

Prevalence and conditions responsible for food contamination: a review

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Abstract— Food and food products may be altered by different contaminants like micro-organisms, chemicals, natural toxins and foreign matter. Food provides an ideal nutritional source for micro-organisms and generally creates an excellent environment for proliferation of these micro-organisms includes virus, bacteria, mould and parasites. Contamination from chemical sources can also occur through accidental mixing of chemical supplies. The use of various chemicals such as food additives, pesticides, veterinary drugs and other agro-chemicals can also pose risk if such chemicals are not properly regulated or appropriately used. Most of the food poisoning incidents occurs as a result of mishandling of food like keeping/storing at inappropriate temperature, incorrect re-heating, and cross contamination. Food may be contaminated during production, processing, preparation and handling. Different type of preventive programs should be used to ensure food safety and quality of processed foods like GMPs, SSOPs, HACCP etc. and other preventive measures are also needed to apply all the way from farm to table.

Keywords— Food, Contaminants, Micro-organism, Toxin, GMPs, SSOPs, HACCP

1 INTRODUCTION

The food system is a complex, concentrated and dynamic chain of activities that begins with the production of raw materials from different industries like agriculture, dairy and poultry etc and moves to value-added processed and manufactured products and then to retail food stores and food-service establishments where the products are prepared and finally sold to consumers [1].

Food provides an ideal nutritional source for micro-organisms and generally creates an excellent environment for proliferation. Major contamination sources are water, air, dust, equipment, sewage, insects, rodents, and employees. Most food poisoning incidents are a result of mishandling food - keeping it at the wrong temperature, incorrect re-heating, and cross contamination [2]. During harvesting, processing, distribution and preparation, food may be contaminated with soil, air and water borne micro-organisms [3]. Contamination from chemical sources can occur through accidental mixing of chemical supplies with foods; these chemical contaminants may be metals, polychlorinated biphenyls (PCBs) and dioxins. The use of various chemicals such as food additives, pesticides, veterinary drugs and other agro-chemicals can also pose risk if such chemicals are not properly regulated or appropriately used [4]. Food-borne diseases result from the ingestion of contaminated foods and food products and include a broad group of illnesses caused by parasites, chemicals and pathogens which contaminate food at different points in the food production and preparation process [5].

Contamination can be minimized through effective house-keeping and sanitation, protection of food during storage, proper disposal of garbage and litter, and protection against contact with toxic substances [3].

2 HISTORY OF FOOD-BORNE DISEASES

Food-borne diseases are a wide spread and continuously

growing public health problem across the globe. The global incidences of food-borne diseases are difficult to estimate, but it has been reported that in 2000 around 2.1 million people died from diarrhoeal diseases. In industrialized countries, the percentage of people suffering from food-borne diseases every year has been reported to be up to 30% [6]. In USA around 76 million cases of food-borne diseases, resulting in 3,25,000 hospitalizations and 5,000 deaths are estimated to occur every year⁵ whereas in Asia about 91 million people infected with shigellosis each year, out of which 4,10,000 children die because of malnourishment [7].

In 1988, an outbreak of Hepatitis A, resulting from the consumption of contaminated clams, affected around 3,00,000 individuals in China [6]. In 1994, an outbreak of Salmonellosis due to contaminated ice cream occurred in USA, affecting an estimated 2,24,000 persons [6]. During 1993–1997, in USA, a total of 2,751 outbreaks of food-borne disease were reported (489 in 1993, 653 in 1994, 628 in 1995, 477 in 1996, and 504 in 1997). These outbreaks caused a reported 86,058 persons to become ill. Among outbreaks, bacterial pathogens caused the largest percentage of outbreaks (75%) and the largest percentage of cases (86%). *Salmonella enteritidis* accounted for the largest number of outbreaks, cases, and deaths. Most of the outbreaks of *Salmonella enteritidis* were attributed to eating eggs. Chemical agents caused 17% of outbreaks and 1% of cases; viruses, 6% of outbreaks and 8% of cases; and parasites, 2% of outbreaks and 5% of cases [8].

In India, the armed forces reported that food poisoning affecting 78 personal at high altitude, wherein *Salmonella enteritidis* was identified as the etiological agent. In Delhi, 2002, a food-borne outbreak affecting 130 nurses from a hospital, associated with eating salad sandwiches, was diagnosed to be due to Norwalk-like virus. In Coimbatore, 2006, nearly 8% of eggs and 7% of egg-storing trays from retail markets were found to be contaminated with *Salmonella* spp. (mainly *Salmo-*

nella enteritidis). In Maharashtra, 2007, *Listeria monocytogenes* was isolated from 105 (5%) milk samples collected from 52 farms. In Madhya Pradesh, 2007, a food-borne outbreak of *Staphylococcal aureus* due to contaminated snack affected more than 100 children and adults. In a study from Cochin, 2009, *Bacillus cereus* was isolated from 29% of fish (finfish, prawns and clams) samples [2].

3 CLASSIFICATION OF FOOD-BORNE DISEASES

Food-borne diseases can be classified into two categories [2]: *Food-borne infections* - caused by consuming foods or liquids contaminated with bacteria, viruses, or parasites. And *Food-borne intoxications* - caused by consuming foods or beverages already contaminated with a toxin.

4 TRANSMISSION OF FOOD-BORNE PATHOGENS AND TOXINS

Food is a very good vehicle for the transmission of microorganisms and other contaminants (for both beneficial and pathogenic) and with pathogenic contaminants it causes serious sickness [8]. Table 1 [9], [10], [11], [12], [13], [14], [15], [16] shows food as a vehicle for transmission of different pathogens and the diseases caused.

TABLE 1
FOOD AS A VEHICLE FOR PATHOGENS

Food source (as vehicle)	Disease	Pathogen
Meats, Stews, Gravies, Vanilla sauce	<i>Bacillus cereus</i> food poisoning	<i>Bacillus cereus</i>
Raw and undercooked poultry, Unpasteurized milk, Contaminated water	<i>Campylobacteriosis</i>	<i>Campylobacter</i> spp.
Meats, poultry, gravy, dried or precooked foods, temperature-abused foods	<i>Perfringens</i> food poisoning	<i>Clostridium perfringens</i>
Undercooked beef, unpasteurized milk and juice, raw fruits and vegetables and contaminated water	<i>Hemorrhagic colitis</i>	<i>Escherichia coli</i> O157:H7
Forage, meat, eggs, pork, unpasteurized milk, raw milk products, seafood	<i>Listeriosis</i>	<i>Listeria monocytogenes</i>
Eggs, poultry, meat, unpasteurized milk or juice, cheese, contaminated raw fruits and vegetables	<i>Salmonellosis</i>	<i>Salmonella</i> spp.
Protein-rich food, meat, poultry, fish, milk, cheese, custards and much handled food such as sandwiches, pasta, potato salad	<i>Staphylococcal</i> food poisoning	<i>Staphylococcus aureus</i>
Food, water or milk that was contaminated by infected food handler	<i>Shigellosis</i>	<i>Shigella</i> spp.

5 CONDITIONS RESPONSIBLE FOR FOOD CONTAMINATION

Food may become contaminated during production, processing, during food preparation and handling [2]. During food production and processing foods can be contaminated if washed or irrigated with contaminated water. Animals naturally harbour many food-borne bacteria in their intestines that can cause illness in humans, but often do not cause illness in the animals. During slaughter, meat and poultry carcasses can become contaminated if they are exposed to small amounts of intestinal contents. Food can be contaminated during food preparation and handling by Infected individuals, Cross-contamination, Inadequate cooking temperature etc. Most food-borne pathogens are present in infected persons and these pathogens may be transferred to others through food via the faecal-oral route. Bacteria present in infected lesions and normal nasal flora may also be transmitted from an infected food-handler to ready-to-eat foods.

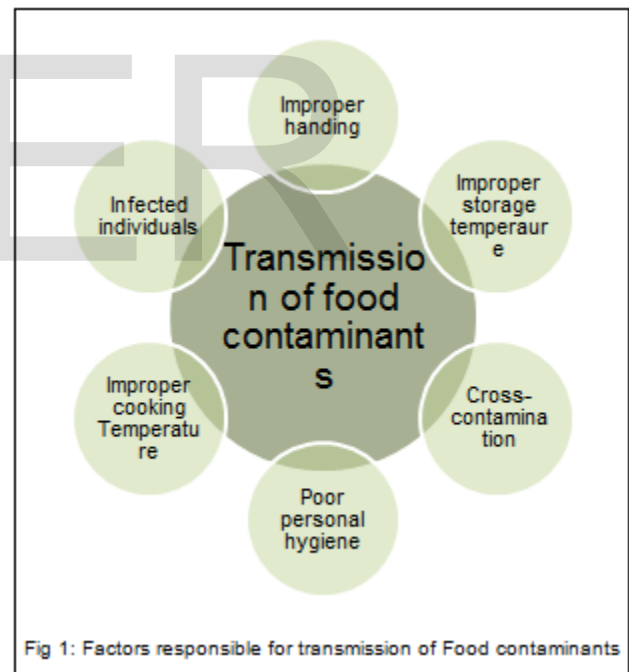


Fig 1: Factors responsible for transmission of Food contaminants

6 TYPES OF FOOD CONTAMINANTS

“All substances are poisons; there is none which is not a poison if present in improper quantity” [17]. Food can be contaminated by different types of contaminants - microorganisms, chemicals, natural toxins or foreign matter etc. The most prominent emerging problems are of microbial origin, other than biological contaminants, chemical agents are also a cause for concern [18]. (Table 2) [19], [20], [21], [22], [23], [24]

TABLE 2
COMMON MICROBIAL FOOD CONTAMINANTS

Bacteria	
Causative agent	Disease caused
<i>Bacillus cereus</i>	<i>Bacillus cereus</i> gastroenteritis
<i>Campylobacter</i> spp.	<i>Campylobacteriosis</i>
<i>Clostridium botulinum</i>	Botulism
<i>Clostridium perfringens</i>	<i>Clostridium perfringens</i> enteritis
Enterotoxigenic <i>E. coli</i> (ETEC)	Travellers diarrhoea
Enteropathogenic <i>E. coli</i> (EPEC)	Hemorrhagic colitis
<i>Listeria monocytogenes</i>	Listeriosis
<i>Salmonella typhi</i>	Typhoid fever
<i>Salmonella paratyphi</i>	Paratyphoid fever
<i>Salmonella</i> spp. (non <i>Typhi</i>)	Salmonellosis
<i>Shigella</i> spp.	Shigellosis (bacillary dysentery)
<i>Staphylococcus aureus</i>	Staphylococcal food poisoning
<i>Vibrio cholerae</i> O1 and O139	Cholera
<i>Vibrio parahaemolyticus</i>	<i>Vibrio parahaemolyticus</i> gastroenteritis
<i>Yersinia enterocolitica</i>	Yersiniosis
Virus	
Hepatitis A virus	Hepatitis A
Hepatitis E virus	Hepatitis E
Norovirus	Viral gastroenteritis
Rotavirus	Rotavirus gastroenteritis
Protozoa	
<i>Cryptosporidium</i> spp.	Cryptosporidiosis
<i>Toxoplasma gondii</i>	Toxoplasmosis
<i>Entamoeba histolytica</i>	Amoebiasis (amoebic dysentery)
<i>Cyclospora cayentensis</i>	Cyclosporiasis

7 CONTAMINATION IN FOOD INDUSTRIES

Food-borne illnesses have an impact in both developing and developed countries. Around 1.5 billion cases of diarrhoea in children under three years of age occur in developing countries [21]. In any public health programmes, food control issues usually receive low priorities. And with a lack of information thus leads to use of contaminated or unsafe food. Food-borne problems have their origin in the farming methods practised. Many farmers are uneducated and follow methods of production that are centuries old. They live in very close contact with their animals, thereby increasing the chances of food-borne zoonosis. Methods of harvesting and storing grain increase the frequency of problems caused by toxic seeds and mycotoxins.

The food industry includes many small concerns that are not well informed about food safety issues. Knowledge of modern techniques, good manufacturing practices, hygiene, hazard analysis, Critical Control Point (HACCP) systems and quality control are often limited or absent. Storage facilities, including cold storage, may be inadequate, and the water used in food processing facilities may not be of a suitable quality. Many of the labourers who handle food in factories and on farms are illiterate and untrained [19].

7.1 Dairy and dairy products

Milk and milk products are a rich and convenient source of nutrients for people. Milk and milk products have the potential to cause food borne illness because almost all dairy animals may carry human pathogens. These pathogens may increase the risk of food borne illness. Moreover, the milking procedure, subsequent pooling and the improper storage of milk may carry the risks of further contamination for human. The composition of milk and milk products makes them good media for the outgrowth of pathogenic micro-organisms. Veterinary drugs, pesticides and other chemical contaminants used for animal health and for increasing production is also raise the risk of contamination.

The two major factors in dairy which destined for the food chain are raw milk and cull dairy cows. A number of pathogenic micro-organisms are transmissible to man through unpasteurized milk, i.e., *Salmonella*, pathogenic *E. coli*, *Listeria monocytogenes*, *Campylobacter jejuni*, *Yersinia enterocolitica* and *Staphylococcus aureus* [10]. There are many factors which can contaminate dairy products such as [25] -

- Animal health
- Unpasteurized milk
- Improper pasteurization
- Post-pasteurization contamination and cross contamination
- Chemical contaminants such as antibiotics and pesticide residues in milk and other dairy products
- Mastitis and shedding of the pathogen directly from the cow's udder into the milk
- Entry of bacteria into the milk from the cow's skin, or via manure and dirt in the dairy environment
- Poor hygienic conditions

Microorganisms usually do not survive pasteurization but they may contaminate dairy products during post-pasteurization from the equipment, hands and clothes of personnel, air [26]. In different products, these micro-organisms multiply and cause defects of flavour, odour and texture [27]. The changes in dairy products caused by metabolic activity of micro-organisms depend on degradation of lactose, secretion of lipolytic and proteolytic enzymes [28]. Different dairy products like cheese (soft cheese, semi-hard cheese and hard cheese), yogurt, curd, ice-cream etc may get contaminated via different pathogenic micro-organisms. Fermentation of residual lactose within the curd by species such as *Kluyveromyces marxianus* produces secondary metabolites as well as carbon dioxide gas that disturb the curd texture. The activity of extracellular proteases and lipases produced by some micro-organism species could alter curd flavour and texture [29]. Microorganisms show a very rapid growth in cheese because of the presence of high level of protein and calcium [30].

Mastitis is a very common and complex, multi-factorial disease with numerous contributing factors that are primarily associated with environmental conditions and milking management [31]. Mastitis leads to change in milk composition (reduction in calcium, phosphorus, protein and fat, and increase in sodium and chlorine), thus, reduces its quality. In addition, the antibiotic used in treating mastitis is an important industrial and public health concern. The presence of antibiotic residue in the milk interferes with the manufacturing processes of many dairy products (cheese and other fermented products). Undesirable flavors reduce the quality of dairy products and the presence of low levels of antibiotics may cause health issues to consumers.

7.2 Poultry and poultry products

Poultry is a category of domesticated birds kept by humans for the purpose of collecting of their eggs, meat, feathers and other products. Poultry represents an important source of food-borne disease organisms.

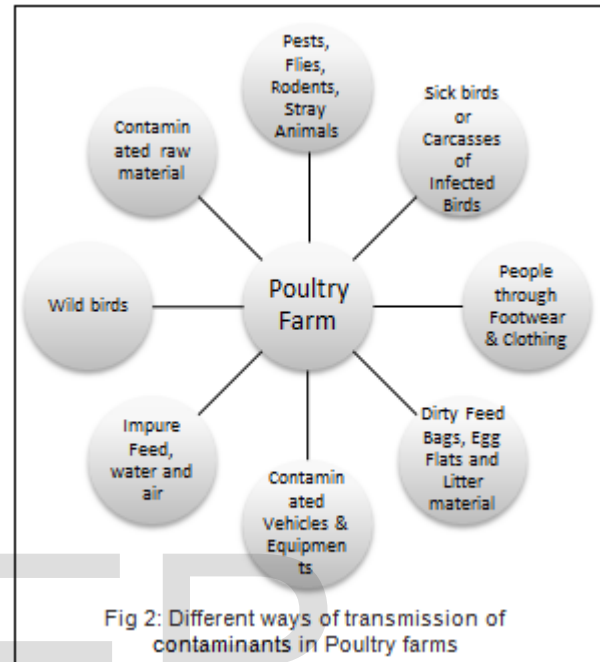
Chickens are usually kept together in a cage or chicken house. They also share the same food and water bowls, which can spread disease and infections from sick to healthy chickens. Different ways through which a disease can be transmitted in Poultry farms are [32] –

- transfer of birds from production area to production area
- dead bird disposal
- feral and domestic animals, insects, rodents, domestic birds
- farm personnel & visitor's hands, boots, clothing, dirty hair
- Vehicles and equipments may be contaminated during transportation process.
- transmission as an aerosol or dust
- water supplies may become contaminated with faeces from contact with avian or other animal species
- Feed may be contaminated by the raw materials used, post-production and during transport or by exposure to rodents and birds on the poultry.

Nutrient substances present in eggs create an excellent environment for the development of bacterial microflora, including pathogenic bacteria [33]. The egg shell contamination may result from deposition of fecal material on the shell, oviduct and gut flora, debris material, egg crates, packing and storage, clothes and hands of poultry workers, dust, the environment, weather conditions, transporting and marketing [34]. Eggs can be infected with different bacteria such as *Salmonella* spp., *Listeria monocytogens*, *Campylobacter jejuni* and *Escherichia coli*. *Campylobacter* is the most common identified cause of food borne disease [35].

Microbial contamination of poultry products can be influenced by transport and slaughtering processes [36]. Transport and slaughter of poultry involves a number of operations that

may substantially affect the extent of poultry contamination. Poultry meat may be contaminated frequently during slaughtering process; the most critical processing steps in this respect include scalding, plucking, evisceration and the type of poultry chilling [37]. High levels of bacterial cross-contamination may occur especially during defeathering and water chilling.



8 CONTROL ON PREVALENCE OF FOOD CONTAMINATION

It is necessary to reduce the risk of contamination by making good efforts at each stage of food manufacturing and processing until food consumed by consumer. Food preparation in the home is a vitally important step of the food chain.

The Food Hygiene Campaign has promoted the 4Cs principles (Cooking, Cleaning, Chilling and Avoiding Cross-contamination) for improving awareness of good food hygiene in the home and at a local level. Good food hygiene in the kitchen can reduce the risk of infection from foods contaminated with food-borne pathogens. Control of cross-contamination is the key to reduction of food-borne disease in both commercial and domestic kitchens [38]. To ensure the food safety, controls should be applied from the beginning to the end of all the stages of food production, preparation and processing so as to reduce any risk of contamination of finished products.

8.1 Different preventive programs

The following programs should be used to ensure food safety and quality of processed foods [39] – Good Manufacturing Practices (GMPs), Sanitation standard and Operation Procedures (SSOPs) and Hazard Analysis and Critical Control Points (HACCP).

The GMPs guidelines describe practices for the safe manufacturing of food. They are required by law (21 CFR 110), and apply to all food manufacturing companies. The SSOPs provide specific step-by-step procedures to ensure sanitary handling of foods and are mandatory for juice and seafood processing plants. And the HACCP program is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product. HACCP is a systematic and preventive approach to food safety focusing on preventing hazards that could cause food-borne diseases.

8.2 Precautions at different stages

Preventive measures should be applied from the beginning to the end of all the stages of food production, preparation and processing to reduce the risk of contamination. But some other precautions should also be used at local level -

Food safety begins with the food producers and farmers involved in agricultural production. Producers should use appropriate types and levels of pesticides, fertilizers, and veterinary drugs. In food preparation- suitable processing methods such as pasteurization, canning or sterilisation should be used. Foods such as meats and poultry should be cooked until their core temperature reaches 75°C. Unsuitable, defective, or dirty equipments should not be used for processing. For storage of food- avoid cross-contamination, such as keeping raw foods and ready-to-eat foods separate, using separate and clean utensils. Storage temperature is an important factor in food contamination and spoilage, so keep chilled foods cold at 5°C or low, and hot food hot at 60°C or more. Some other personnel hygiene should also be followed like wash hands with soap and warm water before and after handling food, wash cooking surfaces thoroughly, insects, animals and birds should not be allowed to enter in kitchen or food storage rooms etc.

9 CONCLUSION

Food provides an ideal nutritional source for human as well as for micro-organisms and generally creates an excellent environment for proliferation of these micro-organisms includes virus, bacteria, mould and parasites. The use of various chemicals such as food additives, pesticides, veterinary drugs and other agro-chemicals can also poses the risk of contamination if such chemicals are not properly used. Most of the food poisoning incidents occurs as a result of mishandling of food like storage at inappropriate temperature, incorrect re-heating, and cross contamination. Food may be contaminated during production, processing, preparation and handling. And it leads to world-wide public health issue.

A variety of good agricultural and manufacturing practices can reduce the prevalence of contaminants among farm animals and thus, prevent the contamination of food and food products. Different type of preventive programs should be used to ensure food safety and quality of processed foods like

GMPs, SSOPs, HACCP etc. Beside this, the food handlers should have the required skills and knowledge of food safety and food handling controls so as to minimise the risk of food poisoning. To ensure food safety, controls should be applied from the beginning to the end of all the stages of food production, processing and preparation so as to reduce any risk of contamination of finished products, other preventive measures at kitchen level are also needed to apply all the way from farm to table.

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