# Most involved microorganisms in foodborne diseases outbreaks: A systematic review

# Microrganismos mais envolvidos em surtos de doenças transmitidas por alimentos: uma revisão sistemática

**Poliana Cristiane do Prado**
Undergraduate in Veterinary Medicine
Federal University of Rio Grande do Sul
Bento Gonçalves Av. 9090 – Porto Alegre/RS
E-mail: policrisprado@gmail.com

**Carolina Laipelt Matias**
Undergraduate in Veterinary Medicine
Federal University of Rio Grande do Sul
Bento Gonçalves Av. 9090 – Porto Alegre/RS
E-mail: nina.laipelt@gmail.com

**Juliana Querino Goulart**
PhD student in Agrobusiness
Universidade Federal do Rio Grande do Sul
Avenida Bento Gonçalves, 9090 – Porto Alegre/RS
E-mail: juquerino@gmail.com

**Andrea Troller Pinto**
PhD in Food Technology
Associate Professor of Preventive Veterinary Medicine Department
Federal University of Rio Grande do Sul
Bento Gonçalves Av. 9090 – Porto Alegre/RS
E-mail: andrea.troller@ufrgs.br

**ABSTRACT**
Foodborne illnesses are caused by the ingestion of contaminated food and water and the main agents are biological. To identify the most related factors that are associated with these diseases, this study aimed to highlight the most frequently reported microorganisms in outbreaks, as well as the main foods involved and the causes of their contamination, present in publications from 2017 to 2021. Therefore, the search on the Web of Science platform was performed using the terms "foodborne diseases", "foodborne outbreaks" and "foodborne illness". The research's scope was restricted by associating "outbreak" to the others. As a result, the publications presented a greater number of foodborne outbreaks caused by *Salmonella* spp., *Escherichia coli* , *Staphylococcus* spp., *Bacillus cereus* and *Vibrio* spp., among bacteria. The most reported viruses were rotaviruses and noroviruses and the parasite *Cyclospora* spp. Among foods, it was clear that cattle and poultry meats were the most frequently reported. For causes of food contamination, it was observed that the lack of hygiene or care in food handling were the factors that most

appeared among the studies. In conclusion, the adoption of stricter sanitary measures is necessary to reduce cases of FBDs, since many of them are related to procedures for handling unhygienic food.

**Keywords:** Salmonellosis, rotavirosis, food security, COVID-19.

**RESUMO**

As doenças transmitidas por alimentos (DTAs) são causadas pela ingestão de alimentos e água contaminados, sendo os principais agentes a elas associados de origem biológica. Visando identificar os fatores mais relacionados ao desenvolvimento destas doenças, este estudo teve como objetivo apontar os microrganismos mais frequentemente relatados em surtos de DTAs, assim como os principais alimentos envolvidos e as causas de contaminação dos mesmos, presentes em publicações de 2017 a 2021. Para isso, uma busca na plataforma *Web of Science* foi realizada utilizando-se os termos *"foodborne diseases", "foodborne outbreaks"* e *"foodborne illness"*. Restringiu-se o escopo da pesquisa associando a palavra *outbreak* às demais. Como resultados, as publicações apresentaram maior número de relatos de surtos de DTAs causadas por *Salmonella* spp., *Escherichia coli*, *Staphylococcus* spp., *Bacillus cereus* e *Vibrio* spp., entre as bactérias. Os vírus mais relatados foram rotavírus e norovírus e o parasita *Cyclospora* spp. Entre os alimentos envolvidos, percebeu-se que carnes vermelhas/frangos foram as mais frequentemente relatadas. Quanto às causas de contaminação dos alimentos, observou-se que a falta de higiene ou cuidados na manipulação do alimento foram os fatores que mais apareceram entre os estudos. Concluindo, a adoção de medidas sanitárias mais rigorosas é necessária à redução dos casos de DTAs, já que muitos deles estão relacionados a procedimentos de manipulação de alimentos pouco higiênicos.

**Palavras-chave:** Salmonelose, rotavirose, segurança dos alimentos, COVID-19.

## 1 INTRODUCTION

Consumer concern about food safety increased with challenges imposed by COVID-19 pandemic. Despite discarding the transmission of SARS-COV-2 through food, other diseases gained greater visibility in this scenario (CHENARIDES et al, 2020; TEIXEIRA and CARVALHO, 2020).

Foodborne diseases (FBDs) are caused by ingestion of contaminated food and water and cause several symptoms, including anorexia, nausea, vomiting and/or diarrhea, and extraintestinal manifestations may also occur. Such illnesses can be caused by physical, chemical or biological agents. Its occurrence is global and may result in impediments to economic development of countries, as barriers may be imposed by food importers, limiting trade and disfavoring the exporter's trade balance. However, data about this theme is not enough available (KLEIN; BISOGNIN; FIGUEIREDO, 2017; MELO et al, 2018).

There are more than 250 types of FBDs identified in the world. The main agents are normally biological, but diseases caused by chemical contamination of food have also been reported. Bacteria and their toxins, followed by viruses and parasites are the biological agents most present in notifications of FBDs. These diseases have an impact on public health, as they can progress to severe infections and lead to death. Therefore, the notification of outbreaks is essential to surveillance, as it triggers an epidemiological investigation of the event and, occasionally, allows the agents and foods involved to be identified (LI et al, 2018; MELO et al, 2018; MINISTRY OF HEALTH , 2018).

In order to preserve health, studies that gather information about FBDs are extremely important. Greater knowledge of biological agents, foods and their respective sources of contamination often involved in outbreaks of FBDs allow agencies to develop adequate preventive measures, reducing their occurrences. Therefore, this study aimed to point out the microorganisms most frequently reported in outbreaks of FBDs, as well as the main foods involved and the causes of their contamination, present in publications from 2017 to 2021.

## 2 METHODS AND MATERIALS

### Search scope

A two-step search was conducted in the *Web of Science* (WOS) database on July 9, 2021. In the first step (A), the presence of the terms *foodborne diseases, foodborne outbreaks* and *foodborne illness* in the titles was searched on published articles in the period 2017 to 2021; the results obtained were evaluated according to WOS categories, year of publication, consolidated organizations, authors and countries of publications. In the second stage (B), the terms searched were *foodborne diseases* and *outbreak*, both should be present in the titles of articles published on the evaluated period. The resulting publications were selected and the author's names, publication titles and abstract were tabulated.

### Inclusion criteria

All publications obtained in the second stage were evaluated by reading abstract. The inclusion criterion were a report of a food outbreak in its content, especially if the microorganism responsible for triggering the reported disease was defined. Another inclusion criterion is the indication of the foods involved, as well as how they became contaminate. In addition, studies that presented data surveys of foodborne illness

outbreaks surveillance were also included. Publications that did not present these prerequisites were excluded from the analysis.

**Data extraction**

From the publications included in this research, data containing the identification of microorganisms, foods and factors related to their contamination were extracted. These results were tabulated, calculating the number of reports of each identified microorganisms in the evaluated publications. The main foods involved in outbreaks and possible causes of contamination were also listed.

## 3 RESULTS

The results obtained in the first and second stages are shown in table 1. The 221 publications resulting from the search carried out in the first stage were evaluated in terms of years, authors, countries, WOS categories and affiliations and their result is shown in Figure 1.

Table 1. Number of publications per search step performed

| Search | Search formula | Number of publications |
|--------|----------------|------------------------|
| A | TI=( foodborne diseases OR foodborne outbreaks OR foodborne illness ) | 221 articles |
| B | TI=( foodborne diseases ) AND TI=( outbreaks ) | 32 articles |

By restricting the number of publications, adding as a requirement that the title contain the word outbreak, the result obtained was 32 publications (Figure 2). After analyzing all 32 resulting publications, 12 publications remained, selected from reading the abstract and applying the inclusion criteria. Such articles are presented in Table 2, with their authors, titles and a brief summary.

The results of the microorganisms involved, foods and causes of contamination extracted from the evaluated publications are presented in tables 3 and 4.

In 7,925 outbreaks reported in the 12 studies, *Salmonella* spp. was the most frequently identified agent among bacteria, having been reported in 27.8% of outbreaks (2,204 of 7,925), followed by *Escherichia coli* in 13.0% (1,034 of 7,925 outbreaks), *Staphylococcus* spp. in 11.9% (942 of 7,925 outbreaks), *Bacillus cereus* in 5.55% (555 of 7,925 outbreaks) and *Vibrio* spp. in 4.73% (374 of 7,925 outbreaks). Among the viruses, rotavirus was the most reported, present in 16.5% (1,304 of 7,925 outbreaks) and norovirus in 7.9% (625 of 7,925 outbreaks). Among the

parasites, *Cyclospora* sp. (15 of 7,925 outbreaks) is the most frequently observed, with 1.5% of reports.

Among foods associated with the outbreaks, beef/chicken was the most frequent, corresponding to approximately 50% (6 of 12 studies), followed by legumes, corresponding to 41.6% (5 of 12 studies) and vegetables, 33.3% (4 of 12 studies). For the causes of food contamination described in the studies, it was observed that the lack of hygiene or care in food handling were the most prevalent factors, approximately 83.3% (10 of 12 studies), while the poor hygiene or lack of care with food, equipment and utensils correspond to 58.3% (7 of 12 studies). Inadequate storage was present in 41.6% of outbreaks (5 of 12 studies).

Figure 1. Percentage of publications by year, authors, countries, WOS categories and affiliations
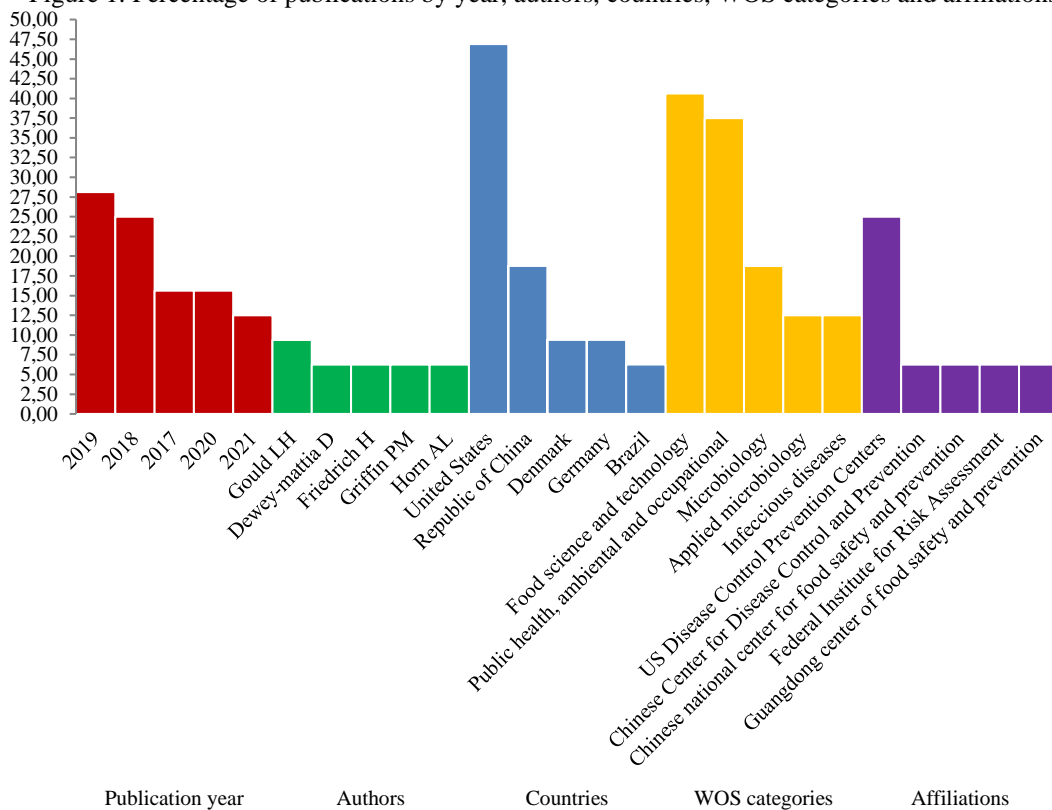
Figure 2. Percentage of publications by year, authors, countries, WOS categories and affiliations when adding the word *outbreak* to the search
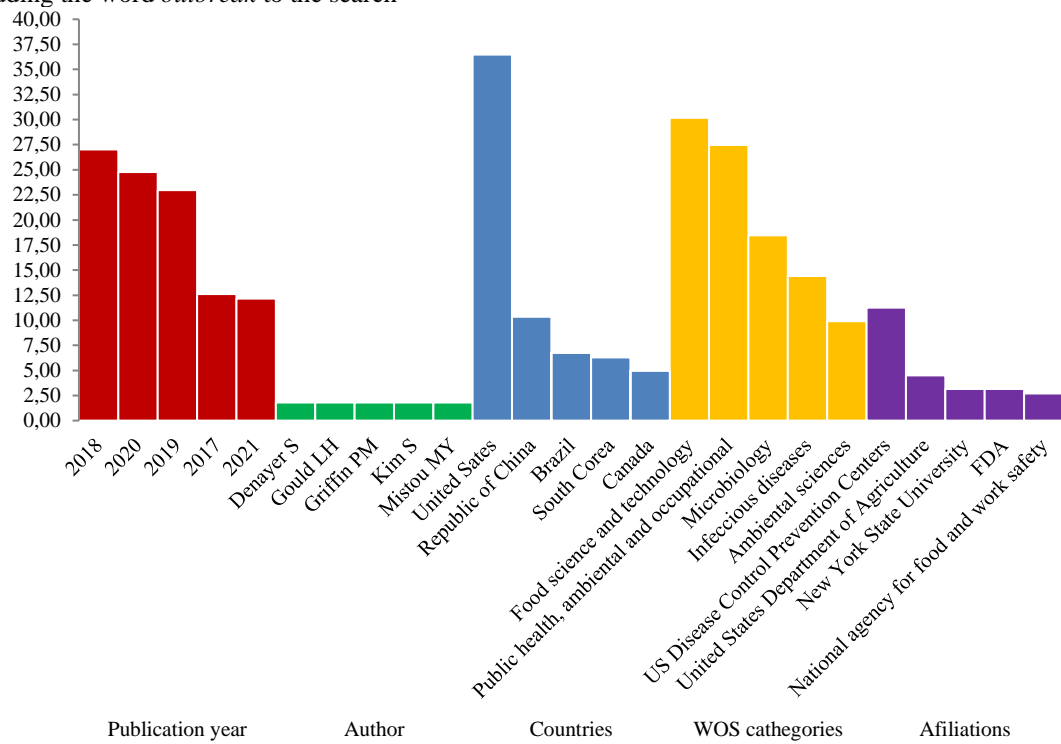
Table 2. Results of pre-selected studies obtained by reading the abstracts and after applying the inclusion criteria with identification of authors, title and abstract

| Authors | Publication title | Brief summary |
|---|---|---|
| (1) Bennett, SD et al (2018) | **Produce-associated foodborne disease outbreaks, USA, 1998-2013** | Analysis of foodborne illness outbreaks reported to the CDC in the US 1998–2013. The most identified etiological agents were norovirus, *Salmonella enterica* and Shiga toxin-producing *Escherichia coli*. |
| (2) Li, X et al (2020) | **Detecting Foodborne Disease Outbreaks in Florida through Consumer Complaints** | Analysis of food disease outbreaks reported to the Florida Outbreak and Complaints Notification System between 2015 and 2018. Complaints were outbreaks of norovirus, *Salmonella enterica* (non-typhoid) and scomboid food poisoning, as well as rare outbreaks of *Clostridium perfringens*, *Cryptosporidium spp*, *Shigella spp*. and *Vibrio vulnificus*. |
| (3) Wu, Y et al (2018) | **Surveillance for foodborne disease outbreaks in China, 2003 to 2008** | Analysis of information from the National Foodborne Disease Surveillance Network from 12 Chinese provinces, between 2003 and 2008. The most reported causes are bacteria, chemical hazards caused by humans and toxins from animals and vegetables were the main causes. |
| (4) Finger, JAFF et al (2019) | **Overview of Foodborne Disease Outbreaks in Brazil from 2000 to 2018** | Analysis of outbreaks of foodborne diseases reported in Brazil between 2000 and 2018. Etiological agents were not identified in most outbreaks, while *Salmonella* was the most reported among those identified. |
| (5) Le, HHT et al (2021) | **Large-Scale *Staphylococcus aureus* Foodborne Disease Poisoning Outbreak among Primary School Children** | Report of an outbreak of food poisoning in Vietnam in 2018 detected *Staphylococcus aureus* in two food items. *S. aureus* was also isolated from stool and vomit samples from patients and from stool samples from kitchen workers, as well as from frozen chicken meat. |
| (6) Kapaya, F et al (2018) | **A foodborne disease outbreak investigation experience in a College in Lusaka, Zambia, 2017** | Outbreak report of unknown etiology in Lusaka, Zambia. Samples from all food handlers (n = 13) produced *Staphylococcus aureus* and all food samples (n = 3) produced *Escherichia coli* , *Staphylococcus aureus* and fecal coliforms. |
| (7) Wu, G et al (2018) | **Epidemiology of foodborne disease outbreaks from 2011 to 2016 in Shandong Province, China** | Analysis of foodborne disease outbreaks from 2011 to 2016 in Shandong Province, China. There were 1,043 foodborne disease outbreaks, resulting in 8,078 illnesses, 2,442 hospitalizations and 17 deaths. |
| (8) Aminarati, F et al (2019) | ***Citrobacter freundii* Foodborne Disease Outbreaks Related to Environmental Conditions in Yazd Province, Iran** | Analysis of foodborne disease outbreaks by *Citrobacter freundii* in Yazd Province, Iran, between 2012 and 2016. The results showed a significant association between *C. freundii* outbreaks and dusty air conditions, age groups and various regional cities . |
| (9) Watier-Grillot, S et al (2017) | **Challenging Investigation of a Norovirus Foodborne Disease Outbreak During a Military Deployment in Central African Republic** | Report of an outbreak in the French armed forces deployed in the Central African Republic in 2016. Norovirus was identified in stool and food samples, confirming an outbreak of foodborne illness. |
| (10) Vardhan, V et al (2021) | **Foodborne Disease outbreak associated with eating Gaajar Halwa at a Wedding - Palghar District, Maharashtra, India, 2018** | Report of an outbreak of foodborne illness in India in 2018. The clinical presentation of the patient-cases and the incubation period were consistent with enterotoxin-producing *Staphylococcus aureus* as a likely etiologic agent. |
| (11) Abdou, HM et al (2019) | **Outbreak Investigation of a Multipathogen Foodborne Disease in a Training Institute in Rabat, Morocco: Case-Control Study** | Report of an outbreak of foodborne illness in 2017. Feces of sick students and a food sample were collected for bacterial testing. Laboratory tests of *briouat, a* typical food in Moroccan cuisine, showed the presence of *Escherichia coli O157 and Staphylococcus aureus.* |
| (12) Li, Y et al (2018) | **Bacteria and poisonous plants were the primary causative hazards of foodborne disease outbreak: a seven-year survey from Guangxi, South China** | Analysis of foodborne disease outbreaks from 2010 to 2016 in Guangxi, southern China. Bacteria (62 outbreaks) and toxic plants (46 outbreaks) were the main etiologies of foodborne diseases in this study. |

Table 3. Main microorganisms related to foodborne outbreaks in the selected studies

| | Identification number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Type of study | A | A | A | A | R | R | A | R | R | R | R | A | |
| **Bacteria** | Hydrophilic Aeromonas | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Bacillus cereus | 1 | - | 111 | 434 | - | - | 9 | - | - | - | - | * | 555 |
| | Brucella spp | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Burkholderia spp | - | - | 6 | - | - | - | - | - | - | - | - | * | 6 |
| | Campylobacter spp | 13 | - | - | - | - | - | - | - | - | - | - | - | 13 |
| | Citrobacter spp | - | - | - | - | - | - | - | 22 | - | - | - | - | 22 |
| | Clostridium botulinum | - | 1 | 1 | - | - | - | - | - | - | - | - | - | 2 |
| | Clostridium spp | 1 | 2 | - | 302 | - | - | - | - | - | - | - | - | 305 |
| | Chronobacter | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Enterobacter spp | - | - | - | - | - | - | 3 | - | - | - | - | - | 3 |
| | Enterococcus spp | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Escherichia coli | - | - | 60 | 974 | - | 1* | - | - | - | - | 1* | - | 1034 |
| | Enteroaggregative Escherichia coli | - | - | - | - | - | - | - | - | - | - | - | * | 0 |
| | Enteropathogenic Escherichia coli | 1 | - | - | - | - | - | 9 | - | - | - | - | * | 10 |
| | Enterotoxigenic Escherichia coli | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| | Escherichia coli (STEC) | 72 | - | - | - | - | - | - | - | - | - | - | - | 72 |
| | Franciella novicide | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | grimotsia hollisae | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 |
| | Listeria monocytogenes | 4 | 1 | - | - | - | - | 1 | - | - | - | - | - | 6 |
| | Shigelloid plesimones | - | - | 5 | - | - | - | - | - | - | - | - | - | 5 |
| | Proteus spp | - | - | 110 | - | - | - | 3 | - | - | - | - | - | 113 |
| | Proteusbacillus vulgaris | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Salmonella spp | 161 | 15 | 115 | 1895 | - | - | 18 | - | - | - | - | * | 2204 |
| | Shigella spp | 17 | 1 | 11 | 263 | - | - | - | - | - | - | - | * | 292 |
| | Staphylococcus spp | - | 4 | 94 | 842 | 1 | 1* | - | - | - | 1 | 1* | * | 942 |
| | Streptococcus spp | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Vibrio spp | - | 25 | 322 | - | - | - | 27 | - | - | - | - | * | 374 |
| | Yersinia enterocolitica | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| **Viruses** | Norovirus | 250 | 43 | - | 329 | - | - | 2 | - | 1 | - | - | - | 625 |
| | Rotavirus | - | - | 1 | 1303 | - | - | - | - | - | - | - | - | 1304 |
| | Toad virus | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Hepatitis A virus | 14 | 1 | - | - | - | - | - | - | - | - | - | - | 15 |
| **Parasites** | Angiostrangylus cantonensis | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | Cryptosporidium spp | 4 | 1 | - | - | - | - | - | - | - | - | - | - | 5 |
| | Cyclospora spp | 13 | 2 | - | - | - | - | - | - | - | - | - | - | 15 |
| | Giardia spp | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| | Trichinella spp | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| | **Total** | 553 | 97 | 836 | 6342 | 1 | 0 | 72 | 22 | 1 | 1 | 0 | 0 | 7925 |

A= Analysis of records by data surveys related to disease outbreak surveillance; R = Outbreak report;
* Microorganism not identified by laboratory tests.

Table 4. Foods and their sources of contamination reported in the evaluated FBDs outbreaks

| Contamination Factors* | | 1 A | 2 A | 3 A | 4 A | 5 R | 6 R | 7 A | 8 R | 9 R | 10 R | 11 R | 12 A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water | - | - | - | X | - | - | - | X | - | - | - | - |
| | *Briouat* [1] | - | - | - | - | - | - | - | - | - | - | X | - |
| | Mixed foods | - | - | - | X | - | - | X | - | - | - | - | X |
| | Cakes/breads | - | - | - | - | - | - | - | - | - | - | - | X |
| | Sprouts | X | - | - | - | - | - | - | - | - | - | - | - |
| | Beef/chicken | - | - | X | X | X | X | X | - | - | - | - | X |
| | Cereals/grains | - | - | X | - | - | - | X | - | - | - | - | X |
| | Mushrooms | - | - | X | - | - | - | X | - | - | - | - | - |
| | Meat products | - | - | - | - | - | - | X | - | - | - | - | - |
| Foods | Dairy products | - | - | - | - | - | - | - | - | - | X | - | X |
| | Fruits | X | - | - | - | - | - | X | - | - | - | - | - |
| | Seafood | - | X | - | X | - | - | - | - | - | - | - | X |
| | Legumes | X | - | X | X | - | - | X | - | - | - | - | X |
| | Milk | - | - | - | - | - | - | - | - | - | X | - | - |
| | Eggs | - | - | - | X | - | - | - | - | - | - | - | - |
| | Fishes | - | - | X | - | - | - | - | - | - | - | - | - |
| | Carrot pudding (*gaajar halwa*) | - | - | - | - | - | - | - | - | - | X | - | - |
| | Underground Roots and Vegetables | X | - | - | - | - | - | - | - | - | - | - | - |
| | Pasta salad | - | - | - | - | - | - | - | - | X | - | - | - |
| | Sown vegetables | X | - | - | - | - | - | - | - | - | - | - | - |
| | Vegetables | X | - | X | - | - | X | X | - | - | - | - | - |
| | Food/equipment/utensils | - | - | X | X | X | X | X | - | - | - | X | X |
| | Improper storage | - | - | X | X | - | - | X | - | - | X | X | - |
| | Ready to eat food | - | X | - | - | - | - | - | - | - | - | - | - |
| | Improper cooking | - | - | X | X | X | - | - | - | - | - | - | X |
| Contamination sources | Lack of treatment/poor water quality | - | - | - | X | - | - | X | X | - | - | - | - |
| | Inadequate slaughter hygiene | - | - | - | - | X | - | - | - | - | - | - | - |
| | Inappropriate handling | X | - | X | X | X | X | X | - | X | X | X | X |
| | Presence of vectors | - | - | - | - | - | - | - | - | - | - | X | - |
| | Products not inspected | - | - | - | - | - | - | - | - | - | X | - | - |
| | Expired product | - | - | - | - | - | - | X | - | - | - | - | - |

A = Analysis of records by data surveys related to disease outbreak surveillance; R = Outbreak report; X = Presence of the factor; - = Absence of the factor * Factors suggested by the author through their own analysis or concluded by laboratory tests; [1] Traditional Indian food prepared with chicken mixed with spices, eggs, onion and vermicelli.

## 4 DISCUSSION

FBDs are public health problems and their notification is essential for their controls to occur. They are highly associated with biological contamination, but poisoning by chemical products has also been reported. Contaminations of a biological nature, such as those caused by bacteria, viruses and parasites, are the most identified

among those affected by foodborne illnesses, many of which are related to the lack of hygiene of food handlers, utensils and improperly washed food, ingestion raw or undercooked food and the acquisition of not inspected food (LI et al, 2018; MINISTRY OF HEALTH, 2018; WU Y. et al, 2018).

Of a total of 7,925 published outbreaks, *Salmonella* spp. was the most frequently identified bacterial agent, followed by *Escherichia coli*, *Staphylococcus* spp. and *Bacillus cereus*. Salmonellosis is one of the main causes of diarrheal diseases worldwide. *Salmonella* spp. can cause diseases with high mortality, especially in poor countries. In Nigeria, one of the main causes of death is typhoid fever, that is caused by a *Salmonella* sorotype. In Brazil, the spread of this bacterium is associated with the production and supply of food without declared origin, mistakes in the process of handling and transporting food, and the lack of basic criteria for hygiene, water and sanitation. This bacterium is present in eggs and poultry meat products that are widely consumed in Brazil. A study by Wright et al (2016), which analyzes *Salmonella* Enteritidis outbreaks attributed to egg-containing foods in the United States between 1973 and 2009, suggests that the implementation of interventions to reduce the exposure of *Salmonella-* contaminated eggshells coincided with a significant decline of foodborne outbreaks (ALBUQUERQUE FERREIRA, 2021; NWABOR, DICKSON and AJIBO, 2015; OLIVEIRA et al, 2013; SÁNCHEZ-VARGAS, ABU-EL-HAIJA and GÓMEZ-DUARTE, 2011).

*Escherichia coli* is also widely reported in outbreaks. Food contamination by *E. coli* is common, even in developed countries. Although this microorganism is resident of the healthy gastrointestinal tract, it can cause diarrhea and extraintestinal illness. The five main foodborne diarrheal pathotypes are enterotoxigenic *E. coli (ETEC), E.* enteropathogenic *coli (EPEC),E.* enterohemorrhagic *coli (EHEC),* Shiga toxin producing *E. coli (STEC)*, *necrotoxigenic E. coli (NTEC).* Some of the main sources of contamination and transmission of this microorganism are water, animal products, among others (COURA et al, 2014; CROXEN et al, 2013; YOUNG et al, 2017).

*Staphylococcus* spp. is part of the microbiota of asymptomatic carriers, not causing disease in these people. However, in contact with food, it multiplies and produces toxins, which are involved in numerous reported outbreaks of FBDs. Staphylococcal food poisoning results from ingestion of enterotoxins produced by enterotoxigenic strains of *Staphylococcus* spp. Among the species, *S. aureus* is the most prevalent, being related to food contamination due to poor hand hygiene by food handlers, problems in packaging

sterilization and also contamination of surfaces, utensils and equipment. FBDs involving *S. aureus* can occur through the consumption of contaminated foods such as meat, sauces, canned goods, ham, salami, milk and its products, bakery products, egg creams, among others. It can cause a simple infection, such as pimples and boils or more serious ones, such as endocarditis, pneumonia, meningitis, toxic shock syndrome and septicemia (ALMEIDA et al, 2017; ANDRADE JÚNIOR et al, 2019; GARCIA et al, 2017; HENNEKINNE, DE BUYSER and DRAGACCI, 2012).

*Bacillus cereus* is a microorganism involved in FBDs. Due their ability to produce endospores, they can be present in many types of cooked food, as they are able to survive high temperatures. It is a major concern for the dairy, being involved in food poisoning due to the ingestion of pre-formed toxins in these products. It has two forms; diarrheal disease and emetic disease. Diarrheal disease is consequence of food infection with enterotoxic *B. cereus* and enterotoxin production after activation and multiplication of bacterial spores in the intestine, while emetic syndrome results from cereulide poisoning, which is previously formed in food contaminated with *B. cereus* emetic. For safer food production, proper cleaning of surfaces and equipment, correct refrigeration temperature for food (<10°C) and proper training for staff involved in food production must be ensured (EHLING-SCHULZ, FRENZEL and GOHAR, 2015; KUMARIA and SARKAR, 2016; OSIMANI, AQUILANTI and CLEMENTI, 2018; TEWARI and ABDULLAH, 2015).

Vibrios multiply in warm, low salinity waters and includes the species *V. parahaemolyticus* , *V. vulnificus* and *V. cholerae*. *V.parahaemolyticus* is a marine and estuarine bacterium, causing acute gastroenteritis when raw or undercooked seafood contaminated with this pathogen is consumed. According to Letchumanan et al (2019), *V. parahaemolyticus* was responsible for many outbreaks globally and infection by this pathogen occurs as a result of improper food preparation and handling, antibiotic resistant bacteria, ability of bacteria to resist the immune system of the host and failure of regulatory bodies to safeguard food quality. *V. vulnificus* is also a micro-organism related in foodborne outbreaks. Heng et al (2017), indicate that this microorganism  is an opportunistic and potentially fatal pathogen. Both *V. vulnificus* and *V. parahaemolyticus* can cause severe disease in immunocompromised patients, resulting in bacteremia. *V.cholerae* produces neuraminidase, which plays a significant role in the pathogenesis of cholera (ABD-ELGHANY and SALAM, 2013; DANIEL et al, 2016; LETCHUMANAN et al, 2019; SILVEIRA et al, 2014).

Viruses, such as rotavirus and norovirus, have also shown themselves to be relevant as causers of outbreaks. According to Prado and Miagostovich (2014), Rotavirus and norovirus are among the viral agents with the greatest impact on public health, as they contaminate multiple Brazilian aquatic ecosystems. Furthermore, for these authors, inadequate sanitary conditions in the communities are related to the high circulation of viruses in the environment. Vieira et al. (2012) also report that norovirus and rotavirus A are the main etiological agents of acute viral gastroenteritis. Outbreaks caused by this microorganism are associated with the consumption of bivalve mollusks, delicatessen foods, fruit and leafy vegetables (GONELLA et al, 2016; PRADO and MIAGOSTOVICH, 2014).

*Cyclospora* spp. is a protozoan implicated in prolonged watery diarrhea, fatigue, and anorexia in humans and other primates. *C. cayetanensis* is currently recognized as an obligate parasite of immunodeficient and immunocompetent humans. The infection is much less severe in the immunocompetent, who may be asymptomatic or have less severe symptoms such as abdominal cramps, nausea, vomiting, and fever, which can last from 3 to 25 days. Transmission is fecal-oral, and the oocysts of these protozoa can contaminate food, such as horticultural products, by irrigation or direct contact (BENNET et al, 2018; ROSE and SLIFKO, 1999)

The contaminated foods most reported as causing outbreaks were beef/chicken and vegetables. Beef and chicken can be contaminated by various microorganisms, which contact with the product in the production process. Inadequate refrigeration facilitates the multiplication of pathogens and lead to FBD outbreaks. Proper cooking conditions for meat products are necessary to eliminate the risk. In addition to meat products, vegetables are often associated with FBDs, especially when consumed raw. Carelessness on food's hygiene allows the presence of microorganisms and they multiply when they have adequate temperatures for this purpose. In addition, unhygienic behavior when preparing food can lead to transfer contaminants from parts of the body, being the most frequent cause of food contamination described in the studies evaluated. Cross-contamination, which harms the food industry, can occur directly, through the lack of care or hygiene of the handlers' hands, or indirectly, through the deficiency in cleaning utensils and equipment. Inadequate cooking, contaminated ingredients and incorrect storage are described in studies as causal factors of contamination and outbreaks. Lack of treatment or neglect of water is a problem that can contaminate food, utensils and handlers' hands at any stage of preparation, triggering food-borne illnesses in some countries

(AMINHARATI et al, 2019; BENNET et al 2018; FINGER et al. al, 2019; WU, G et al, 2018; WU, Y et al, 2018).

Comparing publications by countries, in America four of them were reported outbreaks that occurred in the USA between 1998 and 2018. Bennet et al (2018), who evaluated raw products such as legumes, green vegetables and fruits, observed that in 534 confirmed outbreaks 46.7% are associated to Norovirus. Li et al (2020) obtained 94 confirmed outbreaks as results, with Novovirus is responsible for 74% of the cases. Among bacterial contaminants, *Salmonella* spp., Shiga toxin-producing *E. coli* (STEC) and *Vibrio* spp. are the most involved in FBDs. Finger et al (2018), evaluating 6342 outbreaks reported in Brazil between 2010 and 2018, obtained as results for bacterial agents involved in FBDs *Salmonella* spp. in 29.8%, *E. coli* in 15.3% and *Staphylococcus* spp. in 13.2%. Among the viruses, Rotavirus had more numerous cases of outbreaks related to it than *E. coli* (20.5%) (BENNET et al. 2018; FINGER et al. 2019; LI et al. 2020).

In Asia, China presented three papers, the first one is a survey of outbreaks in Shandong Province, located in eastern China (WU G. et al. 2018), and other from Guangxi Province (LI et al. 2018). The third is a survey of data from the National Surveillance System for foodborne outbreaks from 12 Chinese provinces (WU Y. et al.2018). In the first two studies, the predominance of the bacterial agents *Vibrio* spp. and *Salmonella* spp., while *B. cereus* was more prevalent in the third, corresponding to 13.2% of the total of 836 confirmed outbreaks. In Vietnam, a report in 2018 identified *S. aureus* as an agent of the FBD outbreak. Intoxication occurred due to the ingestion of thermostable staphylococcal enterotoxins found in foods such as milk and dairy products (cheese and cream), meat and fish. In the province of Yazd, Iran, a study was carried out on the bacterium *Citrobacter* spp. between 2012 and 2016, since this pathogen was the cause of 22 foodborne outbreaks and, from confirmed cases, it was identified that the species *C. freundii* caused FBDs in 57 people during the period evaluated. In India, areport in the year 2018, the cause of the outbreak was *S. aureus* associated with the ingestion of *gaajar halwa* (carrot pudding) prepared with *khoa* , a perishable dairy product (AMINHARATI et al, 2019; LE et al, 2021; VARDHAN et al, 2021; WU Y. et al, 2018).

In Africa, a publication from Zambia was observed. It was a report of an outbreak in 2017, in which the main agents identified were *S. aureus* and *E. coli*, which were related to unsanitary food handling. In the year 2016, an outbreak caused by Norovirus

was reported among the French armed forces deployed in the Central African Republic. In Morocco in 2017, an outbreak of FBD involving *S. aureus* and *E. coli* 0157H7 was reported in *Briouat*, a sweet or salty puff pastry typical of Moroccan cuisine (ABDOU et al, 2019; WATIER-GRILLOT et al, 2017).

Due to the numerous outbreaks of FBDs that have been reported and the negative impact of these diseases on public health, it is important to carry out studies that compile the identification data of the pathogens and foods most commonly involved in outbreaks and the predisposing factors for contamination. Thus, it is possible to adopt preventive measures against new outbreaks of FBDs. Some of these measures such as hand hygiene for food handlers; wash and disinfect fruits and vegetables properly before consumption; control food storage temperature; avoid eating raw or undercooked foods; not consuming products not inspected are essential to the control of FBDs. In addition, the notification of suspected FBDs allows the investigation of cases, something necessary for the effective control of them. Therefore, education and awareness are essential, as well as public investments are essential to reduce cases of FBDs.

## 5 CONCLUSIONS

FBDs are a public health problem. The biological agents that contaminate food and cause most outbreaks are *Salmonella* spp. and *E.coli* , both microorganisms that are part of the intestinal microbiota of animals. Therefore, contamination is basically due to unhygienic handling of food. This is repeated when looking at data on viruses, where rotavirus and norovirus are the most reported. Adoption of stricter sanitary measures is necessary to reduce cases of FBDs.

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