CHAPTER 17

INTEGRATION OF THE HACCP FOOD SAFETY MANAGEMENT SYSTEM INTO THE TECHNOLOGY OF THERMOSTABLE SAUCES

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INTRODUCTION

The modern development of the food industry is characterized by increasing requirements for the quality, safety, and stability of food products, driven both by stricter regulatory frameworks and growing consumer expectations. The globalization of food markets, expansion of international trade, and harmonization of requirements for food production are shaping new approaches to organizing technological processes and quality management systems. Under these conditions, ensuring product safety is considered not only a mandatory legislative requirement but also one of the key factors of competitiveness for food industry enterprises.

In modern conditions, the HACCP (Hazard Analysis and Critical Control Points) food safety management system is recognized as an internationally accepted tool for risk prevention and control of hazardous factors at all stages of production. The HACCP concept is based on the principle of preventive management, which enables timely identification of potential biological, chemical, and physical hazards and ensures their control before nonconformities appear in the finished product. Unlike the traditional approach focused mainly on final product inspection, HACCP principles provide systematic risk management through hazard identification, assessment, and implementation of preventive measures directly within the technological process.

For the production of thermostable sauces, the integration of the HACCP system is of particular importance, as this category of products is highly sensitive to changes in physicochemical parameters, temperature conditions, microbiological stability, packaging processes, and storage conditions. Insufficient control of technological factors may result in loss of structural stability, deterioration of organoleptic characteristics, reduction of thermal resistance, and the emergence of potential risks for consumers. Special attention should be paid to the stages of raw material reception, preparation of formulation components, homogenization, heat treatment, packaging, and storage condition control, since these stages form the critical control points for ensuring product safety.

Furthermore, the implementation of the HACCP system into thermostable sauce production technology allows not only minimizing risks to consumer health but also improving process management, ensuring product quality reproducibility, reducing technological losses, and optimizing the use of enterprise resources. This approach contributes to the transition from a reactive control model to a proactive production management system that meets modern requirements of sustainable development and international food safety standards.

1. Theoretical foundations of integrating the HACCP food safety management system into food production

The current stage of food industry development is characterized by profound structural changes associated with market globalization, intensification of production processes, expansion of international trade, and increasing requirements for the quality and safety of food products. The food industry is one of the most socially significant sectors of the economy, as it directly affects public health, the level of food security, and the overall quality of life. Under these conditions, ensuring food safety acquires strategic importance and is considered a complex task that combines technological, organizational, regulatory, and managerial aspects[1, 2].

Traditional approaches to product quality control have long been based primarily on assessing the characteristics of the finished product after completion of the production cycle. Such a model involved laboratory testing and selective control of individual indicators without considering the risks generated at earlier production stages. However, the development of modern technologies and the increasing complexity of food systems have demonstrated the limitations of this approach. Control of only the final product does not allow timely prevention of hazardous factors and does not provide a sufficient level of food safety assurance.

The modern concept of food safety management is based on the principles of preventive risk management and is focused not on eliminating consequences

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[1] Silva E., Associados P. et al. Food Safety Management Systems. Luxembourg : European Commission, Erasmus+ Programme, 2019. 302 p.

[2] Radu E., Dima A., Dobrota E. M., Badea A.-M., Madsen D. Ø., Dobrin C., Stanciu S. Global trends and research hotspots on HACCP and modern quality management systems in the food industry. *Heliyon.* 2023. Vol. 9 (8). Article e18232.

but on preventing hazardous situations. For this reason, the HACCP (Hazard Analysis and Critical Control Points) system has become widely adopted in international practice and is currently recognized as one of the most effective tools for managing food safety[3].

Historically, the HACCP system was developed in the second half of the twentieth century within programs aimed at ensuring safe food for space missions. The initial objective was to create a control mechanism that would virtually eliminate the risk of hazardous factors occurring in food products. Subsequently, the system was adapted for industrial production and integrated into international standards for quality and food safety management.

The main idea of the HACCP system is to identify potential hazards at all stages of the product life cycle – from raw material procurement to the distribution of the finished product – and to implement control mechanisms at the most critical points of the technological process. Such an approach makes it possible to minimize the probability of risk occurrence and ensure production stability[4, 5].

Within the HACCP system, all hazards are traditionally classified into three main categories: biological, chemical, and physical. Biological hazards include pathogenic microorganisms, yeasts, molds, and their metabolic by-products. Chemical hazards are associated with residues of cleaning agents, heavy metals, toxic compounds, allergens, or excessive use of food additives. Physical hazards refer to foreign objects that may enter the product during production.

The effectiveness of the HACCP system is ensured through the implementation of seven fundamental principles. The first stage involves conducting hazard analysis and risk assessment. The next step is identifying critical control points – stages of production where monitoring can be applied to prevent hazards. For each critical control point, critical limits, monitoring procedures, corrective actions, and system verification mechanisms are established.

A distinctive feature of the modern approach to HACCP implementation is the integration of the system directly into the enterprise's production processes. The system ceases to function as a separate control tool and is transformed into a comprehensive mechanism for managing the entire production activity. Such an approach enables the integration of product quality, resource efficiency,

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[3] Radu E., Dima A., Dobrota E. M., Badea A.-M., Dobrin C., Stanciu S**.** Recent trends in food safety management systems and HACCP implementation in the global food industry. Heliyon. 2024. Vol. 10. DOI: 10.1016/j.heliyon.2024.

[4] Awuchi C. G. HACCP, quality, and food safety management in food and agricultural systems. Cogent Food & Agriculture. 2023. Vol. 9. DOI: 10.1080/23311932.2023.2176280.

[5] Zarid M. et al. The Green HACCP Approach: Advancing Food Safety and Sustainability Integration. Sustainability. 2025. Vol. 17 (17). Article 7834.

environmental sustainability, and economic performance within the production system[6].

The implementation of HACCP requires the establishment of an appropriate organizational structure within the enterprise. The integration process involves a cross-functional team of specialists, including technologists, quality assurance professionals, production personnel, laboratory representatives, and management staff. Such a model makes it possible to develop a systematic understanding of risks and ensure effective control over production processes.

The principle of product traceability plays a significant role in the functioning of the system. Traceability provides the ability to identify the origin of each component, determine the specifics of its use in production, and monitor product movement throughout the entire value creation chain. This enables enterprises to respond promptly to cases of nonconformity and minimize economic losses[7].

Digitalization of production plays a separate and increasingly important role in modern food safety management systems. The use of automated monitoring systems, electronic document management, digital control of technological process parameters, and analytical platforms significantly improves the effectiveness of HACCP implementation. Automation enables continuous monitoring of critical parameters and ensures greater accuracy in managerial decision-making.

An important prerequisite for the effective functioning of the system is compliance with prerequisite programs (PRPs), which include sanitary and hygienic measures, equipment condition control, organization of the production environment, personnel training, and the provision of proper manufacturing conditions. These prerequisite programs create the foundation for the further functioning of the HACCP system and determine the level of its effectiveness[8].

The food safety management system is also closely connected with the concept of sustainable development and modern international approaches to responsible production. Today, product safety is considered not only a technological characteristic but also a component of the environmental and social responsibility of an enterprise. Rational resource utilization, reduction of production losses, minimization of food waste, and improvement of energy

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6 Peres F. A. P., Bondarczuk B. A., Gomes L. C., Jardim L. C., Corrêa R. G. F., Baierle I. C. Advances in food quality management driven by Industry 4.0: A systematic review-based framework. *Foods*. 2025. Vol. 14. Art. 2429.

7 Thume M., Lange J., Unkel M., Prange A., Schürmeyer M. Blockchain-based traceability in food supply chains: Requirements and challenges. *Int. J. Sustain. Agric. Manag. Inform.* 2022. Vol. 8. P. 243–258.

8 Dadhaneeya H., Nema P., Arora V. Internet of Things in food processing and its potential in Industry 4.0 era: A review. *Trends Food Sci. Technol.* 2023. Vol. 139. Art. 104109.

efficiency are increasingly being integrated into food safety management policies[9].

At the international level, the HACCP system has been integrated into the requirements of the ISO standards series and is used as a fundamental element of food safety management systems. For food industry enterprises, compliance with these requirements has become a necessary condition for entering international markets and enhancing competitiveness. International certification and implementation of food safety management systems not only confirm product compliance with established requirements but also contribute to strengthening consumer confidence, expanding export opportunities, and improving the overall efficiency of enterprise operations.

Therefore, the integration of the HACCP food safety management system into food production represents a logical response to the current challenges facing the food industry. The application of a risk-based approach, systematic control, and preventive management creates the conditions necessary to improve product quality, ensure production stability, and strengthen consumer confidence. Under modern conditions, the HACCP system serves not only as a tool for meeting regulatory requirements but also as a strategic component in the development of efficient, competitive, and sustainable food production.

2. Scientific and practical aspects of HACCP implementation in thermostable sauce technology

Ensuring food safety is one of the key priorities of the modern food industry, as product quality and safety directly affect public health and consumer confidence in manufacturers. In the context of the globalization of food markets, the implementation of food safety management systems based on scientifically grounded approaches and international standards has become increasingly important [3–7]. One of the most effective and internationally recognized systems for ensuring food safety is the Hazard Analysis and Critical Control Points (HACCP) system[10, 11, 12].

The HACCP system is based on a preventive approach to risk management, the core principle of which is the identification of potential hazards at all stages of the technological process – from raw material reception to the production

9 Alimadani R., Adedeji A.A., Narimani M. A review of IoT applications in food processing and related fields. *J. Food Process. Preserv.* 2025, *2025*, 3064441.

10 Codex Alimentarius Commission. General Principles of Food Hygiene CXC 1-1969 (Rev. 2020). Rome: FAO/WHO, 2020.

11 ISO 22000:2018. Food safety management systems — Requirements for any organization in the food chain. Geneva: International Organization for Standardization, 2018.

12 Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. *Official Journal of the European Union*, 2004.

and distribution of finished products – and the prevention of their occurrence through the establishment of appropriate control measures. This approach significantly reduces the likelihood of hazardous situations and ensures the consistent safety of food products[13, 14].

The implementation of the HACCP system is of particular importance in food production, especially in the manufacturing of sauces, which are characterized by complex formulations and multi-stage technological processes. Thermostable sauces contain a wide range of ingredients of both animal and plant origin, increasing the risk of biological, chemical, and physical hazards. Therefore, the application of a systematic risk management approach is an essential prerequisite for ensuring the consistent safety of such products.

At the initial stage, a detailed product description was developed, including composition, key physicochemical and microbiological characteristics, storage conditions, and shelf life. In addition, the intended use, type of consumer packaging, target market, and other relevant product attributes were identified. This approach enables clear product identification and provides the foundation for further hazard analysis within the HACCP system (Table 1).

Table 1

Product Description

Section / Requirement Name	Product Characteristics
1	2
Name	Thermostable sauces based on dairy raw materials (assorted range)
Target Market	Food industry enterprises and HoReCa sector (restaurants, cafés, catering), as well as retail consumers using thermostable sauces for quick preparation and consumption
Intended Use	The product is ready for consumption or used as an ingredient in prepared dishes; reheating is allowed without loss of stability and quality
Known and Potential Foreseeable Misuse and Associated Hazards	Use by individuals allergic to milk proteins (or other allergens) → allergic reactions of varying severity. Use not intended by the manufacturer (e.g., in infant or specialized nutrition without composition assessment) → non-compliance with dietary requirements and potential health risks
Regulatory Document	TU U 10.8-44234755-001-2024 “Hot Sauces Based on Dairy Raw Materials”

13 Про основні принципи та вимоги до безпечності та якості харчових продуктів : Закон України № 771/97-ВР від 23.12.1997 (зі змінами).

14 Про затвердження Вимог щодо розробки, впровадження та застосування постійно діючих процедур, заснованих на принципах НАССР : наказ Міністерства аграрної політики та продовольства України № 590 від 01.10.2012.

Continuation of table 1

1	2
Method of Distribution	Distributed through wholesale supply to food industry enterprises and HoReCa establishments, as well as retail trade (supermarket chains and stores)
Composition	Prepared drinking water, sunflower oil, modified corn starch, **whey protein concentrate [MILK]**, **dried cream [MILK]**, **butter (cream from cow's milk) [MILK]**, xanthan gum thickener, salt, sugar, allspice, nutmeg
Physicochemical Characteristics	Dry matter content, %; Protein content, %; Fat content, %; Carbohydrate content, %; Mineral content, %
Microbiological Criteria	Total viable count of lactic acid bacteria; Coliform bacteria (*E. coli*); Pathogenic microorganisms; *Staphylococcus aureus*; *Listeria monocytogenes*; Yeasts and molds
Allergens	Milk
Packaging	Doy-pack pouches suitable for filling at temperatures not lower than 92 °C
Labelling / Instructions on the Label	Product name, processing method, name and address of the food business operator, list of ingredients, quantity of specific ingredient groups, quantity of food product in established measurement units, storage conditions, "use by" date, nutritional information per 100 g of product, batch identification and designation (L), ingredients causing allergic reactions highlighted in bold
Shelf Life	45 days
Storage Conditions	Store at 1–6 °C
Target Consumer	General consumer population, including different age groups and food service establishments. The product is not recommended for individuals with allergies to milk and other ingredients included in the formulation

Hazard identification is a key stage in the development of a food safety management system, as it enables the determination of factors that may potentially adversely affect the safety and quality of the finished product. For the developed thermostable sauces, this analysis was conducted taking into account the product formulation, characteristics of raw materials, production conditions, and storage requirements.

Analysis of biological hazards. Biological hazards include pathogenic and opportunistic microorganisms that may enter the product through raw materials, water, or as a result of non-compliance with sanitary and hygienic production conditions. The most probable microbiological risks associated with sauces include bacteria of the genera Salmonella, Listeria monocytogenes, and Escherichia coli, as well as yeasts and molds.

It was determined that particular attention should be paid to dairy ingredients in the formulation – whey/milk protein concentrate, butter, and dried cream – since dairy-derived products may represent potential sources of microbiological contamination. In addition, hazards may arise from the use of water if it does not comply with sanitary requirements. Spices may also contain a significant microbial load, as they are plant-derived products with naturally occurring microflora. To minimize biological risks in thermostable sauce production technology, heat treatment of the product plays a critical role, together with strict compliance with good sanitary and hygienic manufacturing practices.

Analysis of chemical hazards. Chemical hazards include residues of cleaning and disinfecting agents, toxic elements, pesticide residues in plant-derived raw materials, as well as potential allergens. In the production of thermostable sauces, one of the main allergenic components is dairy ingredients, particularly whey proteins, cream, and butter. In addition, spices may serve as a source of chemical hazards, as they can contain residual amounts of pesticides or mycotoxins. Another potential source of chemical contamination includes residues of lubricants from processing equipment or cleaning agents used during sanitation of production surfaces.

To control chemical hazards, it is necessary to ensure rigorous quality control of raw materials, use only approved food ingredients and additives, and comply with established requirements for the application of cleaning and disinfecting agents.

Analysis of physical hazards. Physical hazards are associated with the possible presence of foreign materials in the product, such as fragments of glass, metal, plastic, or other solid particles. Such hazards may arise during raw material storage, processing operations, or packaging of the finished product.

The main sources of physical hazards may include equipment damage, the use of inadequate packaging materials, violations of technological discipline, or insufficient process control. To prevent such hazards, it is necessary to implement a foreign object control system that includes regular equipment maintenance, the use of metal detectors, packaging integrity inspection, and compliance with personnel hygiene requirements.

A generalized list of ingredients with the identification of potential hazards is presented in Table 2.

Following the identification of potential hazards, a risk assessment was carried out based on determining the probability of occurrence of each hazardous

Table 2

Generalized List of Ingredients with Identification of Potential Hazards

Raw Material Name	Potential Hazards			Regulatory Document
	Physical (P)	Chemical (C)	Biological (B)	
Main Raw Materials				
Drinking water	–	++	+++	DSTU 7525
Refined deodorized sunflower oil	+	++	–	DSTU 4492
Whey protein concentrate	++	–	++	According to applicable regulatory documentation
Dried cream	++	+	++	DSTU 4273
Butter	+	+	+	DSTU 4399
Xanthan gum	+	–	–	According to applicable regulatory documentation
Modified corn starch	+	–	+	DSTU 4380
Auxiliary Raw Materials				
Salt	++	–	–	DSTU 3583
Sugar	++	–	–	DSTU 4623
Nutmeg	++	–	++	DSTU 7411
Allspice	++	–	++	DSTU ISO 959-2
Packaging Materials				
Doy-pack	+	++	–	According to applicable regulatory documentation
Legend: +++ high probability of contamination ++ medium probability of contamination + low probability of contamination – contamination level does not pose significant hazards				

factor and the severity of its potential consequences. During this analysis, those hazards requiring the establishment of specific control measures within the HACCP system were identified.

For the technology of thermostable sauce production, the most significant hazards were microbiological risks associated with the use of dairy ingredients and water, as well as the risk of cross-contamination during production processes. Particular attention was also given to allergenic factors related to the presence of milk proteins in the formulation. Although physical hazards demonstrated a lower probability of occurrence, they must also be effectively controlled within the framework of prerequisite programs (PRPs) (Table 3).

Table 3

Summary of Hazard Analysis for Raw Materials and Packaging Materials

Raw Material Name	**Biological Hazards**	**Chemical Hazards**	**Physical Hazards**	**Control Measures**
Drinking water	*E. coli*, *Salmonella*, *Listeria monocytogenes*, total viable count	Nitrates, heavy metals, chlorine, CIP residues	Sand, rust	Water analysis, disinfection, filtration
Refined deodorized sunflower oil	–	Pesticides, oxidation products, solvents	Metal, plastic	Certificates, quality control, storage conditions
Whey protein concentrate	*Salmonella*, *Listeria monocytogenes*, *Bacillus*	Antibiotics	Metal, lumps	Certificates, storage conditions
Dried cream	*Salmonella*, *Listeria*, microbial spores	Fat oxidation products, antibiotics	Lumps, foreign particles	Certificates, storage conditions
Butter	Total viable count, *Salmonella*, *Listeria monocytogenes*, coliform bacteria	Oxidation products	Foreign inclusions	Certificates, storage at specified temperatures
Xanthan gum	Microbial spores	Residues of production reagents	Dust, lumps	Certificate, sieving
Modified corn starch	*Bacillus* spores	Residues of modification reagents	Lumps, foreign impurities	Certificate, sieving
Table salt	–	Impurities, anti-caking agents, heavy metals	Stones, foreign impurities	Certificate, visual inspection, sieving
Sugar	Osmophilic yeasts, rarely	Sulfites	Foreign impurities, threads from bags	Certificate, sieving
Nutmeg	*Salmonella*, yeasts and molds	Pesticides, mycotoxins	Foreign impurities	Certificate, spice sterilization if necessary
Allspice	*Salmonella*, yeasts and molds	Pesticides, mycotoxins	Foreign impurities	Certificate, spice sterilization if necessary
Doy-pack packaging	Secondary contamination	Migration of substances from packaging material	Plastic, foreign particles	Certificate, visual inspection

Thus, the conducted hazard analysis of raw materials and packaging materials made it possible to identify the key risks characteristic of thermostable sauce production technology and to establish the foundation for further determination of Critical Control Points (CCPs) and the development of an effective HACCP system.

The determination of Critical Control Points (CCPs) was carried out using the algorithm recommended by the Codex Alimentarius, which involves a step-by-step assessment of each stage of the technological process through the application of the so-called decision tree. This tool is based on a series of questions regarding the existence of a hazard, the possibility of controlling it, and the role of a specific process stage in preventing or eliminating the identified risk.

In particular, the CCP determination algorithm included:

– assessment of hazard significance (probability of occurrence and severity of consequences);

– identification of available control measures at a particular process stage;

– evaluation of whether subsequent processing stages can eliminate or reduce the hazard to an acceptable level;

– determination of whether the given stage is critical for ensuring product safety.

The flow diagram of thermostable sauce production with the identification of CCPs and Operational Prerequisite Programs (OPRPs) is presented in Figure 1.

A Critical Control Point was defined as a stage at which control is necessary and sufficient to prevent, eliminate, or reduce a hazard to an acceptable level. As a result of applying the specified algorithm, the pasteurization stage was identified as a CCP because it ensures the inactivation of pathogenic microflora. In addition, the storage stage of the finished product was classified as a CCP, as it provides control over residual microbial growth and maintains product safety throughout the entire shelf life.

At the same time, several other stages of the technological process were classified as Prerequisite Programs (PRPs). This approach is consistent with the recommendations of the Codex Alimentarius, according to which a significant proportion of hazards can be effectively controlled through prerequisite programs, including Good Manufacturing Practices (GMP) and Good Hygiene Practices (GHP). Within the proposed scheme, the processes of mechanical and thermal treatment of raw materials, as well as the packaging process, were classified as PRPs. Although packaging does not directly eliminate hazards, it is considered critical in terms of preventing secondary microbiological contamination of the product after pasteurization.

Therefore, the application of the Codex Alimentarius decision-making algorithm enabled a scientifically justified differentiation of technological process stages into Critical Control Points (CCPs) and Prerequisite Programs

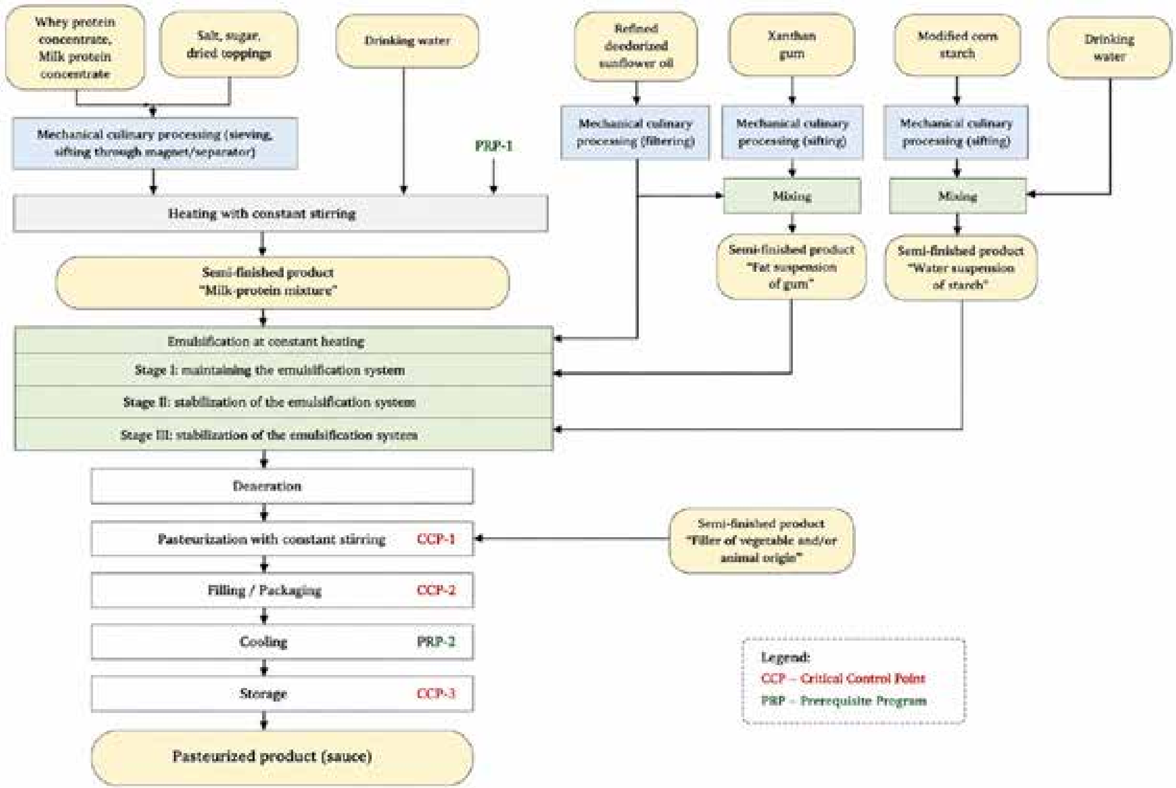

Fig. 1. Flow diagram of thermostable sauce production with identification of critical control points (CCPs) and prerequisite programs (PRPs)

(PRPs). Critical Control Points ensure direct control of hazardous factors, whereas operational prerequisite programs establish the systemic foundation for food safety management aimed at preventing the occurrence and spread of hazards within the production environment.

Based on the comprehensive analysis of hazards that may arise at all stages of the technological process of thermostable sauce production, a HACCP plan was developed to ensure an appropriate level of safety and quality of the finished product (Table 4).

The first Critical Control Point (CCP) was identified at the stage of pasteurization of the formulation mixture, which is carried out under continuous agitation. This stage is considered a key operation within the technological process, as it ensures the destruction of pathogenic microorganisms, including Salmonella, Listeria monocytogenes, and Escherichia coli. The critical limits established for this process include maintaining a temperature not lower than 90–92 °C for a specified technological holding time. Control is performed through continuous temperature monitoring using measuring and control instruments, accompanied by appropriate record keeping. In the event of deviation from the established parameters, the process is immediately stopped, the affected product batch is isolated, and, following identification of the cause of nonconformity, a decision is made regarding either repeated heat treatment or withdrawal of the batch. Therefore, pasteurization was identified as the primary Critical Control Point because biological hazards are effectively eliminated at this stage.

The second Critical Control Point was determined to be the storage stage of the finished product. Following pasteurization and packaging, the product is not sterile; therefore, violations of the temperature regime may promote the growth of residual microflora, leading to a reduction in product safety and quality. For this stage, the critical limit was established as a storage temperature not exceeding 6°C throughout the entire shelf life. Monitoring is performed through regular temperature measurements in refrigeration equipment and documentation using logbooks or automated recording systems. In cases where acceptable temperature limits are exceeded, refrigeration equipment functionality is inspected, product safety is assessed, and a decision is made regarding further use of the product or withdrawal of the affected batch from circulation.

Mechanical culinary processing of raw materials (PRP-1), which includes sieving of dry ingredients, filtration of liquid components, and the use of magnetic separators, is aimed at eliminating physical hazards, particularly metal particles and other foreign matter. The effectiveness of these control measures is ensured through proper technical condition of the equipment,

Table 4

Plan HACCP

Technological Process Stage	Hazard Factor	CCP / PRP No.	Critical Limits	Monitoring (What / Where / How / When / Who)	Control Measures	Corrections and Corrective Actions	Validation	Verification
1	2	3	4	5	6	7	8	9
Pasteurization	Biological	**CCP-1**	Temperature: 90–92 °C; holding time: 7–10 min according to technological instructions	**What:** temperature and time; **Where:** pasteurization tank; **How:** internal temperature measurement; **When:** each process; **Who:** operator	Chief technologist/ process engineer records parameters at least 5 times per shift	***Corrections***: stop process, isolate affected product, restore parameters. ***Corrective actions***: cause analysis, equipment calibration, process adjustment, personnel training, strengthened monitoring, re-pasteurization/ testing/disposal	Microbio-logical testing of finished product; scientific justification of temperature–time regime	Periodic microbio-logical testing; audit of monitoring records; calibration of measuring equipment
Storage	Biological	**CCP-2**	Storage temperature: 1–6 °C	**What:** storage temperature; **Where:** refrige-ration chamber; **How:** thermo-meter readings; **When:** twice per shift; **Who:** warehouse manager / laboratory engineer	Monitoring storage conditions and analyzing records	***Corrections***: inspection of refrigeration system, isolation of product, restoration of temperature. ***Corrective actions***: equipment maintenance, improved loading conditions, personnel training	Confirmation that ≤6°C suppresses microbial growth; microbio-logical testing during shelf life	Temperature record review; microbio-logical studies; calibration; internal audits

Continuation of table 4

1	2	3	4	5	6	7	8	9
Mechanical Culinary Processing of Raw Materials (Sieving)	Physical	**PRP-1**	No foreign materials allowed; sieve opening $\leq$ 1 mm	**What:** foreign materials; **Where:** sieving area; **How:** visual inspection; **When:** beginning of each shift; **Who:** operator	Daily reporting and equipment supervision	***Corrections*:** stop process, isolate raw materials, clean or replace sieves. ***Corrective actions:*** maintenance review, repair, personnel instruction	Confirmation of sieving effectiveness; compliance of sieve specifications	Inspection of sieve integrity; review of records; internal audits
Packaging	Physical	**PRP-2**	Prevention of contamination caused by inadequate sanitary conditions	**What:** equipment sanitation, packaging integrity, personnel hygiene; **Where:** packaging area; **How:** visual inspection and microbiological swabs; **When:** every 2–4 h and monthly; **Who:** packaging operator / laboratory engineer	Monitoring sanitation, packaging quality, hygiene, cleaning and disinfection	***Corrections:*** stop packaging, isolate product, sanitize equipment, replace packaging. ***Corrective actions*:** sanitation review, personnel training, increased monitoring	Confirmation of effectiveness of sanitation procedures; microbio-logical testing of swabs	Review of sanitation records; microbio-logical control; packaging compliance audits

regular maintenance procedures, and continuous monitoring of operational performance.

Particular importance among the Prerequisite Programs is assigned to the packaging stage (PRP-2), which is considered critical in terms of the risk of product recontamination following heat treatment. Hazard management at this stage is based on compliance with the principles of Good Manufacturing Practice (GMP), including the use of clean packaging materials, maintenance of sanitary conditions of equipment, control of personnel hygiene, and monitoring of production environment parameters. Monitoring activities are carried out through sanitary documentation records, visual inspections, and periodic microbiological testing.

3. Evaluation of the effectiveness of HACCP system integration and prospects for improving thermostable sauce technology

The integration of the HACCP food safety management system into thermostable sauce production is an important tool for ensuring the stability of technological processes, improving product quality, and minimizing risks associated with the occurrence of hazardous factors. Under modern operating conditions of food industry enterprises, the evaluation of the effectiveness of implemented management systems becomes particularly significant, as it enables assessment of the degree of achievement of established objectives, evaluation of the effectiveness of applied control measures, and identification of directions for further production improvement.

The HACCP system is regarded not only as a mechanism for compliance with regulatory requirements but also as a comprehensive tool for managing technological processes and ensuring product competitiveness. Therefore, the evaluation of the effectiveness of its integration should be carried out comprehensively and should include technological, microbiological, organizational, economic, and managerial indicators.

One of the key criteria for evaluating the effectiveness of HACCP integration into thermostable sauce technology is ensuring the stability of finished product quality indicators. Thermostable sauces belong to multicomponent dispersed systems for which maintaining emulsion structure integrity, rheological stability, resistance to thermal stress, and preservation of specified organoleptic properties throughout the entire shelf life are of particular importance.

Evaluation of system performance involves the analysis of a set of indicators, among which the physicochemical characteristics of the product are of special significance. These include active acidity (pH), moisture content, fat content, viscosity parameters, emulsion stability, water-holding capacity, and structural stability after thermal treatment. Monitoring of these parameters enables timely identification of deviations and prevention of undesirable changes in the finished product.

An equally important evaluation criterion is the microbiological safety of thermostable sauces. The effectiveness of HACCP system integration is confirmed by reducing the risk of the growth of pathogenic and opportunistic microorganisms, decreasing the incidence of non-compliance with sanitary standards, and stabilizing the microbiological purity indicators of the product. To achieve this, particular importance is assigned to the control of temperature regimes, duration of heat treatment, sanitary condition of equipment, and packaging conditions.

During the evaluation of system performance, it is also important to consider indicators of production stability. These include the level of product defects, frequency of technological deviations, number of corrective actions, and volume of production losses. Practical implementation of the HACCP system demonstrates that systematic monitoring of Critical Control Points (CCPs) significantly reduces the number of customer complaints, minimizes raw material losses, and improves overall process controllability.

A separate aspect of evaluation is the economic effectiveness of HACCP system integration. Despite the need for initial investments in equipment modernization, personnel training, and documentation development, enterprises obtain substantial economic benefits in the long term. The main outcomes include reduced quality control costs, lower product return rates, increased production efficiency, and optimized resource utilization.

The application of the HACCP system in thermostable sauce technology also contributes to improving production traceability. Modern enterprises are increasingly implementing digital monitoring systems, automated control of technological parameters, and electronic databases for recording monitoring results. The use of digital tools enables more efficient managerial decision-making and reduces the influence of the human factor.

A promising direction for improving thermostable sauce technology is the implementation of the concept of risk-based design of technological processes. This approach involves considering potential hazards already at the stage of formulation development and selection of processing conditions. Such an approach enables the development of more stable products and minimizes the need for subsequent corrective actions.

The use of innovative functional ingredients is becoming increasingly relevant, as these components simultaneously perform technological and stabilizing functions. The application of natural thickeners, modified protein systems, plant-based stabilizers, and next-generation emulsions makes it possible to improve the structural stability of thermostable sauces and reduce the risks of quality deterioration.

One of the most promising directions is the application of digitalization technologies and the Industry 4.0 concept in sauce production. The integration of automated systems for monitoring temperature, humidity, pH, and rheological parameters creates opportunities for transitioning to predictive management of production processes. The analysis of accumulated data enables not only control of current production conditions but also prediction of potential risks and prevention of their occurrence.

Further improvement of thermostable sauce technology is also associated with the implementation of sustainable development principles and resource efficiency. Particular importance is attached to reducing raw material losses, reusing resources, decreasing energy consumption, and implementing environmentally safe technological solutions. Under modern conditions, an effective food safety management system should ensure not only compliance with regulatory requirements but also support the environmental and economic sustainability of production.

An important prerequisite for the further development of food safety management systems is the improvement of personnel qualifications. The effectiveness of HACCP largely depends on the level of employee training, their ability to identify risks, and their capacity to respond promptly to deviations in technological parameters. Therefore, personnel training and the development of a food safety culture become integral components of the operation of modern food enterprises.

Thus, the evaluation of the effectiveness of HACCP system integration into thermostable sauce technology confirms its significant potential for improving product safety, stability, and competitiveness. Further development in this area is associated with production digitalization, implementation of innovative technological solutions, application of functional ingredients, and transition toward comprehensive quality and risk management throughout all stages of the product life cycle.

CONCLUSIONS

The conducted study confirmed that the integration of the HACCP food safety management system into thermostable sauce technology is an effective and scientifically justified approach to ensuring product safety, stability, and quality under modern food production conditions. The implementation of preventive risk management principles enables systematic identification, assessment, and control of potential hazards throughout all stages of the technological process, from raw material reception to storage and distribution of the finished product.

The analysis of theoretical foundations demonstrated that modern food safety management is based on a transition from traditional final product inspection toward integrated preventive control systems aimed at minimizing risks before they occur. In this context, the HACCP system serves not only as a regulatory compliance mechanism but also as a strategic management tool that contributes to increasing production efficiency and strengthening enterprise competitiveness.

The scientific and practical assessment of HACCP implementation in thermostable sauce production made it possible to identify the most significant biological, chemical, and physical hazards associated with raw materials, processing conditions, and storage requirements. Special attention was given to microbiological risks related to dairy ingredients and water quality, allergenic factors caused by milk-derived components, and potential sources of physical contamination. Based on hazard identification and risk assessment, Critical Control Points (CCPs) and Operational Prerequisite Programs (OPRPs) were established in accordance with Codex Alimentarius recommendations.

The study confirmed that pasteurization and storage conditions represent the most critical stages in ensuring product safety, while prerequisite programs and operational controls create the necessary environment for maintaining hygienic production conditions and preventing secondary contamination. The developed HACCP plan provides a systematic approach to monitoring, corrective actions, verification procedures, and documentation management.

Evaluation of the effectiveness of HACCP integration demonstrated its positive impact on product quality indicators, microbiological safety, process stability, production traceability, and economic performance. The implementation of continuous monitoring and control mechanisms contributes to reducing production losses, minimizing nonconformities, improving resource utilization, and enhancing consumer confidence.

The research also identified further development of thermostable sauce technology, including the application of risk-based process design, implementation of innovative functional ingredients, digitalization of production systems, and integration of Industry 4.0 technologies. Particular attention should be devoted to sustainable production principles, resource efficiency, environmental responsibility, and continuous personnel training as essential components of an effective food safety culture.

Therefore, the integration of the HACCP system into thermostable sauce production should be considered not only as a requirement for food safety compliance but also as a strategic direction for technological modernization, sustainable development, and long-term competitiveness of food industry enterprises.

SUMMARY

This study focuses on the integration of the Hazard Analysis and Critical Control Points (HACCP) food safety management system into the technology of thermostable sauce production. The implementation of HACCP is considered an effective preventive approach for identifying, assessing, and controlling biological, chemical, and physical hazards throughout the production process.

Particular attention was given to thermostable sauces due to their complex formulation and sensitivity to technological conditions. Hazard analysis was conducted considering raw materials, processing operations, packaging, and storage conditions. Based on the Codex Alimentarius approach, Critical Control Points (CCPs) and Operational Prerequisite Programs (OPRPs) were established. Pasteurization and storage were identified as the main CCPs ensuring microbiological safety and product stability.

A HACCP plan was developed including critical limits, monitoring procedures, corrective actions, validation, and verification measures. The study confirmed that HACCP implementation improves product safety, process control, traceability, and production efficiency while reducing technological losses.

The results indicate that further improvement of thermostable sauce technology should be associated with digitalization, Industry 4.0 solutions, innovative functional ingredients, and sustainable production principles. Thus, HACCP integration represents not only compliance with food safety requirements but also a strategic approach to increasing competitiveness and ensuring sustainable development of food enterprises.

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