***Review Article***

**MICROBIAL CONTAMINANTS IN SRI LANKAN POULTRY, FISH, AND MEAT: A REVIEW OF PREVALENCE AND IMPLICATIONS FOR FOOD SAFETY**

**ABSTRACT**

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| Microbial contamination of food poses significant public health risks globally, which can lead to foodborne illnesses. In Sri Lanka, poultry, fish, and other types of meat are consumed by the majority in the country. Hence, proper food safety is crucial to minimize microbial contamination and thereby reduce the occurrence of foodborne illnesses. This review aims to discuss and summarize existing literature on the common types of microbial contaminants found in poultry, fish, and meat products sold in Sri Lanka. While numerous studies have addressed microbial contamination in individual food categories in different countries, there remains a lack of comparative analysis across different product types and regions. This review will contribute to bridge that research gap by by synthesizing existing data to highlight patterns, emerging threats and significantly enhance understanding of possible microbial contaminants in these products and take necessary precautions to ensure food safety. The review examines the common types of microbial contaminants found in chicken meat, eggs, fish, and other meat and meat-based products. Additionally, it provides an overview of the prevalence of microbial contaminants associated with these foods. All existing studies freely available in online databases and journals are included in this review. The review reveals that among the microbial contaminants; *Salmonella* spp. and *Escherichia coli* tend to contaminate chicken more compared to other microorganisms. In Fish, *E. coli* is the most prevalent microbial contaminant, while in shrimps it's *Vibrio* spp. Eggs were the least found to be contaminated, but when contaminated, *Salmonella* spp. is the common microbial contaminant. Therefore, it is needed to strengthen public awareness of having proper storage and proper food safety measures to minimize microbial contaminants and prevent foodborne illnesses. |

*KEYWORDS****:*** *Microbial contaminants, Chicken, Eggs, Fish, Escherichia coli, Salmonella spp., Sri Lanka*

# Introduction

The assurance of food safety is a paramount concern for public health. In recent years, the emphasis on food safety has heightened, acknowledging it as a fundamental human right that directly impacts individual and population health. Food possesses the potential to harbour microorganisms that can lead to foodborne illnesses (Aladhadh, 2023; Bavoria et al., 2021; Visciano and Schirone, 2020; Bukar *et al.*, 2010). Lack of proper food safety leads to foodborne illnesses, and many cases have been reported globally in recent years. According to the World Health Organization (WHO) Estimates of the Global Burden of Foodborne diseases by the WHO and the Foodborne Disease Burden Epidemiology Reference Group (FERG), in 2010, there were 31 foodborne hazards, which include viruses, bacteria, protozoa, helminths, and chemicals. They have caused 600 million foodborne illnesses and 420,000 deaths worldwide. Notably, the predominant causes of foodborne illness were *Norovirus* and *Campylobacter* spp. while non-typhoidal *Salmonella enterica* is the major cause of foodborne death (WHO, 2024; WHO and FERG, 2015).

Microbial contamination in food products poses a significant public health risk, leading to foodborne illnesses and economic losses worldwide. Poultry and meat products are particularly susceptible to microbial contamination due to improper maintenance of hygienic conditions and slaughterhouse handling during slaughter processes (Ahmed and Al-Mahmood, 2023; Enver et al., 2021; Bakhtiary *et al.*, 2016). Furthermore, there is also a risk of contamination in retail shops that sell meat due to poor hygiene (Alimi et al., 2022); Ali *et al.*, 2010).

While viruses are more frequently implicated in most foodborne diseases, bacterial agents often bear responsibility for hospitalizations and fatalities associated with these infections. Notably, foodborne bacterial agents are the primary agents behind severe and fatal cases. About 90% of foodborne illnesses are caused by microorganisms like *Bacillus, Vibrio, Listeria, Salmonella, Clostridium, Campylobacter, and Escherichia coli* (Fung et al., 2018; Chowdhury et al., 2024). Therefore, ensuring the microbial quality in food is essential for maintain food safety, safeguarding the public health and preserving consumer trust. According to the U.S Food and Drug Administration (FDA, 2022), the symptoms of foodborne illness could range from moderate to severe, and it depends on the type of foodborne pathogen involved. Most foodborne illnesses show signs and symptoms such as nausea, diarrhoea, and vomiting. Foodborne illnesses, however, may cause major issues for some individuals. Gastrointestinal complications, sepsis, haemolytic uremic syndrome, Reiter's syndrome (reactive arthritis), Neurological complications like Guillan-Barré syndrome (nerve paralysis), stillbirths, and even death are possible outcomes of these severe consequences (Linscott, 2011).

In Sri Lanka, the consumption of poultry, fish, and meat products is one of the major components of the diet, making it essential to ensure their safety. Sri Lanka, being an island in the Indian Ocean, has a large variety of fishing resources and is capable of making a greater contribution towards the gross domestic production (GDP) at around 1.4% in fulfilling the requirements of the country population (MOF, 2024). According to the Ministry of Fisheries, the total fisheries production in 2021 is 435,910 MT (MOF fisheries statistics, 2022).

Fish that inhabit water contaminated by human and animal waste may be carrying significant amounts of bacteria, including *Salmonella* spp.*, Vibrio cholerae, Clostridium botulinum, Escherichia coli,* and other coliforms (Jayasinghe & Rajakaruna, 2005). According to Jianadasa *et al.* (2014a), maintaining the code of practice concerning the handling of the catch, icing, post-harvesting procedures, and storage is crucial to maintaining good microbial quality of fish. Moreover, Fish contaminated with harmful microbes are often the result of improper handling techniques, unclean utensils, contaminated water and ice, and insufficient ice (Ariyawansa *et al.*, 2016).

Poultry and other types of meat, such as beef, mutton, and pork, are also consumed in Sri Lanka. However, according to the Department of Animal Production and Health (DAPH) in Sri Lanka, the economic contribution given by livestock has only been 1% of GDP in recent years, which is less than that of the fishing industry. The country had 34.86 million chickens and 1.6 million cattle, followed by goats (0.77 million) and swine (0.17 million) in 2022 as the main livestock species. Moreover, from those industries, nearly two hundred thirty-six thousand seven hundred ninety metric tons; 236. 79 (‘000 MT) of chicken was produced, followed by beef twenty-seven thousand eight hundred sixty metric tons; 27.86 (‘000 MT), pork nine thousand eight hundred twenty metric tons; 9.82 (‘000 MT), mutton two thousand five hundred metric tons; 2.5 (‘000 MT), and nearly 2935 million eggs have been produced (DAPH Statistical Bulletin, 2022). Recently, foodborne illnesses caused by microbial contamination have posed a significant public health concern in Sri Lanka. According to the Performance and Progress Report, 2023 by the Ministry of Health, Sri Lanka, the country has intensified its surveillance and control programs mainly targeting the zoonotic and foodborne pathogens. This report highlights the risks, challenges and ongoing efforts to control and prevent these illnesses (Ministry of Health Sri Lanka, 2023).

Chicken meat is the most popular meat consumed globally as well as in Sri Lanka (Prabakaran, 2003). This may be due to fewer religious and cultural barriers between multi-ethnic and cultural groups of Sri Lanka. Potentially harmful pathogens like *Salmonella* spp*.*, *Campylobacter* spp*.,* *Staphylococcus aureus, Escherichia coli*, and *Listeria* spp. are frequently detected in poultry meat. However, the most common foodborne pathogens in the poultry industry are thought to be *Salmonella*, *Campylobacter*, and, to a lesser extent, *Listeria* (Bhaisare *et al.*, 2014).

Eggs, which are popularly consumed by Sri Lankans and used as an ingredient to prepare a variety of food, especially short-eat food, can also be contaminated with microbes. According to (Mayes & Takeballi, 1983), there are many methods by which eggs can be contaminated with microbial contaminants. Eggs can be contaminated after laying as well as before laying. The contamination of eggs after laying depends on where the eggs are laid. Microbial contaminants in dirt can enter the egg through pores found in eggshells. Microbes such as *Salmonella* spp. can contaminate eggs by invading the yolk in a hen's ovaries before laying. Therefore, as mentioned in (Awny *et al.*, 2018), both egg contents as well as eggshells can be contaminated with many microbial contaminants, and the most common bacterial contaminants contaminating eggshells are *Escherichia coli*, *Salmonella* spp., and *Staphylococci*.

Apart from the above-mentioned factors, seasonal and geographical variations also appear to significantly influence microbial contamination patterns in animal-derived foods. As Sri Lanka is a tropical country, warmer temperatures and increased humidity during certain months can enhance bacterial growth, while rainy seasons may contribute to higher contamination through runoff and waterborne pathogens. Geographical disparities, such as differences in infrastructure, food handling practices, and environmental conditions, further shape the microbial risks associated with these foods. These trends highlight the need for region-specific and seasonally adaptive food safety strategies (Chen et al., 2024; Lipp et al., 2001).

This review was aimed at discussing and summarizing existing literature on the common types of microbial contaminants found in poultry, fish, and meat products sold in Sri Lanka. This will contribute to identifying the gaps in research for further investigation and enhance the understanding of these products significantly.

# Microbial contaminants of poultry, fish and meat products

## Poultry

### Chicken and other chicken products

Few studies were done in Sri Lanka to investigate microbial contaminants in poultry meat. One study, dated back to 1995, investigated the occurrence of Listeria monocytogenes in various food items, including chicken. In this study, 38 samples of raw chicken were collected, and it was found that 13 (34%) of the samples were contaminated with *L. monocytogenes.* Interestingly, chicken is ranked as the second most contaminated food item, with vegetables exhibiting the highest contamination rate at 49%. Dairy products showed the lowest contamination rate at 26% in this study (Gunasena *et al.*, 1995).

Another study by Jayaweera *et al.* (2020) from 2012 to August 2013 investigated *Salmonella* spp. in broiler chicken sold in Sri Lanka. 260 broiler chickens were collected randomly from different parts of the country. In this research, isolation and identification of *Salmonella* spp. were done using the culture-based method and were further confirmed using the polymerase chain reaction (PCR) method. After that, serotyping was done on those isolates. The results showed that among the 260 broiler chicken meat samples tested, 30 isolates (11.6%) were identified as *Salmonella* spp. using culture-based techniques. Of these 30 isolates, 23 (89%) were subsequently confirmed as *Salmonella* spp. through PCR analysis. Serotyping was performed on some confirmed isolates via PCR, revealing that 11 out of 23 (47.8%) were classified as *Salmonella Typhimurium*, while 6 isolates (26.1%) were attributed to *Salmonella Enteritidis*. The remaining six isolates (26.1%) that tested positive through PCR were not subjected to serotyping.

In 2014, a study conducted in the Badulla district aimed to assess the prevalence of *Escherichia coli* and *Salmonella* spp. in various cuts of chicken meat sourced from retail markets. The study randomly selected 20 retail shops across 7 secretarial divisions within the district. From each selected shop, two whole chicken samples were collected, yielding 200 chicken parts for analysis, including breast, back, thigh, wings, and whole chicken. The findings revealed that 41.5% of the samples tested positive for *Salmonella* spp., while 40.5% tested positive for *E. coli*. Table 1 compares the number of positive samples across different cuts.

**Table 1 Contamination rate on different cuts**

|  |  |  |
| --- | --- | --- |
| Chicken part | *Escherichia coli* | *Salmonella spp.* |
| No. of positive samples | % | No. of positive samples | % |
| Breast | 21 | 25.93 | 17 | 20.48 |
| Back | 20 | 24.69 | 16 | 19.28 |
| Thigh  | 17 | 20.99 | 24 | 28.92 |
| Wing  | 9 | 11.11 | 11 | 13.25 |
| Whole | 14 | 17.28 | 15 | 18.07 |

Notably, the research indicated that no significant association was observed in *Salmonella* contamination across different cuts. However, a significant association was observed in *E. coli* contamination among different chicken parts (Madhurangi *et al.*, 2014).

In 2019, another study in Kandy in retail shops showed that foodborne pathogens like Salmonella spp., *Escherichia coli*, and *Campylobacter* spp. were contaminated in raw chicken. In addition to raw chicken, chicken products such as sausages and meatballs were contaminated. In this study, 25 out of 51 raw meat samples tested were contaminated at least with *Campylobacter, Salmonella* or *E. coli.* Of them, 7 samples (13.7%) were contaminated with *Salmonella*, 8 samples (15.7%) were contaminated with *Campylobacter,* and 5 samples (9.8%) were contaminated with *E. coli*.When considering meat products, 48 were tested, of which 26 were sausages and 22 were meatballs. Meat products were less frequently contaminated with *Salmonella* and *Campylobacter* at 4% (2/48) compared to unprocessed raw meat. However, higher amounts of *E. coli* contamination were discovered, with sausages showing 42% (11/26) and meatballs showing 31% (7/22) (Kulasooriya *et al.*, 2019).

In 2021, another study was done in Kandy, but on small-scale farms, which is higher than the retail market in the meat supply chain. According to this study, most chicken samples were found to be contaminated with *Salmonella* spp. and *E. coli.* This study detected *Salmonella* contamination in 22 / 37 (59.5%) meat samples, whereas 26 / 37 (70.3%) were contaminated with *E. coli.* (Gamage *et al.*, 2021).

Another study in the same year, 2021, was done in small-scale retail shops within the limits of Kandy city. In this study, 32 chicken samples were randomly selected and investigated for *Campylobacter, Escherichia coli, Salmonella,* and *Staphylococcus aureus*. According to the results, *Escherichia coli* was found in all the samples, and Staphylococcus aureus was detected in as many as 90.6% (29 out of 32). Additionally, the investigation showed that *Campylobacter* was present in chicken samples at a rate of 65.6% (21 out of 32), whereas Salmonella was found in 40.6% (13 out of 32). Furthermore, 84.4% (27 out of 32) of the samples contained more than three of the aforementioned types of bacteria (Thilakarathne *et al.*, 2012).

A recent study in 2022 was done to find the prevalence of *Escherichia coli* in chicken meat and edible poultry organs collected from retail shops and supermarkets in the North-Western province of Sri Lanka. In this study, 250 chicken samples were collected, comprising 144 samples of chicken meat and 106 samples of edible chicken organs. These samples were gathered from 181 retail shops and 69 supermarkets across 25 divisional secretariat divisions within the North-Western province of Sri Lanka for the year 2018. Out of the 250 samples, 167 (66.80%) of chicken meat and edible organs had *E. coli* contamination. The isolated *E. coli* was further confirmed using PCR identification. Furthermore, this study also investigated the level of contamination by finding the MPN (Most Probable Number) value of the samples collected. It was determined that the prevalence of *E. coli* in supermarkets and retail stores was 66.67% and 66.85%, respectively. Interestingly, the MPN value for *E. coli* contamination between supermarkets and retail stores is not significant, according to statistical analysis at a 95% confidence level (Ranasinghe *et al.*, 2022).

In the same year, 2022, a large-scale study conducted by (Ubeyratne *et al.*, 2022) investigated the prevalence of *Salmonella* spp. within wet markets across Sri Lanka. This investigation involved the study of the collection of meat samples from each vendor operating within these markets. A total of 123 wet market vendors were randomly selected from cities spanning seven out of nine provinces in Sri Lanka, encompassing both high and low-poultry-producing regions. Moreover, swabs were taken from meat contact surfaces comprising 123 knives and 123 cutting boards from all selling locations. Out of 123 wet market vendors sampled, 59 were contaminated with *Salmonella* spp., with an overall prevalence of 47.97%. Among the 59 wet market operations that tested positive for *Salmonella*, boutiques comprised the highest proportion at 89.83% (53 out of 59), followed by community markets and households, each accounting for 5.08% (3 out of 59), respectively. It is worth highlighting that wet market vendors in community markets are often examined by public health inspectors, which may account for the lower prevalence of *Salmonella* in these settings. Therefore, the high incidence of *Salmonella* in boutiques can be due to a lack of observation by public health inspectors. Regarding the poultry meat sold, the prevalence of *Salmonella* was 30.89% (38/123), while meat cutting boards and knives were 24.39% (30/123) and 23.58% (29/123), respectively. This indicates improper and ineffective cleaning and disinfection practices in these stalls, possibly leading to *Salmonella* cross-contamination.

Back in 2014, a study was done to understand *Salmonella* cross-contamination in retail markets of the Kandy district. In this study, 15 random chicken outlets were selected in Kandy; 57 swab samples were collected from various utensils, including knives, cutting boards, weighing scales, and meat-containing trays/buckets. The findings of this study showed that there is Salmonella cross-contamination in all types of these utensils, and 12 swabs tested positive, with an overall prevalence of 21%. Table 2 shows the prevalence of *Salmonella* in different meat contact utensils (Alwis *et al.*, 2014).

**Table 2. Prevalence of *Salmonella* in different meat contact utensils**

|  |  |  |  |
| --- | --- | --- | --- |
| Meat contact utensil | Sample No.  | No. of Positive samples | % |
| Knives | 14 | 2 | 14.3 |
| Cutting boards | 12 | 3 | 25.0 |
| Weighing scales | 9 | 3 | 33.3 |
| Trays/ Buckets | 11 | 3 | 27.3 |
| Showcases | 11 | 1 | 9.1 |
| Total | 57 | 12 | 33.3 |

Therefore, this study shows that even if chicken meat is free from *Salmonella* there is a possibility of healthy chicken meat being contaminated from chicken meat contaminated with *Salmonella* through cross-contamination.

### Eggs

As mentioned in (Awny *et al.*, 2018), both egg contents and eggshells can be contaminated. Few studies have been found in Sri Lanka investigating microbial contaminants of eggshells and egg contents sold in local markets.

In 2017, a study was conducted by (Kalupahana *et al.*, 2017) to investigate the occurrence of non-typhoidal *Salmonella* in retail table eggs sold in the Kandy district. Both eggshell washings and egg contents were studied. A total of 100 retail outlets were selected from densely populated areas in the Kandy district. 10 eggs from each retail outlet were collected for the study. Out of all the eggs studied, 15 samples were found to be positive with *Salmonella* spp. From the 15 egg samples, 12 samples were contaminated with *Salmonella* spp. on eggshells, while the remaining 3 eggs had contaminated egg contents with *Salmonella* spp*.* Interestingly, none of the eggs were contaminated by eggshell washings or egg contents.

Another study published in 2021 was done in selected backyard and commercial poultry farms in Kosgama. According to this study done by Sharuni *et al.*, 2021), a total of 60 eggs were studied; out of them, 35 were collected from backyard farms, and the remaining 25 were collected from commercial farms. The study was carried out on both eggshells and egg content separately. From their study, 4 eggs were positive for Salmonella spp., 3 were contaminated eggshells, and the remaining had contaminated egg content. Interestingly, none of those eggs were contaminated in the eggshell or egg contents. Moreover, out of those 4 eggs, 3 were from the backyard farm, and the remaining were from a commercial farm. However, statistical analysis showed no significant difference in contaminated *Salmonella* spp. on eggs between backyard and commercial farms. The prevalence of *Salmonella* spp*.* in the study sample was 6.7%.

Therefore, from the few studies done in Sri Lanka, eggshells are found to be more prone to be contaminated by microorganisms than egg content.

## Fish

Few studies have investigated the microbial quality of fish sold in Sri Lanka. One study in 2014 by Jianadasa *et al.* (2014b) did a comparative study on microbial quality of five types of fish, namely Yellowfin tuna (*Thunnus albacares*), sailfish (*Istiophorus platypterus*), salaya/ sardine (*Sardinella gibbose)*, shrimp (*Fenneropenaeus indicus*), and squids (*Loligo duvaucelii*). Samples were analyzed for the presence of *Escherichia coli* and *Salmonella spp.* Furthermore, total plate count/APC (aerobic plate count) was examined to better understand microbial quality. Between February 2012 and November 2012, 155 fresh fish samples—37 yellowfin tuna, 36 sailfish, 26 sardines, 36 shrimp, and 20 squid—were taken from 19 randomly chosen locations. *Salmonella* spp. was detected in 12% of samples. *Salmonella* testing yielded positive results in 16% of yellowfin tuna, 19% of sailfish, 8% of sardine, and 8% of shrimp; however, no squid samples tested positive.

For every fish under study, *E. coli* levels ranged from undetected to >1100 (MPN/g). Of the samples, 8% had more than 1000 MPN/g of *E. coli*, 1 sample had 500 MPN/g, and the remaining samples had < 200 MPN/g, with 33% being *E. coli*-free.

The total plate counts obtained from the microbiological analysis of the samples ranged from 7 x 103 to 1.2 x 108 CFU/g. Of the samples, 28% had < 5 x 105 CFU/g while the remaining 72% had > 5 x 105 CFU/g. Table 3 displays the average APC for each type of fish.

**Table 3: Average APC of various fish types**

|  |  |
| --- | --- |
| Fish type. | Average APC (CFU/g) |
| Yellowfin tuna | 1.02 x 107 |
| Sailfish | 1.57 x 107 |
| Sardine | 9.36 x 106 |
| Squids | 7.74 x 106 |
| Shrimp | 3.93 x 106 |

The International Commission on Microbiological Specifications for Food (ICMSF) established 1 x 107 and 5 x 105 CFU/g as the top (rejectable) and lower (marginal) levels of acceptability, respectively. 21% of yellowfin tuna, 28% of sailfish, 11% of sardine, 20% of squids, and 8% of shrimp at Sri Lankan retail markets were deemed unfit for human consumption when the APCs of the fish samples were compared to these requirements.

Another study in 2016, done by Ariyawansa *et al.* (2016), investigated the microbial quality of fish in a supply chain in Negombo. 60 samples of small fish (*Amblygaster sirm, Pterocaesio chrysozona*, *Stolephorus commersoni*, and *Sardinella albella*) and 100 samples of large fish (*Katsuwonus pelamis* and *Euthynnus affinis*) were taken at six and five sampling visits, respectively, at various stages of a supply chain. Aerobic plate counts (APC) at 37 °C, coliforms, faecal coliforms, *Escherichia coli*, *Salmonella* spp., and *Listeria monocytogenes* were examined in all 160 fish samples.

APC levels in large and small fish ranged from 2.0 x 102 - 2.0 x 106 and 8.0×103 - 2.0×108 CFU/g, respectively. In large fish, the range of faecal coliform counts was between not detected (ND) and 90 MPN/g, while in small fish, the range was between ND and >1100 MPN/g. *E. Coli* contamination in large fish varied from ND to 15 MPN/g, accounting for 5% of cases. 70% of the small fish samples had *E. Coli*, with counts ranging from ND to >1100 MPN/g. Nine times out of 160 fish samples that were analysed, Salmonella spp. was found. Out of which, three huge fish (two *Euthynnus affinis* and one *Katsuwonus pelamis*) and the remaining 6 were small fish (four *Amblygaster sirm*, one *Epinephelus malabaricus*, and one *Sardinella albella* fish*). L. monocytogenes* was discovered in one *Sardinella albella* fish and eight *Katsuwonus pelamis* out of 160 fish samples.

In 2012, a study was conducted to investigate the prevalence of *Vibrio* spp. in farmed shrimps (*Penaeus monodon*) of the Northwestern province of Sri Lanka. One week before the harvest, 170 shrimp samples (100 g of whole shrimp each) from a total of 170 different ponds from 54 farms were collected. There were one to twenty ponds on each of these farms, spread across five areas in the Puttalam District of Northern Province. *Vibrio* spp. was detected in shrimps from 98.1% of the farms (53 of 54) and 95.1% of the ponds; the most prevalent species at the pond level was *V. parahaemolyticus* (91.2%), followed by *V. alginolyticus* (18.8%), *V. cholerae* non-O1/non-O139 (4.1%), and *V. vulnificus* (2.4%) while at farm level the highest prevalence was found for *V. parahaemolyticus* (98.1%), followed by *V. alginolyticus* (34.6%), *V. cholerae* non-O1/non-O139 (13.5%), and *V. vulnificus* (7.4%). 26% of the ponds had multiple *Vibrio* spp. identified in them (Koralage *et al.*, 2012).

Another study was conducted in 2005 to investigate the bacterial contamination of fish sold in fish markets in the central province of Sri Lanka. A total of 60 samples of tuna, approximately 250 g of each sample, were collected from eight selected towns in three different climatic zones based on the ambient temperature. The levels of *Salmonella*, *V. cholera*, total bacterial count (TBC), total coliform (TC), faecal coliform, and *E. coli* were determined. The microbiological analysis showed that *V. cholerae* and *Salmonella* spp. were absent in any of the examined samples. TBC > 106/g was found in 56.6% of the tested fish samples, which is unsuitable for consumption. TC levels >103/g were present in about 73.4% of the fish samples, which may have harmed human health. Of the fish samples examined, faecal coliform levels were >102/g in 40% of the cases and <50/g in 35%. While 16.67% of the fish samples had *E. coli* counts >103/g, most had values >10/g. Consequently, the study's notably elevated coliform and *E. coli* levels suggest that faeces have heavily contaminated fish (Jayasinghe & Rajakaruna, 2005).

A study by Ginigaddarage *et al.* (2018) examined the microbiological quality of several varieties of dried fish available for purchase in Sri Lankan markets. Samples of nine different varieties of dried fish were gathered and categorized into three groups: locally made, imported dried fish before, and after distribution to the retail market. This review was only covered the dried fish samples sold only in the Sri Lankan market. From March to November 2014, 79 dried fish samples, each weighing approximately 500 g of from various varieties were obtained, including tuna (*Katsuwonus pelamis*), sprats (*Stolephorus* spp.), catfish (*Arius* spp.), sailfish (*Istiophorus* spp.), katta (*Scomberoides lysan*), shark (*Carcharhinus* spp.), prawns (*Penaeus* spp.), herrings (*Amblygaster* spp.), and pannawa (*Johnius* spp.). Analyses of the samples included Aerobic plate count (APC), halophilic count, total coliforms, *E. coli*, *Staphylococcus aureus*, yeast, and mould. The samples did not detect *Staphylococcus aureus, Halophilic bacteria,* and *Escherichia coli*. Coliform counts were not detected in all locally produced samples. However, 3 of the 46 imported samples that were analysed had coliform counts found in them. Two of the samples had <100 MPN/g and >1100 MPN/g was found in one sprat sample. Most samples had aerobic plate count, yeast and mould count all within the acceptable range. The APC values of locally manufactured samples ranged from 1.7 × 104 – 2.0 × 107 CFU/g, while imported samples sold in the local market exhibited values between 7.6 × 104 – 9.7 × 106 CFU/g. Of the samples that were produced locally, 58% had an acceptable APC of less than 1.0 × 105. It is unsatisfactory that 33% of the samples had an APC of more than 5.0× 105 CFU/g. About 60% of the imported samples that were taken from the retail shops were found to be acceptable in terms of APC, with counts less than 1.0 x 105 CFU/g. Reject level (>5.0×105 CFU/g) comprised 22% of the sample.

Sri Lanka Standards Institution (SLSI) guidelines state that a dried fish's yeast mould count is acceptable if it is less than 1000 CFU/g and unsuitable if it is more than 10,000 CFU/g. Of the samples produced locally, 92% were of good quality, and 4% had poor quality. 82% of the imported samples that were taken from shops were of good quality, while 7% fell into the rejection range. The acceptance percentages of dried fish based on APC and the counts of yeast and mould are summarized in Table 4.

**Table 4: Acceptability percentages of dried fish based on APC and yeast and mould counts.**

|  |  |  |
| --- | --- | --- |
| Sample type | Acceptable % | Unacceptable % |
| APC | Yeast & mould | APC | Yeast & mould |
| Locally produced dry fish samples sold in the retail market | 58 | 92 | 33 | 4 |
| Imported dry fish samples sold in the retail market | 60 | 82 | 22 | 7 |

## Other meat and meat-based products

No reported research has been found on other meat sold in Sri Lanka, such as Beef, Mutton, and pork, which are also purchased among Sri Lankans. However, little research has been done on already processed meat that was ready to be consumed.

In 2012, a research study was done on Chinese-style fried rice to determine the prevalence of Bacillus cereus in Colombo. A variety of fried rice of 200 samples were examined, including chicken (20.0%), vegetable (18.0%), seafood (10.0%), egg (5.0%), mixed (2.0%), and beef (1.0%). Out of the 200 fried rice samples that were examined, 112 (56.0%) had *B. cereus* found in them, while the remaining 88 (44%) did not. 28 (14%) of these positive samples had colony counts > 106, indicating the infectious dose. Concurrently, *B. cereus* colony counts of <106 were found in 84 (42%) samples. When considering counts over 106,the highest prevalence was found in Chicken fried rice (23.7%). *B. cereus* over 106 was not found in any beef-fried rice samples. When it came to counts under 106, beef fried rice had the lowest prevalence (20%), while both seafood and egg fried rice had the most significant prevalence (44.4%) (Perera & Ranasinghe, 2012).

In 2016, a microbiological study was done on chicken-based short-eat food collected from recognized restaurants in Kadawatha City (Wagawaththa & Wijayanayake, 2016). A total of six chicken-based short-eat food products were analysed, including burgers, club sandwiches, bread roll sandwiches, roti, and hot dogs with mustard cream. Analyses of the samples included Total viable count (TVC), Total coliform count (TCC), *Escherichia coli* count (ECC), *Staphylococcus aureus* count (SAC), and the presence of *Salmonella*.

Various foods, including burgers, club sandwiches, bread roll sandwiches, and rotis, exceeded the suggested guideline (5 log CFU/g) for TVC. Club sandwiches had the greatest TVC of 7.51 log CFU/g, while hotdogs with mustard cream had the lowest TVC of 3.05 log CFU/g. Every food item, aside from the hotdog with mustard cream, had a TCC found to be higher than 10 MPN/g. Only the burger (4 MPN/g), bread roll sandwich (4 MPN/g), and club sandwich (9 MPN/g) had *E. coli*. Four food samples included *S.* *aureus*, with roti having the highest SAC of 4.48 log CFU/g. However, none of the examined foods had *Salmonella* in them.

A recent study in 2022 was done on cooked beef curries and chicken curries collected from households to detect *Clostridium perfringens*. A Total of 100 chicken curries and 100 beef curries were collected from 200 households registered under the Colombo Municipal Council. *Clostridium perfringens* was detected in 47 (47%) of the chicken curries, while in beef curries, 31 (31%) were found (Ranasinghe *et al.*, 2022).

Another recent study in 2023 was done on commercially available ready-to-eat meat street food donor kebabs in the Colombo district. A total of 150 kebab samples were collected randomly from 3 regions of Colombo: Aluthkade, Kibulawala, and Kailasa. The study detected eight harmful bacterial species, including *Vibrio* spp. (07%), *Protease* spp. (07%), *Salmonella* spp. (20%), *Escherichia coli* (20%), *Pseudomonas spp*. (07%), *Klebsiella* spp. (13%). *Enterobacter aerogenes* (20%) and *Shigella* spp. (07%). At least three different kinds of bacteria were present in all three areas. The greatest significant contamination levels of *Salmonella* spp. (40%) and *Enterobacter aerogenes* (40%) were found in Kailasa, while *Escherichia coli* (40%) was found in Aluthkade (p < 0.05) (Mahawatte *et al.*, 2023).

**Preventive strategies and Policy implications**

Based on the prevalence and types of microbial contaminants identified in these foods, following preventive strategies were recommended in existing literature. Implementing Good Agricultural Practices and Good Hygienic Practices at farm levels, reenforce hazard analysis and critical control points in meat processing facilities, proper cold chain management, routine surveillance and testing in slaughterhouses , markets and retail outlets, educate food handlers, consumers about safe food handling, cooking and storage practices (Microbiological risks and JEMRA, 2025; CDC, 2024).

When discussing about the policy implications, global food safety authorities emphasize the importance of integrating microbiological risk assessments into national policies to strengthen regulatory frameworks and decision-making. Organizations like the FAO and WHO, through initiatives such as JEMRA, advocate for this approach to better manage foodborne risks. In parallel, the CDC highlights the value of centralized surveillance systems and cross-agency collaboration to enhance the monitoring and response to food safety threats. Recognizing the diversity of food producers, the FAO also stresses the need to support small-scale operators by providing training and infrastructure that enable them to meet safety standards. Additionally, both the FAO and WHO have identified antimicrobial resistance (AMR) in foodborne pathogens as a growing concern, urging countries to incorporate AMR monitoring into their food safety strategies (Microbiological risks and JEMRA, 2025; CDC, 2025).

# Conclusion

Chicken, eggs, fish, and other meats such as beef, mutton, and pork are commonly purchased and consumed among Sri Lankans. Among the pathogenic microorganisms, *Salmonella* spp. and *Escherichia coli* tend to contaminate chicken more than other microorganisms. Cross-contamination can also contribute to the contamination of chicken meat. Therefore, proper food handling and storage can reduce cross-contamination. Eggs are mostly sterile due to their natural protection from microorganisms by eggshells. Hence, the condition of eggs is important. For example, cracks in eggshells can give less assurance of eggs being contaminated. Therefore, the probability of Eggshells being contaminated is higher than the inner egg content being contaminated. *Salmonella* spp. is the most probable microbial agent that causes contamination in eggs. In fish, *E. coli* tends to contaminate more compared to other microorganisms due to fish being more prone to faecal contamination in water bodies. Shrimp in shrimp farms are more likely to be contaminated with *Vibrio* spp. Cross-contamination will likely occur among shrimps harvested in ponds containing shrimps contaminated with *Vibrio* spp. Due to high salt content, dry fish is less likely to be contaminated with pathogenic microorganisms. No reported research has been found to understand the microbial quality of other meat sold in Sri Lanka. Therefore, more research should be encouraged to further our understanding of the prevalence of microbial contaminants in other meat samples. Despite contamination of raw meat sold in retail shops, proper storage, washing, and cooking with proper food safety measures can destroy most harmful microbial food pathogens and prevent foodborne illnesses.

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Details of the AI usage are given below:

1.

2.

3.

**REFERENCES**

1. Ahmed, A., Al-Mahmood, O., 2023. Food Safety Programs that should be Implemented in Slaughterhouses: Review. Journal of Applied Veterinary Sciences 0, 0–0. <https://doi.org/10.21608/javs.2023.185918.1208>
2. Aladhadh, M., 2023. A Review of Modern Methods for the Detection of Foodborne Pathogens. Microorganisms 11, 1111. https://doi.org/10.3390/microorganisms11051111
3. Ali, N. H., Farooqui, A., Khan, A., Khan, A. Y., and Kazmi, S. U. (2010). Microbial contamination of raw meat and its environment in retail shops in Karachi, Pakistan, *Journal of Infection in Developing Countries*, 4(6), pp. 382–388. <https://www.jidc.org/index.php/journal/article/view/20601790>
4. Alimi, B.A., Lawal, R., Odetunde, O.N., 2022. Food safety and microbiological hazards associated with retail meat at butchery outlets in north-central Nigeria. Food Control 139, 109061. https://doi.org/10.1016/j.foodcont.2022.109061
5. Alwis, U. S., Mudannayake, D. C., Jayasena, D. D., and Ubeyarathna, K. J. H. (2014). Evaluation of *Salmonella* cross contamination at retail chicken meat outlets in Kandy, Sri Lanka, *Korean Journal of Agricultural Science*, 41(1), pp. 35–40. [https://koreascience.kr/article/JAKO201416747604821.pdf](https://onlinelibrary.wiley.com/doi/10.1111/jfq.12243)
6. Ariyawansa, S., Ginigaddarage, P., Jinadasa, K., Chandrika, J. M., Arachchi, G. G. and Ariyaratne, S. (2016). Assessment of Microbiological and Bio-chemical Quality of Fish in a Supply Chain in Negombo, Sri Lanka, *Procedia Food Science*, 6, pp. 246–252. <https://www.sciencedirect.com/science/article/pii/S2211601X1600033X?via%3Dihub>
7. Awny, C., Amer, A., and El-Makarem, H. (2018). Microbial Hazards Associated with Consumption of Table Eggs, *Alexandria Journal of Veterinary Sciences*, 59(1), p. 139. <https://www.alexjvs.com/fulltext/31-1521642606.pdf?1733210133>
8. Bakhtiary, F., Sayevand, H. R., Remely, M., Hippe, B., Hosseini, H., and Haslberger, A. G. (2016). Evaluation of Bacterial Contamination Sources in Meat Production Line, *Journal of Food Quality*, 39(6), pp. 750–756. <https://onlinelibrary.wiley.com/doi/10.1111/jfq.12243>
9. Bavoria, S., Langeh, S., Mir, L.A., 2021. Food safety in India: a public health priority. Int J Community Med Public Health 8, 3193. <https://doi.org/10.18203/2394-6040.ijcmph20211917>
10. Bhaisare, D., Punniamurthy, Natesan, Bhaisare, D. B., Thyagarajan, D., Churchil, R. R., and Punniamurthy, N. (2014). *Bacterial Pathogens in Chicken Meat: Review*, *International Journal of Life Sciences Research*. Available at: <https://www.researchpublish.com/papers/bacterial-pathogens-in-chicken-meat-review>
11. Bukar, A., Uba, A., and Oyeyi, T. I. (2010). Occurrence of some enteropathogenic bacteria in some minimally and fully processed ready-to-eat foods in Kano metropolis, Nigeria, *African Journal of Food Science*, 4(2), pp. 32-36 <https://academicjournals.org/journal/AJFS/article-full-text-pdf/78D134721554>
12. CDC, 2025. Guidelines and Guidance Library [WWW Document]. Infection Control. URL https://www.cdc.gov/infection-control/hcp/guidance/index.html (accessed 5.23.25).
13. CDC, 2024. CDC’s Core Infection Prevention and Control Practices for Safe Healthcare Delivery in All Settings [WWW Document]. Infection Control. URL https://www.cdc.gov/infection-control/hcp/core-practices/index.html (accessed 5.23.25).
14. Chen, C.-Z., Li, P., Liu, L., Sun, Y.-J., Ju, W.-M., Li, Z.-H., 2024. Seasonal variations of microbial communities and viral diversity in fishery-enhanced marine ranching sediments: insights into metabolic potentials and ecological interactions. Microbiome 12, 209. <https://doi.org/10.1186/s40168-024-01922-w>
15. Chowdhury, U.S., Sultana, R., Acharjee, M., 2024. Screening the Microbiological Contamination in Salad Samples and Analysis their Antibiotic Sensitivity Pattern. Journal of Advances in Microbiology 24, 189–197. <https://doi.org/10.9734/jamb/2024/v24i12883>
16. DAPH Statistical Bulletin (2022) *Livestock Statistical Bulletin 2022. Department of Animal Production and Health Sri Lanka*. (Accessed 30 July 2024). <https://daph.gov.lk/files/uploads/documents/downloads/Statistical_Bulletin2022.pdf>
17. Enver, K., Senita, I., Sabina, O., Saud, H., Almir, T., Nermina, Đ., Samir, M., 2021. Microbiological Contamination of Fresh Chicken Meat in the Retail Stores. Food Nutr. Sci. 12, 64–72. <https://doi.org/10.4236/fns.2021.121006>
18. Food safety and quality: Microbiological risks and JEMRA [WWW Document], 2025. URL https://www.fao.org/food/food-safety-quality/scientific-advice/jemra/en/ (accessed 5.23.25).
19. Fung, F., Wang, H. S., and Menon, S. (2018). ‘Food safety in the 21st century’, *Biomedical Journal*. Elsevier B.V., pp. 88–95. doi.org/10.1016/j.bj.2018.03.003 <https://doi.org/10.1016/j.bj.2018.03.003>
20. Gamage, B. Y. I., Thilakarathne, D. S., Abayawansha, K. G. R. and Kalupahana, R. S. (2021). Preliminary investigation on *Salmonella* and *Escherichia coli* contamination of chicken meat sold at small-scale farm shops in Kandy District, Sri Lanka, *Sri Lankan Journal of Infectious Diseases*, 11(0), p.3 <https://sljid.sljol.info/articles/10.4038/sljid.v11i0.8439>
21. Ginigaddarage, P. H., Surendra, I. H. W., Weththewa, W. K. S. R., Ariyawansa, K. W. S., Ganegama Arachchi, G. J., Jinadasa, B. K. K. K., Hettiarachchi, K. S. and Edirisinghe, E. M. R. K. B. (2018). *Microbial and chemical quality of selected dried fish varieties available in Sri Lankan market*, *Sri Lanka J. Aquat. Sci*.

<https://sljas.sljol.info/articles/10.4038/sljas.v23i1.7552>

1. Gunasena, D. K., Kodikara, C. P., Ganepola, K. and Widanapathirana, S. (1995). *occurrence of listeria monocytogenes in food in sri lanka*, *J. Natn. Sci. Coun. Sri Lanka*.

<https://jnsfsl.sljol.info/articles/5848/files/submission/proof/5848-1-20817-1-10-20130720.pdf>

1. Jayasinghe, P. S. and Rajakaruna, R. M. A. G. G. (2005). Bacterial contamination of fish sold in fish markets in the central province of Sri Lanka, *Journal of the National Science Foundation of Sri Lanka*, 33(3), pp. 219–221.

<https://jnsfsl.sljol.info/articles/10.4038/jnsfsr.v33i3.2328>

1. Jayaweera, T. S. P., Ruwandeepika, H. A. D., Deekshit, V. K., Vidanarachchi, J. K., Kodithuwakku, S. P., Karunasagar, I. and Cyril, H. W. (2020). Isolation and identification of *Salmonella* spp. From broiler chicken meat in Sri Lanka and their antibiotic resistance, *Journal of Agricultural Sciences - Sri Lanka*, 15(3), pp. 395–410. <https://jas.sljol.info/articles/10.4038/jas.v15i3.9031>
2. Jianadasa, B. K. K. K., Ginigaddarage, P. H. and Ariyawansa, S. (2014a). A Comparative Quality Assessment of Five Types of Selected Fishes Collected from Retail Market in Sri Lanka, *American Journal of Food Science and Technology*, 2(1), pp. 21–27. <https://www.sciepub.com/ajfst/abstract/1434>
3. Kalupahana, R. S., Rajapaksa, D. I. G., Fernando, P. S., Thilakarathne, D. S. and Abeynayake, P. (2017). Occurrence and characterization of nontyphoidal Salmonella in retail table eggs in Kandy district of Sri Lanka, *Food Control*, 72, pp. 244–248.

 <https://doi.org/10.1016/j.foodcont.2016.04.024>

1. Koralage, M. S. G., Alter, T,, Pichpol, D,, Strauch, E., Zessin, K. H. and Huehn, S. (2012). Prevalence and Molecular Characteristics of *Vibrio spp*. Isolated from Preharvest Shrimp of the North Western Province of Sri Lanka, *Journal of Food Protection*, 75(10), pp. 1846–1850.

<https://doi.org/10.4315/0362-028X.JFP-12-115>

1. Kulasooriya, G. D. B. N., Amarasiri, M. K. U. T., Abeykoon, A. M. H. and Kalupahana, R. S. (2019). *Salmonella, Campylobacter and Escherichia coli* in raw chicken meat, chicken products and cooked chicken in retail markets in Kandy, Sri Lanka, *Sri Lanka Veterinary Journal*, 66(1), p. 19.

<https://slvj.sljol.info/articles/10.4038/slvj.v66i1.33>

1. Linscott, A. J. (2011). Food-Borne Illnesses, *Clinical Microbiology Newsletter*, 15 March, pp. 41–45. <https://doi.org/10.1016/j.clinmicnews.2011.02.004>
2. Lipp, E.K., Kurz, R., Vincent, R., Rodriguez-Palacios, C., Farrah, S.R., Rose, J.B., 2001. The effects of seasonal variability and weather on microbial fecal pollution and enteric pathogens in a subtropical estuary. Estuaries 24, 266–276. <https://doi.org/10.2307/1352950>

1. Madhurangi, G. H. P., Fernando, T. S. R., Bulumulla, P. B. A. L. K. and Chandrasena, G. (2014). Prevalence of *Escherichia coli* and *Salmonella* on Different Cuts of Retail Chicken Meat in Badulla District, *KDU IRC*, pp. 112–115.

<http://ir.kdu.ac.lk/handle/345/1568>

1. Mahawatte, D. I. Y., Kudagodage, S. S., Rajakaruna, P., Weerasinghe, E., Bandara, H., Perera, O. D. K. and Bodhinayaka, V. A. (2023). Microbiological Quality of Commercially Available Ready-to-Eat Meat Street Food Doner Kebab in Colombo District, Sri Lanka. <http://ir.kdu.ac.lk/handle/345/6730>
2. Mayes, F. J. and Takeballi, M. A. (1983). Microbial Contamination of the Hen’s Egg: A Review, *Journal of Food Protection*, 46(12), pp. 1092–1098. <https://www.sciencedirect.com/science/article/pii/S0362028X23016058?via%3Dihub>
3. Ministry of Fisheries (MOF) Sri Lanka. (2024) *Overview*, *Ministry of Fisheries*. Available at: [https://www.fisheries.gov.lk/web/index.php?option=com\_content&view=article&id=16&Itemid=118&lang=en](https://d.docs.live.net/3348801af73e0310/LSM%20Waidyasuriya) (Accessed 30 July 2024).
4. Ministry of Fisheries Sri Lanka .MOF fisheries statistics (2022) *Fisheries statistics 2022*. Maligawatta. <https://www.fisheries.gov.lk/web/index.php?option=com_content&view=article&id=44&Itemid=153&lang=en> (Accessed 30 July 2024).
5. Ministry of Health Sri Lanka (2023) Performance and Progress Report 2023. [online] Available at: <https://www.health.gov.lk/wp-content/uploads/2023/12/P-P-Report-2023-English_compressed.pdf> [Accessed 23 May 2025].
6. Perera, M. L. and Ranasinghe, G. R. (2012). Prevalence of *Bacillus cereus* and associated risk factors in chinese-style fried rice available in the City of Colombo, Sri Lanka, *Foodborne Pathogens and Disease*, 9(2), pp. 125–131. <https://doi.org/10.1089/fpd.2011.0969>
7. Prabakaran, R. (2003). *Good practices in planning and management of integrated commercial poultry production in South Asia*. Food and Agriculture Organization of the United Nations.

 <https://openknowledge.fao.org/handle/20.500.14283/y4991e>

1. Ranasinghe, G., Perera, M. L. and Perera, I. (2022). Detection of *Clostridium perfringens* and associated preventive measures to appraise the safe meat curry consumption in the Colombo city, *Journal of Science of the University of Kelaniya*, 15(1), pp. 52–66. <https://josuk.sljol.info/articles/10.4038/josuk.v15i1.8053>
2. Ranasinghe, R. A. S. S., Satharasinghe, D. A., Anwarama, P. S., Parakatawella, P. M. S. D. K., Jayasooriya, L. J. P. A. P., Ranasinghe, R. M. S. B. K., Rajapakse, R. P. V. J., Huat, J. T. Y., Rukayadi, Y., Nakaguchi, Y., Nishibuchi, M., Radu, S. and Premarathne, J. M. K. J. K. (2022). Prevalence and Antimicrobial Resistance of *Escherichia coli* in Chicken Meat and Edible Poultry Organs Collected from Retail Shops and Supermarkets of North Western Province in Sri Lanka, *Journal of Food Quality*, 2022. doi.org/10.1155/2022/8962698. <https://doi.org/10.1155/2022/8962698>
3. Sharuni, A. A. G. U., Sumaiya, M. R. F., Ekanayake, E. M. D. N., Chandrasiri, N. S. and Arachchi, A. M. P. S. (2021). Contamination of chicken eggshell and egg contents with *Salmonella* species from selected farms in Kosgama, Colombo district, *Sri Lankan Journal of Infectious Diseases*, 11(0), p. 2.

 <https://sljid.sljol.info/articles/10.4038/sljid.v11i0.8369>

1. Thilakarathne, D. S., Kottawatta, K. S. A., Kalupahana, R. S. and Abeynayake, P. (2012). Investigation of *campylobacter, salmonella, escherichia coli* and *staphylococcus aureus* in chicken meat at small scale retail shops in kandy city limits, *Annual Scientific Sessions of the Sri Lanka Veterinary Association*, p. 13. <https://slvj.sljol.info/articles/10.4038/slvj.v66i1.33>
2. Ubeyratne, J. K. H., Jayaweera, M. D. N., Lokugalappatti, L. G. S., Wickramasinghe, S. and Tun, H. M. (2022). Market characteristics, *Salmonella* prevalence and associated risk practices in poultry processing environments in wet markets in Sri Lanka, *Sri Lanka Veterinary Journal*, 69(2), pp. 9–20. <https://slvj.sljol.info/articles/10.4038/slvj.v69i2.62>
3. U.S Food and drug Administration [FDA] (2022) *What You Need to Know about Foodborne Illnesses | FDA*, *U.S Food and Drug Administration*. Available at: <https://www.fda.gov/food/consumers/what-you-need-know-about-foodborne-illnesses> (Accessed 12 March 2024).
4. Visciano, P., Schirone, M., 2020. Rapid Methods for Assessing Food Safety and Quality. Foods 9, 533. https://doi.org/10.3390/foods9040533
5. Wagawaththa, W. A. I. K. and Wijayanayake, W. M. J. I. (2016). A preliminary microbiological study of chicken-based short-eat food in Kadawatha, Sri Lanka, *Proceedings of the International Research Symposium on Pure and Applied Sciences*, p. 71.

 <https://www.semanticscholar.org/paper/A-preliminary-microbiological-study-of-short-eat-in-Wimalasekara-Gunasena/97b6021d3b4c710566f9b18b8daacba7c21fdb30>

1. WHO and FERG (2015) *WHO estimates of the global burden of foodborne diseases*. Edited by World Health Organization. <https://iris.who.int/bitstream/handle/10665/199350/9789241565165_eng.pdf> (Accessed 12 March 2024).
2. Food safety (2014) World Health Organization. Available at: <https://www.who.int/news-room/fact-sheets/detail/food-safety> (Accessed: 22 May 2025).