

Food Defense: An Introduction

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ABSTRACT

The global food system became extremely vulnerable in the 21st century. The intentional threats and intentional contamination of the food chain is a real threat to society. This has the potential to disrupt food distribution, consumer loss of confidence in government and the food supply.

Food and water chains are very important infrastructures, and it is the country's or government's obligation to ensure the provision of sufficient qualities and quantities of food and water to its population. Intentional food contamination can, among other motives, originate from an act of terrorism (with political or ideological motives) with the aim of causing fear (terror) among people. Food defense systems are to help in accessing vulnerabilities, determine mitigation strategies for terrorist attack, estimate risks, and to prevent a terrorist attack.

This paper presents a brief introduction on food defense, challenges and the way forward.

KEYWORDS: Food defense, Food terrorism, Food defense systems, Contamination, Foodborne diseases

INTRODUCTION

Food defense is the protection of food products from intentional contamination or adulteration by biological, chemical, physical, or radiological agents introduced for the purpose of causing harm. Its additional concerns include physical, personnel and operational security [1].

Food defense is one of the four categories of the food protection risk matrix which include:

- Food safety – This is based on the unintentional or environmental contamination that can cause harm.
- Food fraud – This is an intentional deception for economic gain,
- Food quality – This is also affected by profit-driven behavior but without intention to cause harm, and
- Food defense - This is the protection of food products from intentional contamination or adulteration by biological, chemical, physical, or radiological agents introduced for the purpose of causing harm.

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The above four categories is “food security” which deals with individuals having access to enough food for an active and healthy life. Along with the protection of the food system, food defense also deals with prevention, protection, mitigation, response and recovery from intentional acts of adulteration [2].

In May, 2016 the Food and Drug Administration (FDA) of the United States of America issued the final rule on Mitigation Strategies to Protect Food against Intentional Adulteration with requirements for covered facilities to prepare and implement food defense plans [3], as shown in Figure 1.

Food defense events are into three types of categories which may be carried out by:

- A disgruntled employee
- A sophisticated insider and or
- An intelligent adversary with a specific goal in mind.

It should be noted that an event may contain aspects of more than one category. This can be [4]:

- Industrial sabotage

- Terrorism and
- Economically Motivated Adulteration (EMA).

HISTORY OF FOOD DEFENSE

After the September 11, 2001 tragic events, the United States government was curiously concerned that terrorist organizations might seek to contaminate parts of American food supply. Therefore, in December 2001, the Food and Drug Administration (FDA) and the United States Department of Agriculture (USDA) dialogued with a number of security professionals in the food industry to determine the current state of readiness against an intentional attack. The information gathered was not encouraging. The protection of food products from intentional contamination was not a priority by some companies.

By 2003, government agencies like FDA, USDA, and the Department of Homeland Security began the use of the term “food defense” to describe the efforts to protect food products from deliberate or intentional acts of contamination or tampering. Documentation of intentional food contamination incidents throughout the world has been on before 2001. The report by G. R. Dalzeil in the study by the Centre of Excellence for National Security (CENS) said that between 1950 and 2008, there were approximately 398 confirmed incidents of contamination and approximately 125 unconfirmed incidents. The study confirmed that 42 percent of the incidents occurred in the US; the UK and Austria combined accounted for 60 percent [5]. In July, 2012, needles were found in sandwiches served on a US based international airline on four separate flights [6, 7].

FOOD CONTAMINANTS

The World Health Organization (WHO) 2002, defined food terrorism as “an act of threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian populations and or disruption of social, economic or political stability”. In this context “food” includes crops, farm animal minimally processed and processed foods and water (whether for drinking, used as a food ingredient or for use in food processing). “Eco-terrorism” by extension, covers the ideologically-motivated destruction of crops or animals and associated research facilities [8].

Biological materials and chemicals are the most likely used agents for food contamination. Just little amount of contaminated product would be sufficient to harm large populations and or cause injury or damage over a broad geographical region, since food is easily transported and distributed quickly over a large

geographical area. The contamination of food has been recorded in history for as early 8,000 years ago; while the growth in agribusiness and globalizations have aided the problem in spreading all over the planet [9].

Salter reported that the US Centre for Disease Control and Prevention has confirmed more than 11,000 foodborne infections in the year 2013, with several agents like viruses, bacteria, toxins, parasites, metals, and other chemicals causing food contamination [10], as shown in Figure 2.

TYPES OF FOOD CONTAMINATION

Food contamination can be of very serious consequences for both the consumers and food businesses. All foods are liable to be affected by any of the four types of food contamination mentioned below:

- Chemical contamination.
 - Microbial contamination.
 - Physical contamination.
 - Allergenic contamination.
- Chemical contamination is as a result of contamination by some kind of chemical substances. It could be from chemical residue in the kitchen e.g. sprays of cleaning chemicals, or from fertilizers and pesticides etc.
 - Microbial contamination is due to contaminations by microorganisms, including bacteria, viruses, fungi, mould, Salmonella or E. coli, and toxins. This is the most common reason for the outbreak of food poisoning.
 - Physical contamination occurs when a food is contaminated by a foreign object, which can occur at the stage of food delivery and preparation. Physical contaminants could be cloth, stones, bones, hairs, jewellery, plastic and pest bodies.
 - Allergenic contamination – this occurs when a food that causes an allergic reaction comes into contact with another food. There are fourteen (14) named allergens, which include things like gluten, peanuts, eggs, mustard, soy, and fish [11, 12].

DEFINITIONS AND SCOPE

Food terrorism (WHO, 2002) is defined as an act or threat of deliberate contamination of food for human consumption with chemical, biological or radionuclear agents for the purpose of causing injury or death to civilian populations and or disrupting social, economic or political stability [13].

The chemical agents in question are man-made or natural toxins, and the biological agents referred to are communicably infectious or non-infectious

pathogenic microorganisms, including viruses, bacteria and parasites. Radioactive agents are defined in this context as radioactive chemicals capable of causing injury when present at unacceptable levels.

Terrorism also has an impact on food supply. According to Zellen, “terrorist attacks on the food supply sector termed agro terrorism includes the contamination of food processing and distribution systems through exposure to chemical, radiological or biological agents, and or the physical destruction of crops” [14]. When terrorists attack food supply, three major effects take place which are: economic destruction, loss of political support and confidence, and social instability. Economic disruption occurs at three levels viz:

- Direct losses resulting from containment measures and the eradication of disease-ridden livestock.
- Indirect multiplier effects from compensation paid to farmers for the destruction of agricultural commodities.
- International costs in the form of protective embargoes imposed by major external trade partners.

POTENTIAL EFFECTS OF FOOD TERRORISM/FOOD CONTAMINATION

- Illness and death – Food is the most vulnerable to international contamination by debilitating or lethal agents. It must be noted that many developing countries lack basic food safety infrastructures and are vulnerable to deliberate acts of sabotage. The impact of contaminated food on human health can be very catastrophic e.g. the unintentional outbreak from one food, such as clams, which affected 300,000 people in China in 1991 and may be largest foodborne disease in history [15]. The potential health effects of a terrorist attack must be taken very seriously by the health community and by those responsible for assessing and countering terrorist threats. The health implications of food contaminants in many cases range from mild to severe.
- Foodborne diseases number about 48m illnesses in the U.S. Gould et al., discovered that chemically contaminated food has serious implications on the health of individuals [16]. The harmful effects range from minor gastric problems to major health fatalities. The major and likely source of human exposure to metals is through food consumption. Metals like cadmium and lead easily enter the food chain. Heavy metals in the body deplete specific nutrients, leading to

decline in the immunological defenses, impair psycho-social facilities, and cause in trauterine growth retardation. The consumption of heavy metals as discovered by Khan et al., was associated with malnutrition and the increased rates of gastro-intestinal diseases [17]. Food contaminants also cause cancer [18]. Food contaminated by Polychlorinated biphenyls (PCBs) can have adverse effect on children’s neurological development and the immune response [19]. Pesticides can also cause severe health implications, such that excessive levels of these chemicals in food could cause neural and kidney damage, congenital disabilities, reproductive problems, and can be carcinogenic [20]. The accumulation of pesticides in the body tissues can result in metabolic degradation [21]. There is also the risk of neurodevelopmental disorders such as attention deficit disorders, autism, cerebral palsy and mental retardation caused by industrial chemicals such as arsenic, PCBs, and lead in both food and water. Exposure to these chemicals in the fetal stages of development can cause brain injury and such lifelong disabilities at much lower doses than those which can affect adult brain function [22].

- Economic and trade effects – Food contamination may have enormous economic implications by terrorists to cause economic disruption, used as a primary motive for deliberate act, targeting a product, a manufacturer, an industry or a country.

For instance, in 1978 in order to damage Israel’s economy, citrus fruit exported to several European countries was contaminated with mercury, which led to significant trade disruption.

The alleged contamination of Chilean grapes in 1989 with cyanide led to the recall of all Chilean fruit from Canada and the USA, and the publicity surrounding this incident resulted in a boycott by American consumers. This consequently resulted to damage that amounted to several hundred million dollars and more than 100 growers and shippers who went bankrupt [23].

- Impact on Public Health – Public health services can be paralysed by foodborne illnesses, whether unintentional or intentional. A look at the 1995 attack with nerve gas on commuters on the Tokyo subway station, while not foodborne, shows the effects of a coordinated terrorist attack on an unsuspecting population. The response however to the incident was prompt and massive [24]. Many countries, most especially the developing countries do not have the capacity to such

massive emergencies, which does not include consideration of food safety.

- Social and political implications – Terrorists have a variety of motives, ranging from revenge to political destabilization. Most often, they target the civilian population in order to create panic and threaten civil order. Fear and anxiety lead to reduced confidence in the political system and government, and can result in political destabilization. When the effects are economic and lead to loss of incomes for some sectors of the society, the political impact can be exacerbated.

GLOBAL BURDEN OF FOODBORNE DISEASES

The 2015 WHO report on the estimates of the global burden of foodborne disease was the first-ever presented estimates of burden caused by 31 foodborne agents (bacteria, viruses, parasites, toxins and chemicals) at global and regional level.

The 2018 World Bank report on the economic burden of the foodborne diseases indicated that the total productivity loss associated with foodborne disease in low-, and middle-income countries was estimated to cost US\$95.2b per year, and while the annual cost of treating foodborne disease is estimated at US\$15b. Annually worldwide, unsafe food causes 600m cases of foodborne diseases (FBD) and 420,000 deaths. 30% of foodborne deaths occur among children under 5 years of age. It has been estimated by WHO that 33m years of healthy lives is lost due to the eating of unsafe food globally each year {i.e. 33m healthy life years (DALYs)} [25], and this number is likely to be an underestimation. Foodborne diseases are preventable and WHO has a critical role in taking leadership in investment and coordinated action across multiple sectors in order to build strong and resilient national food safety systems and provide consumers with tools to make safe food choices. With food safety receiving relatively little political attention, especially in developing countries, having a reliable data on the actual national burden of foodborne diseases is essential to draw attention and mobilize political will and resources to combat foodborne diseases. After eating contaminated food 1 out of 10 people fall ill. Diarrheal are the most common illnesses resulting from the consumption of contaminated food, causing 550m people to fall ill and 230m deaths annually. Unsafe food creates a vicious cycle of disease (diarrhea) and malnutrition, affecting particularly infants, young children, elderly and the sick, threatening the nutritional status of the most vulnerable. Foodborne diseases impede socioeconomic development by straining health care

systems, and harming national economies, tourism and trade [26].

ENSURING FOOD SAFETY

Unsafe food poses global health threats, endangering everyone. The most vulnerable are infants, young children, pregnant women, the elderly, and those with underlying illness. Every year 220m children contract diarrheal diseases and of which 96,000 die. Unsafe food creates a vicious cycle of diarrheas and malnutrition, threatening the nutritional status of the most vulnerable.

The International Conference on Food Safety held in Addis Ababa in February 2019, and the International Forum on Food Safety and Trade held in Geneva in 2019, reiterated the importance of food safety in achieving the Sustainable Development Goals.

Governments at various levels should make food safety a public health priority, by developing policies and regulatory frameworks, and establishing and implementing effective food safety systems as shown in Figure 3.

The contamination of food can occur at any point of production and distribution, and the primary responsibility lies with food producers. A large proportion of foodborne disease incidents are caused by food improperly prepared or mishandled at home, in food service establishments or at markets.

What are the “Big 5” foodborne pathogens? The Big 5 is a group of highly infectious foodborne pathogens, which are [27]:

- Norovirus
- Salmonella
- Clostridium perfringens
- Campylobacter
- Staphylococcus aureus (Staph)

The less frequent causes of foodborne illness may include:

- Clostridium botulinum (botulism)
- Listeria
- Escherichia coli (E. coli)
- Vibrio

CHALLENGES

Some of the challenges to safe food among others include [28, 29]:

- Changes in consumer habits, urbanization, travels, which have increased the number of people buying and eating food prepared in public places.
- Globalization has also increased consumer demand for a wider variety of foods, resulting in an increasingly complex and longer global food chain.

- Due to increase in the world population (population growth), there would be intensification and industrialization of agriculture and animal production to meet the ever increasing demand for food, which further creates both opportunities and challenges for food safety.
 - Climate change is also predicted to impact food safety.
 - Greater responsibilities are now placed on food producers and handlers, as well as governments to ensure food safety as a result of these challenges, locally, nationally and globally.
 - In developing countries where financial resources are scarce, food control issues usually receive low priority in public health programmes. Foodborne illnesses are perceived as mild, self-limiting diseases and their health and economic consequences are often overlooked.
 - Lack of information in most developing countries leads to underestimation of the health significance of unsafe food.
 - In the developing countries, no resources at all are assigned to food safety, and food control measures and while foodborne disease investigation and surveillance are neglected.
 - As no data on foodborne illnesses or other health and economic effects of unsafe food are generated, policy-makers continue to give the subject low priority, and so the cycle continues.
 - When there is a serious foodborne disease outbreak, food control matters receive attention for a few days and are highlighted by the media, once the emergency is over, it is soon forgotten and the experience gained is not translated into management decisions.
 - Many farmers are uneducated and use century old methods of production, and they live in very close contact with their animals, increasing the likelihood of foodborne zoonoses.
 - Methods of harvesting and storing grains increase the likelihood of problems caused by toxins and mycotoxins.
 - Lack of control over sales and use of veterinary drugs and pesticides.
 - Irrigation water is most often polluted.
 - Distance to markets and or processing centres are often long, coupled with inefficient transport system.
 - Lack of technology to prevent contamination of agricultural products, thereby rendering such products unsuitable/unsafe for export.
 - Food industries in developing countries/small concerns are not well informed or lack knowledge about food safety issues or their own responsibilities in this regard.
 - Lack and or limited knowledge of modern technologies, good manufacturing practices, good hygiene, Hazard Analysis and Critical Control Point (HACCP) systems and quality control.
 - Inadequate storage facilities/cold storage systems, and while water used in food processing facilities may not be of suitable quality.
 - Most labourers in the factories that handle food and those on the farms are uneducated or untrained and illiterates.
 - Poor household food handling and storage practices that cause foodborne illness create a drain of funds that could have been used for development. Hence, the need for consumer education and the communication of information on emerging foodborne hazards, since many foodborne diseases originate/have their origin in the household kitchen.
 - Under Laws, Regulations and Standards: Food safety legislation may be absent, rudimentary, fragmented, outdated and not in harmony with Codex Standards and related texts.
 - Food law enforcement, including import control, is fragmented and uncoordinated. There is no national food safety monitoring or surveillance systems or databases, coupled with poor communication between government agencies and the food industry.
 - Some developing countries are unable to participate in international bodies such as the Codex Alimentarius Commission (CAC) and the World Trade Organization (WTO), resulting in the lack of understanding of national obligations.
 - Resources: Food safety personnel are scarce and not optimally trained.
- CONCLUSION**
- Considering the fact that food and agriculture form part of the critical infrastructure of every country in the world, it then behooves everyone involved in these sectors to support the establishment of a coordinated strategy at the regional and national level to protect the food supply by conducting reasonable risk assessments and developing realistic defensive strategies.
- The World Health Organization (WHO), cum other international organizations should synergize all efforts to combat foodborne diseases globally, since

the impact will affect everyone, with the most vulnerable being the infants under 5 years of age, young children, pregnant women, and the elderly. Food defence systems to counter agriterrorism (food terrorism) must urgently be put in place by all developed and developing nations to prevent human destruction in the nearest future by the terrorist groups worldwide, through mitigation strategies against attack.

Developing countries, particularly need to brace up to this challenge in allocating enough financial and human resources with other logistics (e.g. improved surveillance, well developed laboratory capacity) to combat foodborne diseases. For this to be achieved in most developing countries, corruption (the bane of underdevelopment) must be fought to a standstill in order to ensure all round development in other critical sectors of the economy. Political leaders must wedge the political will, in collaboration with government agencies and food industry to ensure and enhance food safety/food security for the ever increasing human population and for socioeconomic development. More information relating to Food Defense can be found on the following Websites:

- Biological and Toxin Weapons Threat to the United States, <http://www.nipp.org/Adobe/Toxin%Weapons2pdf>
- WHO, <http://www.euro.who.int/foodsafety>
- European Union, Food safety, http://europa.eu/pol/food/index_en.htm

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Food Defense: Essential to a Comprehensive Emergency Management Plan

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Readiness and Emergency Management for Schools Final Grantee Meeting ~ National Harbor, Md. ~ Aug. 5, 2009

Figure 1. Food Defense Plan.

Source:https://commons.wikimedia.org/wiki/File:2009_Food_Defense_United_States_Department_of_Education.pdf



Figure 2. Food Contamination
Source: <https://en.wikipedia.org/wiki/Salmonellosis>

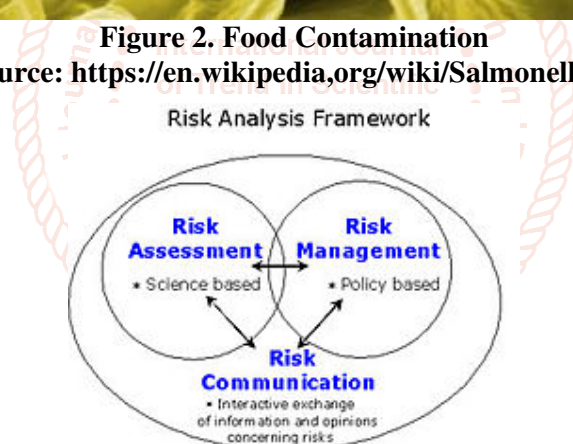


Figure 3. Food Safety System.
Source: https://en.wikipedia.org/wiki/Food_safety_risk_analysis