Clinical and Experimental Health Sciences

Bacterial Foodborne Diseases in Sudan: A Review

Azza M. Khalid[1], Wifag M. Rabih [2], Elfatih Yousif Eldoma[3], Amani M.A. Bakhiet[4], Salma Elhadi Ibrahim Mekki[5], Abdalbasit A. Mariod[6,7], Siddiqa M. A. Hamza[8], Rihab Ahmed Hassan[9], Sana Abd Elgany Yousif Fageer[10], Hwida Elamin Elwida Elamin[11], Abdel Moneim E Sulieman[12], Hind TajAlser Hamid[13], Mohamed A.M.A. Abasher[14]

[1] Marational Food Research Center (NFRC), Food Safety& Biotechnology Department, Khartoum north, Sudan.
[2] Ibn Sina University, Faculty of Medicine, Microbiology Department, Khartoum, Sudan.
[3] Merowe University of Technology Abdulatif AL Hamad. Faculty of Medicine and Health Science Merowe, Sudan.
[4] Hafr Al-Batin University, College of Sciences, Hafr Al-Batin, KSA.
[5] Umm Al-Qura University, Faculty Medicine at Al-Qunfudah, Department of Physiology, Al-Qunfudah, KSA.
[6] University of Jeddah, College of Science and Arts, Department of Biology, Alkamil, KSA.
[7] Ghibaish College of Science and Technology, Indigenous Knowledge Center, Ghibaish, Sudan.
[8] Umm Al-Qura University, Faculty of Medicine at Al-Qunfudah, Department of Pathology, Al-Qunfudah, KSA.
[9] University of Dongola, Faculty of Medical Laboratory Sciences, Dongola, Sudan.
[10] El-imam El-Mahdi University, Faculty of Medical Laboratory Science, Department of Clinical Chemistry, Kosty, Sudan.
[11] Al-Neelain University, Faculty of Medical Laboratory Science, Department of Hematology, Khartoum , Sudan.
[12] University of Hail, College of Sciences, Department of Biology, City, KSA.
[13] University of Dongola, Faculty of Medicine and Health Sciences, Dongola, Sudan.
[14] Dongola University, Faculty of Medical Laboratory Sciences, Dongola, Sudan.

Correspondence Author: Abdalbasit Adam Mariod
E-mail: basitmariod58@gmail.com, aalnadif@uj.edu.sa
Received: 04.04.2022 **Accepted:** 14.12.2022

ABSTRACT

Objective: To determine the role of the bacteria associated with foodborne diseases in Sudan and to help health policymakers introduce strict intervention measures control.

Methods: The review uses up-to-date data via manual screening of the titles and abstracts of retrieved articles using string foodborne diseases in Sudan and foodborne illnesses as keywords to obtain publications from the electronic databases PubMed and Google Scholar using the publish or perish tool. However, priority has been given to the scientific papers, reports, and literature issued within the past 5 years.

Results: The review reported that many types of research revealed that foodborne infection is a critical, life-threatening health problem in Sudan and that different food pathogens are responsible for people and outbreaks of foodborne illness.

Conclusion: Foodborne diseases are considered one of the main reasons for illness and death, particularly in countries that suffer from poor economic conditions, such as Sudan. The review concluded that the most bacteria that caused foodborne disease in Sudan were *Escherichia coli, Salmonella spp,* and *Staphylococcus aureus*.

Keywords: Foodborne diseases, Sudan, Bacteria, Food safety.

1. INTRODUCTION

Food poisoning results from eating food contaminated with pathogens, toxins, and chemical secretions. Food poisoning occurs when an infection in the digestive system or the presence of neurological symptoms in the injured or in animals that have eaten a meal during the last three days. Undoubtedly, there are harmless and useful bacteria used in making some foods such as yogurt and cheese. There are chemicals among the natural components of food because diseases are transmitted through the food itself, and some of them are accidentally added during the manufacturing processes, either by mistake, neglect, or pollution. Bacteria are responsible for 66% of foodborne disease causes, followed by chemicals (26%), viruses 4%, and parasites 4% (1). Common food-related bacterial pathogens of animal origin are *Staphylococcus aureus*, *Salmonella typhi*, *Campylobacter jejuni*, *Listeria monocytogenes,* and *Escherichia coli*. Since bacteria are among the most important foodborne pathogens because they form spores that make them heat resistant (for example*, Clostridium botulinum*, *C. perfringens*, *Bacillus subtilus*, and *Bacillus cereus* (2). Some types of these bacteria

DOI: 10.33808/clinexphealthsci.1098014

can grow under cold conditions or temperatures below 25-45 degrees Celsius (3).

2. BACTERIAL FOODBORNE DISEASES

2.1. Escherichia coli (E. coli)

Escherichia coli (*E. coli*) are Gram-negative bacteria, classified as normal flora of the lower parts of the alimentary tract in animals and humans. However, most of the strains are harmless. However, certain pathogenic *E. coli* strains can infect the gut area and cause severe foodborne diseases. Different types of *E. coli*, such as Shiga toxin-producing *E. coli* (STEC), are responsible for a diarrheal disease that is considered the second cause of death among children worldwide, as well as septicemia, urinary tract infections (UTIs), and neonatal meningitis (4). *E. coli* can affect humans when they consume contaminated foods such as raw meat products, raw milk, and contaminated raw vegetables and sprouts. A pathogenic strain of *E. coli* (*E. coli* 0157:H7) was reported as the causative agent of illness in the two outbreaks in different countries (5). Food handlers and livestock are occasional carriers of pathogenic *E. coli*. However, these carry the facilitation of the introduction of infected serotypes of *E. coli* to the environment through food, crops, and meat contamination (6).

2.1.1. Pathology and Pathogenicity of E. coli

The pathology and pathogenicity of the pliability of *E. coli* have led to the evolution of this bacteria into pathogenic strains that cause illness in humans and animals (7). Nevertheless, *E. coli* is very diverse, as it encompasses both commensal, probiotic (bnign) and pathogenic strains. Various strains pollute water and vEarious kinds of food (8). There are six distinguished varieties of *E.coli* as a source of enteric infection: enteropathogenic *E.coli* (EPEC), enterohaemorrhagic *E. coli* (EHEC), enterotoxigenic *E. coli* (ETEC), enteroaggregative *E. coli* (EAEC), enteroinvasive *E. coli*, (EIEC), and diffusely adherent *E. coli* (DAEC)(9). This grouping is dependent on harmful factors, clinical sickness, phylogenetic profile, and the creation of poisons. Enterohemorrhagic *E. coli* (EHEC), specifically *E. coli* O157: H7, has been identified as one of the microorganisms responsible for foodborne human disease worldwide. This group uses major outbreaks to primarily affect developing countries and is capable of diarrheal sickness in addition to genuine clinical complexities like hemolytic uremic syndrome (HUS) (7). Besides, Shiga poison delivers *E. Coli* (Shiga causes genuine illnesses, which can be perilous).

2.1.2. Escherichia coli as causative foodborne diseases in Sudan

Food poisoning and foodborne disease outbreaks documented in Sudan are very few, although different studies have confirmed bacterial contamination of poultry, fish, camels, and meat in different areas (10).

However, epidemiological studies tracing the level of contamination of products in different areas of Sudan pointed to *E. coli* as quite possibly the most well-known causative specialist of high levels of contamination of some items like meat, milk, and eggs (11),(12). A recent study conducted by Hamid and others in 2020 which reported high contamination of broiler chains in the Khartoum North locality (13). Due to poor hygiene practices, 30% of poultry farms were found positive for *E. coli* contamination. *E. coli* was also isolated from swabs of 30 fresh chicken carcasses in Khartoum State (12).

Analysis of a total of 75 random samples of raw meat collected from different localities in Khartoum, Sudan revealed animal products such as vended red meat as a major source of *E. coli* and other pathogens associated with foodborne illnesses. *E. coli* incidence was 36% and different species were isolated; *E. coli* represented 20%, *E. vulneris* (6.6%), *E. albertii* (5.3%), and *E. fergusonii* (4%) (11). Additionally, pathogenic bacteria were isolated from vending foods in Atbara City (Naher Elneel State), Northern Sudan, and *E.coli* was the most prevalent besides other bacterial strains such as *Staphylococcus aureus* and *Bacillus sp* (14).

2.2. Salmonella spp

Salmonella belongs to the family Enterobacteriaceae, Gram-negative bacteria, oxidase-negative, catalase-positive, non-spore-forming rods, and facultative anaerobes. *Salmonella* are all motile bacteria that live in the environment and cause a variety of diseases in humans and animals. It causes many diseases for humans, such as typhoid and septicemia, and causes local diseases in different types of cells and diseases of the digestive system. Non-typhoid spp. caused about 1027561 and about 387 deaths in the US in 2011. There were 2659 Salmonella serogroups in 2014, with approximately 2639 *Salmonella enterica* and 20 *Salmonella bongori* (15). Salmonella lives in the guts of different animals, and there are several serogroups of Salmonella due to the difference in antigen from one type to another (15). Salmonella was divided into three categories: enteric fever, diarrheal diseases, and invasive non-enteric fever diseases (15) .

Salmonella is an important type of bacteria that may lead to diseases such as typhoid fever in humans and animals. There are about 1.4 million Salmonella cases recorded annually in the United States, and nearly 35,000 cases are isolated by public health laboratories and monitored by the Centers for Disease Control and Prevention (CDC) (16) . The severity of Salmonella sickness differs depending on the type of salmonella serogroup and according to the health status of the infected person. Kids below 5 years of age and the elderly, in addition to people with weak immunity, are more susceptible to contracting the disease compared to healthy people. Most types of Salmonella are considered disease-causing because of their ability to penetrate, live,

and multiply inside human cells, which leads to the disease's becoming a fatal disease (17).

2.2.1. Epidemiology

Salmonella is viewed as perhaps the main source of diarrheal sickness, which prompts central illnesses and lethal infections. In 2010, typhoid fever was recorded as having about 11.9 million cases of illness and 129,000 deaths, while there were about 3.4 million infections and six hundred eighty thousand deaths due to invasive non-typhoidal Salmonella in the same year (18). Enteric salmonellosis is the second bacterial cause of infection related to bacterial foodborne illness. About 95% of Salmonella cases are identified with the utilization of contaminated foods such as milk, poultry, eggs, meat, and seafood. The disease can be cured, but sometimes it leads to serious complications such as bacteremia. Antibiotics are always used to treat diseases (19) .

2.2.2. Resistance of Salmonella to antibiotics

The appearance of resistance in Salmonella to antibiotics is one of the most important health issues all over the world. The first case of Salmonella was recorded as resistant to chloramphenicol in 1960, and then it began to increase the resistance of Salmonella to antibiotics in several states, such as the USA, Saudi Arabia, and the UK. The first conventional treatment for Salmonella was with antibiotics such as chloramphenicol, ampicillin, trimethoprim, and sulfamethoxazole. Then Salmonella began to show resistance to these antibiotics, leading to multi-drug resistance (MDR) (17).

In Sudan, Emad and his colleagues in 2012 conducted studies regarding resistance to salmonella enterica isolated from humans and animals to antibiotics. Experiments were conducted on 119 Salmonella isolated from the faces of humans, camels, poultry, and cattle. The results showed resistance to about 10 types of commonly used antibiotics, such as chloramphenicol, gentamicin, ampicillin, cefalexin, furazolidone, nalidixic acid, ciprofloxacin, colistin, sulfamethoxazole, and tetracycline. 80.67% of Salmonella was resistant to at least one of the antibiotics used and of the 45 isolates of Salmonella, 37.82% had multidrug resistance. In comparison to resistance to antibiotics, the study showed that Salmonella isolated from humans was more resistant to antibiotics than Salmonella isolated from animals. Ciprofloxacin, colistin, gentamicin, and tetracycline were more effective against Salmonella, while the study indicated decreased resistance of salmonella to chloramphenicol, ampicillin, furazolidone, and sulfamethoxazole + trimethoprim (19).

2.2.3. History of Salmonella research in Sudan

The first Salmonella infections in cattle reviewers were reported in Sudan in 1946 by Horgan. Following an outbreak reported by Soliman and Khan in 1959 at Wad Madani City and Dublin, a serovar was isolated from stool samples of two people who became ill after eating a meat meal. The same strain was also isolated from infected calves and some apparently healthy animals. In 1970, Khan conducted a survey in Khartoum city to find out the incidence of Salmonella among the animals, and the result of the survey showed 230 Salmonella isolated from various samples, and 63 serogroups were discovered. Later, 15 serogroups were discovered in Khartoum and Malakal and were added to the Salmonella list in Sudan. In 1971, Sari Eldin recorded the emergence of different strains of Salmonella. Salmonella was also isolated from sheep liver by Salih and Ibrahim. In 1987, Yaqoub and Mohamed isolated 57 strains of Salmonella from chickens slaughtered in Omdurman and North Khartoum. Salmonella Dublin was also isolated from the feces of some animals from Kuku, Omdurman, and Alobeid. In 1999, Al-Tom and others isolated Salmonella enterica from three goats from the city of Omdurman. New strains have also appeared in Khartoum city, which were isolated from 3.4% of stool samples in Khartoum city by Haj Alsafi in 2009 and in 2010 by Elhussain Salmonella enterica can be isolated from both cooked and uncooked foods (20).

There are several other studies that have been done in Sudan regarding Salmonella and salmonellosis that have been observed in animals. In 1992, Mamoun and his colleagues isolated 21 strains of Salmonella from poultry farms from 3 different states in Sudan. *Salmonella enteritidis* was isolated from 1.43% of raw milk samples in 2005 by Yagoub and his colleagues (21) (Mamoun et al., 1992). Also in 2006, Yagoub and others worked on samples of white cheese collected from markets and restaurants in Khartoum and Omdurman. *Salmonella paratyphi* A and *Salmonella paratyphi B* were discovered in 6% of the samples. In 2007, a search was conducted to find out the health and safety of foods sold on the road, and the study was done by taking samples of a Sudanese food sold on the road called Um-Jinger, made from cooked ground pearl millet, sugar, plus yogurt and lemon. Salmonella was isolated in 5% of the samples (22).

Salmonella was isolated from fish by Yagoub in 2009, and the study proved the presence of Salmonella in 6.2% of the samples. There were other studies conducted on food handlers in 2010 by Saeed and Hamed, and it was discovered that 30.1% of food handlers were carriers of Salmonella (20). In 2018, Honua isolated 0.6% of stool samples taken from kids below 5 years of age with acute diarrhea (23) .Also, in 2018, a study was conducted by collecting 30 samples from chicken carcasses, and the project proved the existence of salmonella in 30% of the samples. The study also demonstrated that chicken carcasses are more susceptible to contamination during the manufacturing process than in storage (12) . Mustafa and Hamad in 2016 conducted a study that included factories for the manufacture of poultry and red meat, and the study revealed that processed meat contains different types of bacteria, and the percentage of Salmonella was 10.4% of the total bacteria (24). In 2013, samples were taken from four markets, (Jackson, Mayo, Alfitaihab, and Souk Seta) in Khartoum state. The samples included meat, milk, and

eggs. The study proved the existence of *E. coli* and Salmonella spp. in all samples in different proportions (25).

2.3. Listeria monocytogenes

Listeria species are more widespread in the environment, including *Listeria monocytogenes* that cause Listeriosis, a dangerous disease that is deadly to humans and animals. *Listeria monocytogenes* has been isolated from broilers sold by retailers and served as meals in fast-food restaurants in Khartoum State. The number of samples collected from broiler chickens reached 250 samples. The results indicated that the percentage of Listeria spp. contamination in the total of 250 samples was 95 (38%) (26).

Also, in 2018, a study showed the presence of *Listeria monocytogenes* in 6.7% of samples that were isolated from 30 samples of fresh chicken carcasses compared to 3.6% of frozen chicken carcasses (12). The study done by Mustafa and Hamad included factories for the manufacture of poultry and red meat, and the study revealed that processed meat contains different types of bacteria, and high disease contaminated *Listeria monocytogenes*. 39% of the total bacteria (24).

2.4. Staphylococcus aureus

Bacteria are the most common cause of two-thirds of food-borne disease outbreaks, and the predominant bacteria species that participates in food-borne diseases is *Staphylococcus aureus*, which causes gastro resistance as a result of ingesting contaminated food with enterotoxins produced by staphylococcus (27), (28). *S.aureus* is the most well-known organism that causes staphylococcal food contamination (29). *S.aureus* is typically discovered in the mucous films of individuals and creatures, such as skin and the nose. However, it causes a wide range of illnesses in both humans and animals. It stands out overall due to high mortality related to drug opposition: penicillin (10µg), ampicillin (30 µg) and oxytetracycline (10µg) (30). In Africa. Separates have a high extent of protection from penicillin (31), co-trimoxazole, and antibiotic medication (32).

2.4.1. Etiology

Staphylococcus aureus is a gram-positive, catalase-positive, coagulase-positive, non-motile (26). It can live in a wide range of temperatures from 7–48C, pH (4.2 to 9.3, with an optimum of 7.0 to 7.5). Because of these properties, the bacteria can survive in a wide range of foods, including processed meats, where other organisms cannot (31). Staphylococcal food poisoning is due to the production of enterotoxin by *S.aureus* bacteria. Methods of prevention include safe food handling and processing practices, proper cleaning of equipment, and food should be handled in a way that ensures good hygiene. In a study conducted in Omdurman city and its suburbs, it was found that 30% of people dealing with meat were carriers of pathogenic organisms, mainly *S. aureus* (28). Another study conducted in Khartoum state, the sample size was 400 (milk 100, meat 100, fish 100, and cheese 100). It was found that bacteria were present in 263 of the samples. 137 isolates (34.25%) were *S. aureus*, and the percentage of staph in the different foods is highest in milk, at 63%, and the lowest percentage is present in cheese, at 20% (33). Food handlers who carry Staphylococci contaminate food by direct contact due to a lack of proper hygienic measures (30). In a study conducted in Khartoum state to isolate Staphylococcus aureus from fermented fish (fasekh), 72% of the study sample was contaminated by S. aureus (30). Also, in a study involving 259 people who deal with meat in the Omdurman area, it was found that 71.8% were S. aureus positive (28).

3. FOOD SAFETY AND FOODBORNE DISEASE

Food safety and foodborne diseases are closely connected. Consumption of unhealthy foods causes disease. Cooperation in the food chain between governments and regional border producers, supporters, distributors, and consumers ultimately lead to healthy food supplementation in the future (31). The safety of healthy food supplies has a great economic role related to disease, as well as to economic pressures at the community and international levels. In Africa, mortality has been recorded to be the equivalent of 70% of the outbreak (32). In 2010, the World Health Organization bore the brunt of the burden of foodborne diseases, which resulted in nearly 420–960 million illnesses and 420,000 (95% UI) deaths. The most common foodborne disease is diarrhea, specifically caused by Norovirus and Campylobacter spp. These pathogens were responsible for about 230,000 (95% UI 160,000–320,000) deaths, precisely non-typhoidal Salmonella enterica. The other most important sources of death are foodborne *Salmonella typhi*, *Taenia solium*, *Hepatitis A virus*, and aflatoxin (34).

3.1. The economic impact of foodborne diseases

Foodborne diseases affect people's well-being as well as impose economic impacts (35). It is also considered a major cause of various costs in terms of medical treatment, detection of infestation, recall of food commodities, and loss of public confidence (36).

3.2. Sources of foodborne diseases

In Africa, however, the knowledge regarding clean milk making and the lack of potable water for cleaning purposes were some of the factors that contributed to the poor sanitary standard of milk from farms to collection points in Khartoum State (37). The same finding was noticed among most milk producers unaware of the effect of animal health and environmental circumstances on producing safe milk due to the absence of employee licenses, the absence of technical staff, and the backwardness of milk production and processing systems, besides lack of training (38).

Zoonosis such as Malta fever and *Mycobacterium Tuberculosis* are transmitted through unhealthy milk and milk derivatives. These diseases have been recorded in different parts of Sudan (38). A similar study was conducted in the brain area of zoonotic animals to differentiate between vaccinated and infected animals (39).

Brucellosis was also reported among other domestic animals (camel, sheep, and goats) in West Kordofan State (40) . A similar finding revealed the existence of tuberculosis in humans and livestock (41). Furthermore, the presence of brucellosis in milk samples collected from a supermarket in Khartoum State was confirmed (42). Many researchers have provided evidence that *Escherichia coli* is sometimes present as a microorganism in milk for various reasons, including lack of hygiene in handling, storing food besides production, inadequate storage, and post-process contamination (43).

The hypothesis is that human extraintestinal pathogenic *Escherichia coli* (ExPEC) may act as a poultry meat reservoir for humans and is considered the main cause of community and hospital-acquired extraintestinal infections such as urinary tract infections (UTI) (44). Various sorts of food controllers who meet food assume a significant part in the spread and transmission of resistant food-borne sicknesses such as intestinal microbes and parasites, which were discovered to spread more between vendors (41%), followed by restaurant workers' (24.4%), bakers' (24.4%), butchers' (5.1%), milk wholesalers' (2.6%), and organic products/ vegetables dealers' (2.6%) (45)(Ali, 2010). The same findings were seen in 29.4% of people who serve food in Wad Medani eateries who were carriers for intestinal protozoa based on stool tests (23). The study also showed a positive association between personal hygiene, education, and hand pollution among the food handlers (46) .

3.3. Factors contributing to the transmission of Foodborne diseases

Various factors have been evaluated among food handlers, such as food safety knowledge, practices, and educational level among street food vendors in Atbara city. Among the studied groups, 28% were male and 72% were female. 48% of them had a primary school level of education while 42% were illiterate. The most isolated organisms were bacteria from cooked meals, bottled drinks, and fresh juices (14). Other surveyed factors were food hygiene information, disposition, and practices among clinic food controllers in El Managil City. Food laborers express their degree of information, conduct, and practice to be 70.1%, 63.81%, and 74.40%, respectively. The well-being status and the significance of instructional classes added to keeping food from tainting, displaying a low practice rate concerning nail cutting and covering the head during food preparation. A factual examination showed a critical correlation between training level and washing the utensils with sanitizers and wearing gloves while performing work. This examination inferred that food treatment in El Managil hospital expresses a medium knowledge level and an uplifting outlook (47). Food hygiene education is the most effective when messages are directed towards changing behavior, the consequences of which are closely related to foodborne diseases. Factors that control pathogens are personal health, good cooking, avoiding accidental contamination, keeping food at a safe temperature, and separating food from unsafe sources (48).

The application of food hygiene training among food handlers represented a major element in the successful control of foodborne diseases, which could be supported by managers encouraging healthy and safe handling of food during work time (49). Studies have proved that there are several reasons for losing training initiation and implementation of healthy and safe food handling in the catering factory, such as low-paid salaries, staff communication problems, levels of learning, background in quality assurance, large quantities of complex meals prepared, poor access to safe food guidance, facilities, equipment, and shift rotation (50). There is no strict commitment by the food control authorities in the Khartoum State towards food safety issues and there is a lack of awareness and training in employees about meat hygiene and safety that was noticed clearly when we assessed bacterial contamination of sheep carcasses before and after wearing gloves, aprons, masks, and caps. Therefore, bacterial counts from workers' hands after treatment showed a significant reduction compared to control and that the sterilization of knives by warm water (82 °C) decreased the level of viable bacteria. A study conducted on broiler food revealed that contamination of *E. coli* at the slaughterhouse was found concentrated in the defeathering machine chain (13). Moreover, this finding was justified by Mohamed Noor, who attributed this finding to the firm attachment of the bacteria to the poultry skin and rubber fingers (10).

Other studies have shown that weather and temperature play an important role in influencing the outbreak of foodborne diseases (51). However, a similar finding was reported that the rise in temperatures between 25 °C and 37 °C can produce a strong biofilm formation of Vibrio para haemolyticus on shrimp, crab, and stainless steel coupons (52). Moreover, the previous findings show that temperature increases also have a profound effect on bacteria remaining on food, such as *E. coli* O157: H7 and *Salmonella spp*. (53).

4. HAZARD ANALYSIS CRITICAL CONTROL POINT (HCCP) IMPLEMENTATION IN FOOD PROCESSING

The appropriate methods of HCCP when applied during slaughtering operations would reduce the occurrence of these microorganisms. The study reported that Salmonella spp. and Escherichia coli contamination in poultry carcasses at an automatic slaughterhouse in Khartoum State (12), and this would affect the safety and quality of poultry meat. Moreover, the right application of HACCP will greatly reduce the bacterial contamination in poultry plants because it involves constant checking of all stages of the processing (12). It was found that the whole country lacks "in-house" experts and consultation bodies officially registered to

provide the necessary technical support for verification and accreditation of implemented HACCP systems in meat processing operations (12). A study has shown that the implementation of HACCP is hampered by a shortage of money and human resources in small food factories (54). Additional studies supported the same idea that had clearly stated the barriers that obstructed the implementation of HACCP in Sudan due to poor premises construction, poor water supply, indigent farms' hygiene as well as milkers' and the gathering of droppings and animal waste that induced insects to spread (55).

5. DIAGNOSTIC DETECTION METHODS TO ENSURE FOOD SAFETY

Fast and precise detection of foodborne microbes is an urgent necessity for public health monitoring, stopping foodborne infections, and ensuring food safety. The diagnosis of FBD involves an enormous technique that mainly depends on the types of food and samples investigated. However, conventional microbiological methods were used to isolate and identify most pathogenic bacteria. Other studies used enzyme immunosorbent assay (ELISA), along with Nested polymrase chain reaction (nPCR), Rose Bengal test, and single intradermal comparative tuberculin test (SICTT) (45). Parasitic causes of foodborne diseases are detected using direct fecal examination, in which Lugol solution is used to identify undifferentiated protozoan cysts. Concentration techniques such as formaldehyde, floatation, and Biermann's technique help to diagnose larvae of *Strongyloides stercoralis* and hookworm (56). Real-time PCR and reverse transcription-polymerase chain reaction (RT-qPCR) combined with partial sequences were used to investigate viral foodborne diseases such as hepatitis E (57). However, the same technique was used in the detection of rotavirus and adenovirus antigens with an immuno-chromatography test (ICT)(58). Another study has utilized enzyme-linked immunosorbent assay (ELISA) antigens to detect Rotavirus in stool samples, combined with genotyping using nested PCR and sequencing (59).

6. CONCLUSION

Foodborne diseases are among the main causes of disease and death, especially in countries that suffer from poor economic conditions, such as Sudan, where there is a social and economic impact of foodborne diseases, which requires these countries to undertake reforms to reduce them. In Sudan, there is no clear control system, which complicates the problem. Therefore, the health authorities in Sudan must greatly enhance the current system for an effective foodborne disease surveillance system. The review concluded that the most common foodborne pathogenic bacteria in Sudan are *Escherichia coli*, *Salmonella* and *Staphylococcus aureus.*

REFERENCES

[1] Addis M, Sisay D. A review on major food borne bacterial illnesses. J Trop Dis. 2015;3(4):1–7. DOI:10.4172/2329-891x.1000176

[2] Bintsis T. Foodborne pathogens. 2017;3(March):529–63. DOI:10.3934/microbiol.2017.3.529

[3] Schmid MW, Ng EY, Lampidis R, Emmerth M, Walcher M, Kreft J, Goebel W, Wagner M, Schleifer KH. Evolutionary history of the genus Listeria and its virulence genes. Syst Appl Microbiol. 2005;28(1):1–18. DOI:10.1016/j.syapm.2004.09.005

[4] Gould LH, Demma L, Jones TF, Hurd S, Vugia DJ, Smith K, Shiferaw B, Segler S, Palmer A, Zansky S, Griffin PM. Hemolytic uremic syndrome and death in persons with escherichia coli O157:H7 infection, foodborne diseases active surveillance network sites, 2000-2006. Clin Infect Dis. 2009;49(10):1480–5. DOI:10.1086/644621

[5] Wells JG, Davis BR, Wachsmuth IK, Riley LW, Remis RS, Sokolow R, Morris GK. Laboratory investigation of hemorrhagic colitis outbreaks associated with a rare Escherichia coli serotype. J Clin Microbiol. 1983;18(3):512–20. DOI:10.1128/jcm.18.3.512.520.1983

[6] Heredia N, García S. Animals as sources of food-borne pathogens: a review. Anim Nutr. 2018;4(3):250–5. DOI:10.1016/j.aninu.2018.04.006

[7] Rojas-Lopez M, Monterio R, Pizza M, Desvaux M, Rosini R. Intestinal pathogenic Escherichia coli: Insights for vaccine development. Front Microbiol. 2018;9(MAR):1–17.

[8] Yang S-C, Lin C-H, Aljuffali IA, Fang J-Y. Current pathogenic Escherichia coli foodborne outbreak cases and therapy development. Arch Microbiol. 2017;199(6):811–25. DOI:10.1007/s00203.017.1393-y

[9] Nataro JP, Kaper JB. Diarrheagenic Escherichia coli. Clin Microbiol Rev. 1998;11(1):142–201. DOI:10.1128/cmr.11.1.142

[10] Mohamed-Noor SE, Shuaib YA, Suliman SE, Abdalla MA. Study of microbial contamination of broilers in modern abattoirs in Khartoum state. Ann Univ Dunarea Jos Galati Fascicle VI-Food Technol. 2012;36(1):74–80.

[11] Ahmed AKAM, Al Sanosi SM. Occurrence of Escherichia species in vended red meat in Khartoum State, Sudan. J Vet Med Anim Prod. 2018;8(1).

[12] Abdel-Rahman E. Elbasheir EAAA and AAOA. Aerobic bacteria isolated from fresh and frozen chicken's carcasses in Khartoum state, Sudan. World J Pharm Pharm Sci. 2019;8(4):1700–10.

[13] Hamid A, Basheir MA, Elhassan MMO, Salman AMA. Risk assessment of E. coli contamination in broiler food chain in Khartoum North, Sudan. :EAS J Nutr Food Sci. 2, (2), (Mar-Apr, 2020): 49-54. DOI: 10.36349/easjnfs.2020.v02i02.004

[14] Abdalla MA, Suliman SE, Bakhiet AO. Food safety knowledge and practices of street food-vendors in Atbara City (Naher Elneel State Sudan). African J Biotechnol 2009;8(24):6967–71. DOI:10.1016/j.foodcont.2007.04.021 15.

[15] Ryan MP, Dwyer JO, Adley CC. Evaluation of the complex nomenclature of the clinically and veterinary significant pathogen Salmonella. 2017;2017. DOI:10.1155/2017/3782182

[16] F. W. Brenner, R. G. villar, FJ. Angulo, R. Tauxe and BS. Salmonella nomenclature. J Clin Microbiol. 2000;38(7):2465–2467. DOI:10.1128/jcm.38.7.2465-2467.2000

[17] Eng SK, Pusparajah P, Ab Mutalib NS, Ser HL, Chan KG, Lee LH. Salmonella: A review on pathogenesis, epidemiology and

antibiotic resistance. Front Life Sci [Internet]. 2015;8(3):284–93. DOI:10.1080/21553.769.2015.1051243

[18] Brenner FW, Villar RG, Angulo FJ, Tauxe R, Swaminathan B. Guest Commentary. Salmonella nomenclature 2000;38(7):2465–2467. DOI:10.1128/jcm.38.7.2465-2467.2000

[19] Fadlalla IMT, Hamid ME, Rahim AGA, Ibrahim MT. Antimicrobial susceptibility of Salmonella serotypes isolated from human and animals in Sudan. 2012;4(January):19–23. DOI:10.5897/jphe11.143

[20] El Hussein AA, S. H, Nor Elmadiena MM, El Siddig MA. Prevalence, detection and antimicrobial resistance pattern of salmonella in Sudan. Salmonella – Distrib Adapt Control Meas Mol Technol. 2012. DOI:10.5772/29928

[21] Mamoun I, Khalafalla A, Bakhiet M, Agab H, Sabiel Y, Ahmed H. Salmonella enteritidis infection in the Sudan. Rev Elev Med Vet Pays Trop. 1992;45:137–8.

[22] Mustafa N, Abdallah M. Bacteriological quality of street-vended *um-jingir*: A traditional Sudanese food. African J Food, Agric Nutr Dev. 2011;11(5):16–9. DOI:10.4314/ajfand.v11i5.70447

[23] Honua MHM. The bacterial contamination of food handlers hands in Wad madani city restaurants, Sudan. Int J Community Med Public Heal. 2018;5(4):1270. DOI:10.18203/2394-6040.ijcmph20181201

[24] Mustafa EA, Hamad I. Review on food safety system with reference to meat operations in Khartoum State , Sudan. RA J Appl Res. 2016;2(07):491–504.

[25] Eltaib, W.A., Ahmed, D.A., Ahmed, H.E., and Zeinelabideen, H.M. Study on the bacterial contamination of some animal products in Khartoum State. Journal IA, No I. 2013;3(8):56–61.

[26] Alsheikh ADI, Mohammed GE, Abdalla MA. Isolation and identification of Listeria monocytogenes from retail broiler chicken ready to eat meat products in Sudan. Int J Anim Vet Adv. 2013;5(1):9–14. DOI:10.19026/ijava.5.5570

[27] Ei-Jakee J, Marouf SA, Ata NS, Abdel-Rahman EH, Abd El-Moez SI, Samy AA, El-Sayed WE. Rapid method for detection of Staphylococcus aureus enterotoxins in food. Glob Vet. 2013.

[28] Yahya M, Ali HA, Ali SO. Molecular detection of Staphylococcal enterotoxins and mecA genes products in food samples collected from different areas in Khartoum state. :1–19. DOI:10.21203/rs.3.rs-59354/v3

[29] Mohammed Hamad MN, Mokhtar AA, Alameldin M, Abkar YM, Eltoum M. Prevalence of intestinal parasitic infections among school aged children in Berber locality, River Nile State, Sudan 2017. J Microbiol Exp. 2019;7(2):85–6. DOI:10.15406/jmen.2019.07.00247

[30] Fung F, Wang HS, Menon S. Food safety in the 21st century. Vol. 41, Biomedical Journal. Elsevier B.V.; 2018. p. 88–95. DOI:10.1016/c2014-0-01094-5

[31] Chambers HF, DeLeo FR. Waves of resistance: Staphylococcus aureus in the antibiotic era. Nat Rev Microbiol [Internet]. 2009;7(9):629–41. DOI:10.1038/nrmicro2200

[32] Havelaar AH, Kirk MD, Torgerson PR, Gibb HJ, Hald T, Lake RJ, et al. World Health Organization Global Estimates and Regional Comparisons of the Burden of Foodborne Disease in 2010. PLoS Medicine. 2015. DOI:10.1371/journal.pmed.1001923

[33] Medveov A, Valk ubomr. Staphylococcus aureus: Characterisation and Quantitative Growth Description in Milk and Artisanal Raw Milk Cheese Production. In: Structure and Function of Food Engineering. 2012. DOI:10.5772/48175

[34] Akbar A, Anal AK. Prevalence and antibiogram study of Salmonella and Staphylococcus aureus in poultry meat. Asian Pac J Trop Biomed. 2013;3(2):163–8. DOI:10.1016/s2221-1691(13)60043-x

[35] Salleh W, Lani M, Abdullah WZW, Chilek TZT, Hassan Z. A review on incidences of foodborne diseases and interventions for a better national food safety system in Malaysia. Malaysian Appl Biol. 2017;46(3):1–7.

[36] Mangen MJ, Plass D, Havelaar AH, Gibbons CL, Cassini A, Mühlberger N, Van Lier A, Haagsma JA, Brooke RJ, Lai T, De Waure C. The pathogen-and incidence-based DALY approach: an appropriate methodology for estimating the burden of infectious diseases. PLoS One. 2013;8(11):e79740. DOI:10.1371/journal.pone.0079740

[37] Abdalla MOM, Elhagaz FMM. The impact of applying some hygienic practices on raw milk quality in Khartoum State, Sudan. Res J Agric Biol Sci. 2011;7(2):169–73.

[38] Khalid HA. Sero–diagnosis of brucellosis and differentiation between vaccinated and infected animals. MSc. thesis, Dep. of Micro., Fac. of Vet. Med., Uof K, Sudan; 2006.

[39] Mahmoud HA. Brucellosis in cattle in the former West Kordofan state. MSc. thesis, Dep. of Micro., Fac. of Vet. Med., UofK, Sudan; 2010.

[40] Saleh YM. Prevalence of brucellosis in cattle, sheep and goats of west Darfur State, Sudan. Master Thesis, Faculty of Veterinary Medicine, University of Khartoum2010.

[41] Naglaa AA. Epidemiological and zoonotic aspect of bovine tuberculosis in Khartoum State, Sudan. MTAH thesis, Dep Prev Med, Fac Vet Med, UofK, Sudan. 2007.

[42] Mohamed NNI, El Zubeir IEM. Evaluation of the hygienic quality of market milk of Khartoum State (Sudan). Int J Dairy Sci. 2007;2(1):33–41. DOI:10.3923/ijds.2007.33.41

[43] Selim S, Warrad M, El-Dowma EF, Aziz MA. Prevalence and antibiotic resistance of food borne bacterial contamination in some Egyptian food. Ital J Food Sci. 2015;27(3):336–44. DOI:10.1016/j.foodcont.2014.10.020

[44] Manges AR. Escherichia coli and urinary tract infections: the role of poultry-meat. Clin Microbiol Infect. 2016;22(2):122–9. DOI:10.1016/j.cmi.2015.11.010

[45] Ali DK, Ismail HM, Abdelgadir AE. Status of milk and meat hygiene in Sudan. Journal of Veterinary Medicine and Animal Production. 2012;3(1):107-124.

[46] Babiker MA, Ali MSM, Ahmed ES. Frequency of intestinal parasites among food-handlers in Khartoum, Sudan. East Mediterr Heal J. 2009;15(5):1098–104. DOI:10.26719/2009.15.5.1098

[47] Omar BA, Shadia SM, Anas SD, Mohammed AE. Food hygiene knowledge, attitude and practices among hospital food handlers in Elmanagil City, Sudan. African J Microbiol Res. 2020;14(4):106–11. DOI:10.5897/ajmr2020.9323

[48] Medeiros L, Hillers V, Kendall P, Mason A. Evaluation of food safety education for consumers. J Nutr Educ. 2001;33:S27–34. DOI:10.1016/s1499-4046(06)60067-5

[49] Seaman P, Eves A. Perceptions of hygiene training amongst food handlers, managers and training providers–A qualitative study. Food Control. 2010;21(7):1037–41. DOI:10.1016/j.foodcont.2009.12.024

[50] Capunzo M, Cavallo P, Boccia G, Brunetti L, Buonomo R, Mazza G. Food hygiene on merchant ships: the importance of food handlers' training. Food Control. 2005;16(2):183–8. DOI:10.1016/j.foodcont.2004.01.010

[51] Hassan NA, Hashim JH, Johar Z, Faisal MS. The implications of climatic changes on food and water-borne diseases in Malaysia: a case study of Kelantan, Terengganu, Johor and Melaka. BMC Public Health. 2014;14(1):1. DOI:10.1186/1471-2458-14-s1-p22

[52] Han N, Mizan MFR, Jahid IK, Ha S-D. Biofilm formation by Vibrio parahaemolyticus on food and food contact surfaces increases with rise in temperature. Food Control. 2016;70:161–6. DOI:10.1016/j.foodcont.2016.05.054

[53] Doyle MP, Diez-Gonzalez F, Hill C. Food microbiology: fundamentals and frontiers. John Wiley & Sons; 2020.

[54] Omer AK, Ahmed MMM, Awad Alkarim Altijani Alfaki AA, Suliman SE, Abdalla MA. Detection of Salmonella spp. and Escherichia coli in poultry carcasses at abattoir in Khartoum State Sudan. 2016. Journal of Science and Technology, 17.

[55] Route N. HACCP and SMEs: a case study. In: Making the most of HACCP. Elsevier; 2001. p. 32–42. DOI:10.1533/978.185.573 6511.2.81

[56] Gamar TA, Musa HH, Altayb HN, Kabbashi M, Alsayed Y, Abakar AD. Prevalence of intestinal parasites among food handlers attending public health laboratories in Khartoum State, Sudan. F1000Research. 2018;7(687):687. DOI:10.12688/f1000research.14681.1

[57] Elduma AH, Zein MMA, Karlsson M, Elkhidir IME, Norder H. A single lineage of hepatitis E virus causes both outbreaks and sporadic hepatitis in Sudan. Viruses. 2016;8(10):1–13. DOI:10.3390/v8100273.

[58] Elhag WI, Saeed HA, Omer EFE, Ali AS. Prevalence of rotavirus and adenovirus associated with diarrhea among displaced communities in Khartoum, Sudan. BMC Infectious Diseases 2013;2–7. DOI:10.1186/1471-2334-13-209

[59] Magzoub MA, Bilal NE, Bilal JA, Alzohairy MA, Elamin BK, Gasim GI. Detection and sequencing of rotavirus among Sudanese children. Pan Afr Med J. 2017;28. DOI:10.11604/pamj.2017.28.87.11008

How to cite this article: Khalid AM, Rabih WM, Eldoma EY, Bakhiet AMA, Mekki SEI, Mariod AA, Hamza SMA, Hassan RA, Fageer SAEY, Elamin HEE, Sulieman AME, Hamid HT, Abasher MAMA, Bacterial foodborne diseases in Sudan: a review. Clin Exp Health Sci 2024; 14: 176-178. DOI: 10.33808/clinexphealthsci.1098014