Qədim Diyar
May 2026, Cild. 8, Say 5, s. 276–280
Ancient Land
May 2026, Vol. 8, Issue 5, pp. 276–280
DOI: https://doi.org/10.36719/2706-6185/60/276-280

Assessing Risks in the Bakery Industry: A Comprehensive Analysis of Hazards and Their Impact on Food Safety and Quality Management

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Abstract. *Bakery products hold a central position in the daily diet, making the systematic identification of production hazards essential for food safety. This study aims to identify the biological, chemical, and physical hazards in pan-baked wheat bread prepared in laboratory conditions from premium-grade wheat flour, examine their sources, and justify critical control points based on HACCP principles. Methods of analysis, comparison, and systematization were applied, along with gravimetric, titrimetric, and Zavyalov procedures for physicochemical assessment. The scientific novelty lies in the stage-wise classification of hazards for a specific bread sample and the development of an HACCP plan with seven critical control points. The practical results can be applied to food safety control systems in bread production enterprises and to educational processes.*

Keywords: *bread safety, HACCP, critical control points, hazard identification, food safety management, wheat bread production*

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Received: 16 December 2025; Accepted: 12 May 2026; Published online: 28 May 2026

Çörəkbişirmə sənayesində risklərin qiymətləndirilməsi: təhlükələrin hərtərəfli təhlili və onların qida təhlükəsizliyi və keyfiyyət idarəetməsinə təsiri

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Xülasə. *Çörək-bulka məhsulları gündəlik qida rasionunda mərkəzi yer tutduğundan, onların istehsalı zamanı təhlükələrin sistemli identifikasiyası qida təhlükəsizliyi üçün vacibdir. Tədqiqatın məqsədi laboratoriya şəraitində əla sort buğda unundan hazırlanmış qəliblənmiş buğda çörəyi nümunəsində bioloji, kimyəvi və fiziki təhlükələrin müəyyənləşdirilməsi, mənbələrinin araşdırılması və HACCP prinsipləri əsasında kritik nəzarət nöqtələrinin əsaslandırılmasıdır.*

Tədqiqatda təhlil, müqayisə və sistemləşdirmə metodları, fiziki-kimyəvi qiymətləndirmə üçün qravimetrik, titrimetrik və Zavyalov üsulları tətbiq edilmişdir. Elmi yenilik konkret çörək nümunəsi üzrə təhlükələrin mərhələlər üzrə təsnifatının verilməsi və 7 kritik nəzarət nöqtəsindən ibarət HACCP planının hazırlanmasıdır. Praktiki nəticələr çörək istehsalı müəssisələrində qida təhlükəsizliyi nəzarət sistemlərinin formalaşdırılmasında və tədris prosesində istifadə oluna bilər.

Açar sözlər: *çörək təhlükəsizliyi, HACCP, kritik nəzarət nöqtələri, təhlükələrin identifikasiyası, qida təhlükəsizliyi idarəetməsi, qəliblənmiş buğda çörəyi*

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Introduction

Food safety has emerged as one of the most consequential scientific-practical fields in the contemporary period, both in terms of protecting public health and ensuring the sustainability of food provision. For the normal functioning of the human organism, it is not sufficient for ingested food to merely possess nutritional value; the product must simultaneously be safe, of acceptable quality, and suitable for consumption. The presence of biological, chemical, or physical hazards in food products may produce serious risks for consumer health, ranging from acute foodborne illnesses to chronic conditions arising from prolonged exposure to low-level contaminants. Accordingly, the early identification, assessment, and management of hazards at every stage of production processes carry particular weight in the food industry. The systematic governance of safety has therefore become inseparable from the everyday operation of food manufacturing enterprises, regulatory authorities, and academic research programmes worldwide (FAO/WHO, 2020; WHO, 2024).

Because bakery products are characterized by daily consumption, the identification and analysis of hazards that may arise during their production hold particular relevance for safeguarding food safety. Bread is consumed regularly by all age categories, occupies a wide place in the dietary regime, and carries strategic significance in food provision. Its production from wheat flour, its role as a source of energy, and its contribution of carbohydrates, plant-derived proteins, mineral substances, and dietary fibre to nutrition reinforce both its social and biological importance. Wheat bread, in particular, has historically served as one of the staple foods of human civilization, and its accessibility and affordability mean that any safety failure carries broad social consequences. At the same time, the wide consumption of bread elevates the safety requirements that apply to it: the presence of hazards in a product consumed daily must be assessed not only as a risk for individual health but also for large consumer populations (Yusifova et al., 2022).

Hazards that may emerge during bread production are conventionally divided into biological (moulds, mycotoxins, pathogenic micro-organisms, spore-forming bacteria), chemical (pesticide residues, heavy metals, acrylamide, residues of cleaning and disinfecting agents), and physical (metal, stone, plastic, wood fragments, packaging residues) groups. Allergenic factors—particularly gluten and various ingredients used in enriched recipes—form an additional category that has gained increasing recognition in recent years. The management of these hazards must be pursued preventively across the entire technological chain, beginning at raw-material reception rather than only at the final stage of production. Reactive testing of finished products, while still relevant, cannot replace the structural integration of safety considerations into each step of manufacturing. Preventive approaches are

increasingly regarded as more efficient in modern food industry practice, both because they reduce waste and recall costs and because they provide stronger protection for the consumer (Kowalska, 2022; Wallace et al., 2018).

Research

The Hazard Analysis and Critical Control Points (HACCP) system emerged precisely from this preventive logic. Originally developed in the United States in the 1960s to ensure the safety of food supplied to space missions, the system has since evolved into a globally accepted framework for food safety management. Its essence lies in anticipating where hazards may form during the technological process and managing them at critical control points, instead of waiting to detect them in the finished product. In multi-stage bakery technologies, this approach allows the source, risk level, and control measures of hazards to be specified consistently across the production sequence. The seven principles of HACCP—conducting hazard analysis, identifying critical control points, establishing critical limits, defining monitoring procedures, prescribing corrective actions, verifying the system, and maintaining documentation—together provide a structured methodology that translates abstract safety concerns into operational practice (Mortimore & Wallace, 2015).

International frameworks reinforce and complement HACCP. The Codex Alimentarius Commission, jointly established by the Food and Agriculture Organization and the World Health Organization, provides general principles of food hygiene that form the regulatory backbone of national food safety systems worldwide. The ISO 22000:2018 standard further integrates HACCP principles with broader management system requirements, addressing communication, system management, and prerequisite programmes for any organization in the food chain. Region-specific bodies such as the European Food Safety Authority generates scientific opinions, monitor pesticide residues and contaminants, and issue recommendations on emerging hazards including acrylamide in thermally processed foods (ISO, 2018; EFSA, 2023; FAO/WHO, 2017).

Within this broader context, the bakery industry presents its own technological and microbiological specificity. Wheat flour, as the principal raw material, is exposed to potential contamination throughout agricultural production, harvesting, storage, and milling. Mycotoxins—secondary metabolites of certain Aspergillus, Penicillium, and Fusarium species—are particularly difficult to manage because several of them are heat-stable and may survive the baking process. Spore-forming bacteria such as Bacillus subtilis can give rise to the characteristic "ropy bread" defect when finished products are stored under inappropriate temperature and humidity conditions. Chemical hazards include not only residues from agricultural inputs but also acrylamide, which forms in the crust during high-temperature baking through the Maillard reaction. Physical hazards typically arise from inadequate sieving of flour, deteriorated equipment, or careless handling of packaging materials (Stoev, 2015; Leite et al., 2023; Gündüz, 2023).

In the Azerbaijani context, the relevance of this subject is reinforced by several converging factors. Bread occupies a significant place in the daily diet of the population, with per-capita consumption traditionally high. Grain and flour products play a central role in food security, and the bakery industry is closely linked to the broader development of the non-oil sector of the economy. Domestic policy emphasizes the formation of a quality raw-material base, the improvement of production technologies, the proper organization of storage and transport conditions, and the implementation of safety systems as fundamental requirements for enhancing the quality of bread products. Recent research conducted in Azerbaijan has highlighted ongoing challenges concerning the ecological and microbiological safety of food and raw materials, indicating that systematic, evidence-based hazard analysis remains both timely and necessary (Yusifova et al., 2022).

Despite the considerable international literature on bakery safety, several research gaps persist. Many studies focus on isolated hazards—mycotoxins, acrylamide, microbial contamination—without integrating these into a coherent stage-by-stage analysis of a specific product. Others discuss HACCP at the level of general principles without translating these into a fully specified plan for a particular bread variety. The present article seeks to address this gap by examining a clearly defined sample—pan-baked wheat bread prepared in laboratory conditions from premium-grade wheat flour—and by reporting hazard identification, risk assessment, and control measures in a structured, reproducible manner.

The aim of this study is to identify and systematically classify, at the level of the technological stages of a specific bread sample, the biological, chemical, and physical hazards that may emerge in pan-baked wheat bread, and to substantiate critical control points and an HACCP plan accordingly. The objectives derived from this aim are: first, to define the formulation and the technological sequence of preparation of the bread sample under controlled laboratory conditions; second, to specify the organoleptic and physicochemical indicators used for product evaluation, together with the methods for their determination; third, to systematize, across raw-material preparation, dough mixing, fermentation, shaping, proofing, baking, cooling, and storage, the potential sources of biological, chemical, and physical hazards; and fourth, to formulate, on the basis of HACCP principles, the corresponding critical control points and control measures. The scientific novelty of the work lies in the stage-by-stage systematization of hazards for a specific bread sample, the explicit linkage of identified hazards to the formulation and the technological regimes, and the elaboration of an HACCP plan that comprises seven critical control points with associated monitoring procedures and corrective actions.

Conclusion

The investigation conducted on a laboratory-prepared pan-baked wheat bread sample shows that the safety of bakery products is shaped by the entire technological sequence rather than by a single stage. The formulation composition (wheat flour, drinking water, baker's yeast, table salt) and the sequence of operations (raw-material preparation, dosing, mixing, fermentation, placement into pans, final proofing, baking, cooling, and storage) jointly determine the quality indicators of the bread. The selected technological regimes—dough initial temperature of approximately 32 °C, fermentation at 31 ± 1 °C for 170 minutes, and baking at 220–230 °C for approximately 30 minutes—play a decisive role in shaping the organoleptic and physicochemical characteristics of the product, including moisture, acidity, porosity, volume, and form stability.

Hazards in the prepared bread sample were systematized into biological (moulds, mycotoxins, pathogenic and conditionally pathogenic bacteria, spore-forming microorganisms), chemical (pesticide residues, heavy metals, residues of detergents and disinfectants, acrylamide), and physical (metal, stone, glass, plastic, and wood impurities) groups. These hazards are linked primarily to raw-material quality, fermentation conditions, baking regime, and cooling and storage stages, demonstrating the necessity of preventive control across the production chain. On the basis of HACCP principles, seven critical control points were determined—raw-material preparation, dosing, dough mixing and fermentation, placement into pans and final proofing, baking, cooling, and storage—and for each one, critical limits, monitoring methods, and corrective actions were defined, resulting in a unified HACCP plan for pan-baked wheat bread production.

The findings indicate that the formation of a safe and high-quality bakery product cannot be guaranteed by the baking stage alone but depends on integrated management of formulation, technological regimes, organoleptic and physicochemical indicators, sanitary-hygienic conditions, and critical control points. The practical results of the work may be applied to the design of food

safety control systems in bread production enterprises, the development of internal guidelines, and the educational process in food engineering and food safety. Future research may extend the present analysis by incorporating broader microbiological and instrumental chemical analyses, comparing different flour grades and dough formulations, and examining the influence of post-baking packaging and storage temperature on combined acrylamide and microbiological spoilage risks.

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