BORNEO EPIDEMIOLOGY JOURNAL | BEJ

REVIEW ARTICLE Open Access

Importance of Hazard Analysis Critical Control Points (HACCP): A Review

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Abstract

Hazard Analysis and Critical Control Points (HACCP) is one of the essential public health interventions to ensure food safety and quality. HACCP has significantly improved public health by reducing the incidence of foodborne illnesses through systematic identification and control of food safety hazards. Economically, it enhances trade opportunities by aligning with international food safety standards, ensuring that food products meet stringent market requirements, and fostering global consumer trust. Industries' role in adhering to the requirements assures the consumers, which subsequently helps to protect public health and the economy. Increasing awareness of the importance of the HACCP is vital to ensure adherence to the HACCP standards. Therefore, this article aims to describe the importance of HACCP. Infectious agent ability; host vulnerability; public awareness; behaviour; methodological advancement; environmental contamination; urbanization and industrialization; and the impact of globalization are among the importance of the HACCP. Adherence to HACCP is indispensable and should be adopted by every level of the food industry to enhance food safety and quality for the public.

Keywords: Hazard Analysis Critical Control Points; HACCP; food safety; food quality.

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Received: 23/08/2024
Accepted: 09/12/2024

Introduction

HACCP (Hazard Analysis Critical Control Points) is a standard and globally recognized food safety assurance method to identify and manage food safety-related risks. In other words, HACCP is a management system where food safety is addressed by identifying food safety hazards. Subsequently, it will be analyzed and controlled from raw material production, procurement, and handling, to manufacturing, distribution, and delivery of the finished food product to the consumer. HACCP ensures the accountability of industries to adhere to requirements to ensure public health and protect economic consequences from food contamination from biological, chemical, and physical contaminants. In various countries, including Malaysia, food manufacturers must be certified for food safety assurance programs; one of the programs includes HACCP (Bahagian Keselamatan dan Kualiti Makanan, n.d.).

HACCP has become the cornerstone of modern food safety management systems worldwide. Its adoption is mandatory in many countries for food production and processing, ensuring compliance with international trade regulations and protecting public health (Domenech et al., 2013; Osimani et al., 2013). For instance, HACCP is integral to food safety regulations in the European Union, the United States, and other high-income nations (Williams et al., 2020; Hunter, 2016). Developing countries also implement HACCP to enhance their export capabilities, ensuring their products meet stringent global standards. Moreover, HACCP aligns with international food safety guidelines, such as the Codex Alimentarius, reinforcing its universal applicability and effectiveness in mitigating risks associated with biological, chemical, and physical food contaminants. Its preventive framework not only safeguards public health but also fosters consumer confidence and economic growth through safer and higher-quality food products.

Since the dawn of history, food safety has been considered one of the significant public health issues. There was much past evidence that there are rules and recommendations related to protecting health impact arising from foodborne disease or food adulteration. Understanding the importance of food safety assurance programs, especially HACCP, is vital so that the food industries, public health officials, and community can take appropriate action to ensure food safety to prevent harmful health, social, and economic consequences. Despite the proven effectiveness of HACCP in ensuring food safety, there is limited understanding from various stakeholders which leads to barriers to HACCP protocols, particularly in low- and middle-income countries (Woh et al., 2016). Therefore, in addressing the issue, this article aims to describe the importance of HACCP. By shedding light on the importance of HACCP, this article can serve as an essential resource for multiple stakeholders, including food manufacturers, public health officials, policymakers, and consumers.

Infectious Agent Ability

Exposure to various biological agents in food can be potentially infectious, toxic, and even cancerous to humans. The common biological agents that cause food borne diseases include bacteria (*Bacillus cereus*, *Campylobacter jejuni*, *Clostridium botulinum*, Clostridium perfringens, *Cronobacter sakazakii*, *Escherichia coli*, *Listeria monocytogenes*, Salmonella spp., *Shigella spp*., *Staphylococcus aureus*, *Vibrio spp*. and *Yersinia enterocolitica*), viruses (Hepatitis A and Noroviruses) and parasites (*Cyclospora cayetanensis*, *Toxoplasma gondii*, and *Trichinella spiralis*) (Bintsis, 2017). *Bacillus cereus* group, for example, can survive various stressful environmental conditions such as heat, ultraviolet, acid, and desiccation. Meanwhile,

salmonella can survive in hardy conditions, including dry environments and water, for several months (World Health Organization, n.d.; Knodler & Elfenbein, 2019).

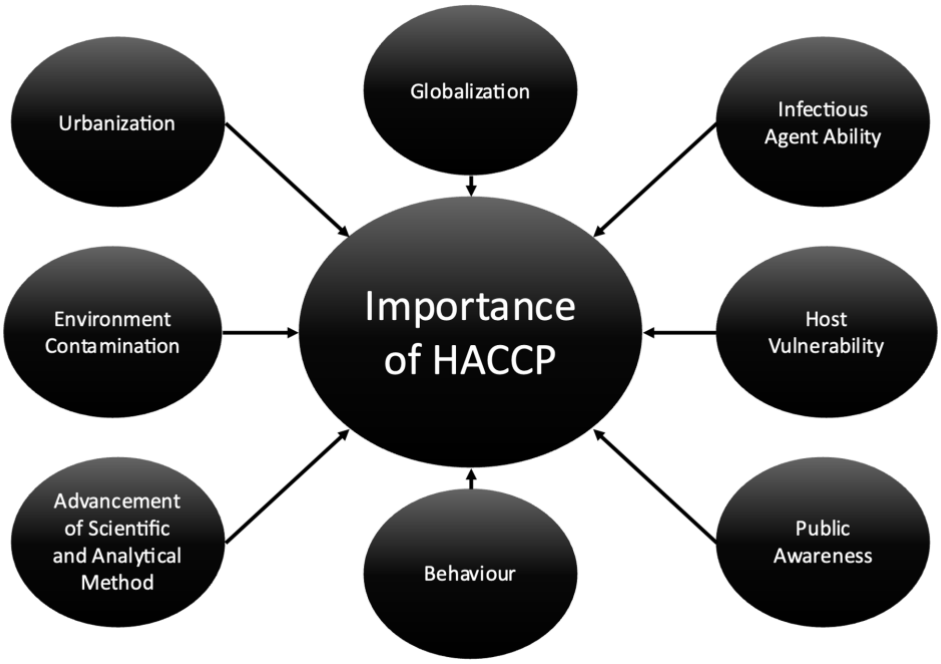

Figure 1: Importance of HACCP

The unique feature of these organisms makes the human susceptible to infection. It causes severe, life-threatening illnesses if the host has low immunity, such as in children and the elderly. World Health Organization (WHO) estimated that almost one out of ten people were ill after eating contaminated food, with more than 400,000 deaths annually (World Health Organization, n.d.). Most pathogens can cause gastrointestinal, neurological, gynaecological, and immunological problems. For example, acute gastroenteritis disproportionately affects children and is among the most common cause of death in children aged five years and below (World Health Organization, n.d.). In addition, people with low social status are more vulnerable to foodborne disease and its impact (Godinez-Oviedo et al., 2020). The emergence and spread of antimicrobial resistance in salmonella and campylobacter serotypes have also become a global public health concern (Marchello et al., 2019; Thomas et al., 2020). These pathogens were ubiquitous in food, animals, and meat (World Health Organization, n.d.), which potentially could be consumed by humans and cause infection.

HACCP serves as a crucial framework for preventing infectious disease risks posed by biological agents in food by systematically identifying, evaluating, and controlling potential hazards throughout the food production process. This proactive system operates by targeting critical control points (CCPs) where contamination risks are most likely to occur, such as during food processing, storage, or transportation. By implementing monitoring and corrective actions at these points, HACCP ensures that foodborne pathogens like Salmonella spp., Escherichia coli, Listeria monocytogenes, and others are effectively controlled before reaching consumers.

For example, temperature controls in CCPs can inhibit the growth of bacteria like Clostridium botulinum, which thrives in anaerobic conditions, while robust cleaning and sanitization practices can reduce the presence of pathogens such as Staphylococcus aureus and Campylobacter jejuni. HACCP also emphasizes the early detection of contamination risks

through regular inspections, microbial testing, and employee training. These measures are particularly important for addressing the unique survivability and resilience of pathogens such as Bacillus cereus and Salmonella, which can persist under extreme conditions.

Host Vulnerability

Most foodborne disease cases cause mild illnesses in humans. However, it can cause severe illness, significant morbidity, and mortality if individuals with the immunocompromised condition are affected. The population such as children, the elderly, immunocompromised states such as diabetes mellitus, people living with HIV, and long-course steroid medication use are vulnerable to severe infection from foodborne illness. According to WHO, the prevalence of HIV-infected people is increasing in trend. There were 37.7 million people estimated to be living with HIV by the end of 2020, with around 680,000 people dying from HIV-related causes (Frydrych et al., 2018). Meanwhile, individuals with uncontrolled diabetes mellitus are physiologically frail and at increased risk of infection and mortality due to sepsis. This condition is believed to be caused by immune system dysfunction triggered by chronic low-grade inflammation (Farouhi & Wareham, 2019). Globally, the prevalence of diabetes is increasing in trend. The number of people with diabetes was estimated to rise from 425 million in 2017 to 629 million by 2045 (Bahia & Suardi, 2019). The rising prevalence of diabetes was fueled by the increasing prevalence of obesity and changing lifestyles such as unhealthy diets and physical inactivity. The impact of globalization also fueled the excessive intake of fat, sugar, and salt, leading to the rising prevalence of diabetes and other associated health conditions.

HACCP is therefore vital in safeguarding vulnerable populations, such as children, the elderly, and individuals with immunocompromising conditions like diabetes and HIV. These groups are at heightened risk of severe outcomes from foodborne illnesses, including life-threatening complications such as sepsis, prolonged hospitalizations, and increased mortality. HACCP's preventive measures address these risks by implementing a structured and proactive system to control foodborne hazards at critical points throughout the food production and distribution process. For example, HACCP protocols ensure strict temperature controls to inhibit bacterial growth, proper handling and processing to avoid cross-contamination, and regular microbial testing to detect potential hazards early. For vulnerable populations, these measures provide a critical layer of protection, as their immune systems are less capable of fighting infections that might be mild in healthy individuals.

Following HACCP standards also ensures consistent monitoring and corrective actions to maintain food safety at every stage, from raw material procurement to consumer delivery. This systematic approach minimizes the risk of foodborne disease outbreaks, which disproportionately affect high-risk groups. Moreover, HACCP fosters accountability within the food industry, ensuring compliance with food safety regulations that protect vulnerable populations.

As the global prevalence of diabetes, HIV, and various comorbidity continues to rise, the implementation and adherence to HACCP become increasingly critical in reducing the burden of foodborne illnesses among these high-risk populations. By prioritizing food safety, HACCP not only protects public health but also reduces healthcare costs and improves the quality of life for the most vulnerable in society.

Public Awareness

Increased access to health information contributes to increased consumer awareness of food safety. Recently, public health officials often used social media and mainstream electronic media to reach various consumer backgrounds to enable every layer of society to access the needed health information. According to Global System for Mobile Communication Association (GSMA), almost half of the world's population are connected to the internet, which mainly contributes to the increased affordability of owning a mobile phone and increased internet access (Gedikoğlu & Gedikoğlu, 2021). High accessibility to mobile phones and internet access provides an opportunity for public health officials to utilize the medium to increase the reachability of food safety information to the public.

Increasing awareness about food safety is vital to enable the community to take action to prevent food-related illnesses. Community is encouraged to protect themselves from foodborne disease by practising self-hygiene, appropriately handling raw and ready-to-eat food, looking for food labelling before buying, and avoiding unhygienic food stalls. Consumer awareness regarding food safety allows the bottom-up approach to advocating the policy maker to improve their confidence about food safety through accreditation activities such as HACCP. A study conducted in the United States (US) found that 50% of its respondents (N=1,016) were willing to pay a premium price for HACCP-certified products (Hossain et al., 2023). Another study in Bangladesh indicates that the consumers are willing to pay a premium of 24.62% more for HACCP-certified frozen major carps (Rane, 2011). The findings show that HACCP certification significantly impacts consumer preferences and behavior by enhancing their confidence in food safety, encouraging informed purchasing decisions, and demonstrating a willingness to pay premium prices for HACCP-certified products, reflecting the growing value placed on food safety assurance.

The public's awareness and desire could drive the policy maker and food manufacturer to adhere to international standards for food safety. World Food Safety Day that is celebrated annually on 7th June can used as a medium for every stakeholder raising awareness regarding food safety that eventually can lead to better cooperation by the industries to adhere to the HACCP standards.

People’s Behavior

In today’s fast-paced world, many consumers rely heavily on external food sources, such as restaurants, food delivery services, and ready-to-eat meals, due to their busy schedules. This reliance heightens the risk of exposure to foodborne illnesses, as these food sources often involve complex supply chains and multiple handling stages where contamination can occur. A previous study found that food stalls are the source of food safety issues involve microorganisms belonging to genus Bacillus, Staphylococcus, Clostridium, Vibrio, Campylobacter, Listeria, and Salmonella (Law et al., 2014). The implementation of HACCP in such contexts is crucial to ensure that these external food sources adhere to rigorous food safety standards, minimizing the risk of biological, chemical, or physical contamination. By establishing critical control points across food preparation and distribution processes, HACCP ensures that food consumed by busy individuals remains safe, enabling them to trust the food industry with their health while maintaining their fast-paced lifestyles. In countries that have a robust HACCP certification program, its implementation has shown evidence of improvement in public health outcomes. In the United States, the implementation of HACCP in the meat, poultry, and seafood industries under the oversight of the USDA and FDA has contributed to a

reduction in foodborne illnesses caused by pathogens like Salmonella and Listeria (Williams et al., 2020).

Advancement of Scientific and Analytical Method

The availability of rapid detection tools to detect various food contaminants through the advancement of scientific and analytical methods emphasized the importance of HACCP in ensuring food safety. Rapid detection tools applied several methods in detection of food contaminants, including nucleic-acid based (i.e., simple polymerase chain reaction [PCR], multiplex PCR, real-time PCR, nucleic acid sequence-based amplification [NASBA], loop-mediated isothermal amplification (LAMP) and oligonucleotide DNA microarray), biosensor method (i.e., optical, electrochemical, and mass-based biosensors), and immunological-based method (i.e., enzyme-linked immunosorbent assay [ELISA] and lateral flow immunoassay) (Rather et al., 2017). The rapid detection tool helps prevent foodborne illness as it generally has high sensitivity and specificity, is cost efficient, saves time, reduces labour needs, and is more reliable than the conventional method. These rapid detection tools allow for the early identification of contaminants in food, thus providing information for policymakers and the public regarding food safety. Information regarding food contaminants emphasized the importance of food safety accreditation programs such as HACCP so that manufacturers are made accountable for the food manufacturing process to protect public health.

The integration of rapid detection tools strengthens HACCP by enabling the early identification of potential hazards at critical control points in the food production process. These methods provide high accuracy and quick results, allowing food manufacturers to act promptly to prevent contaminated products from reaching consumers. Additionally, these tools help food manufacturers maintain accountability, as the data generated can be used to demonstrate compliance with HACCP standards. For policymakers, the availability of precise information about food contaminants supports better decision-making and enforcement of food safety regulations. For the public, it increases trust in food safety systems, ensuring that HACCP-certified products meet stringent safety standards and protect public health effectively.

Environmental Contamination

Food contamination from the environment could occur due to natural phenomena or be introduced artificially by human activities. Many points in food manufacturing, from the processing of harvesting raw materials, processing, packaging, transportation, and storage, could be potentially at risk of contamination by biological, physical, and chemical contaminants (Wigley et al., 2005). Naturally occurring contamination in food can occur in several mechanisms, such as:

(i) some bacteria, viruses, and parasites have naturally inhabited the surface of foods;
(ii) raw food materials also can be contaminated by surrounding conditions such as sewage, soil, water, and animals that might be carrying the pathogenic organism;
(iii) the food materials originated from diseased animals; or
(iv) food materials also can be contaminated by chemicals that were accidentally consumed by the animal or plants.

Meanwhile, food contamination also can occur during food production, processing, packaging, delivery, and storage phases. In the production phase, the activity includes growing the plants to be harvested or raising the animal for future consumption. In the production phase, one example of food contamination is that Salmonella enterica serovar Pullorum can infect an

egg's yolk from an infected hen's reproductive organ (OECD, n.d.). During food processing, for example, animal slaughtering or cutting into pieces before the packaging, contaminants can enter the food materials. Subsequently, during the packaging, contaminants can enter the food product by a foreign object (i.e., glass, wood, stones, metal, etc.), chemical contamination from the packaging itself, or biological contamination due to improper packaging practices.

Furthermore, the food product can be contaminated during transportation because of prolonged exposure to suboptimal temperatures for food storage in the loading docks. Therefore, HACCP is required to identify critical points for controlling any identified hazard systematically. In addition, the rapid development of economic activities may also involve the innovation of new food products, which further emphasizes the importance of food safety accreditation activity.

Urbanization and Industrialization

Urbanization has become a global phenomenon in the 21st century. Urbanization has predominantly risen because of economic interest, leading to increased migration, the growth of new urban areas and the extension of urban administrative boundaries. Some people tend to move from one location to another due to pull and push factors. Urbanization occurs when there is an increasing proportion of population in certain areas, leading to a large number of people becoming concentrated in a relatively small area, forming a city (Abdullah et al., 2012). Urbanization can be an issue contributing to food safety. Urbanization can result in soil, air, and water pollution from waste and emissions from residential areas, industries, and vehicles.

A study in Klang Valley, Malaysia, one of the urban areas in Malaysia, found that the metropolitan area has severe acidified rain with the highest number of unhealthy days of air quality level (Hossain et al., 2015). The increased concentration of ground ozone level, particulate matter and various air pollutants could contaminate the soil and water and subsequently contaminate the feeding area for livestock and plants for human consumption. Another study in Gebeng Industrial City, Pahang, Malaysia, shows high mean concentrations of arsenic, barium, cadmium, copper, mercury, nickel, lead, and zinc in industrialized soils (Onakpa et al., 2018). The soil and water pollution, as well as the usage of pesticides in the urban and industrialized area, are most likely to cause heavy metal contamination to food crops and is associated with an adverse health outcome, such as cancer (FAO, 2024). Furthermore, urbanization can result in higher food demand to meet increasing population density. Protection of food safety through HACCP can potentially help prevent contamination of heavy metals and other contaminants into food products for urban inhabitants' consumption. Additionally, with urbanization comes the rise of food delivery services, which introduce risks related to improper handling, temperature abuse, and microbial growth during transportation. HACCP implementation in urban food service providers helps monitor and maintain the cold chain, ensures proper packaging, and reduces risks of contamination, ensuring the safety of ready-to-eat meals delivered to urban dwellers.

Integration of food safety measures into the design and management of urban environments could ensure sustainable and safe living conditions for growing urban populations. For example, urban farming initiatives are becoming a popular solution for increasing local food production in cities. HACCP can be applied to identify and control risks such as soil contamination, water quality issues, and improper use of fertilizers and pesticides (Hannan et al., 2022). This ensures that food produced in urban areas is safe for consumption and aligns with public health goals.

Globalization

Globalization is a process of interaction and integration related to social, cultural, and economic aspects. Globalization has accelerated economic growth, partly due to advancements in transportation and communication technology. The development of a new city stimulates the migration of people, contributing to the increasing population. High population density subsequently contributes to the growing food demand. To meet the rising food demand requires large-scale food production and process and will be distributed over greater distances. Expansion of food trading has increased the chance of unsafe food produced in one country and affects consumers in other countries.

Furthermore, the high volume of imported foods, as well as the diversified origin and growing complexities of technology used, the traditional method of monitoring food safety might no longer be adequate. Without a standardised form of overseeing trading partners' production process, it is pretty impossible for authorities in charge of food safety to adequately address the issue and protect the consumer in the country. Implementing a food assurance program such as HACCP that is universally recognized and accepted food assurance could potentially ensure that imported food is safe for consumption in the receiving countries.

The United States mandates HACCP compliance for seafood imports under FDA regulations. Countries like Vietnam and Thailand, major seafood exporters, implemented HACCP systems in their processing plants to meet U.S. safety standards, resulting in increased market access and reduced rejection rates of their exports. A study showed that Thailand's adoption of HACCP for shrimp processing improved product quality and helped maintain its position as a leading exporter to the U.S. and European Union (Hannan et al., 2022). In addition, the European Union (EU) requires all imported dairy products to comply with HACCP standards. Countries such as New Zealand, known for its robust HACCP implementation in dairy production, successfully export high volumes of dairy products to the EU without significant regulatory barriers (Fonterra, n.d).

Conclusion

The HACCP is an effective method for food safety assurance. Its implementation effectively prevents harmful social, health, and economic consequences. Implementation of HACCP through targeted control of significant food risks, the industry can assure its customers that its food products are safe based on the scientific method. Furthermore, reduction of food risk also can enhance public health protection. The increasing trend of food and waterborne disease, drug-resistant infection, ageing population and non-communicable disease, changing consumption patterns, advancements in scientific and analytical methods, environmental contamination, urbanization, and globalization emphasized that HACCP is indispensable and should be adopted by every food industry.

Conflicts of Interest

The author would like to declare that there is no conflict of interest.

Acknowledgements

The author would like to thank the Universiti Malaysia Sabah for permission to publish this paper.

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