Research Information Model in the Food Industry

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Abstract: A comprehensive tool with the use of modern digitalization methods and information modeling technologies is an actual solution that allows optimizing production processes. The current state of research in the field of heat treatment processes of products is presented, where special attention is paid to the selection of the optimal temperature profile using computer modeling. The article discusses the analysis of existing information modeling methods and the development of a research information model for the sterilization of food products in autoclaves. The description and structure of the information model is proposed in the form of interconnected databases, units of physical and simulation modeling and an expert system. In conclusion, the possibilities of the model are presented, thanks to which it can be applied in other areas of industry.

1 INTRODUCTION

The key guideline of digital transformation, taking into account current economic risks, is the introduction of new solutions that optimize production processes. When creating new food products that require heat treatment in autoclaves, the key document is a scientifically based sterilization regime approved in accordance with the established procedure. The relevance of this article is conditioned by the need to create and use in scientific research a comprehensive tool using modern methods of digitalization and information modeling technologies in relation to the development of food sterilization regimes.

The purpose of the research presented in this article is to develop a research information model for food sterilization processes in autoclaves. To achieve this aim , the following tasks are defined:

- analysis of existing information modeling methods;
- development of a research information model for the development of food sterilization regimes.

The current state of the mentioned scientific problem is reflected in a number of works that are relevant to the topic of this study. Many scientists in their research pay great attention to the processes of heat treatment of products at a variable temperature of the environment of the sterilization chamber of the autoclave (variable regime) as a prospecting method that can improve the quality of the finished product and achieve the efficiency of the process as a whole by reducing energy costs for production. As an alternative to traditional modes of heat treatment, the variable regime (Chen, C. R. et al., 2004) was first proposed in the works of researchers of thermal processes in the second half of the twentieth century (Durance, T. D. et al., 1997), (Teixeira, A. A. et al., 1975). Since the 1990s, researchers of thermal processes have been receiving new advantages of using variable regimes in the field of reducing energy consumption, process duration and thermal effects on the product surface (Almonacid - Merino, S. F. et al., 1993), (Banga, J. R. et al., 1991), (Noronha, J. et al., 1993). However, the use of variable regimes with variable retort temperature (VRT) at commercial enterprises is still not in demand. In the article (Simpson, R. et al., 2020), the authors quantified the effectiveness of the implementation of VRT processes based on the parameters of a model

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processing plant and concluded that the use of VRT is cost-effective at a real plant. By the beginning of the XXI century, it became clear to researchers that the key to the development of food heat treatment regimes is to solve the problem of multifactor optimization – choosing the optimal temperature profile for each combination of food and canned food. This problem can be effectively solved using computer modeling with the use of intelligent technologies that do not require much time and allow you to get solutions faster than conventional optimization methods (Chen, C. R. et al., 2004), (Chen, C. R. et al., 2002) and (Mokrushin, S. A. et al., 2020).

Arias-Mendez A. and his colleagues developed the AMIGO software for real-time decision-making in the management of thermal sterilization of packaged foods in retorts in order to preserve nutrients as much as possible while complying with safety restrictions (Arias-Méndez, A. et al., 2011). Abakarov A. in his software, OPT-PROx has shown the advantages of variable regimes of heat treatment of food products compared to traditionally used processes with constant temperature in terms of total processing time and the quality of the final product (Abakarov, A. et al., 2013). The adaptive random search algorithm together with correction functions and the finite difference method together with the third-order spline approximation are used to solve the tasks. The PRSC software, developed by the staff of the Department of Automation and Computer Engineering of Murmansk Arctic University, performs mathematical modeling of the sterilization regime of a food product, calculates the values and allows you to select the optimal sterilization regime of canned food for certain types of products and sterilization equipment using the simplex method according to the criteria of actual lethality and energy consumption for the process (Stolyanov, A. et al., 2019, December). The paper (Erdogdu, F. et al., 2017) concluded that virtualization and mathematical modeling will soon become the main factors of great importance for the field of food industry engineering, while already today they determine the basic requirements for the development, optimization and innovation in food production technology.

Researchers devote great attention to modeling the processes of food sterilization, studying new sterilization regimes, reducing energy costs for the process and improving the quality of finished products. The development of a comprehensive information modeling tool in relation to the development of food sterilization regimes contributes to improving the effectiveness of such studies.

2 RESEARCH METHODOLOGY

There is a known approach in the construction industry when a research information model is used as a comprehensive tool, which includes design and physical models, mathematical modeling methods and digital twin technology (Kuzmenkov, A. et al., 2023), (Kaychenov, A. et al., 2023), (Kuzmenkov, A. A. et al., 2021, December). The use of the research information model will allow for: data collection, analysis, forecasting of possible changes in technological parameters when changing the operating modes of objects, as well as external random influences during operation. When implementing a comprehensive study based on a research information model, model construction objects become full-fledged digital (virtual) polygons for testing criteria for green construction.

In Soviet literature, a similar approach to conducting complex research when creating a new technique is known. This approach is called the automated system of scientific research (ASSR).

ASSR is a software and hardware complex based on computer technology, designed for conducting scientific research or complex tests of samples of new equipment based on obtaining and using models of the objects, events and processes under study.

The main links of the ASSR are subsystems and means of support. There are object and service subsystems of ASSR. The object subsystem is necessary for obtaining and processing experimental data from the object under study. The ASSR service subsystem manages and processes information regardless of the characteristics of the object or process being studied.

The means of ASSR support are components consisting of the following support: informational (ASSR database, which stores a priori information), methodological (information on how to use a priori information and research methodology), software (computer programs and documents for their functioning), technical (devices that ensure the functioning of ASSR subsystems), organizational and legal (documents on the interaction of departments during the creation, operation and development of ASSR).

The structure of the ASSR is shown in Figure 1.

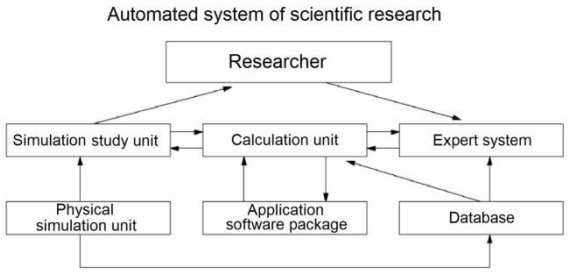

Figure 1: Automated system of scientific research.

The method of information modeling in the form of IDEF (Integrated DEFinition) information diagrams is known, which allows solving problems of modeling complex systems, displaying and analyzing models of the activities of a wide range of complex systems. At the same time, the completeness of the studied processes is determined by the developer himself, which allows not to overload the model with unnecessary data. The method is most focused on unified modeling of business processes, but also allows you to describe functional blocks, various objects in the company and actions on them, the state and dynamics of the development of the company as a whole.

3 RESULTS

To carry out research in the field of developing food products sterilization regimes in autoclaves, a research information model (RIM) has been developed, presented in Figure 2. The input parameters of RIM regimes of food sterilization are laws, regulations, knowledge, as well as existing problems. For RIM to function, it is necessary to apply methodology, concepts, research and research programs. RIM outputs are: theoretical information, knowledge, and problem solving. At the research stage, the RIM input parameters are corrected by the researcher.

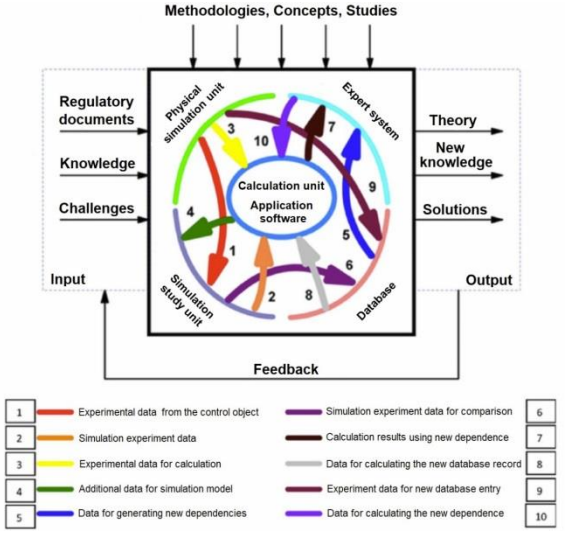

Figure 2: Research information model of food sterilization regimes.

The relationships between the main components are shown inside the model: the database, the blocks of physical and simulation modeling and the expert system. The colored arrows in the figure show the information flows between the models. Real experimental data 3 are received in the calculation unit. Information stream 1 characterizes the information transmitted for correction of the simulation model object of physical modeling. The use of mathematical modeling makes it possible to supplement the calculation unit with the results of numerical modeling of regimes, states and situations that the physical model does not allow to implement due to structural, energy and other limitations. Data from the simulation model (autoclave) 2 and the database 8 are fed into the RIM calculation unit. To verify and validate the simulation model, the numerical simulation values are compared with the values from real experimental data and allow to correct the simulation model 4. The calculation results are sent to the expert system 7. The analytical unit of the expert system allows to prepare data for correcting existing modes 10 based on the database 5. The database is formed based on the results of real physical modeling 9 and simulation modeling 6.

4 CONCLUSIONS

The presented information model of research makes it possible to implement a systematic approach to the development of food sterilization regimes. This approach differs significantly from the traditional

research method using ASSR and from the information modeling method using IDEF notifications.

The use of RIM allows for comprehensive research: to collect, analyze data, predict the effect of the modes of sterilization processes when changing products and sterilization devices, as well as external accidental influences during the process. The implementation of RIM allows you to get a full-fledged digital (virtual) testing ground for testing the sterilization modes of canned food.

The research information model can also be used when conducting research in other areas of industry, since it combines the following principles:

1. The possibility of solving a wide range of problems using the same model structure, while ASSR are specially developed for a specific scientific problem.

2. Variability of tasks, research objects and mathematical support without replacing the model structure.

3. The variety and wide limits of the recorded parameters that are stored in the database and used by the expert system.

4. High speed and low cost of the experiment.

5. The possibility of irregularity of the operating mode associated with the need to comprehend the results obtained, changing the conditions of the experiment, replacing sensors, changing the mathematical support, etc.

6. The possibility of operational control of the experiment using the display of up-to-date information in the form of tables, graphs, numerical data, etc., since most scientific research is carried out under human control.

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