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IMPROVEMENT OF MEAT PRODUCT TRACEABILITY SYSTEM USING DIGITAL TECHNOLOGIES

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This research work addresses the issue of enhancing the effectiveness of the meat product traceability system using modern digital technologies. In the context of increasing demand for food safety and minimizing risks to consumer health, ensuring accurate and reliable traceability of the origin, production conditions, and storage of meat products has become a crucial aspect. The aim of the study is to create an integration between the meat product traceability system and contemporary digital technologies. During the work, an analysis of existing problems and shortcomings in the current traceability system is planned, as well as an exploration of experiences from other industries where digital technologies have been successfully implemented to ensure transparency and data authenticity. In analyzing technological risks, all possible types of threats were considered. The sources of danger include incoming raw materials, the technological line of semi-smoked sausages, and their storage. The use of digital technologies allows for continuous data monitoring using Wi-Fi, combined thermometers, and quality logs. It is anticipated that the implementation of such a system will significantly reduce risks, improve product tracking, and enhance consumer trust in the quality and safety of meat products. The outcomes of this research will be valuable for food industry enterprises, regulatory bodies, and the scientific community that are striving to improve the control and traceability system of food products, utilizing cutting-edge digital innovations.

Keywords: digital technologies, meat products, quality, HACCP (Hazard Analysis and Critical Control Points), traceability.

ЦИФРЛЫҚ ТЕХНОЛОГИЯЛАРДЫ ПАЙДАЛАНЫП ЕТ ӨНІМДЕРІН ҚАДАҒАЛАУ ЖҮЙЕСІН ЖЕТІЛДІРУ

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Бұл зерттеу жұмысы заманауи цифрлық технологияларды қолдана отырып, ет өнімдерін бақылау жүйесінің тиімділігін арттыру мәселесіне арналған. Азық-түлік қауіпсіздігін қамтамасыз ету және тұтынушылардың денсаулығына қауіп-қатерді азайту қажеттілігінің артуы жағдайында ет өнімдерінің шығу тегін, өндіріс жағдайларын және сақталуын дәл және сенімді бақылауды қамтамасыз ету негізгі аспект болып табылады. Зерттеудің мақсаты-ет өнімдері мен заманауи цифрлық технологияларды бақылау жүйесінің интеграциясын құру. Жұмыс барысында ағымдағы қадағалау жүйесіндегі бар проблемалар мен кемшіліктерді талдау, сондай-ақ деректердің ашықтығы мен дұрыстығын қамтамасыз ету үшін цифрлық технологиялар сәтті енгізілген басқа салалардың тәжірибесін зерделеу жоспарлануда. Технологиялық тәуекелдерді талдау кезінде қауіптердің барлық мүмкін түрлері қарастырылды. Қауіптілік көзі ретінде кіріс шикізаты және жартылай ысталған шұжықтардың технологиялық желісі және оны сақтау келтірілген. Цифрлық технологияларды пайдалану Wi-Fi, аралас термометрлер және сапа журналы арқылы деректерді үздіксіз бақылауға мүмкіндік береді. Мұндай жүйені енгізу тәуекелдерді айтарлықтай азайтуға, өнімді бақылауды жақсартуға және тұтынушылардың ет өнімдерінің сапасы мен қауіпсіздігіне деген сенімін арттыруға мүмкіндік береді деп күтілуде. Бұл зерттеудің нәтижелері алдыңғы қатарлы цифрлық инновацияларды пайдалана отырып, азық-түлік өнімдерін бақылау және қадағалау жүйесін жетілдіруге ұмтылатын тамақ өнеркәсібі кәсіпорындары, реттеуші органдар және ғылыми қоғамдастық үшін пайдалы болады.

Негізгі сөздер: сандық технологиялар, ет өнімдері, сапа, HACCP (тәуекелдерді талдау және сыни бақылау нүктелері), бақылау.

СОВЕРШЕНСТВОВАНИЕ СИСТЕМЫ ПРОСЛЕЖИВАЕМОСТИ МЯСНЫХ ПРОДУКТОВ С ИСПОЛЬЗОВАНИЕМ ЦИФРОВЫХ ТЕХНОЛОГИЙ

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Данная исследовательская работа посвящена проблеме повышения эффективности системы прослеживаемости мясных продуктов с применением современных цифровых технологий. В условиях увеличивающейся потребности в обеспечении безопасности пищевых продуктов и минимизации рисков для здоровья потребителей, обеспечение точной и надежной прослеживаемости происхождения, условий производства и хранении мясных продуктов становится ключевым аспектом. Целью исследования является создание интеграции системы прослеживаемости мясных продуктов и современных цифровых технологий. В ходе работы планируется анализ существующих проблем и недостатков в текущей системе прослеживаемости, а также изучение опыта других отраслей, где цифровые технологии успешно внедрены для обеспечения прозрачности и достоверности данных. При анализе технологических рисков были рассмотрены все возможные виды угроз. В качестве источников опасности приведены входящее сырье технологическая линия полукопченных колбас и его хранение. Использование цифровых технологий позволяет вести непрерывный мониторинг данных с применением Wi-Fi, комбинированных термометров и журнал качества. Ожидается, что внедрение такой системы позволит существенно снизить риски, улучшить отслеживание продукции и повысить доверие со стороны потребителей к качеству и безопасности мясных продуктов. Результаты данного исследования будут полезны для предприятий пищевой промышленности, регуляторных органов и научного сообщества, стремящихся к совершенствованию системы контроля и прослеживаемости продовольственной продукции с использованием передовых цифровых инноваций.

Ключевые слова: цифровые технологии, мясные продукты, качество, ХАССП, прослеживаемость.

Introduction

Starting from July 1, 2013, the Technical Regulation of the Customs Union TR CU 021/2011 «On Food Safety» came into effect. Compliance with the requirements of the Technical Regulation of the Customs Union 021/2011 «On Food Safety» is mandatory for any food enterprise operating within the territory of a member country of the customs union, including the territory of the Republic of Kazakhstan. One of the mandatory provisions of TR CU 021/2011 'On Food Safety' is the requirement for the development, implementation, and maintenance of procedures based on HACCP (Hazard Analysis and Critical Control Points) principles. The most effective way to demonstrate compliance with this requirement of TR CU 021/2011 'On Food Safety' is to possess a HACCP system certificate [1]. HACCP serves as a fundamental tool in ensuring quality and safety in global practice, consisting of seven principles outlined in Codex Alimentarius documentation, EU Directive No. 852/2004, ISO 22000-2007 standards, BRC Global Standard Food, IFS Food, SN NS-ISO 31000:2009, and other sources. "In the legislative framework of the Republic of Kazakhstan, this system is represented by the following standards: ST RK 1179-2003 «Quality Systems. Quality Management of Food Products Based on HACCP Principles» and ST RK ISO 22000-2019 «Food Safety Management Systems. Requirements for Organizations in the Food Chain». ST RK 1179-2003 establishes requirements for Food Safety Management Systems (FSMS) based on the seven principles of HACCP. In fact, it is a management system focused solely on Critical Control Points (CCP). ST RK ISO 22000-2019 is an extended standard that, in addition to the core HACCP principles, includes requirements concerning information exchange and preliminary condition programs. This means control is exercised over the entire production chain. Furthermore, an integrated FSMS model can be considered based on the international standard FSSC 22000 (Food Safety System Certification Standard). This standard encompasses requirements from ISO/TS 22000-2007, ISO/TS 22003-2007, ISO/TS 22002-1-2009, and certain additional requirements.

As of today, another key factor in production is the enhancement of food product quality and the

provision of data in digital format. This involves creating an informational environment that considers society's need for obtaining accurate information about product quality.

The experience of foreign countries includes a range of studies involving digital technologies. For instance, a sensor-based network architecture utilizing Internet of Things (IoT) components, autonomous embedded modules, and radio-frequency identification tags (RFID) has been employed. The IoT idea gained prominence in the year 2000, with the development of the Auto-ID at MIT and the subsequent market research reports. In IoT, these systems communicate, perceive, and connect with internal & external state embedded technologies [2]. RFID is one of such pervasive technology which is now increasingly utilized in food logistics, supply chain management, cold chain monitoring These technologies automatically collect data covering the entire lifecycle of a food product and all factors affecting its chemical composition [3]. In China, a pilot project based on the Internet (Radio) network was introduced, with integrated advanced technologies of service-oriented architecture, global identification, syntactic analysis, and electronic pedigrees for agricultural products [5].

A recent technological advancement involves the revolutionary breakthrough in decentralized information technology known as Blockchain [6]. This technology offers a traceability system for food supply chains, enabling the real-time tracking of food products using HACCP principles, blockchain, and the Internet network. It establishes an information-sharing platform for all participants in the supply chain, fostering principles of openness, transparency, neutrality, reliability, and security. Furthermore, there's a growing adoption of sensor technologies to ensure the safety and quality of food products. This includes the use of temperature sensors for monitoring the cold chain and sensors for other critical parameters like humidity and light [5].

Moreover, most of the sensors used record data, which is subsequently employed to identify the causes of quality issues. However, the utilization of wireless sensors, especially Bluetooth, Zigbee, Wi-Fi, and GPRS, is still in its infancy. Furthermore, a majority of chemical sensors сөзін қосыңыз and biosensors, as well as chips, are also in the experimental stage of development [7].

The definition of traceability is provided in Technical Regulation 021/2011 "On Food Safety The aforementioned technologies provide an excellent opportunity for participants in the product lifecycle to conduct monitoring, control, planning, and optimization of business processes remotely and in real-time through the Internet, based on virtual objects.

The aim of the research is to enhance the traceability system in the production of semi-smoked sausages using digital technologies.

Materials and research methods

Research Object:

The research is conducted on the technological process of producing semi-smoked sausages with vegetable additives.

Research Method:

The risk analysis employs a method of risk analysis considering probability and severity. To determine control points and corrective methods, the «Decision Tree» method is utilized.

Methodology:

Risk Identification: Initially, potential hazards and risks are identified at various production stages, including biological, chemical, and physical aspects.

Risk Analysis: For each identified risk, an assessment is made of the probability of its occurrence and the severity of consequences. Special attention is given to control points where risks can be minimized.

Documentation Development: Specifications, instructions, work sheets, and data recording forms are created. These documents help establish standards and transparent procedures.

Implementation of Monitoring Methods: Modern information technologies, sensors, and sensory devices are introduced for continuous monitoring of production parameters.

Data Recording and Analysis: The state of the products and production is regularly documented. The collected data is analyzed to detect anomalies and issues.

Self-assessment and Correction: Regular self-assessment of system effectiveness is conducted. If weaknesses are identified, adjustments are made to the methods.

Results and their discussion

In the process of identifying and assessing technological risks associated with the production of semi-smoked sausages, a comprehensive catalog of potential hazards spanning microbiological, chemical, and physical aspects was created. Through the utilization of risk analysis and the implementation of determination algorithms, we pinpointed Critical Control Points that have a significant impact on both the quality and safety of

the sausages (Table 1). To reduce their number, CCP were combined according to the following rules: «control is performed by a single responsible person at one workstation; control of a single parameter is conducted using one methodology (different operators are possible)». As a result, CCP-1 «Incoming Inspection» and CCP 2-5 "Production and Storage of Semi-Smoked Sausages" are established (Table 2).

Temperature is a crucial factor in the growth and proliferation of microorganisms, exerting a direct influence on the quality of products and consumer health. Therefore, to ensure safety, temperature monitoring and the continuous cold chain are imperative For this purpose, temperature control is carried out during the reception, production, and storage of products. When monitoring the temperature of food products during reception, production, and storage, it is especially important for the measuring instruments used to provide consistently stable results. Even the slightest deviation from specified parameters poses a threat to the safety of food products.

The application of digital technologies enables real-time acquisition and control of temperature and humidity values, which are automatically measured and continuously documented.

Employing WiFi loggers, which can strategically positioned within refrigeration chambers and equipment, represents a vital aspect of information technology utilization. Temperature and humidity readings are transmitted for storage in the Cloud. In the event of deviations from the set limits (critical threshold), emergency notifications are automatically sent SMS or email to mobile modules for operators

Table 2. Consolidated CCP summary table

№	Name of the technological operation	Initial CCP number	United CCP number	Factor to consider
1	Reception Department	4	CCP 1	number of MAFFanM, sulfite-reducing clostridia
2	Preparation of raw materials	5	CCP 2	number of MAFFanM, sulfite-reducing clostridia
3	Ripening	6	CCP 3	number of MAFFanM, sulfite-reducing clostridia
4	Smoking	7	CCP 4	number of MAFFanM, sulfite-reducing clostridia
5	Save	8	CCP 5	number of MAFFanM, sulfite-reducing clostridia

A WiFi logger data system allows measurement results to be accessed from anywhere and through any device (PC, smartphone, or tablet). For temperature measurement, a combined infrared and penetration thermometer is recommended. This type of thermometer enables non-contact scanning of individual products or entire packages, which is very convenient during product reception.

All measured values are presented in the form of a table or graph and can be imported into a report, and subsequently shared via email in PDF or Excel file formats. The application of digital quality technologies enables continuous monitoring of Critical Control Points (CCPs) and reduces the risk of hazards.

Conclusion

The present research is dedicated to enhancing the traceability system of meat products using modern digital technologies. The primary objectives of the research were to develop integration between the traceability system of meat products and contemporary digital technologies, as well as to analyze issues within the current system and draw from successful digital innovation integration experiences in other industries.

Through a comprehensive examination of technological risks within the semi-smoked sausage production process, potential hazards spanning biological, chemical, and physical domains were identified at different production stages. Utilizing risk analysis methodologies, Critical Control Points (CCPs) were pinpointed, exerting significant influence on product quality and safety. By streamlining their quantity, CCPs were established, encompassing incoming inspection and semi-smoked sausage production stages.

Table 1. Exploration of Technological Risk Factors Associated with Semi-Smoked Sausage Production

Operation	Managed manifestations	Factors to take into account when assessing risks	Precautionary measures
1	2	3	4
Intake	Sensory characteristics;	Chemical, physical, microbiological	Supplier evaluation; Documentation verification; Raw material temperature inspection; Vehicle condition assessment upon receipt; Incoming inspection of each raw material batch.
Preserve	Supporting paperwork	Microbiological	Temperature monitoring; Shelf life assessment; Sanitary condition inspection of the warehouse.
Preparation of raw materials	Organoleptic indications	Physical, microbiological	Compliance with sanitary and hygienic requirements for personnel; compliance with sanitary and hygienic requirements.
Cookingthe minced meat	Technical and sanitarycondition of equipment	Main raw materials:	Compliance with the requirements for washing and sanitary and hygienic treatment of equipment and dishes; compliance with the parameters of conducting a technological operation.
Cutterization	Equipment condition;	Microbiological, physical	Compliance with the requirements for washing and sanitary and hygienic treatment of equipment; compliance with the parameters of technical operations; control the duration of cupping; raw material cooling temperature control; control the amount of water added.
Ripening	quality of finished mincedmeat	Main raw materials:	Compliance with the requirements for washing equipment, dishes and sanitary and hygienic treatment; Compliance with the parameters of the technological operation; compliance with personal hygiene requirements at the enterprise; pressure control in the syringe for filling.

Continuation of the table

1	2	3	4
Cooking	Heat treatment; sanitary condition of equipment; shell integrity; cooking temperature; cooking duration;	Microbiological	Compliance with the requirements for washing equipment, dishes and sanitary and hygienic treatment; compliance with the parameters of the technological operation; compliance with personal hygiene requirements at the enterprise; pressure control in the syringe for filling;
Refrigeration	Monitoring storage conditions and durations; Assessing product quality throughout storage; Cooling duration control; Temperature control during cooling and storage; Equipment sanitation inspection; Temperature assessment within the bread's interior.	Microbiological	Adherence to equipment and dish washing and hygiene standards; Temperature monitoring within the thickness of the Baton; Supervision of cooling duration; Monitoring of cooling temperatures.
Conveyance	Thermal conditions;	Microbiological, chemical	Inspection of finished product quality per regulatory documents; Assessment of vehicle condition during product shipment; Verification of accurate completion of required documentation.

Temperature plays a crucial role in the growth and proliferation of microorganisms, influencing product quality and consumer health. Therefore, temperature control and the cold chain are essential aspects of ensuring product safety imperative. The application of digital technologies enables continuous real-time monitoring and control of temperature and humidity. WiFi loggers automatically measure and record temperature and humidity readings, with emergency notifications sent to operators in case of exceeding established limits.

The use of WiFi sensors allows data accessibility from any location and device, ensuring continuous control over CCPs and reducing the risks of hazardous situations.

In this manner, the implementation of digital technologies not only enhances monitoring and control efficiency but also elevates the level of safety and quality in meat products. This approach instills consumer confidence and trust in the product's integrity.

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