

# *Synergistic Synthesis of Multi-Range Food Technology Systems*

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**Abstract**—The article is devoted to peculiarities of the design of multi-product complex food technological systems designed in the agro-industrial complex (AIC). The focus is on the problem of creating industrial agro complexes, implementing technology in agricultural production, its storage and processing. Particular attention is paid to the fluctuations of the processes of «large» technological systems 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 conditions of self-organization of system technological complexes and on their main characteristics: openness, nonlinearity and instability are summarized. The principles of designing such complexes and the dialectic of mutual reinforcement of technologies combined into a complex are outlined. The necessity of industrialization of agricultural technologies as a dialectical inevitability of creating industrial agro-complexes realizing a new stage of innovative development in the agro-industrial complex is substantiated. The main provisions of the paradigm of development of agro-industrial complex technologies are formulated.

**Keywords**—*synergistic synthesis, technology, system, self-organization, module, forecast.*

## I. INTRODUCTION

The purpose of the article is to analyze the engineering and scientific problems of the design of the agro-industrial complex, taking into account its inherent systemic patterns. The solution of the food problem in the developed countries of the world is inextricably linked with the development of the sixth technological order, the period of which falls approximately in the years 2025-2080. This way of life will be characterized by the use of bio- and nanotechnologies, genetic engineering, membrane and quantum technologies, micromechanics, robotics, artificial intelligence systems. The

concept of «technology» is now becoming more and more relevant capacious concept. Technologies from the purely industrial sphere stepped into the spheres of science, politics, social management and became the subject of independent theoretical research. In real conditions of interaction in the agro-industrial complex of three systems – technological, raw materials and consumer determines the quality of products. Therefore, their consideration on the scale of the integrated complex, taking into account the interaction of these subsystems, makes it possible to optimize production and bring it to a qualitatively new level. Without knowing the essence of the phenomena occurring in the integrated complex of the AIC, it is impossible to create a new whole.

## II. THEORETICAL ANALYSIS OF THE PROBLEM

Analyzing the quality of technologies in various industries, we can note the characteristic feature of technological evolution, which is that from structure to structure, the structural complexity of the technology as a whole increases while simultaneously increasing stability, sustainability, accuracy, manageability and reliability of leading processes. This is where the dialectic patterns of nature's development are manifested: the complexity of the structure and the simplification of the functioning of objects, including man-made ones. Therefore, modern scientific and engineering activity in the agro-industrial complex requires a transition to infrastructure solutions of the sixth technological order. The basis of these decisions is the systemic interconnection of basic research [1], in the field of agriculture and processing technologies, which should ensure the high quality of connections along the entire food production chain. It is important to choose the right key areas of research and allocate resources. This explains the complexity of the task facing the science of the agro-industrial complex of Russia: in

the coming decades to become one of the states with the sixth technological order in food production.

The dialectic development of food technology has not been the subject of research so far. The tasks of improving technologies, equipment, controls and automation were solved, each time some internal contradiction of technology was resolved, for example, interrelation – “performance – quality”. Since ancient times, philosophers have been debating about the relationship between quantity and quality from the standpoint of the dialectical law of the transformation of quantity into quality: the sum of the “system” properties of subsystems is not equal to the quality of the system. For example, in nuclear physics, this law of system synergy is expressed in the concept of “mass defect”.

As noted by the founder of synergetics G. Haken, [2, 9], “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 synergistic approach is that “order parameters” are distinguished, which describe a small number of essential parameters of subsystems that have a significant number of degrees of freedom. Subsystem-modules are part of intricate systems and are in complex interactions with each other. All types of possible motion-interaction between processors in the subsystems also turn out to be “subordinate” (the principle of subordination) and can be predicted enough predictably through order parameters using a hierarchy of simplified models including a small number of the most significant degrees of freedom.

Today we already have examples of highly developed automated and robotic enterprises, where human participation in the formation of a product is minimized. 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 stimulate suppliers to fight for the consumer), the quality stability is ensured by the stability of the technological parameters of production, the influence of the human factor on the formation of quality is minimized.

We are talking about industrial technologies, which will allow us to create machine technologies for crop production, starting with precision sowing of seeds on agrotechnical parameters, and technology of livestock products with factory features. This industrial agricultural production makes it possible to receive it in a narrow range of technological properties needed for the organization of systems of automatic processes in recycling technologies, including the rotary lines of rotary technology.

At the same time, the most important condition should be an 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 domestic technological and technical base, saturated with automation and electronics, which meets the conditions for the implementation of the sixth technological order.

The basic principle of the sixth technological structure in the agroindustrial complex is as follows: man serves not hectares of the field and not individual animals, but automation equipment. This principle is precisely the foundation of industrial crop production and livestock to processing and food companies, which guarantees relatively stable raw material quality indicators for the organization of automatic technology of its processing.

The entry of the production process flow of any product into the area of highly organized systems requires the robotics of both the modules of the production processes and the whole process. It will lead the organization of the technology to an ideal state, ensuring the minimum entropy of the state of the technological system with given tolerances on the technological properties of semi-finished products. The concept of “system” in recent years has been significantly enriched due to a deeper meaning in terms of information and management, as well as taking into account the processes of self-organization, both in inorganic systems and in biological and, especially, in anthropogenic systems with human participation.

### III. SYNTHESIS OF TECHNOLOGY SYSTEMS

In the control circuits for self-organizing machine technology systems (automation and automated lines), in which people are involved, the control subsystem can be a mechanical, electronic or other technical device. In mechanized lines, the control subsystem is human. The developing subsystem can be either a person or a technical device that has a thesaurus, i.e. complete software and systematized data bank, allowing the robotic system in it to orient itself, including distinguishing objects of the external world and acting independently (third generation robots).

It leads us to believe that the problem of increasing the level of organization is associated with the development and creation of technological systems of the next generation [3]. This leads to a structural complication of food technology, i.e. increasing the number of sub-systems, the introduction of feedback, subsystems working out corrective actions and, ultimately, to the creation of a complex system, and by including the appropriate processing of agricultural production systems, technological storage and distribution of finished products.

When solving the problems of integration of different-quality groups of food technologies, the choice of adequate criteria for the upcoming transformations acquires special significance. In this choice, we proceed from the concept of qualitative differences of the fifth and sixth technological structures from the preceding ones.

The fifth and sixth orders are developing in an environment of post-industrial society, emerged as a civilized response to the destructive nature of the biosphere and the human impact of the industrial age technologies. Therefore, these structures should combine in their development the technological dimension with the humanistic, environmental and social dimensions. Thus, the priority criteria for the formation of the sixth technological order in the field of the agro-industrial sector are health-saving, the nutritional value

of products, environmental safety, the massive creation of high-tech jobs. Automation and robotization of agro-industrial technologies are relevant in those forms that meet these priority criteria.

#### IV. RESULTS AND DISCUSSION

The analysis leads us to the concept of “agrarian-food technology of product”, which suggests that instead of addressing the issues of transformation (modernization and improvement) of existing food technologies, which is extremely difficult and expensive, we include in the process flow the subsystem of agricultural production, ensuring the quality indicators of raw materials with already obviously 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 of this system complex, primarily at the stage of the agrarian technological system. As it is known, the deviation of the parameters of the processes beyond the tolerances serves as a stimulus for their return to the tolerance. And it is even better not to allow this deviation due to its prevention on distant approaches, i.e. in the production and collection of agricultural raw materials, both plant and animal origin, changing its conceptual framework and significantly increasing the technological and scientific level.

In this case, the problems of the quality of the finished product, its production technology, the system 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, it is understood not the selection of the necessary raw materials for conditions, which is the case at present, but the production of plant and animal products for specified, rather narrow quality indicators, which will ensure high reliability and efficiency at all stages of the production of the through-food and food technology. The creation of scientific foundations of technological support for the formation of the quality of such technology is possible on the basis of the formation of environmental conditions, the system of technological impact, working modules, equipment complex, providing processes and technological impacts, identifying patterns of interaction of these systems [4, 5]. All components of the systems must comply with the requirements of the quality of raw materials, equipment, safety and product quality, information compatibility, comply with the block-modular construction principle.

All levels of structural systems should contain information about the quality features of the system elements: functional, constructive, consumer. The complexity of the problem poses the need for a systematic approach, the creation and analysis of algorithms for parametric synthesis and identification of complex systems, modern methods of mathematical modeling. An important task is to develop 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 predetermines the need to develop the structure and type of information model of the process unit, the subsequent development and implementation of the synthesis logic of such a process flow model, the formation of sets of equipment, tools and technology materials.

During the period of a leap in development, both a radical change in the structure and a surge in functionality occur, as a result of which internal contradictions are weakened, for example, «productivity – quality». Therefore, with the achievement of a new, higher level of organization, the technology becomes less pronounced contradictions. However, the contradictions do not disappear at all, instead of some others appear, but, as a rule, less acute, characteristic of a higher level of organization. Further development of technology is in the form of evolutionary changes: the improvement of processes and modernization of equipment.

The scientific component of the problem under consideration is to anticipate a dialectical leap, understand its mechanism, reveal the patterns of organization, structure, functioning and further development of agro-food technologies [3].

On the basis of equipment performance studies, mathematical models should be created to evaluate their relationship with the system technology. It allows to simulate both equipment and technology, and create a modernized operator models of subsystems of product formation. Thus, the prerequisites can be created for the creation of robotic machines and equipment of the future, allowing to regulate the physical and chemical processes at all stages of the formation of the finished product.

Synthesis of the system at the first stage is reduced to the definition of its structure and functioning processes, its ability to realize a given set of functions based on a set of modular operating subsystems made up of operators figuratively describing the system of processes. Primary functionality — the goals of the system being created, which are to obtain, for example, instant polydisperse food products, and the secondary nature of the formation of its structure, which can be formed depending on the existing multifunctional or specialized equipment, determine various criteria of the functional-structural approach to synthesis. In those cases when it is necessary to synthesize a universal process flow for small enterprises close to the producer of agricultural raw materials, it is rational to predominate multifunctional equipment, which makes it possible, after minor changeovers, 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 functionality, the most effective is a system with a less complex structure,

containing the smallest number of components, but at the same time providing a given set of implemented functions and a certain performance.

The tasks of the synthesis of multi-range production include the selection of the optimal technological and organizational structure of the system and its hardware design [6]. Thus, the synthesis of systems for small processing

agricultural enterprises is inherently structural-parametric and cannot be carried out without analyzing technological processes, 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 cause-effect connections between modules.

Synthesis of the system involves not just attaching one processor to another, one subsystem to another, but structuring them in accordance with the developed technology in order to bring it to an optimal mode or suggest ways for its further development, taking into account the type and class of product, raw materials used, technical conditions of acceptance, program of release, as well as information about the equipment, physico-chemical and microbiological processes.

The process flow synthesis procedure begins with the system information technology support, which is modeled using operator models, which are graphical representations 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 and be changed over time. The elemental base of operator models is more conservative, which allows building typical functional and structural models. The ultimate goal of the synthesis of many production assortment with batchwise process organization is to provide a process, hardware and organizational support for a given quality of output and the desired range at the lowest possible cost.

The formation of the technological structure of the synthesized system is associated with the classification of 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 characteristics selected as a result of expert evaluation, are classified into groups. The similarity of technological flows of various productions is established on the basis of the figurative modeling of the technological subsystems making them, considering their systems of processes. In particular, the consideration of energy problems is carried out due to heterogeneity, which determines the presence of interfaces between separate phases. Heterogeneity is quantified by surface tension – the quantity that characterizes the energy per unit of surface. Therefore, energy analysis brings us to the analysis of the dynamics of phase changes in the conditions of powerful energy flows, ensuring the design of specific criteria: step of overlapping paths and interconversions of structures (coagulation, crystallization, condensation).

Thus, a nonequilibrium thermodynamic process creates conditions for the state when the influx of energy from the

outside not only compensates (suppresses) the growth of entropy, but also reduces its amount [7, 8].

The principle of the disintegration of a complex system modules enables their independent development with the subsequent assembly of these, depending on the purpose, and taking into account the performance and quality indicators of the different structures of process streams.

## V. CONCLUSION

In determining the characteristics of the created multi-product production system and its constituent subsystems, a pre-project analysis of methods for the formation of this type of production was carried out, which made it possible to develop technological schemes by analogy with the existing prototypes. In the presence of several analogues, selection criteria were established (economic, hardware, quality, etc.). For comparison, the best of them is selected according to a generalized complex indicator.

The sixth technological structure in the AIC 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 domestic and foreign information sources, including those far from the problems of agriculture, the 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.

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