FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 7 No. 6, December (Special Issue), 2023, pp 140 -148
DOI: https://doi.org/10.33003/fjs-2023-0706-2179

FOOD CONTACT SURFACE CONTAMINANTS: A REVIEW

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ABSTRACT

Food contact surfaces are major sources of food contamination. They harbour contaminants which are further transferred to the food that comes in contact with them. These contaminants could be of biological or chemical origin. The biological contaminants are microorganisms such as *Staphylococcus aureus, Campylobacter* spp, *Escherichia coli, Shigella* spp, *Salmonella* spp, *Listeria monocytogenes, Vibrio cholerae, Bacillus cereus*, norovirus, hepatitis A virus, etc. The chemical contaminants are chemicals that may be transferred to the food through food contact materials such as packaging materials or residues of cleaning agents. These chemicals are hazardous to human health. Both the biological and chemical contaminants are harmful to humans when consumed. As such, food contact surfaces should be cleaned and sanitized properly to avoid contaminating food with such contaminants and also to ensure that safe food is supplied to the public.

Keywords: food contact, contamination, human health

INTRODUCTION

An essential part of food service operations is food safety. Most people, however, feel that this issue takes the least amount of attention and focus. There are various linked elements that influence microbial contamination of foods, such as the method of preparation, the sanitary conditions of catering and canteen facilities, or the handling, storage, and distribution of food (Erdogan & Pamuk, 2020). About 97% of food poisoning cases have been connected to inappropriate food handling by the food service industry, which is a major problem (Soares *et al*., 2012).

Pathogens can be harboured and introduced into food through food contact surfaces (Tenna *et al*., 2023). Trimming, slicing, grinding, shredding, peeling, mechanical abrasion, and many types of disintegration can introduce contaminants when conducted on contaminated surfaces (Wirtanen *et al*., 2003).

Food contact surfaces that have not been properly cleaned and sanitized may constitute a health concern (Nahar & Mahyudin, 2018). Even after cleaning and sanitizing, a variety of food spoilage bacteria can attach to and stay on food contact surfaces (Mafu *et al*., 2010). These organisms' ability to attach to these surfaces is known as biofilm development. This makes them difficult to eradicate and resistant to antimicrobial treatments (Khelissa *et al*., 2017). Water is a critical component in the contamination of kitchenware and the formation of biofilms (Srey *et al*., 2016). As a result, the temperature and microbial makeup of the dishwashing water have an effect (Nicolas *et al*., 2006). Bacteria such as *Salmonella* spp., *Shigella*, *Escherichia coli* (members of the Enterobacteriaceae family), *Listeria monocytogenes*, *Campylobacter* spp, and *Staphylococcus aureus* are the most common causes of food-borne outbreaks (Texeira, 2007; Mafu *et al*., 2010; Tenna *et al*., 2023). Contaminated kitchen utensils are responsible for 27% of outbreaks and infections caused by food-borne pathogens (WHO, 2000; Greig *et al*., 2007;Soares *et al*., 2012). The main causes of foodborne diseases are eating food contaminated with microbial pathogens, chemicals, or bacterial biotoxins (WHO. 2008; Ali *et al*., 2016; Rather *et al*., 2017). The main reasons of contamination, according to Kibret & Abera (2012), include low water quality and scarcity, a lack of training and experience among food handlers, insufficient monitoring and oversight, poor sanitation standards, inadequate storage facilities, and unsuitable locations for food operations.

As a result, in addition to regular cleaning and sanitization, regular evaluation of the efficacy of cleaning regimens may be an important precaution against potential foodborne outbreaks. It is essential to use testing methodologies that provide timely feedback for the periodic microbiological assessment of high-risk food service establishments so that preventative measures can be implemented before cross-contamination occurs (Masuku, 2012).

Chemical contaminants include cleaning agents like detergents and sanitizers, pesticides, toxic chemicals in metals and plastics, heavy metals, and others in addition to microbiological contaminants, which are also referred to as biological contaminants (Canadian Institute of food safety, 2022). The aim of this review is to highlight the impact of food contact surfaces in transmission of contaminants into food.

Food Contact Surfaces

Food contact surface is regarded to be the primary source of foodborne viruses because improper cleaning or handling practices may result in food contamination that is detrimental to the general public's health. Food contact surfaces are those that have pathogenic bacteria on them and come into direct contact with food (Sa'ad *et al*., 2019). According to Ismail *et al*. (2017), the majority of foodborne illness outbreaks were connected to bacterial cross-contamination or recontamination on food contact surfaces. To avoid foodborne illness outbreaks, it is necessary to keep the amount of pathogenic and food spoilage bacteria at safe levels by regularly and efficiently sanitizing food contact surfaces (Begani *et al*., 2012). Knechtges (2012) asserted that regular sanitation is an efficient means of guaranteeing food safety.

The type of contact surface is one factor in the cross-contamination of foods with microbes. Regardless of whether the surface in touch with food is a source of contamination, there is a risk of cross-contamination due to a lack of surface separation and poor cleaning management (Nhlapo *et al*., 2014). Wood has grown less popular as a cooking tool over the last 20 years due to its difficulty in cleaning due to its absorbency. As a result, such materials have been replaced in the food industry by others such as plastic and stainless steel (Sa'ad *et al*., 2019). Ismail *et al*, (2017) suggested that as long as the wooden shelves were cleaned properly, wood had no effect on food safety. It is recommended that suitable washing

and sanitation procedures should be followed to reduce cross-contamination (Tenna *et al*., 2023).

Some examples of food contact surfaces as given by Food Safety Savvy (2022) are; gloves, clothing, and hands, Food Storage Containers (made with materials such as plastic, metal, glass, acrylic, brushed stainless steel, porcelain, canisters) and utensils such as spoon, fork, chopping boards, knives, forks, spoons, hand blenders, graters, spoons for serving, cooking pots, pans, mugs, glasses, and cups, pestle and mortar.

Meat Contact Surfaces

The microbial quality (MQ) of beef contact surfaces was studied by Zailani *et al.* (2015). Total aerobic plate count and *E. coli* O157 isolation were performed using 240 swab samples (SS) from microscopy, culture, and sensitivity (MCS). The average value found in the study was 7.1 0.3 log10 CFU/cm2. Ningi abattoir on-cutting utensils had the lowest value of 6.4 0.6 log10 CFU/cm2, while tables at Darazo abattoir had the highest value of 7.8 0.3 log10 CFU/cm2. Only three (1.2%) of the 240 MCS SS tested positive for *E. coli* O157 using the latex agglutination kit. Similarly, Cetin *et al*. (2006) conducted a microbiological survey for several red meat processing factories in Istanbul, Turkey. Food contact surfaces and environmental surfaces were swabbed for 10 cm^2 surface samples. Each sample had its total mesophilic aerobic count (TMC), coliform count (CC), Escherichia coli count (ECC), and *Escherichia coli* O157:H7 count determined. TMC surface counts from floor, wall, and food contact surfaces were from 2.71 to 3.15 log10 CFU/cm^2, 0.69 to 1.56 log10 CFU/cm^2, and 2.23 to 3.0 log10 CFU/cm^2, respectively. Floor and food contact surfaces were tested for coliforms and *Escherichia coli*. *Escherichia coli* were not found in samples obtained from four different walls. Gurmu & Gebretinsae (2013) investigated the microbiological quality of meat contact surfaces in 12 randomly chosen meat stores in Mekelle, Ethiopia. A total of 72 swab samples were collected from butcher knives, processing tables, and employees' hands. The mean bacterial count (log10 CFU/cm^2) from pre-processing swabs has been found to be 6.28, 5.67, and 5.30 from tables, hands, and knives, respectively. Post-processing results were 6.56, 6.15, and 6.89 from tables, hands, and knives, respectively. The most common isolate was *E. coli* (32%), followed by *Staphylococcus* species (28%). *Streptococcus* species and *Salmonella* species had the lowest frequency of isolation (20% each). The study discovered a greater risk of meat contamination from working surfaces.

Ayalew *et al*. (2015) did another investigation to investigate the microbiological quality and sanitary standards of meat touch surfaces at abattoirs and retail establishments in Jigjiga, Ethiopia. A total of ninety swab samples were collected from the slaughterhouse floor, butchers' hands, hooks and knives, and cutting boards. The study discovered that retail house (6.430.34 CFU/cm^2) and abattoir (6.030.03 CFU/cm^2) butchers' hands had the highest average *S. aureus* and *E. coli* O157:H7 levels. *Campylobacter* species were exclusively found on the slaughterhouse floor surface. *Campylobacter* spp. were detected in 3.33% of the samples, while *L. monocytogenes* were not detected in any of the meat contact surface samples. The slaughter house floor surface had the greatest FCs (6.250.075 log10 CFU/cm^2) and Y&Ms (5.190.513 log10 CFU/cm^2) counts, whereas butchers' hands had the highest APCs (6.080.126 log10 CFU/cm^2). This finding suggests that slaughterhouse and retail meat touch surfaces might be sources of meat contamination.

Sudheesh *et al*. (2013) conducted a study to determine the overall microbiological load and the prevalence of harmful microorganisms on food contact surfaces in Oman's seafood retail marketplaces. Food Stamp RodacTM (Replicate Organism Detection and Counting) plates and the ATP sanitation monitoring system were used to investigate the microbiological and hygienic conditions on food contact surfaces in four retail fish markets. The prevalence of contaminating and harmful bacteria in seafood retail outlets was discovered in this study, highlighting the urgent need to enhance the hygienic state of retail fish markets in the Sultanate of Oman.

School Contact Surfaces

Sibanyoni & Tabit (2019) investigated the hygienic quality and pathogen incidence of food contact surfaces in food preparation facilities of schools conducting school feeding programs in Mpumalanga Province, South Africa. According to the study's findings, only 16.2% of food contact surfaces exhibited good hygiene condition, with surface aerobic colony counts of less than 2 log CFU/cm. Only 3% and 6% of the workbench and dry storage surfaces, respectively, were in good condition. *Listeria monocytogenes* and *Staphylococcus* aureus were the most common pathogens found on food contact surfaces, accounting for 53.1% and 25.5% of all cases, respectively. *Bacillus* species were found to be the most prevalent in aerobic growth isolates of food contact sources, with *Bacillus subtilis* being the most abundant. The majority of food contact surfaces in food preparation facilities of schools delivering school feeding programs were in poor hygienic condition, posing a food safety concern to pupils enjoying meals at school.

Similarly, Abdulkareem *et al*. (2013) conducted a food safety audit at five boarding schools in Zaria, Kaduna State. The investigation focused on dangers connected with microbiological contamination and critical control points (CCPs) in food preparation and handling in schools. The results indicated that water samples for drinking, cooking, and dishwashing were contaminated with coliforms in concentrations less than 2 log10 cells/ml. The food and water samples had acceptable counts, but the isolation of enterotoxigenic strains of *B. cereus* and *Escherichia coli*, hazards such as inadequate (5 - 10 min) time/temperature exposure of foods (akamu, tuwo, eba), high level initial contamination associated with raw foods, food ingredients, food contact surfaces, food handlers, and inadequate cleaning of food utensils raise concerns.

Nhalpo *et al*. (2014) evaluated the cleanliness of the food contact surfaces of meals delivered to students in central South Africa under the National School Nutrition Programme. Microbiological samples were taken from the food handler's dominant hand and apron, as well as the preparation surface. The study's findings revealed that overall viable counts were high across the board, with the majority of colonies being too numerous to count (above 100 colonies per plate). The number of organisms counted was rather low, with 20% of the surfaces providing unacceptable enumeration of *S. aureus* and *E. coli* and 30% creating unsatisfactory enumeration of coliforms. Yeast and mould yielded 50% and 60% unacceptable counts, respectively, from preparation surfaces and aprons. There were no statistically significant differences in the microbiological counts of the surfaces, suggesting that cross-contamination may have occurred.

Similarly, Trindade *et al*. (2014) evaluated the food safety and quality procedures of a municipal school food program (MSFP) in Jequitinhonha Valley, Brazil. Nine (81.8%) institutions were rated as bad quality, while two (18.2%) were

rated as medium quality. In food samples, no *Salmonella* or *Listeria monocytogenes* were found. Coliforms, *E. coli*, and *Staphylococcus aureus* were found in 36 (52.9%), 1 (1.5%), and 22 (32.4%) of the food samples, respectively, and 24 (40.7%), 2 (3.3%), and 13 (22.0%) of the food contact surfaces. Coliforms and *Staphylococcus aureus* levels ranged from 1 to 5.0 log CFU/g of food, respectively. The average number of aerobic mesophilic bacteria was 3.1 log CFU/100 cm2 of surface area. Coliforms, *E. coli*, and *Staphylococcus aureus* were found on the hands of 33 (73.3%), 1 (2.2%), and 36 (80%) food handlers, respectively. The findings highlighted the necessity to adjust the GMP employed in MSFP food service in terms of food safety, especially because children served in these venues are frequently the most socially disadvantaged.

Restaurants Contact Surfaces

Akpoka *et al*. (2019) investigated the microbiological composition of ready-to-eat prepared food, ready-to-use serving plates, and food handlers' hands at six restaurants in Okada, Edo State, Nigeria. *Enterobacter* species, *Streptococcus* species, *Micrococcus* species, Bacillus species, *Staphylococcus aureus*, and *Saccharomyces* species were isolated. Total aerobic viable counts, total coliform counts, and total *Staphylococcus* counts were 3.67 0.33 102 CFU/g - 2.71 0.05 104 CFU/g; 3.33 0.33 102 CFU/g - 2.39 0.04 104 CFU/g; and 0.00 0.00 CFU/g - 3.70 0.21 103 CFU/g, respectively. In the hands of the food handlers, the concentration of microorganisms on the food contact surfaces of ready-to-use serving plates was 0.00 0.00 CFU/cm^2 to 14.67 0.33 CFU/cm^2 and 0.00 0.00 CFU/cm^2 to 22.67 0.33 CFU/cm^2. As a result, the foods served to customers at these eateries are of poor microbiological quality.

Lani *et al*. (2014) investigated the risk of contamination through food contact surfaces. The Aerobic Plate Count (APC), Enterobacteriaceae count, *Staphylococcus aureus* count, *Pseudomonas* count, and presence of *Salmonella* sp. were determined in swab samples from ten selected food contact surfaces at two popular 'Satar' establishments in Terengganu. When compared to food contact surfaces in Premise B, the results revealed that all food contact surfaces in Premise A were heavily contaminated with indicator microorganisms (aerobic mesophilic organisms, Enterobacteriaceae, and *Pseudomonas*). This study suggests that microbial contamination in 'Satar' might be caused by contaminated food contact surfaces.

Tenna *et al*. (2023) investigated the microbiological quality of food contact surfaces (utensils) from Addis Ababa hotels and restaurants. The study found that trays had the highest median count of log total coliform among hotel and restaurant utensils (5.93 log10 CFU/100cm2 in hotels and 5.00 log10 CFU/100cm2 in restaurants). In 14.37% and 3.12% of the utensils, respectively, fecal coliform and *E. coli* were found. The highest log *S. aureus* median count was 5.95log10CFU/100cm2 on tray in hotel and 5.57 log10 CFU/100cm2 on dipper in restaurant, while the highest log APC median count was 9.37 log10 CFU/100cm2 on tray in hotel and 8.51 log10 CFU/100cm2 on spoon in restaurant. The findings revealed a significant microbiological load and insufficiency of washing and cleaning services at Addis Ababa's hotels and restaurants. As a result, there is an urgent need to enhance the monitoring and supervisory systems in hotels and restaurants.

Nahar & Mahyudin (2018) assessed the microbiological quality of spoons in five Klang Valley eateries. Restaurants C and B had the greatest and lowest total plate counts (TPC), respectively, according to the results. Samples from three of the five eateries (restaurants C, D, and E) tested positive for *E. coli*, owing to inadequate dishware cleaning. Negative findings for the presence of *E. coli* were connected with the advance cleaning approach, which employed a more sanitary method with dishwashers.

Mohammed *et al*. (2018) studied the prevalence of *Escherichia coli* and *Staphylococcus aureus* on food contact surfaces in Kaduna State University restaurants. The cleanliness of the surfaces that come into touch with food was assessed at five (5) chosen restaurants at Kaduna State University. 13 (26%) of the 50 samples tested positive for *E. coli*, but none tested positive for *Staphylococcus aureus*. 8 (61.5%) of the 13 positive for *E. coli* were from plates, 3 (23.1%) from chopping boards, and 1 (7.7%) from each table and spoon. Mohammed *et al*. (2018) recommended that food handlers should be educated on the need of appropriate hygiene procedures, such as implementing Hazard Analysis and Critical Control Point (HACCP) systems in food production and processing.

Wiatrowski *et al*. (2023) assessed the cleanliness of food truck (FT) surfaces utilizing the standard technique as well as alternatives such as PetrifilmTM and the bioluminescence method. *S. aureus*, Enterobacteriaceae, *E. coli*, *L. monocytogenes*, and *Salmonella* spp. were all tested for. Swabs and prints were collected from five surfaces (refrigeration, knife, cutting board, serving board, and working board) in 20 food trucks in Poland for the study. The visual evaluation of cleanliness was very excellent or good in 13 food trucks, although TVC was determined to surpass log 3 CFU/100 cm^2 on diverse surfaces in 6 FTs.

Fasoyiro (2012) investigated the probable causes of food risks in locally prepared and street-sold foods. He said that probable sources of contamination include operations including washing, grinding, packing, and storage, as well as raw materials and ingredients, cooking utensils, equipment, and handlers. Fasoyiro (2012) highlighted the necessity of building hazard analysis key control points for these goods and advocated personalizing training programs for local processors and street vendors. Controlling food waste is also emphasized in order to maintain environmental safety.

Food Contact Surfaces and Food

Ali *et al*. (2016) assessed the hygiene of confectionery and supplemental food production facilities. For the analysis of Enteric indicator bacteria, 10497 tests were done on 3499 swab samples taken from food facilities and handlers. 1277 (12.2%) isolates were detected from swabs, with Enterobacteriaceae being discovered with the highest frequency 604 (47.3%), followed by Coliforms 293 (30.8%) and *Escherichia coli* 280 (21.9%). The majority of the floor surfaces were significantly filthy, and improper washing and sanitation methods were observed. Essential food safety and hygiene criteria were not met by workers. In general, a larger ratio of Enteric bacteria was discovered, which might have a stronger impact on food quality and quantity, as well as some effects on consumer health.

Jovanovic *et al*. (2021) evaluated the efficacy of sanitary measures (cleaning, washing, and disinfection) used on food contact surfaces and food workers' hands in a Serbian retail chain. The study's findings revealed that 15.66% (57 of 365) swabs of food contact surfaces and 5.81% (5 of 86) swabs from food handlers' hands failed to fulfill the requirements outlined in the food company operators' self-control plans. As a result, ongoing employee training on correct sanitation methods is critical for effective GHP and HACCP.

Saad *et al*. (2019) investigated the efficacy of self-regulation in non-commercial residential facilities. Swab analysis was

used to determine the level of cleanliness of cleansed food surface contacts. Following a 24-hour incubation period, the RIDA® count plates detected light blue colonies as total coliforms, indicating the presence of contamination on the majority of the chosen food contact surfaces. Saad *et al*. (2019) strongly encourage the use of a basic scientific instrument to assure accuracy and efficiency in the assessment of hygiene and sanitisation, since it may impact the customers' quality of life.

Erdogan & Pamuk (2020) investigated the presence and association of harmful microorganisms isolated from food, kitchen equipment, and food handlers' hands. During the 2017-2018 academic years, 212 microbiological samples were collected from surfaces, foods, and food handlers' hands in six different canteens on the Afyon Kocatepe University campus. The study's findings revealed that meals, food preparation surfaces, and foodhandler's hands at canteens were contaminated with microbes that were similar to one another. In addition, based on the number of isolates, the hands of food handlers have the highest level of contamination.

Fahim *et al*. (2022) investigated the hygiene of food contact surfaces, including food handlers' hands, and the influence on the microbiological safety of the RTEs produced. A total of 150 samples of food contact surfaces swabs (64), food handler's hand swabs (41), and RTE meals (45) were collected and microbiologically analyzed from four restaurants in Cairo governorate, Egypt. Swabs from food contact surfaces revealed substantially high levels of aerobic mesophilic microbes and coliforms, with mean counts of (7.32 6.99 log10 CFU and 6.89 6.58 MPN/cm^2, respectively P0.05). The hand swabs were positive for total *Staphylococci* and *S. aureus* (7.18 6.15 and 6.15 6.15log10 CFU/cm^2, respectively). The swabs and RTEs were positive for yeast and mold with no significant differences (P≥.05). The data demonstrated a high positive association between surface contamination and the contamination level of RTE meals, proving that germs are transmitted to RTE foods via food contact surfaces and handler's hands. As a result, food handler training must be prioritized, as well as the implementation of appropriate sanitation systems, GMPs, and HACCP.

Hospital Contact Surfaces

Touimi *et al*. (2019) assessed the microbiological quality of food contact surfaces in a Moroccan hospital kitchen. According to the study's findings, the baking worktops (77%), serving meal worktops (50%) and vegetables cutting boards (45.83%) had the greatest rates of compliance with appropriate sanitary conditions. Some surfaces, on the other hand, have a low amount of compliance, such as raw meat cutting boards (96%). *S. aureus*, coagulase-negative *staphylococci*, *Escherichia coli*, *Serratia marcescens, Serratia odorifera, Raoultela ornithiaolytica, and Pseudomonas aeroguinosa* were among the microorganisms found. Touimi *et al*. (2019) concluded from the study's findings that there is an obvious need to enhance the sanitary process and implement a HACCP system at this facility.

Foodborne Bacteria

Listeria monocytogenes

Listeria monocytogenes is a bacteria that is non-sporeforming, grampositive, and can survive both in an environment that has oxygen and an environment that has no oxygen. It is the most harmful species to humans and a variety of other animals among the 19 *Listeria* genus members (Dojiad *et al*., 2018). In comparison to other foodborne microbial pathogens such as *Campylobacter jejuni, Salmonella* spp., and *Escherichia coli*, *Listeria monocytogenes* is responsible for listeriosis outbreaks worldwide, particularly in the United States of America, the European Union, Australia, Nigeria, and Asia (Whitworth, 2018; Smith *et al*., 2019). Infected people, particularly the susceptible category of immune-compromised, young, pregnant and old, might experience septicaemia, stillbirths, gastroenteritis, fever, meningitis, and eventually demise (Chen et al., 2021).

L. monocytogenes can survive pH conditions ranging from 4.5 to 9.5, multiply at low refrigeration temperatures as low as -1^{o}C, and remain viable in high salt conditions at 40% w/v (Al-Nabulsi *et al*., 2015). This extremophile grows easily on many food surfaces and produces biofilm. Thus, biofilm development is a significant source of *L. monocytogenes* contamination, which can lead to disease (Chen *et al*., 2021).

Chen *et al*. (2021) investigated the incidence of *Listeria monocytogenes* in food and food contact surfaces from food processing industries and food service establishments in Perak, Malaysia. A total of 26 food samples (15.29%) tested positive for *L. monocytogenes*, with the highest frequency seen in processed and minimally processed foods (33.33% and 31.25%, respectively), followed by ready-to-eat and raw foods (4.26% and 26.32%). Food-contact surfaces, on the other hand, had a greater incidence of *Listeria monocytogenes* at 11.83% compared to non-food contact surfaces at 6.78%. These findings indicated the possible danger of *L. monocytogenes* contamination in food, which might be attributed to the bacteria's exposure on food processing surfaces. As a result, the local authorities should perform frequent monitoring and stringent evaluation to ensure the safety of food intake for Perak inhabitants.

In humans, *Listeria* can cause two types of disease:

The first can range from mild to severe symptoms of nausea, vomiting, pains, fever, and, occasionally, diarrhoea, and normally resolves spontaneously.

And the second, which is Invasive Listeriosis is a more lethal type of the infection that arises when the infection spreads beyond the gut to locations such as the blood or the brain. This can result in blood infections, meningitis (infection surrounding the brain), and other potentially fatal complications. *Listeria* infection in pregnant women can lead to miscarriage, stillbirth, preterm labor, and severe sickness or death in the new born (food and drug administration, 2012).

Staphylococcus aureus

Staphylococcus aureus is a Gram-positive facultative anaerobic coccus that is non-spore-forming, non-motile, and catalase and coagulase positive. *S. aureus* can grow in a various temperatures, pH levels, and sodium chloride concentrations (up to 15% NaCl). *S. aureus* is a leading cause of food poisoning due to enterotoxins (Erdogan & Pamuk, 2020). This commensal and opportunistic pathogen is usually isolated from the nose, skin, oropharynx, and faeces of people. As a result, human-induced contamination is the world's third food-borne diseases causing agent (Normanno *et al*., 2005). Food poisoning has been reported to occur in 14-20% of outbreaks involving contaminated food as a result of infection with enterotoxigenic strains of *S. aureus* (Dagnew *et al*., 2012). A toxin dose of less than 0.1 g in contaminated food causes staphylococcal intoxication symptoms. *S. aureus* contamination, on the other hand, can be easily avoided by heat treating food (Teixeira *et al*., 2007).

Escherichia coli

Escherichia coli is a gram-negative bacillus that does not produce spores. It has a diameter of 0.5um and a length of 1.0-3.0um. It comes in pairs or alone. It can be non-motile or

motile in liquid by the use of peritrichous flagella, and it can have micro-capsules or capsules (Flatamico & Smith, 2006). It belongs to the Enterobacteriaceae family (Adams and Moss, 2008). There are hundreds of *Escherichia coli* (Gram-negative bacterium) strains. Even though most of the strains are innocuous, the strain known as *E. coli* O157:H7 produces a potent toxin that can cause serious sickness. The physiological effects of *E. coli* O157:H7 range from diarrhoea to serious and perhaps fatal diseases. *E. coli* O157:H7 has been discovered in the intestines of healthy cattle, deer, goats, and sheep. *E. coli* O157:H7 is the most common cause of foodborne disease (Teixeira, 2007).

***Salmonella* spp**

Salmonella spp. are members of the Enterobacteriaceae family. They are Gram-negative, rod-shaped bacteria that do not generate spores and are generally motile (Adams & Moss, 2008).

Salmonella spp. are spread through fecal oral route (contaminated food and water). *Salmonella* infects the host's intestinal epithelial cells and produces a heat-labile enterotoxin, causing gastrointestinal sickness. Even at low concentrations, *Salmonella* can cause disease. Salmonellosis symptoms often appear 12 to 36 hours after infection and include nausea, vomiting, diarrhoea, cramps, and fever. These symptoms last for a 4 to 7 days, though occasionally longer (Teixeira *et al*., 2007).

Campylobacter

Campylobacter spp. are Gram-negative bacteria that do not form spores and are motile with an S-shaped morphology. *Campylobacter* spp. are microaerophilic (they grow best at 5-6% O2) and necessitate particular incubation conditions for cell separation and growth. Campylobacteriosis, a gastrointestinal condition caused by *Campylobacter*, is most commonly associated with *C. jejuni* and *C. coli*. The majority of human illnesses are caused by *C. jejuni* (Food Standards Australia, 2018).

***Shigella* spp**

Shigella spp are members of the Enterobacteriaceae family. They are Gram-negative, non-motile, non-spore forming rods that are catalase-positive (except *S. dysenteriae* serotype 1), oxidase-negative, and facultative anaerobes (Steven & Williams, 2014). With the exception of some strains of *S. sonnei*, they are unable to ferment lactose, a trait shared by most *Salmonellas*. They are typical mesophiles, with a growth temperature range of 10-45 1C and heat sensitivity comparable to other family members. They thrive in the pH range of 6-8 and cannot survive below pH 4.5 (Rock & Donnenberg, 2014).

Shigella spp cause bacillary dysentery in humans and other higher primate species. The incubation period can range from 7 hours to 7 days, while foodborne outbreaks are typically characterized by shorter incubation periods of up to 36 hours (Food and Drug Administration, 2012). Symptoms include abdominal discomfort, vomiting, and fever, as well as diarrhoea that range from a characteristic dysenteric syndrome of bloody stools including mucus and pus in the cases of *S. dysenteriae, S. flexneri*, and *S. boydii*, to a watery diarrhoea in the case of *S. Sonnei* (Percival & Williams, 2014).

Bacillus cereus

This is a spore-forming bacteria found in the environment (for example, soil and vegetation). The spores may survive in severe settings such as typical cooking temperatures. *B. cereus* is linked to two forms of foodborne illness: emetic (vomiting) and diarrhoeal (Food Standards Australia, 2018). The emetic syndrome is caused by swallowing a heat stable pre-formed emetic toxin synthesized in food during vigorous bacterial growth. The diarrhoeal syndrome is caused by diarrhoeal toxins produced by bacteria during their proliferation in the small intestine when significant amounts of bacteria are consumed (Adams & Moss, 2008). High bacteria levels (more than 105 cfu/g) in implicated foods are often connected with foodborne disease. The onset of disease is relatively quick (1-5 hours for emetic syndrome; 8-16 hours for diarrhoeal), and symptoms are generally moderate and brief (Jenson & Moir, 2003).

Vibrio cholerae

Vibrios are Gram-negative pleomorphic (curved or straight), short rods that are motile and have (usually) sheathed, polar flagella. Catalase and oxidase-positive cells are facultatively anaerobic and capable of both fermentative and respiratory metabolism. Sodium chloride promotes the growth of all species and is an obligate necessity for some. The optimal level for the growth of therapeutically relevant species is 1-3% (Adams & Moss, 2008).

Cholera is a non-invasive illness in which the bacterium colonizes the intestinal lumen and produces a toxin. In severe cases, the enterotoxin-induced hypersecretion of sodium, potassium, chloride, and bicarbonate leads in a profuse, pale, watery diarrhoea including flakes of mucus, referred to as rice water stools (Food Standards Australia, 2018). The diarrhoea is followed by vomiting but no nausea or fever. If the huge fluid and electrolyte losses are not replenished, blood volume and pressure decline, blood viscosity rises, renal failure occurs, and circulatory collapse occurs. Death happens within a few days in fatal situations (National Institutes of Health, 2012).

Food Borne Parasites

Parasites are microscopic organisms that live within another organism. Parasitic illnesses are uncommon in affluent countries such as the United States. Cryptosporidium parvum and Giardia intestinalis are parasites that spread by polluted water from infected individuals or animals' faeces (Gould *et al*., 2009). These parasites can contaminate foods that come into contact with contaminated water during growth or preparation. Infected food preparers can potentially contaminate foods if they do not completely wash their hands after using the restroom and before handling food. Trichinella spiralis is a parasitic roundworm. Consuming raw or undercooked pork or wild game may result in infection with this parasite (National institutes of health, 2012).

Food Borne Illnesses

Foodborne illnesses are gastrointestinal (GI) tract infections or irritations are caused by food or beverages containing hazardous bacteria, parasites, viruses, or chemicals (National Institutes of health, 2012). Foodborne infections vary from very minor, self-limiting gastrointestinal disturbances to potentially fatal disorders like botulism (Adams & Moss, 2008). A foodborne illness affects an estimated 48 million people in the United States each year. Foodborne infections kill approximately 3,000 people in the United States each year (Scallan *et al*., 2011). Pathogenic bacteria and viruses cause the vast majority of foodborne illnesses. Parasites and chemicals can also cause foodborne illnesses (Centers for disease control, 2010).

Food illnesses can be classified into two; food infection and food intoxication. Food infection is established when a person

eats food contaminated with microorganisms thereby, causing illness by multiplying in the body. While food intoxication is the consumption of toxins produced by microorganisms (Alexis, 2022).

Chemical Contamination Through Food Contact Material

According to Thermofisher scientific (2018) Food contact materials are any materials that come into direct or indirect touch with food or beverages at any stage along the food chain, from farm gate to kitchen. Materials range from wood, ceramics, and metals to polymers, rubber, and paper and board. Fruit and vegetables harvested on the farm, for example, may be stored and transported in plastic crates, but food manufacturers may use pipes, conveyor belts mechanical equipment, valves, mixing vessels, and other containers for storage and delivery. All of these items are made from materials that must meet regulations governing their appropriateness for use in food contact (Thermofisher Scientific, 2018).

Food packaging can be made after processing using a wide variety of plastics, paper and board, composites, glass, metal, or cork. Combinations of materials, such as coatings on metal cans and paperboards, laminated plastic are frequently used for packaging, as are diverse materials for primary and secondary food packaging (Rather *et al*., 2017). Although food packaging material is advantageous, it can still become a threat to human health as a result of addition of various additives like antioxidants, stabilizers, slipping agents, and plasticizers, to improve the packaging material properties (Marsh & Bugusu, 2007). However, any contact between the food and the packing material, whether direct or indirect, may result in the transfer of these chemicals from the container into the meal which is known as migration (Geueke *et al*., 2022)

Chemically contaminated food has major consequences for people's health (Rather *et al*., 2017). Chemical contaminants in food can lead to acute episodes after a single exposure for example, cancer of the liver caused by prolonged consumption of food contaminated with mycotoxins (Choudhary *et al*., 2022).

Biofilm Formation

Microbial biofilms may be harmful and undesired in food processing facilities. Pathogenic bacteria such as *Campylobacter Salmonella, Klebsiella, Pseudomonas,* enterohaemorrhagic *E. coli* O157:H, and Listeria have been found to form biofilms (Mafu *et al*., 2010). When produced on contact surfaces, such biofilms could be a continual source of contamination for foods that come into contact with them (Movassagh & Karami 2010).Bacteria cling to accessible surfaces in industrial settings and can grow into large biofilms (Srey et al., 2013). A biofilm is a complex association of microorganisms embedded in an extracellular matrix. Biofilms are thought to have a heterogeneous structure made up of microcolonies (Sutherland, 2001). Food-processing settings present a number of conditions that may favor the production of biofilms, such as the presence of moisture, nutrients, and inocula of microorganisms from raw materials (Bower *et al*., 1996). Such a biofilm is a possible source of food contamination, which could lead to deterioration or the transfer of foodborne pathogens (Srey *et al*., 2013). Furthermore, individual microbes can easily spread when a biofilm disengages from abiotic surface (Myscka & Czasyk, 2011).

The production of biofilms by *Escherichia coli* O_{111} on routinely used food contact glass surfaces was investigated by Movassagh & Karami (2010). 12 glass chips (food grade) were utilized in this investigation. The *E. coli* strain was introduced to the beakers together with the samples and Tryptic Soya Broth. On glass surfaces, *Escherichia coli* O_{111} developed a biofilm with a mean cell density of 5.03 0.14 log CFU/cm. Based on these findings, it is possible to conclude that *Escherichia coli* O_{111} may build biofilm on food contact glass surfaces.

Escherichia coli O157:H7, *Aeromonas hydrophila, Staphylococcus aureus Salmonella Enteritidis*, and were examined by Mafu *et al*. (2011) for adherence to hydrophilic and hydrophobic surfaces in cultures with different pHs (6, 7, and 8). The results showed that the type of material had no effect on microbe attachment capability; however ambient pH influenced the adherence of *A. hydrophila, E. coli*, and *S. aureus* to both solid substrates. *S. Enteritidis* adhesion (P>.05) was unaffected by substrate type or culture pH, but *E. coli* had the least affinity for both polystyrene and glass surfaces. Except for *S. aureus*, no association was found between the physicochemical parameters of the materials or the bacterium and the rate of bacterial adherence. Surfaces were contaminated by tiny clusters of *S. Enteritidis*, whereas *S. aureus* invaded the food contact surfaces in the form of minute chains or cell aggregates, according to photomicrographs.

Mechanisms Of Biofilm Formation

Biofilm production is a five-step process that begins with;

i. A reversible attachment of planktonic microorganisms to solid surfaces;
ii. Transition from reversible to irreversible attachment via bacterial production of extracellular polymers (EPS);
iii. Early development of biofilm architecture;
iv. Development of microcolonies into mature biofilm;
v. Dispersion of cells from biofilm into the surrounding environment (Myszka and Czacyk, 2011).

Prevention Of Contamination With Food Contaminants

Cross contamination can be prevented or eliminated by properly cleaning and sanitizing food contact surfaces prior to food preparation. Food remnants on kitchen surfaces can be sources of contamination for other foods (DeCasare *et al*., 2003). Food contact surfaces can become contaminated with harmful bacteria during use. As a result, it is of the utmost importance to clean and sanitize food contact surfaces (Miller & Fraser, 2013). Cleaning is done to eliminate filth and is required prior to sanitization. It consists of two steps:

i. Washing with water and detergent. The detergent aids in lowering the surface tension of water, allowing it to lift dirt from the surface.
ii. Rinsing with warm water to remove the detergent and suspended dirt (Miller & Fraser, 2013).

Sanitisation is the process of reducing the amount of dangerous agents by using heat or a chemical solution that is not as strong as a disinfectant (Graves, 2012). Disinfectants are not used on food contact surfaces because they can leave dangerous residues (Cobsy *et al*., 2008).

The usage of a dishwasher, which uses heat, can produce sanitisation via application of heat. In the absence of a dishwasher, plates and utensils can be soaked in hot water for 30 seconds before being removed. (Miller & Fraser, 2013).

Chemical sanitization can be accomplished through the use of sanitizers such as chlorine solutions. Sodium hypochlorite is the most common chlorine compound. After applying the chemical sanitizer, the surface should be left to air dry (Miller & Fraser, 2013). Furthermore, separate utensils should be used for raw and cooked items. Personal hygiene should also be enhanced by thoroughly washing hands, especially after using the restroom. (Schneider *et al*., 2017).

Lambrechts *et al*. (2014) measured the microbiological load of eight convenience food production factories by sampling stainless steel food contact surfaces after they were cleaned and sanitized at the conclusion of a day's shift. According to the Foodstuffs, Cosmetics, and Disinfectants Act, 59% of the total areas sampled for TPC failed to meet the regulatory criteria for surfaces (100 cfu.cm-2). *Salmonella* and *Staphylococcus aureus* were not found, although *Listeria* was found in 23% of the samples and *E. coli* in 1.3%. Fifty percent (50%) of the plants employed traditional cleaning methods for cleaning and sanitation, while the other half used low-pressure foam (LPF). The mean TPC values of the traditional cleaning technique (14 358.82) were different (P 0.05) from those of the LPF method (2 386.51), in terms of *Listeria* species isolates obtained from both cleaning procedures, there was no significant difference ($P \geq 0.05$). They concluded that the LPF approach was the optimum cleaning option for decreasing TPC counts.

There are laws in place to limit the amount of various substances in food. Unhealthy additives and adulterants are illegal under the law. However, elective surveillance and response systems are required to avoid chemical hazards from entering the food supply and causing harm to people (Rather *et al*., 2017). Pesticide concentrations should not exceed the limit set by the Food and Drug Administration. However, errors in conforming to the calculated concentration and parameters are conceivable (Bajwa & Sandhu, 2011).

CONCLUSION

Food contact surface are important sources of cross contamination. They harbour food contaminants both biological and chemical and contaminate food during food processing which can lead to food borne illnesses. As such, it is important to clean and sanitize these surfaces properly so as to avoid food borne disease outbreaks. Furthermore, the food handlers need to be educated on how to properly clean and sanitize the surfaces and how to maintain good personal hygiene.

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