



Food safety – From pioneering steps to the modern scientific discipline

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ABSTRACT

Food safety is a story that unites all civilizations, cultures, and nations, and it is interlaced with various methods for making food safer. Concern for nutritious and safe food is as ancient as humankind itself, and many of the food safety issues that persist today are not new. Diverse records from the ancient world, as well as the religious writings of the three monotheist religions, actually refer to food, its intake, and prohibitions, as well as pathological diseases that may follow from inappropriate intake. Over time, food safety has evolved into a scientific discipline concerned with the handling, preparation, transport, and distribution of food to avoid the transmission of illnesses. The current state of food safety knowledge is the result of past discoveries, innovations, and laws. In modern times, the right to consume safe food is a fundamental human right. It contributes to and promotes sustainable development while supporting the economy, trade, and tourism. Nevertheless, despite significant improvements, we still know relatively little about food-borne illnesses and how infections affect humans.

Keywords: Food safety development; foodborne diseases; history

INTRODUCTION

Concern for food safety is probably old as human history itself. Today's knowledge of food safety is the result of numerous discoveries, inventions, and regulations whose pioneering steps can be found in the history of civilization (1). Food safety has evolved into a modern scientific discipline that focuses on a complex process that begins on the farm and ends with the consumer (2). It describes the handling, preparation, and storage of food in a manner that prevents foodborne illness (3).

The incidence of foodborne illness is a significant health problem regardless of the level of economic development of countries. Harmful pathogens or chemicals present in unsafe foods can cause more than 200 different diseases of varying severity. Their prevention is possible through proper food preparation. It is estimated that 1.8 million people die each year from diarrheal diseases, and most of these cases are due to contaminated food or water (4). It is believed that the actual prevalence of foodborne illness is

300–350 times higher than the number of reported cases and that the available data on the incidence of the disease represent only the “tip of the iceberg” (5).

Food safety is one of the most important public health issues (6). It is a fundamental right of every individual (7), and governments around the world are stepping up efforts to ensure rights that are critical to sustaining life and promoting good health (5). Its importance is reflected in the United Nations goals to “end hunger by 2030, ensure access to food for all, especially for poor and vulnerable populations, including young children, and ensure that everyone has a safe, nutritious, and sufficient amount of food throughout the year” (8).

FOOD SAFETY IN THE OLD WORLD

Food safety is a story that runs through civilizations and nations. It is believed that ancient peoples began to develop basic forms of food preparation, storage, and preservation to provide themselves with sufficient quantities during periods of bad weather. From today's perspective, we can say that these were rudimentary attempts to consume safer food (9). The development of the first silo is associated with the ancient Egyptians. The Bible and the Qur'an describe the famous story of Jacob's son Joseph who, in years of plenty, ordered the storage of harvested grain to bridge 7 years of

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severe grain shortages. Ancient books also describe various methods by which the ancient Egyptians protected stored grain from pests, using dust, some forms of fumigation, and pyrolysis of olibanum (9). The ancient Romans were also known to salt food to preserve it. In regions with large salt deposits (Mesopotamia), they discovered that this mineral was essential for survival and was a natural preservative. Although they did not know that harmful microorganisms needed moisture to survive, they knew that meat dried in salt could be preserved much longer than fresh meat and that it had no harmful effects on them (10). The Chinese Confucian Analects from 500 B.C. warned against eating sour rice, rotten fish or meat, and food that were too stale or undercooked as part of consumer education (11).

One of the earliest reports of food safety in the market dates back to the Zhou Dynasty (1046–256 BC). Several rules for food trade were codified in the Book of Rites. One of the rules states that unripe fruits should not enter the market. The rulers of the Ming and Qing dynasties (1368–1111 B.C.) decided that food-related deaths were crimes equivalent to assault and murder. During the Tang Dynasty (618–907 BC), it was legislated that any food that could cause poisoning due to corruption should be burned immediately. Merchants and officials who dealt with this type of food were severely punished (12).

During the Vedic period in India (1700–500 BC), a highly developed culture of food preparation developed. They believed that mental health was related to the purity of food. Before preparing and eating meals, they were required to practice increased personal hygiene measures. Food processors were required to bathe before preparation and were not allowed to speak, cough, or spit. Indo-Aryans were also particular about hygiene and cleanliness of dishes. Earthenware plates had to be baked in a fire before they could be used for serving (13).

It is very difficult to say exactly what food-borne diseases our ancestors suffered from because there is no direct evidence. However, based on an understanding of their environment and lifestyle, we can assume that they were related to the consumption of animal and fish flesh, poisonous mushrooms, and raw, indigestible grains (1). One of the most famous cases of foodborne illness occurred in India in 483 BC. According to tradition, Gautama Buddha died near the city of Kushinagar in North India after allegedly ingesting contaminated food offered to him by a blacksmith named Cunda. The various texts do not agree on the content and nature of this meal, but given the short period of time between illness and death, one of the possible causes of death could be the toxin of *Bacillus cereus*, often present in cooked rice that had been stored for a long time in unsuitable conditions (13). According to Greek historians, the 32-year-old ruler Alexander the Great (323 BC) developed abdominal pain and malaise after a meal. The illness worsened until death. For centuries, it was believed and suspected that he was poisoned by his enemies, until, in 1998, scientists from the University of Maryland set out to investigate the historical data. They concluded that he probably died from a foodborne illness, so he was diagnosed with typhoid fever with intestinal perforation and paralysis (14).

THE BIBLICAL RECORD OF FOOD AND FOOD HYGIENE

The laws of ancient Israel contained advice on foods to avoid, preparation methods, and the importance of food hygiene. The Book of Leviticus, two thousand years before Christ, states that Moses instituted laws to protect his people from foodborne illness, such as washing clothes and bathing after slaughtering sacrificial animals (15). There are several references in the Old Testament to food, its consumption, prohibitions, and diseases that can result from improper consumption. Interestingly, one of the first laws listed in the Bible is the law concerning food: "... you may eat of every tree of the garden, but of the tree of the knowledge of good and evil you shall not eat; for in the day that you eat of it you shall die" (16). Probably, the reference to "every tree in the garden" refers to God's intention that all humans be vegetarians to begin with (14). After the Flood, however, God allowed Noah and his followers to eat animal flesh under certain conditions, with the Book of Genesis establishing the first restriction on blood consumption that served as the basis for all the remnants of Jewish dietary law (12). "Everything that moves and lives shall be food for you. And as I have given you the green plants, so I give you everything. But you shall not eat flesh with its life, that is, its blood" (17). It has a deeper meaning and statement. Apart from the tendency of the Jews to behave differently toward the peoples around them, the prohibition of blood consumption is also recognized as a preventive measure due to the possible transmission of the disease through infected animals. The laws and prohibitions of the Old Testament were formulated very simply and purposefully not only with a religious motive but also with a deeper scientific and health background that led to a healthy daily life for the Jews. The Book of Leviticus also contains instructions on the proper disposal of the blood of captured animals (17:13), the prohibition of eating fat (7:22-24), and the division of animals allowed for food (11:2-48) (18). From a scientific point of view, these prohibitions can be considered justified. Considering the fact that the Jews lived in a rather warm climate, the instruction that meat must not contain blood so that it could be consumed is explained by the fact that blood is an extremely good substrate for the growth and development of many microorganisms (19). Moreover, it is now known that the intake of high-calorie fats leads to obesity and cardiovascular disease. The Holy Book also points out the importance of hygiene and the proper use of utensils (19:15) to protect against contamination. In the 19th century, this was demonstrated by Louis Pasteur in experiments with wine and the causes of spoilage (20).

FOOD FROM THE PERSPECTIVE OF THE QUR'AN

The Qur'an instructs Muslims and tells them that they may eat any food that is halal (Arabic word, means lawful or permitted) (21). In the Qur'an, 119 verses are dedicated to eating and drinking. In Surah Al-Baqarah, the first laws on eating are written down: "O people! Eat from the permissible and pure things on earth and do not follow the footsteps of Satan" (2:168), "O believers! Eat of the pure things with which We have provided you, and give thanks to Allah if it is He whom you serve" (2:172), "He has forbidden you only the carrion and the blood and the flesh of swine and that over

which the name of other than Allah has been pronounced. However, whoever is compelled (to eat of them) – and he does not desire them and does not exceed the indispensable measure – he does not commit a sin. Allah is Oft-Forgiving, Most Merciful” (2:172-173) (22). The Qur’an emphasizes that food must be consumed in appropriate amounts, that is, neither too little nor too much. It is recommended that during the meal, one-third of the stomach be filled with food, the other third with water, and the third-third be left empty. This prevents overeating and greed and is also a form of learning. Apart from the definitions related to halal food, Muslims must follow numerous instructions regarding the quality of food and the stages of processing. There are numerous verses that refer to the appropriate choice of soil for cultivation (7:48), storage of good food (8:37; 4:100; 3:179), and consumption of good fresh food (3:141; 7:147; 20:81). Concealment of quality, adulteration, and evil deeds are not accepted in Islam and are not loved by Allah (28:77; 2:204) (23). Islam, like Judaism, assumes that man is affected as a whole, his body, mind, emotions, and soul. If we compare these attitudes with the World Health Organization’s definition that “health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” (24), we conclude that the holy books attached special importance to the elements of health and its maintenance.

FOOD SAFETY – FROM SKILL TO SCIENCE

Historical records contain very little information about foodborne pathogens. In principle, it can be said that the history of food safety itself does not exist, but that numerous discoveries, many of which were accidental, various inventions and regulations have led to the present knowledge and development of food safety as a very important branch of public health (1). Even ancient civilizations knew that food could spoil and cause disease, and evaluation was within the realm of human experience and subjective judgment. However, it is surprising that these scientists were very successful in terms of the number of recognized associations between certain contaminants and their negative effects on health. For example, the earliest record of Egyptian medicine, the Papyrus Ebers (1500 BC), contains data on more than 800 recipes and formulas describing many poisons that lead to various health disorders (25). Furthermore, early food regulations were not enacted to make food safer, but to prevent food adulteration and possible economic fraud (1). Attempts to adulterate food were widespread in antiquity. The ancient writer Pliny the Elder (I AC) documented the greed of merchants and their deception by stating that many poisons are used to adapt wine to our tastes and that we should not be surprised if it is not healthy (26). The development of food safety continued with Hippocrates and his students. Much of their work reflected concern about the purity of air, water, and food and included excellent descriptions of the effects of the environment on public health. For example, the ancient Greeks and Romans respected the fact that clean water and food were essential for good health (27). Hippocrates-related general human health and disease to natural, not supernatural, causes. At the same time, the “Chinese Hippocrates” Pien Chio published studies that contained similar correlations. Both

Hippocrates and Pien Chio recognized certain useful techniques for mitigating the effects of natural pollutants on human health. However, until various other factors were introduced into the food safety assessment process itself, it remained a retrospective observation of events rather than a predictive, preventive process. In addition, the nature of the observation process limited the assessment to an acute toxic phenomenon. It was difficult for people to intuitively attribute the observed phenomenon several years after the event itself, so the chronic effects of contaminants in food were not considered at that time.

The development of food safety assessment capabilities required the transformation of the process from an observational one to a science. Early English laws primarily required that certain quantities of food be sold at a certain price. However, it soon became apparent that food prices could not be controlled without adequate regulation of food quality. Therefore, in 1266, the English Parliament passed the Assize of Bread and Ale Regulation, which prohibited the sale of all staple foods that were “not wholesome to the human body” (28). This was the first law in British history to regulate the production and sale of certain foods, affecting the price, weight, and quality of bread and ale produced and sold in towns and villages (29). In France, a comprehensive economic document, the *Livre des métiers*, states, “Everything that can cause harm, everything that is a counterfeit, must be prevented, and forbidden.” It also mentions the subjects to whom these rules apply, “bakers, butchers, cooks, etc.,” details such as “forbidden addition of saffron because of the false impression of the use of eggs, as well as concealment of the spoilage of food” (30). In the mid-16th century, the German natural scientist Paracelsus wrote: “Every substance is a poison; the right dose distinguishes between poison and medicine.” This aphorism first formulated the concept of a dose-response curve and is considered the beginning of modern toxicology and food safety risk assessment (31). In some European cities, laws and regulations on street cleaning existed as early as the 14th century. However, the collected waste was often dumped into the rivers near the cities, resulting in contamination of fish that were carriers of various diseases such as dysentery and cholera. Salmonellosis and staphylococcal infections were common during this period, especially in South France and in the Pyrenees (32).

Microorganisms have been unknown for thousands of years. Francesco Redi, an Italian physician and poet, challenged theories about the spontaneous generation of organisms in 1668. However, this was not enough to convince the sceptics. In 1665, Robert Hooke published the first illustrated book on microscopy, *Micrographia*, with a detailed description of the structure of *Mucor* spp. In 1676, Antonie van Leeuwenhoek observed a drop of water from a pond with a microscope designed by Hooke and found that small living things were moving, in which he called “animalcules.” It was the first documented depiction of a living microworld and a confirmation that there are living things that are invisible to the naked eye and that we can only see when we use technology to magnify them. Nevertheless, it took another 100 years to establish the existence of microorganisms and their capacity for fermentation processes. Thus, it was not until 1768 that the Italian scientist Lazzaro

Spallanzani finally disproved the theory of spontaneous generation (33).

Louis Pasteur shed light on the relationship between food spoilage, disease, and microorganisms with his work on fermentation and pasteurization in the 1860s and 1870s. In 1872, German scientist Ferdinand Julius Cohn published a three-part study on bacteria, establishing microbiology as a science. He was the first to attempt to classify bacteria into genera and species, and he was the first to describe bacterial spores. In 1876, based on Pasteur's principles, Robert Pasch published the first demonstration that a particular microorganism could cause a particular disease in an animal model. In 1881, he published his technique of isolating pure bacterial cultures, which led to the isolation and characterization of all bacterial causes of disease known at the time. His assistant Julius Richard Petri proposed the use of shallow glass vessels with lids, now called Petri dishes after him. In 1884, he published what became known as Koch's postulates (34). However, the concepts developed by Pasteur and Koch were not applied to problems of foodborne illness until several decades later. A major advance in food preservation was the development of canning, which followed the research of Nicolas Appert in France and the subsequent activities of Peter Durand in England in the early 19th century. The discovery by French inventor Nicholas Appert, also known as the "father of canning," that food could be preserved longer by heat treatment and vacuum packaging led to the development of the modern science of food processing and safety. Appert used stoppered glass bottles to preserve food, while Durand introduced the concept of metal cans (35).

In 1835, James Paget and Richard Owen first described the parasite *Trichinella spiralis*. German pathologists Friedrich Albert von Zenker and Rudolph Virchow first noted the clinical symptoms of trichinosis in 1860. However, the link between trichinosis and the parasite *Trichinella spiralis* was not recognized until much later. In 1855, a non-pathogenic form of *Escherichia coli* was discovered. It later became an important research tool for biotechnology and food safety. In 1857, William Taylor, an Englishman, showed that typhoid fever could be transmitted by milk. Daniel Salmon, an American veterinarian, described a microorganism in 1885 that, when ingested through contaminated food, causes gastroenteritis and fever. These bacteria were later named *Salmonella* (36). August Gaertner, a German scientist, was the first to isolate *Bacillus enteritidis* and confirmed it as the cause of food poisoning after eating the meat of a sick cow. Emilie Pierre-Mare van Ermengem, a Belgian bacteriologist, first isolated the causative agent of botulism, the bacterium *Clostridium botulinum*, in 1895. The case occurred after eating uncooked, salted ham. Twenty-three people became ill and three died. Van Ermengem isolated *C. botulinum* from both the ham and the intestines of one victim. He demonstrated that the microorganism grows in an oxygen-free environment and produces a toxin that causes disease (1). In 1897, Samuel C. Prescott and William Lyman Underwood published an article demonstrating for the 1st time that foodborne illness was due to microbial contamination and that heat treatment could destroy these organisms. This led to the establishment of time-temperature relationships necessary to ensure predictable and consistent commercial sterility of heat-treated foods (37). The first half of the 20th century was

marked by the discovery of "traditional" bacterial pathogens in food. *Salmonella* spp. was found to originate from warm-blooded animals, *C. botulinum* from improper food preservation, while M. A. Barber demonstrated that *Staphylococcus aureus* was associated with poor hygiene and caused food poisoning (34). In 1945, *Clostridium perfringens* was first recognized as a causative agent of food poisoning. It was not until 1975 and 1985 that some of today's most important foodborne pathogens were discovered – *Campylobacter jejuni*, *Yersinia enterocolitica*, *E. coli* O157: H7, and *Vibrio cholerae* (1).

MODERN TIMES

The rapid development of international trade and the expansion of food distribution systems have significantly increased the potential for the possible spread of foodborne diseases. This has caused great concern among consumers themselves, as well as in the food industry. Existing food control systems that guaranteed safety have been challenged. As a result, many countries have embarked on a major reform of their food safety management systems to find effective ways to protect consumers.

In 1976, the Food and Agriculture Organization of the United Nations (FAO) and WHO took great interest in improving the efficiency of national food control systems. They produced guidelines that provided advice to developing countries on strategies to protect public health, prevent fraud and deception and adulterated foods, and facilitate trade. Over the years, there have been developments and advances in all areas, starting with technology, scientific discoveries, and the promotion of culture. The flip side of the coin was the emergence of new foodborne diseases, and some of the old diseases became more resistant and common. Lifestyles were changing, as were food technology itself. The importance of raising food safety and quality standards was addressed in a new code entitled Assuring Food Safety and Quality, published in 2003 by FAO and WHO. This updated document and guidelines focused on developing an integrated food control system based on risk assessment. The guidelines are based on scientific principles and involve all sectors of the distribution chain, providing a preventive approach to food control. This was particularly important for countries where the effectiveness of food control is compromised by fragmented legislation, different responsibilities, and weaknesses in control and monitoring. Efforts were made to enable authorities to approve and adopt the most appropriate options for their food control systems in terms of legislation, infrastructure, and enforcement mechanisms. The entire program is based on a range of safety threats and food-related crises. Governments have recognized that their systems are not capable of ensuring consumer health protection. There was a need to update and modernize all food inspection regulatory systems. Today, many governments are centralizing their food inspection systems to fully restore consumer confidence. Experience in some countries has shown that consistency in implementation has increased, communication has become more efficient, and coordination of food safety activities has improved (38). In addition, consumer demand for safe and high quality food is growing daily. According to a survey conducted by the Croatian Food Agency in Croatia, 32%

of respondents believe that the food they eat is very or fairly likely to harm their health (39).

Today's goals of healthy food production are to provide hygienic, safe food and thus reduce foodborne illness, lower the cost of treatment and hospitalization, and increase labor productivity, as well as overall economic progress. This is achieved by taking the necessary measures to apply Codex Alimentarius standards to imported and exported foods, as well as to production and trade in a given country, and by complying with the International Code of Ethics for Food Trade to ensure that food products meet national requirements and/or international food safety requirements. With the globalization of the market, food safety and quality have become more important internationally and are the responsibility of governments, producers, as well as consumers. The globalization of the market offers the opportunity to improve nutrition and health by providing a sufficient quantity of biologically valuable food, but it also poses dangers and new risks to food safety if someone in the complicated chain of food production, distribution, and consumption does not comply with existing standards or ethical codes. Previously, responsibility for food safety was attributed exclusively to producers and legislation; today, increasing emphasis is being placed on the consumer (40).

A series of food-related incidents in the late 1990s drew attention to the need to establish general principles and requirements regarding food for humans and animals at the European Union level. The European Commission has, therefore, developed an integrated approach to food safety "from field to table," most notably outlined in the White Paper on Food Safety. This sets out the principles and plans of European food safety policy, such as modernizing legislation into a coherent and transparent regulatory framework, strengthening field-to-table controls, and improving the capacity of the scientific advisory system to ensure a high level of protection, human health, and consumer protection (41).

The adoption of European food law or Regulation (EC) No. 178/2002 established a new approach to food safety. Regulation (EC) No. 178/2002 of the European Parliament and of the Council of January 28, 2002, laying down the general principles and conditions of food law, establishing the European Food Safety Authority (EFSA) and laying down procedures in matters of food safety. Regulation (EC) No. 178/2002, the implementation of which is ensured by the Food Act, provides the basis for ensuring a high level of protection of human health and consumer interests in relation to food, in particular taking into account the differences in food supply, including traditional products, while ensuring the efficient functioning of the internal market. EC Regulation (EC) No. 178/2002 lays down the general principles governing food and feed in general, and food and feed safety in particular, at the level of the European Union. These principles, which are applied in the framework of the integrated approach "from field to table," that is, at all stages of production, processing, and distribution of food and feed, include in particular risk analysis and prevention, the precautionary principle, and the protection of consumers' interests. Under food law, it is not permissible to place on the market food that is unsafe or harmful to health and/or unfit for human consumption. In determining whether a food is unsafe, the following factors must be considered: The normal

conditions of use of food, the information provided to the consumer, possible immediate or delayed effects on human health, possible cumulative toxic effects, and the particular health sensitivities of specific consumer groups (42).

Hazard Analysis and Critical Control Point – an acronym for HACCP – is a systematic method for identifying, evaluating, and controlling food safety hazards. HACCP was developed in the United States in the early 1960s to facilitate food preparation for astronauts. At the same time, following a *S. aureus* poisoning incident, the U.S. Army was investigating a system to produce safe food for its troops. The National Aeronautical and Space Administration (NASA) commissioned Pillsbury to develop a zero-tolerance food safety system that became HACCP. The system was first used in the U.S. meat industry before being adopted by other sectors of the food industry. It is a tool for identifying and evaluating potential hazards in food production and establishing preventive control procedures for identified hazards. Because the emphasis is on hazard prevention, traditional inspections and testing of the final product are reduced. HACCP is internationally recognized as an effective means of ensuring food safety. The concept can be applied to new or existing products or processes throughout the food chain from primary production to consumption. It is compatible with existing management system standards ISO 9001 and ISO 22000, and its application is mandatory at all stages of the food chain worldwide. Although the HACCP concept was not originally prescribed for primary production, it is now used in a simplified form to ensure safety in the food supply chain, especially for retail chains and large companies (43).

CONCLUSION

Food safety has evolved over time into a scientific discipline concerned with the handling, preparation, and processing of food to prevent the occurrence of diseases transmitted through it. As a result, all scientific opinions on food safety issued today by the relevant administrative bodies and agencies are always under the scrutiny of producers and consumers. The focus is on producers, that is, the companies that produce food and that are required by law to bring safe-to-eat and high-quality food to the market. Foodborne illness and the impact of pathogens on humans are still largely unknown. Data that predict trends in the incidence and intensity of foodborne illness often cover multiple industrialized countries and multiple pathogens. On the other hand, diseases causing diarrhea due to contaminated food and water are often found to be on a declining trend based on the assumption that microbiologically safe food production, transportation conditions, and especially retail conditions have improved, especially in the developing countries trying to compete in the global market.

DECLARATION OF INTERESTS

There are no conflicts of interest to declare by any of the authors of this study.

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