergence of new structures, their complication and determination occur. All this, as a rule, is typical for the process of self-organization.

The three directions for stabilization of food technology production processes, shown earlier, and which are associated with their adaptation to external conditions, today have largely exhausted themselves, as well as machine technologies of continuous production in the form of mechanized and automated process lines with robots of the second and first generations. The creation of lines of the third and next generations is associated with the development of technology, mathematical and software material, taking into account the development of complex structured systems. It should be borne in mind that the deviation of the parameters values of the process from the nominal one can occur with different speeds, depending on the power of the external factors impact. And if so, then there is the problem of accounting the dynamics of a process. Its solution is to develop a control action with the necessary feed-forward function, even with a small amount of the deviation that has begun, taking into account the nature of external influences and not allowing an excessive increase in the deviation, even under the effects of considerable power. Thus, the process of self-regulation is optimized and the object is kept in the homeostasis.

This brings us to the idea that the problem of raising the level of organization is associated with the development and creation of technological systems of the next generations [6,7]. What leads to the structural complication of food technology, that is to say, an increase in the number of subsystems, the introduction of feedback communication, subsystems for the development of corrective actions and, finally, the creation of a system complex, by integrating in it the technological system of the relevant agricultural production, and, perhaps, technological storage and sales systems for finished products.

RESULTS

The analysis leads us to the concept [9] of “agri-food technology of food products”, which suggests that instead of solving the problems of transformation (modernization and improvement) of existing food technologies, which is extremely difficult and expensive, we include in the process flow (at the entrance) the subsystem of agricultural production, thereby ensuring the quality indicators of raw materials with already known stable parameters, and development in the system complex will be provided by people.

The object of our consideration is the food technology of the system complex (as an open system). The impact of the external environment will cause a deviation of the parameters in this system complex, primarily at the stage of the agrarian technological system. As we know, the parameters deviation of the processes beyond the tolerance zone serves as a stimulus for their return to the tolerance zone. And it is even better not to let this deviation arise, preventing it at the distant approaches to the processing plant, to food technologies, in other words, during the production and collection of agricultural raw materials, both of plant and animal origin, changing its conceptual foundations and significantly increasing the technological and scientific level.

In this case, the quality problems of the finished product, its production technology, systems of processes and equipment are considered in conjunction with agricultural production. Moreover, the integration involves the adaptation of agricultural production to food technology. At the same time, this is not about the selection of the raw materials with certain quality, which is used to be nowadays, but the production of plant and animal products for specified, rather strict quality indicators, which will ensure high reliability and efficiency at all stages of the through agri-food technology production. The creation of the scientific basis for technological support of high quality for such technology is possible on the basis of the environmental systems formation, a system of technological impact, working modules, a set of equipment providing processes and technological impacts, identifying patterns of interaction between these systems. The complex of these systems can be represented by an expanded graph of its structure (Figure 1) [12]. All components of the systems must comply with the quality requirements for raw materials, equipment, safety and product quality, information compatibility, and the block-modular construction principle.

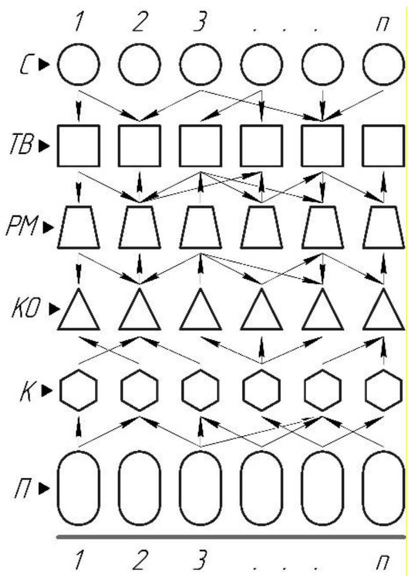

Figure 1 The expanded graph of the three systems structure: C - TB - PM
(C - Environment TB - technological impacts; PM - operators of the technological operation;

KO - equipment complex; K - components of the process unit (processors);
П - machine (apparatus); n - signs of system elements).

All levels of structural systems should contain information about the attributes of the system elements quality: functional, structural, consumer. The complexity of the problem poses the need for a systematic approach, creating and analyzing algorithms for parametric synthesis and identification of complex systems, modern methods of mathematical modeling. An important task is the development of an information base for the creation of such systems.

A large number of factors characterizing the environment, objects of failures, types of processors and operators in the process flow, process modes, determine the need in developing the structure and type of information model for the technological unit, the subsequent development and implementation of the synthesis logic of such a model for technological flow, formation sets of equipment, facilities and technological materials.

Such an agri-food technology integrated in time and space is not a simple change of scale, it is a new qualitative level of production when the combination of agricultural production technologies (assembly of plant or animal production) with processing technologies (disassembly and assembly methods) of raw food products, gives a new quality of this great through technology.

The international essence is manifested in the fact that all physic mechanical, physicochemical, and biotechnological processes, previously so distant from each other in time and space, and therefore weakly interacting with each other, sometimes not depending on each other, are now coming closer, are "combining" by so strict tolerances of the input and output parameters, both in time and in space, that they begin to directly influence each other. At the same time, the efficiency of reflection processes (reaction to disturbances from the outside) increases, the role of cause-effect relationships increases too, new interactions arise. This new through agri-food technology will have properties that previously, before the combination, were not inherent to it or which the agricultural and food technologies did not possess.

At the same time, it is necessary to take into account the abruptness of the revolutionary and evolutionary periods in the dialectic of food technology, including both the development of the agro-industrial complex and the development of culture and nutrition priorities. The last one is associated with urbanization of the population, advertising, an increase in the range of products, climate change, the nature of work, medical indications, etc.

During the period of a development leap, both a radical change in the structure and a surge of functional opportunities occur, which provoke internal contradictions weakening, for example, "productivity - quality". Therefore, with the achievement of a new, higher level of the technology organization, contradictions become less pronounced. However, the contradictions do not disappear altogether, instead of some, others appear, but, as a rule, less acute, with a higher level of organization. Further development of technology is in the form of evolutionary changes: the improvement of processes and modernization of equipment.

Asking the question, what is the prospect of agri-food technologies [10]? Or, paraphrasing this question, what is the dialectic of leaps, if the process of the agricultural food technologies development is interpreted as a process of targeted accumulation of information? It shows that, having reached the level of high organization and determination, this technology again finds its "optimal architecture" and stops, or rather, significantly slows down its further change, meeting the requirements of its own time.

With increasing requirements, new structures are beginning to form again on the basis of already developed structures, but at an even higher hierarchical level. Therefore, it is possible that further there will be again a stage of relative differentiation, and then a stage of new integration.

Apparently, with the implementation of agri-food technologies, the revolutionary transition from the old technological basis of the "industrial era" to the qualitatively new information basis of technologies in the form of unified computer-integrated food production will be completed. After this step, scientific and technical progress will be carried out evolutionarily on the basis of improving the technical and information base, as well as electronic control technology. Of course, the dynamics of the different agri-food technologies transformations will be different, but the vector of these transformations is one.

The scientific component of the problem is to consciously anticipate the dialectical leap, understanding its mechanism, revealing the patterns of organization, structure, functioning and further development of agri-food technologies [6,11]. Analysis of food production and technology makes it possible to classify the methods and processes used in the manufacture of a product, assess its product range, product quality indicators, productivity and production volume.

On the basis of equipment performance studies, mathematical models should be created, allowing evaluating their relationship with the system technology. This will allow modeling both hardware and technology, creating modernized operator models of product formation subsystems. Thus, the prerequisites can be formed for creating robotized machines and equipment of the future, allowing regulating the physicochemical processes at all stages of the finished product formation.

Food enterprises of medium-sized businesses are, as a rule, small-tonnage multipurpose enterprises, having their own specificity in the formation of flexible technological systems, the structural and functional, multivariate complexity, making it difficult to synthesize them by traditional methods. The majority of food production is organized in the form of individual enterprises oriented toward a specific product, with a rigid technological and organizational structure. In addition, the existing design methodology is focused on products of a fixed range, which is in no way consistent with the activities of small enterprises and farms. The tasks of synthesis at the stage of designing a multipurpose low-tonnage process flow with high mobility include both the determination of the optimal technological and organizational structures of the system and its optimal hardware design. The synthesis of such complex technical and technological systems is not possible without a combination of meaningful (heuristic, intuitive and formal) algorithmic methods.

Synthesis of the system at the first stage is reduced to the definition of its structure and processes of its functioning, that is to say, its ability to implement a given set of functions based on a set of modular operating subsystems, made up of operators figuratively describing a system of processes. The primary purpose of the functional purpose is the goal of the system being created, which consists in obtaining, for example, instant solid-dispersed food products, and the secondary nature of the formation of its structure, which can be formed, depending on the available multifunctional or specialized equipment, according to various criteria, functional and structural approach to synthesis. The quantitative and qualitative relationships between the specialized and multifunctional equipment depend on the economic, social and technical capabilities of the technology for the system creation and, with no doubt, affects the quality of products. In those cases, when it is necessary to synthesize a universal process flow system for small enterprises, close to the producer of agricultural raw materials, the predominance of the multifunctional equipment is rational, which gives an opportunity, after a minor changeover, to process various types of agricultural products. At the same time, the equipment load level should be high. From the theory of reliability, it follows that with equal multifunctional capabilities, the most effective is a system with a simple structure, containing the smallest number of components, but, at the same time, providing a given set of the implemented functions and a certain performance.

The task of the low-tonnage multipurpose production synthesis includes the selection of the optimal technological and organizational structure of the system and its hardware design [1,3,9]. Thus, the synthesis of systems for small processing agricultural enterprises is inherently structural-parametric and cannot be carried out without analyzing the essence of the processes, technologies, the state of raw materials and semi-finished products at all stages of the process flow, taking into account the physicochemical, biophysical, biochemical patterns and vague cause-effect relationships between modules.

In this case, it is advisable to build technological subsystems in the form of individual and combined technological units, making it possible to use equipment without upgrading it. In this case, the process flow is formed on the principle of block-modular composing of such technological processes and equipment. Structural synthesis of such a process flow is not possible without optimal decomposition of technological processes according to the criterion of hardware and machine analogy of their technological stages, which implies a wide use of unification, allowing to significantly reducing costs and time for the development of new technology. Optimization of a multipurpose low-tonnage flow occurs at the stage of parametric synthesis, along the way from the system of processes to the system of devices and machines. The effectiveness of such a flexible technological system is determined by the quality of the technological process design, which should ensure its correct functioning even under the influence of adverse factors, including, the predominance (up to 90% of all equipment) of devices with periodic operation.

Synthesis of the system [2] involves not just connecting one processor to another, one subsystem to another, but structuring them in accordance with the developed technology, so that later, based on the analysis, bring it to the optimal mode or suggest ways for its further development, taking into account the type and class of product, used raw materials, the technical conditions of acceptance, the release programs, as well as information about the equipment, physicochemical and microbiological processes.

The designing of the process flow is performed by exhaustive search of options in a limited, by the type of production, set. The synthesis procedure of the technology flow begins with the system information technology support, modeled using operator models, which are graphic images of the process system. At the same time, the issues of machine and hardware design are deliberately not affected, since the technological process can be implemented by various technological systems, which can change over time. The elemental base of operator models is more conservative, and this allows the construction of standard functional-structural models. The ultimate goal of the synthesis of a multipurpose production with a periodic method of organizing technological processes is the creation, at the lowest possible cost, of technological, instrumental and organizational support for the products production with a given quality and required assortment.

The technological flow of low-tonnage production is most conveniently organized in a block-modular type, then in the synthesis process, a set of standard subsystems — modules are formed and, depending on the product, for each technological scheme, [3,9,13] its own stream is formed, which can be described variously by organized systems.

The process flow, organized in a periodic variant, consists of separate, sequential technological stages. Subsystems function, in accordance with the technology, is defined by the scheme. Therefore, the optimization of a periodic technological process flow means the simultaneous optimization of the schedule for operation of the subsystems and the volumes of the tanks for redundant products at each stage.

The first stage in the creation of a complex newly created system at the design stage of the production of any product group is the selection of the basic technological scheme, which, if possible, includes all used subsystems for the whole range of manufactured products. Disintegration of the process flow into individual and combined periodical subsystems allows the production to be universalized. At the same time, it is necessary to ensure the real compatibility of the technological processes, implemented with individual and combined schemes. For example, grinding protein meal, starch or sugar can be done without additional inter-processing equipment, but when we evaporate the juice of beet and apple, between them, washing and processing of the squeeze press, evaporator and other related equipment and containers is required.

The modular organization of the technological processes system in the periodic variant gives a significant variation in the technological parameters in each subsystem that is included in various technological schemes, in which each stage of the process has a relative independence. Synthesis of multivariate schemes can be understood as the best fit of the technological equipment set to a group of technological processes and optimization of the computer-hardware system structure.

The formation of the synthesized system technological structure is associated with the classification of all technological processors on the basis of their hardware analogy. All technological processes of the designed or researched production are given figurative descriptions, which, according to the selected attributes, as a result of expert evaluation, are classified into groups. When determining the similarity of technological flows of various industries, first, the similarity of their technological subsystems should be determined, on the basis of figurative modeling, passing to their consideration from the angle of the system of processes.

Let’s consider the formation of a process flow on the example of agglomerating polydisperse multicomponent structures, such as granules, briquettes, etc.

One of the effective ways to increase the provision and preservation of the system elements quality is the reliable observance of the quality indicators of raw materials and the processes technological modes in the process flow. The required combination of effects that ensure the required quality of the product is expressed by the following equation [15]:

$$\overline{S}(R,\sigma,\alpha,\beta,\gamma)\cdot\overline{V}=\overline{K}\cdot a \quad (1)$$

Where: $\overline{S}$ - vector-function, describing the distribution of quality indicators (Figure 2);

R and β - generalized indicators of micro and macro geometry of the finished product or semi-finished product;

σ - a generalized indicator of intercrosses or interlobular communications;

α - An indicator characterizing the generalized physical, chemical, physicochemical or other properties of the produced product;

γ - The indicator of communication within the manufactured product (structure-forming, filling-up, etc.) (Table 1 [8,12]).

$\overline{V}$ - Vector of conditions of use or use;

a - is the set of methods used in the cumulative technological process of forming a granule

$\overline{K}$ - State vector.

Table 1 Classification of disperse systems [8]

<table>
<tr><td>Attributes of disperse structure</td><td colspan="5">Type of disperse system structure</td></tr>
<tr><td rowspan="2">Form of particles</td><td>Isometric structure</td><td colspan="4">Anisometric structure</td></tr>
<tr><td>Spherical $\nu=1$</td><td colspan="3">Plate-like $\nu<<1$</td><td>Acicular $\nu>>1$</td></tr>
<tr><td rowspan="4">Particle size</td><td colspan="5">Monodisperse structure $\psi_1=\psi_2=\psi_3=1$</td></tr>
<tr><td colspan="5">Polydisperse structure $\psi_1\neq1$, $\psi_2\neq1$, $\psi_3\neq1$</td></tr>
<tr><td>Coarsely dispersed $a>10^{-3}$ cm</td><td>Finely dispersed $10^{-3}>a>10^{-5}$ cm</td><td colspan="2">Colloidal $10^{-5}>a>10^{-7}$ cm</td><td>Permolecular $a<10^{-7}$ cm</td></tr>
<tr><td colspan="2">Particle are not involved in Brownian motion</td><td colspan="3">Particle are involved in Brownian motion</td></tr>
<tr><td>Particle packing in volume</td><td>Isotropic structure</td><td colspan="3">Orthotropic structure</td><td>Anisotropic structure</td></tr>
<tr><td>Density</td><td>Highly diluted structure $0<Kt<0,25$</td><td colspan="2">Porous structure $0,25<Kt<0,50$</td><td>Dense structure $0,50<Kt<0,75$</td><td>Very dense structure $0,75<Kt<1,00$</td></tr>
<tr><td>Aggregate state</td><td>1st type structure – particles do not interact with each other</td><td colspan="3">2nd type structure – particles form aggregates</td><td>3rd type structure – aggregates form floccules</td></tr>
<tr><td>Parameters variability</td><td>Steady structure</td><td colspan="4">Developing structure</td></tr>
</table>

From here it is possible to propose an algorithm for calculating combined physicochemical and physic mechanical method, based on the vector of external influence (Figure 2).

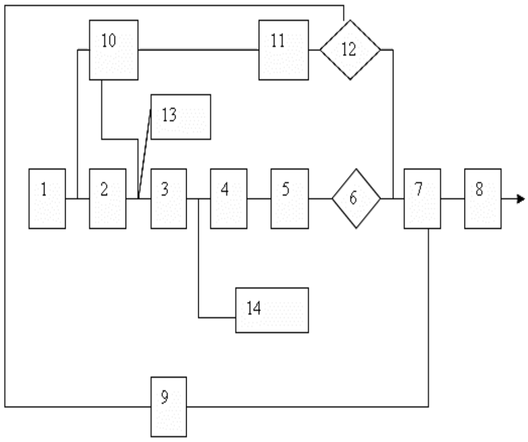

Figure 2 Calculation algorithms for the combined physicochemical and physic mechanical method [13]

The algorithm is based on the iterative process of changing the vector - an external effect corresponding to a specific vector of the produced product parameters (recipe composition, dispersion and structure, etc.). Separate elements contain systems of differential equations, approximations of experimental dependencies, blocks of logical functions.

Let's consider the operation of the algorithm in Figure 2.
Unit 1 - priori data. Based on the proposed recipe of the product, the choice of materials is made; the initial value of the vector of external influence $\overline{K}_o$ is set, using a priori data.

Unit 2 - the intended product model contains a system of equations describing the change in the physicochemical properties of the product with a certain vector $\overline{S}$. The unit has four subsystems: a dependency system, describing the process of phase transformations; system of equations, describing heat transfer; a system of equations, describing the stress state, a system of equations characterizing the bacterial component, and a system describing the change in geometric parameters.

Unit 3 is a block of intermediate, due to technology, output parameters of the dispersed subsystems structure, specified by the vector $\overline{S}$.
Unit 4 - the models of generalized impact on raw materials and semi-finished products, describing the regularities of changes in its structure and physicochemical properties.

Unit 5 contains the output parameters Z, characterizing the quality indicators of the finished product, its shelf life.

Unit 6 compares the obtained and the required indicators of product quality using vector $\overline{K}$. If this condition is not fulfilled, the vector $\overline{K}$ value changes.

In Unit 7, the vector $\overline{K}$ is decomposed into composite vectors, with spatially-temporal separation in specific methods, which is carried out by means of identification tables in all the considered methods.

Unit 8 converts each composite vector $\overline{K}_i$ to the parameters of a specific technological process, taking into account the useful energy and losses in the system.

Unit 9 modifies the vector of external influence $\overline{K}$, using the gradient method with smaller values of physicochemical, microbiological, organoleptic indicators.

Unit 10 connects the output parameters of the granule structure $\overline{S}$ with the vector of external influence $\overline{K}$. Through linearization and simplifications, this dependence is reduced to analytical, with a set of experimentally or theoretically derived coefficients.

Unit 11, similarly to unit 10, analytically interconnects the structure of the product $\overline{S}$ with the vector $\overline{Z}$, which lets, in the process of theoretical calculations, continuously refine the approximate dependencies of the criteria for technological impact and use them in the development of the process flow, as well as technical conditions and instructions.

In Units 13 and 14, the parameter volumes of a solid body are used in the calculations for grain, briquette, solution, suspension, mixture. The volumes are generated using sensors of random numbers and the corresponding distribution signs.

The solution for the problem of purposeful shaping the properties of a product under the influence of external influences is made by considering and describing its interaction with the carrier of influences, formalized by the state vector. This methodological description includes a number of mathematical models, relating the parameters of the state vector to changes in the quality characteristics of the product structure, both when solving energy and structural problems, and when describing the formability of wet dispersed systems.

In particular, the consideration of energy problems is carried out by taking into account the heterogeneity, which determines the presence of interfaces between individual phases. Heterogeneity, as is known, is quantitatively determined by surface tension - the value characterizing the energy per surface unit. Therefore, energy analysis brings us to the analysis of the phase change dynamics in the conditions of powerful energy flows, ensuring the design of specific criteria: step of the overflow paths and interconversions of structures (coagulation, crystallization, condensation) (Figure 3, Table 2). These dependencies are part of Unit 2 (Figure 2) [12].

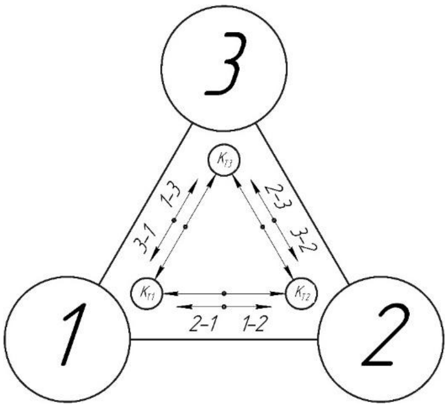

Figure 3 general schemes of possible interconversions
1 - Coagulation structure; 2 - condensation structure; 3 - crystallization structure

Table 2 Possible interconversions of structures

Interconversion type	System, substance	Conversion conditions	The level of change in the volume concentration of the solid phase
1→2	Granule, briquette (S-L-G)	Forming	$K_{T1}>0,4$; $K_{T2}<0,8$
2→1	Granule, briquette (S-L-G)	Moisturizing, heating	$K_T≈0,4-0,7$
2→3	(S-G)	Drying	$K_{T3}≈0,85-1$
3→2	β-2CaO*SiO_2	Polymorphic transition β-C_2S→γ-C_2S	$K_{T3}=1$; $K_{T2}≈0,9$;
3→1	Paraffin, crystallohydrates	Heating	$K_{T3}=1$, $K_{T1}≈0,95$;
1→3	Paraffin, crystallohydrates	Cooling	
2←1→3	Concentrated serum	Heating-cooling	$K_{T1}>0,4$; $K_{T3}=0,8-0,9$
1←2→3	Water-salt systems	Depending on the initial state of aggregation and the amount of the introduced water	
2←3→1	Water-salt systems		

The formability of wet disperse systems, and, consequently, the dynamics of the structure formation is determined by the distribution [8] Solid-Liquide-Gaseous (coefficients $K_s+K_l+K_g=1$) in the process of formation, including accounting of performance parameters of the studied object $\overline{\nabla}$, expressed by generalized equations, describing the value of the structural-energy parameter, characterizing the degree of the disperse system restructuring.

The description of the vector $\overline{S}$ is given in Table 1 [13].

Such an approach makes it possible to create a number of combinations for physicochemical and physic mechanical processes and apparatuses (rolling, rubbing, pressing, drying, drying with satellites, etc.). The use of a unified energy approach with a generalized state vector helps to predict the optimal combinations of external influences and, on their basis, to create parallel-sequential combined methods that ensure the improvement of specific quality characteristics.

The creation of new types of structures in the formation of dispersed structures indicates a transition from chaos and disorder to organization and order. These dissipative dynamic microstructures are prototypes of the future states of the system, so-called fractals, formed at various primary forms (slips) of several dispersed particles, with certain free moisture content and pressures of about 5 MPa. Most of the fractals are either destroyed, not fully formed, or remain. At the bifurcation point there is a kind of natural selection of fractal formations. The formation "survives", if it is the most adapted to environmental conditions. In the process of the formation of these structures in the first stage of "disassembling" of raw materials and mixing, the entropy increases. In case of non-equilibrium phase transitions, which corresponds to bifurcation points through which the process of self-organization goes, the system moves along the path corresponding to the lower value of entropy production? This means that the smaller the entropy production, the more organized the system. This is the main meaning of the process of self-organization, the creation of certain structures from the chaos of an irregular state. Open systems would somehow structure the energy of their environment, while the ordered part of the energy remains inside the system, and the disordered energy is discharged by the system back into the environment.

Thus, a non-equilibrium thermodynamic process creates conditions for a state where the influx of energy from the outside not only compensates the growth of entropy, but also reduces its amount [1, 2].

For example, the process of granulating instantiated polydisperse products in granulators shows that this process includes three stages of granule formation [8, 12]: nucleation, growth, and compaction. At the same time, the rate of granulation of polydisperse materials is significantly restrained by the phenomena of nucleation. The formation of unclean depends on the following factors: the moisture content of the dispersed mixture, the physicochemical properties of the liquid and solid phases, the operating and structural parameters of the granulator and the presence of skull.

The method of choosing the rational way for forming dispersed systems in agglomerates [8] or other forms is based on a sequential review of processes in the process flow according to three criteria: applicability, ensuring the required quality indicator and technical-economic efficiency [13].

The criterion of applicability or technological criterion can be defined as:

$$К_m = f(М_д; Ф_д; D_д; И_д; Н_д; \sum_{i=1}^{m} T_i), \quad (2)$$

Where: $М_д$ - material;

$Ф_д, D_д$ - The shape and diameter of the granules;

$И_д$ - Moisture level of the granules;

$Н_д$ - Performance-structural parameters;

$\sum_{i=1}^{m} T_i$ - a set of technological features of this method.

The rationality of a set of operators can be determined by the quality factor - $К_Д$:

$$К_Д = К_и \, К_в \, К_с, \quad (3)$$

Where: $К_и$, $К_в$, $К_с$ - coefficients, describing the quality after the mixer, the structuring and dryer, respectively.

The final decision on the feasibility of using the selected method is made according to the technical and economic criterion $С_в$, which connects the production costs with the quality indicators of the finished product:

$$С_в \geq К_Д \, С_н, \quad (4)$$

where: $С_в$ is the cost of variant 1,

$С_н$ is the cost of variant 2.

Thus, we can propose a scheme, an algorithm for solving the problem of ensuring the required quality indicators [4, 12]. It contains:

"1" - organoleptic characteristics, nutritional value, cost, safety, structural and mechanical properties, as well as functionality.

"2" – components of "1": organoleptic indicators - taste, smell, color, appearance and texture; nutritional value - proteins, fats, carbohydrates; the energy value; safety - the presence of toxic elements, radionuclides, pesticides and microbiological elements; structural and mechanical properties - strength, bulk mass, flowability, porosity, time of dissolution; functionality - the content of antioxidants and biologically active substances.

Building a modular process involves the following main steps:

- classification of granule assembly technology in processes;
- processes analysis for manufacturability;
- the choice of technological sequence of processes;
- formation of the process flow;
- design of processes and processors.

The principle of the disintegration of a complex system according to the modules makes it possible to independently develop them, with subsequent assembly of them, depending on the purpose and, taking into account productivity and quality indicators, various structures of technological flows.

This helps to present the synthesis of an operator model of any production in the form of stages:
- determine the purpose of the system modeling;
- set the attributes, characterizing both the system itself and the system-forming elements;
- form the system hierarchy.

DISCUSSION

In determining the characteristics of the created system for low-tonnage multipurpose production and its constituent subsystems, a pre-project analysis of the formation methods for this type of production in related industries, such as chemical industry or light industry, is held [3,5,15], which helps to develop technological schemes by analogy with the existing prototypes. If there are several analogues, then the selection criterion is established (economic, hardware, quality, etc.) and the best of them is selected in comparison by a generalized complex indicator. In the absence of analogue, the design object is compared in accordance with the quality indicators of the prospective sample. A prospective sample is understood as a figurative structural and, if possible, parametric, description of the most possible variant of technology, based on the analysis of the achievements and development of technology or equipment in this field.

In this regard, the problem of scientific and technical forecasting, which is focused on the provisions of the sixth wave of innovation in the agricultural sector of Russia, in research organizations of the Department of Agricultural Sciences of the Russian Academy of Sciences and universities of agricultural and food engineering technology is rather relevant. Scientific and technical forecasting is aimed at revealing the features of the future development of science and technology. The following tasks are characteristic for studies on the prediction of the agro-industrial complex:

• assessment of the possibility for using certain principles, laws and regularities, when creating a new technology and equipment;
• search for alternatives to create technological and technical systems;
• formulation of scientific, technical and organizational-technological problems, which solution will provide the possibility of creating new technological processes and new technology;
• formation of parametric lists of promising technical systems.

It should be emphasized that the problem of determining the directions of the innovative technologies and equipment development is central to the establishment of research priorities for their improvement. The main way to identify priorities is to predict trends and prospects for the development of research, basing on data about their current state, taking into account the depth of the forecast.

Scientific and technical forecasting is a probabilistic assessment of possible ways of developing an object for the future.

The practice of forecasting shown that for improving the efficiency of work, it is necessary to create a forecasting system that helps to continuously produce forecast information. The system of continuous forecasting is a combination of methods and techniques for their implementation, data banks, technical means and a group of specialists, involved in forecasting. The principle of the forecasting continuity is the systematic adjustment of previously developed forecasts, taking into account the newly coming scientific-technical, technical-economic and other information [3,10].

Any forecast always contains four mandatory elements:
• A specified time period of forecasting;
• forecast of the overall situation in a particular area of the study;
• Predictable characteristics of the forecasted object quality, if possible in the form of quantitative parameters;
• The probability of achieving the changes, predicted in the forecast, by the agreed time.

There are many different prediction methods, each has its own advantages and disadvantages [4,6,8].

For forecasting the development of technological and technical equipment of the various agro industrial complex branches and determining the priorities of scientific research on the development of the production technological processes, and conversion of raw materials into finished products, the most effective method of engineering forecasting is based on the work of V.G. Gmoshinsky and G.I. Fliorent [1,2]. Using the method of engineering forecasting allows us to reveal the potential development of equipment and technology reflects the world level of their current and subsequent state, characterizes the advance, retardation or compliance of a particular industry with the world level of development.

The engineering forecast method makes it possible to process various sources of information in the form of research and new product development materials, articles, dissertations, monographs, reports, patents, etc. Having formalized the flow of such information by entering its weighted estimate, it is possible to transform a qualitative description of an object into its generalized quantitative estimate, which makes it possible to use parametric and non-parametric information in forecasting.

When analyzing information sources, engineering forecast reveals the characteristic directions both of the future development of the industry as a whole and the ways of improving individual machines and technologies.

By nature, engineering forecast is multivariate. This means that the direction and pace of the equipment and technology development depend on the initial forecast situation, the rate of new information, the economic situation in the country and the world, and, consequently, the rate of the scientific research development, demands and needs of the economy and society. All this should be taken into account when making forecasts.

In forecasting, there is an extremely important task to learn how to select and sort the information, used as a source for making forecasts. It is necessary to have a system of criteria to evaluate the quality and suitability for predicting information from various sources and its significance for obtaining a reliable, scientifically and practically reasonable forecast.

All this provides a method of engineering forecast. It is quite simple, reliable and has the necessary accuracy to predict the development of scientific, technological and technical equipment of the agro-industrial complex branches.

Methodically the forecasting is made in the following way.
A General Definitional Table is compiled, which represents a set of ranked characteristics, reflecting the pre-formed requirements for the assessed technology, a technical tool or a technological process. Its layout is presented in Table 3.

Table 3 Layout of the General Key Table

Characteristics, i	Position, p	Estimation (points), j(i)	Estimation, with respect to the characteristics importance
i_1	p_1 p_2 p_3 p_n	1 2 3 n	$1\phi(i_1)$ $2\phi(i_1)$ $3\phi(i_1)$ $n\phi(i_1)$
i_2	p_1 p_2 p_3 p_n	1 2 3 n	$1\phi(i_2)$ $2\phi(i_2)$ $3\phi(i_2)$ $n\phi(i_2)$
i_n	p_1 p_2 p_3 p_n	1 2 3 n	$1\phi(i_n)$ $2\phi(i_n)$ $3\phi(i_n)$ $n\phi(i_n)$

In this table, “i” is a characteristic reflecting the strength of technical and technological solutions in the direction “n”;
“p” is the position for the characteristic solution “(i)”; “j (i)” - decision estimation, points;
“ϕ(i)” is the characteristic importance “(i)”.
The importance of each characteristic is set by the function:

$$\phi(i) = i/2^{i-1} \quad (5)$$

Then for technology of the technical means or technological process, for example, which is estimated by five characteristics, their importance values will be: 1; 1; 0.75; 0.50; 0.31.

As for the accuracy of "ε", it cannot exceed the accuracy of the characteristics importance estimation. In the limit "ε" = ϕ(i). Based on this, using the above formula, the number of necessary characteristics that correspond to the specified accuracy of the estimate can be determined. If such accuracy is high enough (about 2%, that is to say, ε = 0.02 or ϕ (i) = 0.02), then we should include up to 10 characteristics of the forecasted technology, technical means or technological process. With a calculation accuracy of 20%, it is sufficient to stop on five or six characteristics.

For a quantitative assessment of the science-intensiveness and competitiveness of a future technology, for example, the following characteristics can be used:
i_1 - Methods for processing raw materials and semi-finished products, on which the technology is based [$\phi(i_1)$= 1];
i_2 - Application of theoretically proved solutions in technology [$\phi(i_2)$= 1];
i_3 - The level of mechanization and automation of technology [$\phi(i_3)$= 0,75];
i_4 - Sanitary, hygienic conditions and safety arrangements in the technology [$\phi(i_4)$= 0,50];
i_5 - The license-conjuncture factor [$\phi(i_5)$= 0,31].

Other characteristics may be used to evaluate a technical or technological process.

As a rule, the choice of characteristics and their ranking by importance does not cause difficulties and can be done by the researcher-forecaster with their subsequent approval at a competent meeting (scientific and technical council, academic council, conference of experts, etc.).
Each of these characteristics is developed in the General Definitional Table by

5 positions, after which the required quantitative assessment of the forecasted technologies level, technical means or technological process is calculated by the formula:

$$K = \frac{q}{Q} = \frac{\sum_{i=1}^{i=n} \phi(i) \times j(i)}{n \sum_{i=1}^{i=n} \phi(i)},$$

(6)
Where q is the sum of the estimates of the forecasted object for each characteristic,
Q - The maximum amount of estimates for the same characteristics.
Thus, it becomes possible to measure with the necessary accuracy the previously not measured characteristics of the object and to fulfill the forecast of its implementation, setting the category of prospectively:

- very promising (K = 0.80-1.00),
- promising (K = 0.60-0.79),
- less promising (K = 0.40-0.59),
- Not promising (K = 0.20-0.39).

Recommendations for the implementation of this method and examples of engineering forecast technologies, individual processes, as well as structures of machines, devices, bioreactors and production lines in general, are given in the book of E.N Tugolukov [9].

CONCLUSION

The sixth wave of innovation in the agro industrial complex involves the creation of new industrial technologies and equipment for the production and processing of agricultural raw materials. Scientific and technical ideas of such developments are already given in various information sources, including those far from the problems of agriculture, food and processing industries. The quality and availability of forecasting objects should be measured quantitatively and recommended for implementation in the agro-industrial complex by the staff of academic research organizations and specialized universities of the country.

Performing such studies, which constitute the essence of scientific and technical forecasting, is the work that requires highly skilled performers and it should be provided with public budget financing. Otherwise, we will remain on the sidelines of the world scientific and technological progress in food production.

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