SYSTEMIC REGULARITIES IN THE STUDY AND DESIGN OF TECHNOLOGICAL COMPLEXES FOR THE PRODUCTION OF INSTANT BEVERAGES

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Abstract: This article is devoted to the state-of-the-art systemic approach to the analysis and synthesis of process flows for the production of instant polydisperse granular functional beverages. The distinctive feature of these studies is the methodological approach developed by Academician V.A. Panfilov, representing a quantitative description of the integrity level of a large production process in a technological complex, based on the results of its diagnostics and comprising sequential transition in studies from a system of technologies to a system of processes and form a system of processes to a system of apparatuses and machines. The definition of a technological system as an interrelated whole creates a certain logic and methodology of its qualitative and quantitative study and develops a system-centered opinion on production.

Keywords: process flow, granular, instant, disperse, system, analysis, synthesis

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INTRODUCTION

Extensive materials accumulated as a result of studies on the production of instant food products currently represent a totality of specific solutions (mainly, empirical) and do not give an insight into the shaping theoretical basics of instantization techniques, economic expediency, and energy consumption, which insistently require systematization and generalization. With all the diversity of technologies for the production of instant, quick-dispersing, and quick-swelling beverages, which are called in a word *instant* in foreign literature, there is neither a single classification nor a single approach to the formation of such production technologies and processes.

Technological flows in the production of dry granular beverages cannot be viewed either as a sum of known individual technologies, the dry concentrate technology, and the granulation and drying technology or as a sum of individual physicochemical phenomena and processes. Each influences both directly and indirectly the process of the formation of a polydisperse multicomponent system with properties of an instant product.

The definition of a technological system as an interrelated whole creates a certain logic and methodology of its qualitative and quantitative studies and develops a system-centered opinion on production. We may say that the technological system actively influences its components and transforms them.

In the real conditions of interaction between these two systems, technological and disperse, it is obvious that they should be considered as a complex, taking into account their integrated essence, optimizing production, and taking it to a totally different level. Without learning the essence of phenomena, it is impossible to create a new whole.

Building a model of fast-prepared beverages also determines the choice of process-flow equipment. In the theory of systems, the making of the most rational decisions and the optimization of system control in the broadest meaning of this term have led to the appearance within system analysis of a section on decision making in the conditions of the so-called unique choice [1, 2, 5, 7, 9].

The unique-choice situation is characterized by three necessary elements: a problem to be resolved, a designer of a technology or a process flow who makes decisions, and a few alternatives from which to choose.

THE PRINCIPLES OF SYSTEMATIZATION OF INSTANT-PRODUCT TECHNOLOGIES

Literary sources [3, 5, 8] give us a number of instant-product technologies. Let us consider the main principles of their systematization. As a rule, decisions in frequently recurring situations also recur and are transferred, proceeding from the similarity criterion, to similar problems. Obviously, these are complex, nonstandard, and unique in their own way situations that deserve special attention of process-flow designers. In addition, we should bear in mind a number of specific features of the principles of systematization of instant-product technologies.

Usually, we fail to assess fully every proposed alternative by one numerical criterion, for example, by porosity or by solubility. However, when making a multicriterion assessment of each alternative, we face two problems:

– whether we have taken into account all material indicators (completeness of the indicator list) and
– methodological difficulties when we simultaneously compare various criteria, for example, the native and

gustative properties of a product, as well as its porosity, solubility, wettability, and strength (the dimensionality rule).

The subjectivity of the quality assessments of alternatives is obvious even in assessments by one criterion, all the more so in multicriterion cases. Such difficulties make solving the problem of the optimal choice anything but simple. A way out of this situation was the creation of expert panels, for example, a commission for the assessment of the organoleptic properties of food products. The problem of choice becomes simpler when we have a large number of publications and patents systematized by certain technical indicators, which allow the developers of process flows to improve to the maximum the level of problem structuralization by making it more transparent.

An increased degree of problem structuralization is a basic problem of system analysis. Let us consider what methods are used to solve problems that are reduced to the comparison of alternatives. The general algorithm of actions when solving the problem of the unique choice according to [4, 9] represents the following scheme:

Determining resources and goals + Determining alternatives for solving the problem + Analytical comparison of alternatives + Choosing the most preferable alternative

The first two stages largely depend on problem specifics. At the current level of system engineering, they should, already at the stage of establishing a scientific rationale, engineering-and-economic solutions, and the terms of reference, take into account the regularities of process-flow development, the need for production modernization and reprofiling, the possible change in the amount of raw materials, the personnel qualifications, etc. If we do not consider the above factors, this may lead to the inanity of implementing the project itself already in the near future. The role of exploratory design, both scientific–engineering and environmental, has increased greatly.

Moreover, the more complex the structure of a newly designed process flow, the more operations and relationships it has, and the more efforts are needed to organize its normal functioning. A newly created object (process flow) will act according to new laws [4, 6, 8, 9]. Therefore, a system of machines (processing line) should be built with regard to the regularities of the system of processes of a specific technology.

Food production is a complex of integral systems. When analyzing one of the integral systems (a process system), the subject of study becomes, primarily, its structure, the laws of combining parts into a single whole, and its integrative regularities. When analyzing a system complex, the subject matter is the relatedness of two or several objects–systems that form a polysystem complex.

Thus, the methodological cycle of creating a highly efficient process line should be as follows: *"from a process flow to a system of processes and from a system of processes to a system of machines*." The most science-intensive notion in this methodological cycle is the system of processes [6, 7].

The work of a scientist or an engineer on a project is reduced to two large stages: the systemic consideration of a problem and system design.

1. **Systemic consideration of a problem**.

– the preliminary formation of a problem,
– the systemic study of the problem,
– the definition of the designed object, and
– the definition of the facility's monitored parameters and limitations to its general characteristics.

2. **System design**.

– The modeling of the designed product,
– finding the best structure and optimizing the object's internal characteristics,
– checking the controllability of the object formation process,
– developing technical requirements on object-forming components, and
– determining the order of technical flow formation by production stages of the end product.

In this case, the problem may be formulated as "How to obtain a dry instant food product that preserves its native properties, has a good looseness and extended storage life, and, at the same time, represents a simple processing technique**."**

The problem cannot always be formulated simply at the start; all the more so, we do not have an answer about the preferable options of its solution at once. The right formulation of a problem is half the battle.

Complex studies include a general overview of similar processes of polydisperse systems in other industries, such as the metallurgical, chemical, agricultural, and food industries [8]. Only after performing all the above studies, it is possible to finally specify the problem, taking into account the possible development of structure formation in disperse systems. Then it is time to state the goals the implementation of which will help resolve the problem of the creation of instant beverages.

At present the main production industries, including the food industry, feel increasingly sharply the need for a systemic approach to the creation of state-of-the-art technological complexes. Most authors of articles, monographs, and textbooks who realize this need see its cause in the fact that, as state-of-the-art technological systems are created, their traditional consideration without using systemic insights already does not allow the adequate accounting for the range of emerging interactions, the nature of the integral properties of a system, the possible anomalous modes and functional side effects, etc. This article focuses on the fact that, **at the current level of complexity of technological systems, their functionality and development are more and more affected by general systemic regularities.** Therefore, the current stage needs transition from moderately elementary and structure-centered versions of the systemic approach, which focus on the study of relationships, interactions, and other structural characteristics, to more developed concepts of systemacity based on the identification of systemic regularities that characterize the structure, dynamics, and organization of a complex object in their integrity. Let us consider the nature of general systemic regularities in their application to technological complexes, relying on theoretical–systemic ideas [1, 2, 7].

According to these ideas, a system is considered as an organized unity whose stability, functionality, and development are based on resolving topical contradictions (problems) in intended environmental conditions. This definition sets the coordinates for the constructive understanding of systemacity, in terms of which the main system-constituting principle is not structure, relation forms, interaction types. etc., but primarily the nature of topical contradictions (problems), the resolution of which allows a system to function and develop. In addition, structure types, methods of operation, forms of interaction with the environment, and other systemic characteristics depend on the logic of the resolution of topical problems, which are primary in systemic studies and predetermine all other systemic parameters.

The main law of complex systems, which expresses their essential specifics, is the law of focused action. The essence of this law is that, in order to resolve topical contradictions (problems), a system acts as a focusing lens: it concentrates the potential of its components, relationships, actions, and resources on the attainment of functional results that resolve these contradictions. The higher the focus of system parameters on the attainment of functional results, the higher its effect is and the better its topical problems are resolved. The good organization of a system differs from the bad one in a higher focus of the system parameters (goals, structures, operating methods, forms of control, etc.) on attaining functional results. Obviously, all other systemic phenomena and regularities should be considered through the prism of the above law, which reflects the basic mechanism of the systemic operation of complex objects.

When assessing or designing technological complexes, the law of focused action is, primarily, oriented at the sequential analysis of the degree of the focus of system parameters (from goals (objectives) to the functional properties of an object and from them to its structure, dynamics, organizational and control forms, and its interaction with the environment). Violation of the focus of the operations of a complex or even the detection of factors of dysfunctional focus can manifest themselves at the level of any of the above parameters. For example, at the structural level, during analysis it is advisable to look at the possible existence of latent dysfunctional structures, formed by subsystem interfaces, communication networks, auxiliary equipment, etc., in the system along with the explicit and purposefully designed structure. Ideally, this analysis should be aimed at achieving the functional unity of operations of the explicit (functional) and latent structures.

In the light of the law of focused action, traditional and seemingly well-known requirements of the systemic approach acquire a substantially new meaning. For example, the well-known requirement of the comprehensiveness of an approach to an object is transformed into the principle of **the combination of the comprehensiveness of studies with the focus of its results on the object's functional characteristics.** This transformation is necessary because an object may have many sides, aspects, and facets, many of which are not topical in terms of problems being resolved. In addition, considering many sides without focusing the analysis on functional characteristics leads not to a systemic but to a summative ("mosaic") picture of the object. Thus, only the combination of comprehensiveness and functionality in consideration yields the final picture that corresponds to the requirements of a systemic representation of an object.

The law of focused action is closely related to the law of functional complementarity, which is also a central provision of the general theory of systems. The essence of the **law of functional complementarity** is that an integral system, unlike a systemless conglomerate, is characterized by complementarity of the functional properties of its elements [2, 10]. In higher systems, the complementarity of properties of elements manifests itself in the fact that they mutually support one another during the process of functioning and contribute to the restoration of defective elements, extending the range of complementary properties, etc**.** **The law of functional complementarity reflects the structural mechanism of the focused operation of a system: the functional complementarity of the properties of elements is the necessary condition for their functionally focused actions.** If we take into account the law of functional complementarity, this will allow us to purposefully design elements of technological complexes, securing a division of processes, properties, and functional modes that will contribute to the complementarity of their properties and, consequently, to the integrity and functional efficiency of a complex. For example, an important aspect of achieving the functional complementarity of the elements of a complex is to ensure their relative equifunctionality. This requirement is associated with the so-called **"law of the least,"** established by A.A. Bogdanov in his *Tectology* [1]. According to this law, the stability (functionality) of a whole is limited by the stability (functionality) of its weakest link. It follows from this law that a significant condition of system optimality is the relative equifunctionality of its elements, the absence of both the "weak" links, which restrict the general functionality (productivity) of a complex, and the excessively "strong" links, whose potential cannot be used fully due to restrictions on behalf of other, functionally weaker, elements

An important regularity of complex systems is **the unequal influence of various elements on the general condition of a system, the results of its functioning, and the way of its development.** Methodologically, this regularity entails the **principle of isolating the main (leading) links and determining their system-integrating relationships and functions in a system.** Since the main functional processes and the main contradictions of a complex are concentrated in the leading links, it is advisable to begin configuration analysis with these links and their integral relationships, which creates the possibility of a more substantiated approach to the study of other, less important, elements of the complex [2, 10]. The identification of the leading ("central" or "backbone") subsystems makes it possible to anticipate their possible functional effects on other subsystems in designing a complex, as well as to predict developmental options for a technological complex as a whole, since possible transformations of these subsystems predetermine the ways of transition to technological systems of qualitatively different types and levels. In characterizing the main links of a system, it is important to pay attention not only to the "leading," but also to the "mass," links, i.e., repeated uniform elements or processes. Even an insignificant improvement of such elements can noticeably upgrade the characteristics of a system as a whole by multiple accumulations of small effects.

A number of significant methodological consequences are predetermined by the law of hierarchy of complex systems. The **law of hierarchy** means that any object (phenomenon) under study has both superior, suprasystemic, and subordinate, subsystemic, metalevels, which are materially related to this phenomenon and which largely determine its nature and quality. For example, if a process flow is the object under study, then the ambient suprasystem for this object will be a workshop or a factory and the subsystems will be complexes, aggregates, machines, apparatuses, tools, mechanisms, implements, and parts. **Methodologically, the hierarchical multidimensionality, typical of systemic objects, and coherence require studies not only at the level of these objects but also at the level where they are affected by both the ambient metasystems and the microcharacteristics of their subsystems** [2, 9]. The consideration of an object with respect to influences exerted on it by its suprasystemic levels and the properties of its subsystems leads to the synthesis of split-level pictures into a multidimensional and volumetric representation, much more manifold and much deeper than the one that we have when we consider this object only at its own level. As we design a specific technological system, the principle of hierarchy makes us consider this system not only with a view to its specifics and objectives but also in the light of the history of designing technological systems in a given industry in general or even in the light of the experience accumulated by the technologically most advanced industries. For example, we know the practices of modernizing several civil industries, where the solutions to numerous technical problems, chronic and formidable for those particular industries, were successfully found by transferring technological experiences accumulated by the military-industrial complex.

The consideration of a technological system from the subsystem level implies taking into account the possible influence of subsystems on the nature of the system's functioning in general, as subsystems that operate in various technological modes; use various raw materials, technological ingredients, and materials; and function under various design options of the subsystems. Such consideration may reveal effects and phenomena predetermined by the nature of the system itself, which often fall out of the sight of designers if they consider and design a technological system within its narrow niche.

The consideration of a technological system within its own scale from a position of the system approach also acquires multidimensionality. The **system approach implies comparison of a system under consideration with similar systems of the same order: competing systems, alternative systems, and systems of the same or congenial type.** Such comparison allows us to take into account the experience of various design approaches, creates opportunities for their fruitful synthesis, and reveals criteria and forms of design thinking beyond the grasp of the "object-oriented" approach. Thus, if we take the principle of hierarchy into account, this allows us to transfer from unidimensional, object-oriented, thinking to multidimensional, system-oriented, thinking and to reach an incomparably deeper level of insight into the nature and essential basics of an object, letting us select the most efficient and reliable solutions.

The dialectical understanding of a complex system implies its consideration as a controversial integrity. Such a vision is not just a possible aspect of thinking; it has a real objective nature, characterized by the **law of contradictory integrity**. The essence of this law is that any complex system has both the system-integrating factors, which ensure the consistency, integrity, and functionality of a given system, and the opposing, system-destroying and disintegrating, factors. The second group of factors very rarely becomes the object of analysis during the design of technological systems, being often initiated as a result of emergencies and engineering disasters. An especially important aspect of analysis of system-destroying factors is associated with their possible transfer from the mode of disconnected operation to the mode of coherent and systemic operation. This particular evolution of system-destroying factors often leads to breakdowns, destructions, and shutdowns of technological complexes or to a sharp drop in the quality of their functioning. Thus, the **consideration of a technological complex as the opposition of system-integrating and system-destroying factors that operate within it and the revealing of their correlation, possible forms, and prospects for synergy and the coherent effect of the destroying factors, are important principles of the system approach,** which is very topical during the creation of state-of-the-art equipment and technologies.

Another relevant consequence of the law of contradictory integrity is the **need to reveal the critical boundaries of change in an object's functional parameters within integrity.** The search for such critical boundaries is currently a major problem for many specific sciences of complex systems. The study of critical boundaries and modes that change functional parameters is also very topical for the creation of state-of-the-art complex technological systems in terms of their reliability, protection, fail safety, and high-quality operation.

Thus, even a very brief and schematic overview of systemic regularities in the light of their possible uses during the study and design of state-of-the-art technological systems shows that the consideration of these regularities is becoming a necessary condition for the creation of new-generation technological systems. The development of engineering and technology has reached a line where the creation of qualitatively new technological systems without using systemic theory and methodology is becoming increasingly ineffective and hazardous. This means that theoretical and systemic knowledge is becoming a component that is no less important for current engineering education than basic technical knowledge.

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