



Bacterial Contamination in Food: Sources, Risks, and Prevention Strategies

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims: to revisited the route of microbial contamination of food which can cause morbidity and mortality to vulnerable individuals and how proper food handling practices and specific intervention can prevent it

Discussion: Unsafe foods due to bacterial contamination contribute to morbidity and mortality and the most common causative agent is bacteria such as *Salmonella thyphi*, *Escherichia coli*, *Campylobacter spp*, *Staphylococcus aureus*, *Listeria monocytogenes*, *Clostridium perfringens*, *Vibrio parahaemolyticus* and *Bacillus cereus*. Poor personal hygiene, improper food handling combined with the existence of this opportunistic organisms can facilitate entry for these bacteria to their host. By tightly controlling the environment and other supporting conditions, potentially harmful bacteria will not be able to survive, grow, and multiply, or in other word will never be able to cause definite illness. In the food processing, controlling potentially harmful and potentially dangerous microorganisms is crucial for ensuring food safety and quality. There are six factors that affect bacterial growth, which can be directed to by the mnemonic FATTOM, namely Food source, Acid,

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Temperature, Time, Oxygen and Moisture. The implications of understanding microbial contamination for public health and its food safety regulations could minimize the risk of bacterial contamination in food.

Keywords: Cross contamination; hygiene; sanitation; FATTOM; food safety; GI tract; food handler; vector.

1. INTRODUCTION

Bacteria are the most common cause of global foodborne diseases [1] which roughly estimates two-thirds of human major food-borne zoonotic diseases worldwide with towering burden in developing countries [2]. "Food contamination during travelling to previously mentioned countries presents unique risks to those affected and recently become a trend in epidemiology. This food contamination can cause infection" [3] of the gastrointestinal (GI) system or even worse, its toxin can cause intoxication of the GI tract [4].

Bacterial gastroenteritis is an infection restricted to digestive tract which solely caused by bacteria. It caused non pathognomonic symptoms include nausea, vomiting, fever, diarrhea, abdominal cramping, and pain [1-4]. Some common bacteria that contaminate food include

- *Salmonella* spp- usually related to consumption of raw or undercooked meat, poultry, and eggs or egg products or by drinking unpasteurized milk [5],
- *Escherichia coli*- contaminate foods like raw or undercooked meat, raw milk, fruits, and vegetables. It can also contaminate foods during preparation if surfaces or utensils are contaminated [6],
- *Campylobacter* spp- prevalent in food animals like poultry, cattle, pigs, sheep, and ostriches, as well as pets like cats and dogs and humans can become infected with *Campylobacter* by consuming contaminated or undercooked food, or by touching animals or their belongings [7],
- *Staphylococcus aureus* which its relationship with the occurrence and development of diabetes mellitus [8] and in the context of Staphylococcal food poisoning (SFP) is a common foodborne illness caused by ingesting *S. aureus* enterotoxins, which are heat resistant and produced in contaminated food [9],
- *Listeria monocytogenes*- a rare but serious foodborne disease with a significant public health concern because of its high mortality rate [10],

- *Clostridium perfringens*- a common cause of food poisoning, and outbreaks are often associated with large groups of people being served food [11],
- *Vibrio parahaemolyticus*- related to the consumption of raw or undercooked shellfish or contaminated water [12], and
- *Bacillus cereus*- a facultative anaerobic, toxin-producing gram-positive bacterium found in soil, vegetation, and food such as beef, turkey, rice, beans, and vegetables [13].

The most common biological agent responsible for food contamination is due to bacteria. Some bacteria have predilection to raw or undercooked food, e.g., the rod shape gram-negative *Salmonella* spp [5], the motile gram negative *Campylobacter* spp [7], the motile gram-negative *E. coli* [6]; while some have the tendency causing food poisoning, e.g., the gram-positive, rod-shaped, non-spore-forming *Listeria* [10], *Staphylococcus aureus* the Gram-positive, coccus-shaped bacterium that forms clusters that look like grapes [8,9], the rod-shaped, gram-positive, anaerobic toxin producer *Clostridium perfringens* [11], the gram-negative, rod-shaped, facultative anaerob *Vibrio parahaemolyticus* [12] and the Gram-positive aerobic or facultative anaerobic, motile, spore-forming, rod-shaped *Bacillus cereus*.

Poor personal hygiene [14], improper food handling [15] combined with the existence of this opportunistic organisms [3] can facilitate the *port de entrée* for these bacteria enter their host. For example, People who carry the bacteria *Staphylococcus aureus* (Staph), which is commonly found on the skin as part normal human microbiota [16], can contaminate food if they do not wash their hand properly before eating [17].

"The world is challenged with nourishing an enormous expanding population with paradoxically more and more limited resources, including the essential food chain" [18]. The increasing complexity of food supply chains, its production, and distribution of food products may increase the risk for sustainable food supply.

“Food contamination with microbial agents can take place at any stage of the food chain, from farm to fork [19]. It can have happened in a number of ways, including due to poor handwashing” [20], cross-contamination which can take place in domestic or public kitchen [21], inappropriate storage which caused food spoilage and food waste [22], cooking temperatures in the danger zone [23] and eat raw food/ ingredients [24]. Foods that are high in water such as ready to reheat vegetable soup [25], starch that high in bread or cereal [26], or protein such as in biofilm formation of spoiled meat [27] are more likely to be contaminated because they facilitate an ideal growing media for bacteria overgrowth [22,28]. Cross-contamination can happen anywhere during processing, packaging, storage, and even transport [21,29]. Serving contaminated food [30] or at least unknown origin of comestibles [31] can lead to food-borne illness outbreaks; A confirmed foodborne disease outbreak is defined as an incident in which two or more persons experience a similar illness after ingestion of a common food or meal or drink and epidemiologic evaluation implicates the meal or food or drink as the source of illness. Confirmed outbreaks may or may not be laboratory-confirmed.

The aim of this mini review was to revisit the route of microbial contamination of food which can cause morbidity and mortality to vulnerable individuals.

2. ROUTE OF CONTAMINATION

The most common cause of food contamination is poor food handling [32]. This includes not washing hands at the appropriate time [33] – before eating [34] and preparing food [35] or after using the toilet [36], or after blowing nose, coughing or sneezing [32]. A study conducted by Mihalache et al [37] revealed that washing hands with warm water and soap for 20 second is the most effective method investigated when hands are either dirty or greasy. Even if not proper washing, rinsing under running water for 5 second is a cleaning procedure that may significantly reduce the probability of cross-contamination, as it removes 90% of the hands’ dirt. Although less effective than water and soap, the usage of antibacterial wipes was significantly more effective than wet wipes, indicating that they are a better choice when water and soap are not available.

“In addition to the food handler contribution to food contamination, using dirty utensils, such as

knives and grater [38], kitchen sponges” [39], other cutlery such as dish, spoon, fork [40], poor practice of not properly washing fruits and vegetables with clean water prior to consumption- even when those fruits and vegetables look so fresh [41], and storing raw and cooked food in the same place which actually increased the risk of cross contamination [42].

“Sick people should not handle food because he/she can contaminate food and spread illness to others. Especially for food handler, he/she should not come to work if he/she have a fever, sore throat, cough, runny nose, or other cold and flu symptoms. They should also not come to work if he/she have vomiting, diarrhea, jaundice, or a fever accompanied by a sore throat” [43,44].

Consuming under-cooked foods, particularly meat, is definitely not recommended [45]. Several publications regarding raw meat which can contain bacteria like *Salmonella* [5,46], *Listeria* [10, 47], *Clostridium difficile* [48], *Campylobacter* [7,49], and *E. coli* [6,50]. These bacteria can live on the meat and spread to other foods if it is not managed properly [51].

Poor farming practices can also allow bacteria to contaminate food. This includes the heavy use of pesticides and antibiotics which favor resistant bacteria strain [52], or watering and irrigating fruits and vegetables using contaminated soil and water [53], or during field cultivation [54]. The practice of implicating inadequately composted or raw animal manure or sewage is also potentially harmful, especially in long term [55].

Fresh foods can lead to a number of illnesses. In Kenya, for instance, the contamination of meat, fruits and vegetables with human waste is relatively common. This is attributed to the use of contaminated water to wash food. Flies carrying contaminants can also directly transfer fecal matter and bacteria onto plant leaves or fruits.

Another aspects of route of transmission is by street foods are another common source of food contamination [56]. These foods are widely consumed in low- and middle-income countries because their affordable price easily accessible [57]. “The hygiene of street food depends heavily on how it is handled while it is raw, cooked, and consumed along with the eating utensils they use” [58]. Unhealthy food handling practices applied by street food vendors are an important cause of food contamination [32,56-58]. These

chain of issues include inappropriate locations for the production of street food [59], poor quality raw materials [59,60], inappropriate water quality and supplies. Besides that, inadequate waste management practice and its disposal facilities also led to potential hazards of contamination [61].

“The general sources of microbiological contamination for these food street vendor include the location of food preparation and food showcase [62], the cooking and serving equipment used, the raw materials used” [63], and the personal hygiene practice of the food handler [66]. Due to the ease contamination of microbes and the growth of foodborne diseases, street foods can be a source of these illnesses [56-64]. Food hygiene and safety all be negatively affected by street food vendors' lack of adequate education background [57] and insufficient understanding due to poor knowledge [56], and may contain contaminants that provide a higher risk due to physical, chemical, and biological elements, necessitating a comprehensive examination of food safety and hygiene conducted by the authority in order to keep the safety margin of this kind of food.

3. CAN IT BE PREVENTED?

By keeping proper food hygiene and hand hygiene practices, until the level of individual, can minimize the spread of foodborne illnesses [65]. Keeping food hygiene is key to preventing the escalate of food safety hazards and foodborne illnesses that can jeopardize human life. Appropriate and proper food handling and storage (e.g., separating between the raw and cooked food) can prevent most foodborne illnesses. In order for pathogens to grow in food, certain conditions must be present, one of them is temperature [23]. By controlling the environment and conditions, even if potentially harmful bacteria are present in the unprepared or raw food [24,45-48, 50], they will not be able to survive, grow, and multiply, or in other word will never be able to cause definite illness.

In the food processing, controlling potentially harmful and potentially dangerous microorganisms is crucial for ensuring food safety and quality. There are six factors that affect bacterial growth, which can be directed to by the mnemonic FATTOM, namely Food source, Acid, Temperature, Time, Oxygen and Moisture. Each of these six factors contributes to bacterial growth in the following ways:

- Food source: Bacteria require food to survive [66]. For this reason, moist [25], starch [26], and protein-rich foods [27] are good potential sources of bacterial growth. Plant-based extracts include several compounds endowed with antimicrobial activity [67], e.g., terpenes [68], phenolic compounds [69] and Allyl isothiocyanates [70]. These three compounds have shown efficacy against spoilage microorganisms (including bacteria, yeasts, and fungi) and foodborne pathogens [68-70]. Plant-based extracts have been extensively applied to minimize microbial growth in different types of foods and to prevent the distribution of foodborne pathogens and antibiotic resistance [71]. The antimicrobial action of plant extracts (e.g., control of microbial growth, reduction in biofilm production) depends on the chemical structure of the extract and the specific microbial targets [72]. Unfortunately, despite the antimicrobial properties of these plant extracts, their application as potent food preservatives are restricted by their stability during processing or storage ambience [73]. Several strategies have been suggested to amplify its stability by way of spray-drying, encapsulation, inclusion in biopolymers, etc.). However, plant extracts can be contaminated with several dangerous toxic substances or have the potency to accumulate unwanted dangerous substance such as mycotoxins, heavy metals, residues of crop protection products [74]. Due to this reason, safety matters regarding the application of plant extracts are of great interest.
- Acid: Bacteria do not grow in acidic environments [75]. This is why acidic foods like lemon juice and vinegar able to inhibit the growth of certain pathogenic bacteria and can be used as preservatives, as reported by Sengun on carrot [76], citric acid in red wine [77], etc.
- Temperature: Most bacteria will grow rapidly between 4°C and 60°C (40°F and 140°F). This is referred to as the danger zone (see the section below for more information on the danger zone).
- Time: Bacteria require time to multiply. When small amount of bacteria is already existing, the initial risk is usually low in the beginning, but extended time with the right conditions will allow the bacteria to multiply and increase the risk of contamination [78]. That is why optimization of food storage

has become a central issue for food science and biotechnology, especially in the field of functional foods [78,79].

- Oxygen: due to the types of bacteria which divided based on their oxygen need, namely the aerobic and anaerobic bacteria. The aerobic necessitate oxygen to grow; without sufficient oxygen, this aerobic will fail to live multiply and also preserve the food better, e.g., in an oxygen-free environment such as a vacuum-packaged container [80]. Anaerobic bacteria will only manage to survive and grow in oxygen-free milieu. Food that has been improperly processed and then stored at room temperature can be at risk to be contaminated by anaerobic bacteria. A common example is a product containing harmful *Clostridium botulinum* (botulism-causing) bacteria [81] that has been erroneously processed during canning [82], and then is consumed without any further cooking or reheating. Recent advancements revealed that in non-thermal physical treatments namely ionizing irradiations present an alternative to thermal sterilization, although with some limitations, to reduce number of vegetative cells and spores of this bacteria [83].
- Moisture: Bacteria need moisture to survive and will grow rapidly in moist foods [84]. Water activity is the most important factors that should be considered in controlling the microbial growth in food products. This is the reason why dry or salted foods are at lower risk of being hazardous from the perspective of bacteria growth inhibition [85].

The implications of understanding microbial contamination for public health and its food safety regulations could minimize the risk of bacterial contamination in food. Good hygienic and manufacturing practices are needed along the entire food chain to prevent microbial contamination. Collaboration between governments, food producers, and consumers is needed to ensure food safety [86,87].

4. CONCLUSION

Unsafe foods or food contamination which contribute to morbidity and mortality commonly caused by bacteria such as *Salmonella* thyphi, *Eschericia coli*, *Campylobacter* spp, *Staphylococcus aureus*, *Listeria monocytogenes*, *Clostridium perfringens*, *Vibrio parahaemolyticus*

and *Bacillus cereus*. Its underlying condition such as poor personal hygiene, improper food handling combined with the existence of this opportunistic organisms facilitate transmission and then entry to the host. By carefully controlling the environment and other supporting conditions, pathogen bacteria will fail to survive, grow, and multiply. In the food processing, controlling potentially harmful and potentially dangerous microorganisms is crucial for ensuring food safety and quality. There are six factors that restrict bacterial growth, which can be directed to by the mnemonic FATTOM, namely Food source, Acid, Temperature, Time, Oxygen and Moisture. The implications of understanding microbial contamination for public health and its food safety regulations could minimize the risk of bacterial contamination in food.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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