



Food Safety and Toxicological Risks in Modern Food Systems

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Abstract

Article history:

Received: January 9, 2025
Revised: February 22, 2025
Accepted: April 18, 2025
Published: June 30, 2025

Keywords:

Food contamination,
Food safety,
Food systems,
Food toxicology,
Health risk.

Identifier:

Zero Open
Page: 48-61
<https://zeraopen.com/journal/fct>

Food safety is a crucial aspect of the modern food system, which focuses not only on food availability but also on the safety of consumption. This study aims to analyze the relationship between food safety and toxicological risks within the context of the ever-evolving global food system. The method employed is a qualitative approach through the analysis of scientific literature from various reliable sources published over the past five years. The findings indicate that food contamination, whether chemical in nature, such as heavy metals and pesticide residues, or biological, such as mycotoxins, has significant potential to cause long-term health impacts, including organ damage, nervous system disorders, and the risk of chronic diseases. Additionally, global factors such as changes in food distribution systems, urbanization, and shifts in consumer patterns further increase the complexity of these risks. A risk-based approach is a critical strategy for identifying, evaluating, and controlling hazards in food. This research underscores that the integration of food safety and food toxicology is essential to support a sustainable food system and comprehensively protect public health.

1. Introduction

Food is a basic human need that has a vital role not only as a source of energy, but also as the main determinant of health and quality of life. In today's global context, attention to the food system is no longer limited to quantity or availability aspects, but also to food *safety* aspects related to potential health risks due to contaminated food consumption. Along with the increasing complexity of modern food production and distribution systems, the risk of food contamination is becoming higher and requires a comprehensive scientific approach, especially through the study of food toxicology (Gourama, 2020).

The development of the global food system driven by globalization, industrialization, and changes in people's lifestyles has led to an increased dependence on processed food products and long supply chains. This condition opens up greater opportunities for the entry of various harmful contaminants into food, both chemical, biological, and physical. Contaminants such as pesticide residues, heavy metals, and pathogenic microorganisms can enter the food chain and have the potential to cause serious health impacts for humans. Research shows that exposure to these contaminants can cause health problems ranging from acute poisoning to chronic diseases such as neurological disorders and cancer (Alengebawy et al., 2021).

In addition, global dynamics after the COVID-19 pandemic have also had a significant impact on the world's food system. Disruptions in the distribution chain, changes in people's consumption patterns, and increasing consumption of instant and processed foods have increased the challenges in maintaining food safety. This

shows that food security cannot be separated from food security, because the availability of sufficient food does not necessarily guarantee that the food is safe to consume. Therefore, the integration between aspects of food security and food security is very important in ensuring a sustainable and healthy food system (Galanakis, 2020).

In the perspective of food toxicology, the main focus lies on the identification, characterization, and evaluation of the risks of various harmful substances that can enter the human body through food consumption. Exposure to contaminants such as heavy metals, pesticide residues, and mycotoxins often occurs indirectly and is accumulative. This condition is a serious concern because the toxic effects are not always seen directly, but rather develop in the long term and can have a significant impact on public health (Beyuo et al., 2024).

Furthermore, a risk-based approach (*risk assessment*) is one of the important methods in analyzing food safety. This approach involves the process of identifying hazards, evaluating the level of exposure, and characterizing the risks to human health. Using this approach, researchers and policymakers can understand the level of harm posed by specific contaminants and formulate appropriate mitigation strategies. However, the implementation of this approach still faces various obstacles, especially in terms of limited data and monitoring systems that are not optimal in various regions (Cattaneo et al., 2023).

On the other hand, behavioral factors and public awareness also play an important role in maintaining food safety. Unhygienic food processing, storage, and consumption practices can increase the risk of harmful microbiological

contamination. Therefore, increasing public literacy regarding food safety is a strategic step in reducing the risk of exposure to harmful substances through food (Kamboj et al., 2020). Proper education can help people in choosing, processing, and consuming food more safely.

Although various studies have discussed food security broadly, studies that specifically integrate aspects of food toxicology in modern food systems are still relatively limited. In fact, this aspect is very important in ensuring that the food available is not only sufficient in quantity, but also safe to consume. Therefore, this study aims to analyze the relationship between food safety and toxicological risk in modern food systems, as well as emphasize the importance of a risk-based approach in maintaining public health in a sustainable manner (Khan et al., 2024).

2. Literature Review

Studies on food safety and food toxicology have evolved significantly in recent years, as the complexity of the global food system and the associated risk of contamination increase. Food safety is not only concerned with the availability of sufficient food, but also includes ensuring that the food consumed is free from harmful contaminants that can threaten human health. In this case, food toxicology plays an important role in identifying and evaluating the impact of harmful substances contained in food on the human body (Gourama, 2020).

One of the main issues in food toxicology is the presence of chemical contaminants such as heavy metals and pesticide residues in the food chain. Heavy metals such as lead, mercury, and cadmium can accumulate in the human body

through the consumption of contaminated food, causing chronic toxic effects. In addition, the use of pesticides in the agricultural sector is also a major source of food contamination that has the potential to endanger human health. Studies show that long-term exposure to these substances can lead to nervous system disorders, organ damage, as well as an increased risk of chronic diseases (Alengebawy et al., 2021).

In addition to chemical contaminants, biological contamination is also an important concern in food safety. Mycotoxins produced by fungi are one example of biological contaminants that are often found in food, especially in suboptimal storage conditions. Mycotoxins are known to have serious toxic effects, including carcinogenic, immunotoxic, and hepatotoxic properties. The presence of these contaminants suggests that food safety depends not only on the production process, but also on the proper storage and distribution of food (Khan et al., 2024).

In an effort to understand and control the risk of food contamination, the *risk assessment* approach is a widely used method in food toxicology research. This approach involves the process of hazard identification, exposure assessment, and characterization of risks to human health. With a comprehensive risk analysis, it is possible to determine the level of danger of a contaminant and the mitigation measures needed to reduce its impact. This approach is also the basis for the formulation of food safety policies in various countries (Ingenbleek et al., 2020).

On the other hand, changes in the global food system influenced by external factors such as the COVID-19 pandemic also affect food safety aspects. Disruptions in the supply chain and changes in people's consumption patterns have increased the risk of exposure to contaminants in food. This condition confirms that food

security must be an integral part of a sustainable food system, especially in the face of increasingly complex global challenges (Wu & Rodricks, 2020).

In addition to systemic factors, individual behavior also has an important role in maintaining food safety. Non-standard food processing and storage practices can increase the risk of microbiological contamination. Therefore, increasing public awareness and knowledge about food safety practices is an important step in reducing the risk of food toxicology. Effective education can help people adopt safer behaviors in food consumption (Kamboj et al., 2020).

3. Methods

This research uses a qualitative approach that aims to understand in depth the phenomenon of food safety and food toxicology in the modern food system. The qualitative approach was chosen because it was able to provide a comprehensive picture of the relationship between food contamination, health risks, and complex global food system dynamics. This research does not focus on quantitative measurement, but on interpretive analysis of various relevant scientific data sources.

The data source used in this study comes from secondary data obtained through searching the scientific literature on the internet. Data is collected from various academic platforms such as international journals, scientific articles, reports of international organizations, as well as scientific publications available online. The selection of data sources was carried out selectively by considering the credibility, relevance of the topic, and the time range of publication, which is between 2020 and

2024, so that the data used reflects the latest conditions and developments in the field of food safety and toxicology.

The data collection technique is carried out through literature *review*, which is by identifying, reviewing, and grouping various studies related to the topic being researched. This process involves searching using specific keywords such as "food safety", "food toxicology", "food contamination", and "risk assessment". Furthermore, the data obtained is analyzed by comparing the results of different research, identifying patterns, and finding relationships between relevant concepts.

The data analysis in this study was carried out in a descriptive-analytical manner, namely by describing the information that had been collected and then interpreted to answer the research objectives. The data collected is systematically compiled to describe food safety conditions and toxicological risks in modern food systems. In addition, analysis is also carried out by identifying research gaps and linking findings from various sources to produce a more comprehensive understanding.

To maintain the validity and reliability of the data, this study only uses sources from trusted scientific publications and has gone through a *peer review* process. In addition, a source triangulation process is carried out by comparing information from various references to ensure data consistency. With this approach, it is hoped that the results of the research can provide an accurate and relevant picture of food safety issues and food toxicology in a global context.

4. Results and Discussion

The results of an analysis of various literature show that modern food systems face increasingly complex challenges, especially in the aspects of food safety and the associated toxicological risks. The increase in global food demand due to population growth has encouraged the intensification of agricultural production and large-scale food industrialization. However, on the other hand, this condition also increases the potential for contamination in the food chain that can have a serious impact on human health. Food contamination does not only come from one source, but is the result of the interaction of various factors such as the use of chemicals, environmental pollution, and improper food handling practices (Gourama, 2020).

In the context of food toxicology, one of the main issues identified is the presence of chemical contaminants in food. Heavy metals such as lead, mercury, and cadmium are contaminants that are often found in various food products due to environmental pollution. These metals can enter the food chain through contaminated soil and water, then accumulate in plants and animals that humans consume. Long-term exposure to heavy metals is known to cause a variety of health problems, including nervous system damage, impaired kidney function, as well as carcinogenic effects (Alengebawy et al., 2021). In addition to heavy metals, pesticide residues are also a major concern in modern food safety. Uncontrolled use of pesticides in the agricultural sector can leave residues on food products that are ultimately consumed by humans, thereby increasing health risks (Beyuo et al., 2024).

In addition to chemical contamination, biological contamination is also one of the important factors that affect food safety. Pathogenic microorganisms such as

bacteria, viruses, and fungi can contaminate food at various stages of production, from the harvesting process to distribution. One of the most dangerous biological contaminants is mycotoxins, which are toxic compounds produced by fungi in certain foods. Mycotoxins have significant toxic impacts, including carcinogenic, immunotoxic, and hepatotoxic effects, which can harm human health in the long term (Khan et al., 2024). The presence of these biological contaminants suggests that food safety depends not only on the quality of raw materials, but also on the proper handling and storage processes.

Changes in the global food system due to the COVID-19 pandemic have also had a significant impact on food security. Disruptions in the global supply chain have led to limited distribution of fresh food, so people tend to switch to processed and ready-to-eat foods. This condition increases the potential for exposure to various additives and contaminants contained in processed foods. In addition, changes in people's consumption behavior during the pandemic have also contributed to increased food security risks, especially in terms of food storage and processing at the household level (Wu & Rodricks, 2020). This emphasizes that food security cannot be separated from food safety, because sufficient food availability does not always guarantee food safety.

The *risk assessment* approach in food toxicology is one of the important methods in identifying and evaluating the risks posed by food contaminants. This approach includes several stages, namely hazard identification, exposure assessment, and risk characterization. Using this approach, researchers can determine the level of risk from various contaminants as well as formulate appropriate mitigation

strategies to reduce negative impacts on human health (Cattaneo et al., 2023). However, the implementation of this approach still faces various obstacles, such as limited accurate data and lack of effective monitoring systems in some regions.

The results of the study also show that environmental factors have a very significant role in determining the level of food contamination. Environmental pollution due to industrial and agricultural activities can lead to the entry of harmful substances into the food chain. Polluted soil and water are the main medium for heavy metals and other chemicals to enter the food system. Therefore, sustainable environmental management is an important aspect in efforts to maintain food security (Beyuo et al., 2024). In addition, climate change can also affect the level of food contamination, for example through increased growth of mycotoxin-producing fungi under certain temperature and humidity conditions (Khan et al., 2024).

On the other hand, the level of public awareness of food safety is still a significant challenge. Many cases of food poisoning occur due to food processing and storage practices that are not in accordance with hygienic standards. Lack of knowledge about food safety can increase the risk of microbiological contamination that is harmful to health (Kamboj et al., 2020). Therefore, public education about food safety practices is an important step in reducing the risk of food toxicology.

In addition to individual factors, government policies and regulations also have an important role in maintaining food safety. Strict regulations related to the use of chemicals in agriculture, supervision of food distribution, and food safety standards can help reduce the risk of contamination. However, the effectiveness of such policies is highly dependent on consistent implementation and oversight

(Ingenbleek et al., 2020). In many cases, weak supervision is one of the factors that cause the still high level of food contamination in various regions.

Furthermore, the results of the analysis show that there is a gap between the increase in food production and the quality of food safety. Too much focus on increasing production often ignores safety aspects, increasing the risk of exposure to harmful contaminants. This suggests that a quantity-oriented approach is not enough to guarantee public health (Alengebawy et al., 2021). Therefore, a more balanced approach between production and food safety is needed.

From a toxicology perspective, one of the main challenges is the often cumulative and indirectly visible nature of exposure to contaminants. Exposure in small but ongoing amounts can cause serious long-term toxic effects. This condition makes food toxicology risks difficult to detect early, so a preventive approach is needed in its management (Beyuo et al., 2024). In addition, interactions between different types of contaminants can also exacerbate the toxic impact caused.

Overall, these results and discussions show that food safety and food toxicology are interrelated and inseparable issues in the modern food system. Various factors such as globalization, changes in consumption patterns, environmental pollution, and low public awareness contribute to the increased risk of food contamination. Therefore, a holistic and integrated approach is needed to overcome this problem, including through increasing public awareness, strengthening regulations, and implementing a risk-based approach in food safety management (Galanakis, 2020).

5. Conclusion

Food safety and food toxicology are two interrelated aspects that play a crucial role in ensuring public health amid the development of modern food systems. Research findings indicate that the global increase in food production and distribution has been accompanied by rising risks of contamination, whether chemical, biological, or environmental. This situation underscores that food availability alone is insufficient; it must be balanced with food safety guarantees to prevent negative impacts on human health. Food contamination from heavy metals, pesticide residues, and mycotoxins poses a serious threat due to their ability to accumulate in the body and cause long-term effects. Furthermore, changes in the food system due to globalization and post-pandemic dynamics have further amplified these risks through shifts in food consumption patterns and distribution. This indicates that modern food systems require a more comprehensive approach to managing existing risks.

A risk-based approach is one solution that can be applied to identify and control hazards in food. However, the effectiveness of this approach heavily depends on the availability of data, robust monitoring systems, and strong policy support. On the other hand, public awareness and behavior also play a crucial role in ensuring food safety, particularly in daily food processing and consumption practices. Based on research findings, integrated efforts are needed among the government, industry stakeholders, and the public to create a food system that is not only sufficient in quantity but also safe in quality. Thus, food safety and food

toxicology must be central components in the planning and management of future food systems to support sustainable public health.

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