https://doi.org/ 10.33472/AFJBS.6.5.2024. 8138-8152

African Journal of Biological Sciences

Microbiological Hazards of *S. aureus* Contaminant in Street Food in Developing Countries: A Literature Review

Tri Yahya Budiarso [1], Suranto [2], Sutarno [3], Ratna Setyaningsih [4]

[1] Doctoral Study Program of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Ir. Sutami 36A street, Surakarta 57 126, Central Java, Indonesia.

[1] Department of Biology, Faculty of Biotechnology, Universitas Kristen Duta Wacana. Dr. Wahidin street, S. 5-25 Yogyakarta, Indonesia.

[2,3,4] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Ir. Sutami 36A street Surakarta 57126, Central Java, Indonesia.

Email: yahya@staff.ukdw.ac.id

Article History
Volume 6, Issue 5, 2024
Received: 22 May 2024
Accepted: 29 May 2024
doi: ***10.33472/AFJBS.6.5.2024. 8138-8152***

ABSTRACT

Aims: This literature review aims to explain the microbiological dangers of *S. aureus* in street food based on the level of contamination, the spread of *S. aureus* from the habitat to entering the food and the dangers posed by this contamination.

Methodology and results: The study was conducted by searching for articles from 2010-2023 from electronic databases such as Google Scholar, Scopus, Science Direct, and PubMed. Articles were extracted using Boolean logic operators (“AND,” “OR,” “NOT”). All articles obtained were analyzed for their relevance to the topic raised in this article. *Staphylococcus aureus*, primarily residing in the nose, throat, skin, and mucous membranes, can contaminate food via unhygienic practices by food handlers. It's prevalent in snacks in developing nations like Nigeria, with contamination rates up to 60%. The bacteria produce heat-resistant toxins causing food poisoning and can lead to infections, contributing to over 100,000 cases of bacteremia annually in the US and 434 food-borne outbreaks in the EU.

Conclusion, significance, and impact of the study: This literature review underscores the critical microbiological risks posed by *Staphylococcus aureus* contamination in street food, particularly in developing countries where street food consumption is widespread. The significance of this study lies in its revelation of the pervasive threat posed by *S. aureus* in street food, which impacts millions of individuals worldwide. The findings of this study have implications for public health interventions, food safety policies, and research agendas aimed at mitigating the adverse effects of *S. aureus* contamination in street food.

Keywords: *Staphylococcus aureus*, Street Food, Food Poisoning, Food Infection

INTRODUCTION

The Global Report on Food Crises in 2022 showed that 258 million people, or 22.7% of the world's population, face acute food insecurity in 58 countries. This situation is projected to affect over a quarter of a billion people in 2023 (FSIN and Global Network Against Food Crises, 2023). Beyond the issue of food insecurity, ensuring food safety is an important concern. Every individual globally has the right to access food that is safe, nutritious, and healthy (FAO/WHO, 2023). The World Health Organization (WHO) estimated that 1 out of 10 people globally falls ill each year due to consumption of contaminated food. Foodborne diseases have led to 600 million people falling sick and 420,000 premature deaths annually with 30% occurring in children under the age of 5 years (Long et al., 2023; Loukieh, 2018; Todd, 2020). Ingesting food that contains harmful substances like bacteria, viruses, parasites, or chemicals such as heavy metals can result in the development of more than 200 different illnesses. Annually, around 5 million people lose their lives due to microbial infections resistant to antibiotics transmitted through food (Banna et al., 2022; FAO/WHO, 2023). The cases of foodborne diseases predominantly occur in many developing countries due to the consumption of street food (Jahan et al., 2018; Jores et al., 2018; Rosales et al., 2023). Following that, street food denotes food and drinks that are prepared and sold by street vendors or hawkers in public areas, which are ready for immediate consumption. (Bellia et al., 2022; Das et al., 2019). RTE food requires no further preparation except reheating (Ayamah et al., 2021). Consuming food contaminated with pathogenic bacteria such as *Staphylococcus aureus, Salmonella typhi, Escherichia coli, Vibrio cholera, Campylobacter jejuni, Listeria monocytogenes, Bacillus cereus,* and *Clostridium perfringens* can lead to foodborne diseases. Among these bacteria, *S. aureus* is the most commonly found in street food (Amare et al., 2019; Sonune, 2022; Tshipamba et al., 2018). *S. aureus* is a commensal bacteria exhibiting pathogenic traits (Fei et al., 2022; Proctor, 2021), colonizing around 30% of the human population (Laux et al., 2019; Martins et al., 2024), and can thrive in food, leading to ingestion by humans and causing foodborne infections. Moreover, it easily grows in food, producing toxins that, when consumed, result in poisoning, commonly referred to as foodborne intoxication (Bintsis, 2017; Nwachukwu et al., 2020; Wan et al., 2021). *S. aureus* is a major foodborne pathogen with 65-85% of the members capable of producing biofilm as a highly significant virulence factor causing various infections in humans (Avila-Novoa et al., 2022; Ballah et al., 2022). Biofilm formation is a crucial factor contributing to *S. aureus* resistance to various antibiotics, posing a threat to treatment efficiency (Derakhshan et al., 2021; Shin et al., 2013; Tahaei et al., 2021). *S. aureus* is also recognized as a significant cause of food poisoning cases associated with the consumption of raw, undercooked, or mishandled food globally. Subsequently, food poisoning occurs due to the presence of stable Staphylococcal enterotoxins (SEs) during food processing (Haghi et al., 2021; Le et al., 2021). This article endeavours to reveal harmful bacterial contaminants in street food that are prevalent in developing countries. Furthermore, it is structured based on a literature review published in international journals related to foodborne diseases resulting from consuming street food contaminated by *S. aureus*. A review of the level of microbiological contamination of *S. aureus* in street food, sources of contaminant bacteria and several cases of food poisoning caused by Staphylococcal enterotoxin and the ability of *S. aureus* to produce biofilms that are closely related to foodborne infections.

Method

This literature review aims to explain the microbiological dangers of *S. aureus* in street food based on the level of contamination, the spread of *S. aureus* from the habitat to entering the food and the dangers posed by this contamination. The study was conducted by searching for articles from 2010-2023 from electronic databases such as Google Scholar, Scopus, Science Direct, and PubMed. Articles were extracted using Boolean logic operators (“AND,” “OR,” “NOT”) with a combination of the main keywords *S. aureus*, street food, food poison, and food infection. All articles obtained were analyzed for their relevance to the topic raised in this article. This study found that the natural habitat of *S. aureus* is the nose, throat, hair, skin, and mucous membranes in healthy individuals and can be transmitted to food through food workers who do not pay attention to hygiene factors.

RESULTS AND DISCUSSION

Contamination levels of *S. aureus* in street food in developing countries

Microbial contamination in food is unavoidable and occurs at every stage of the food chain, from harvesting in agricultural fields and processing to serving at the dining table. At each stage, contact with the hands of workers, equipment, and the surrounding air presents a potential source of contaminant, posing potential health risks (Erdoğan & Pamuk, 2020; Tropea, 2022). Foodborne diseases have posed serious global health concerns, as evidenced in the United States in 2020, with 299 instances leading to 5,987 cases of illness, 641 hospitalizations, and 40 fatalities. Similarly, in Europe, there were 3,166 reported incidents of foodborne illnesses, resulting in 22,010 cases of illness, 1,838 hospitalizations, and 48 deaths. (Zheng et al., 2023). The global focus on the primary cause of the diseases revolves around the microbiological quality of food (Nethathe et al., 2023). The microbiological quality of RTE food sold on the street has raised public health concerns, specifically in developing countries (Ibrahim, 2020; Sonune, 2022). In India, a test of 120 street food samples in the Amravati region of Maharashtra showed that 68 samples were contaminated with *S. aureus,* representing the highest contamination level at 56.67%. Additionally, *Escherichia coli* was found in 60 samples (50%), *Enterobacter* in 44 samples (36.7%), *P. aeruginosa* in 32 samples (26.67%), and *Salmonella* sp. in 20 samples (16.67%). All samples had an average total viable count (TVC) $\geq 10^5$ CFU/g (Sonune, 2022). In South Indian City, analysis of a consistent set of 142 samples tested from July to December 2017 showed predominant contamination levels with *K. pneumoniae* (40%), *P. aeruginosa* (40%), *Proteus* sp. (29%), *E. coli* (31%), and *S. aureus* (23%) (Siddabathuni, 2019). In Pakistan, the test of contaminant bacteria in raw and cooked cow, goat, and fish meat included 150 samples. Contaminant bacteria in raw meat were dominated by *E. coli* (45%, 30%, and 25%) and *S. aureus* (30%, 25%, and 25%). Meanwhile, cooked meat showed a decrease in *E. coli* (25%, 25%, and 20%) and *S. aureus* (15%, 15%, and 10%) (Ansari *et al*., 2022). In Nigeria, the highest contamination level from testing 30 street food samples was dominated by *P. aeruginosa* (90%), followed by *S. aureus* (60%), *Enterobacter* spp. (50%), *E. coli* (40%), *B. cereus* (40%), *Salmonella* spp. (30%), *Micrococcus* spp. (30%), and *Alcaligenes faecalis* (10%) (Osalumhense, 2021).

In Cambodia, an investigation on contaminant bacteria in chicken meat and pork was predominantly represented by *Salmonella* spp. at 42.1% (155/532) and *S. aureus* at 29.1% (155/532). This contamination level was determined by testing 532 samples collected from 52 traditional markets and 6 supermarkets across 25 provinces from October 2018 to August 2019 (Rortana et al., 2021). In a contaminant bacteria test of 17 restaurants, *S. aureus* was found to dominate at 46.88% in sushi samples (75/160) and 34.29% in sashimi samples (Tiengtip, 2020). The test on RTE Kebabs sold on the KNUST campus and the surroundings in Ghana showed that all samples contained *S. aureus* contaminant at $3.1 \times 10^2 - 9.6 \times 10^6$ CFU/g for beef kebabs and $3.6 \times 10^3 - 2.9 \times 10^7$ CFU/g for chevon kebabs (Ayamah *et al*., 2021). In South Africa, the contamination level of bacteria in RTE Street-Vended Foods (SVFs), based on the test of 205 samples, was dominated by *L. monocytogenes* (46.36%), *S. aureus* (31.8%), and *Salmonella* spp. (21.8%) (Asiegbu et al., 2020). In Northwest Ethiopia, 44 out of 72 SVFs tested (61.1%) were found to be contaminated with bacteria. Among the 44 contaminated samples, 63 isolates were found with 34 identified as *S. aureus* (53.96%), *E. coli* (23.8%), *Enterobacter* (15.87%), and Citrobacter (6.3%) (Amare et al., 2019). In Malaysia, the test of 31 Street-Vended Beverages in Chow Kit, Kuala Lumpur, showed that approximately 90.3% were contaminated with coliform, *E. coli*, and *S. aureus*. The highest contamination levels were coliform (71%) and *S. aureus* (58.1%) with only 1 sample testing positive for *E. coli* (Nawawee et al., 2019). In Bangladesh, research on bacteria loads in beef carcasses was conducted in various slaughterhouse locations in Barishal City from April to October 2017. Contaminant bacteria test from 200 swab samples showed that *S. aureus* (78.5%), *Salmonella* spp. (64.5%), and *E. coli* (64.0%) were the most commonly found bacteria on the surfaces of freshly slaughtered beef carcasses (Das et al., 2019). In Vietnam, a contaminant bacteria test was conducted on 2 popular street foods in 4 districts of Can Tho City, including 263 sandwich samples and 131 sugar cane juice samples. The average contaminant bacteria count in sandwich samples was dominated by coliform at 2.5-7.9 log CFU/g, followed by yeast and mold (2.0-7.4), *S. aureus* (1.7-6.6), and *E. coli* (1.0-5.9) log CFU/g. The test results for sugar cane juice samples were also dominated by coliform (6.02±1.21), followed by yeast and mold (5.56±0.71), *E. coli* (2.26±1.31), and *S. aureus* (1.47±0.77) log CFU/g (Thi, 2021).

Sources of *S. aureus* contamination in street food

S. aureus is a commensal bacteria capable of forming colonies on the skin, nasal cavities, and the human digestive tract. Subsequently, food contamination can occur through manual hand contact or respiratory secretions, serving as a source for both foodborne infections and staphylococcal food poisoning (Bencardino et al., 2021). The human body is an ecological habitat for various microbial communities, such as the skin inhabited by *Staphylococcus*, *Propionibacterium*, and *Corynebacterium*. Although Staphylococcus aureus is present in the nasal microbiome of approximately 30% of people, it has the potential to become a dangerous and potentially fatal pathogen (Laux *et al*., 2019). Transmission of *S. aureus* from the human nasal habitat to food can occur directly or indirectly through the hands of contaminated food handlers. During preparation and processing, food handlers may introduce enterotoxigenic *S. aureus* isolates from the nasal cavity into the food (Akinnola et al., 2022; Mahdi, 2023), acting as a vector for the transmission of microbes responsible for foodborne diseases, a major public health concern globally. Poor hygiene during food preparation remains a primary source of diseases caused by pathogenic microbes (EL-Maghraby et al., 2018; Sharma et al., 2021).

Street food serves as a source of foodborne infections, with *S. aureus* playing a crucial role as an infectious agent transmitted through various sources, including street food (Sivakumar *et al*., 2019). *S. aureus* is commonly found in milk, meat, and processed products, including sausages and pork (Ghabbour et al., 2022; Pal, 2022; Rashed & Zaid, 2022). According to Anihouvi *et al*. (2020), *S. aureus* contamination can originate from raw materials used in processed food products, equipment used in processing and selling environments, workers' hands, and less hygienic processing methods. One of the most frequently used raw materials in almost all street food products is water, both as a raw material and for washing equipment used in the processing, and can be a source of *S. aureus* contamination. During March 2017 and March 2018, microbial tests conducted on 552 samples from drinking water fountains in four public parks in Sao Paulo City, Brazil, showed that 25.2% were contaminated with *S. aureus* (Salamandane et al., 2021). The test results of water raw materials in 40 Panipuri street food samples collected aseptically from various areas in Morbi City-Gujarat, India, showed that 82% of Panipuri water samples had high levels of pathogenic bacteria, namely *Escherichia coli* (42%), *S. aureus* (30%), *Klebsiella* sp. (20%), and *Pseudomonas* sp. (6%) (Mehta, 2020). Subsequently, the use of ice in meat preservation also served as a source of microbial contamination. The collective bacterial examination findings for seafood, poultry, and livestock meat were 4.88, 4.18, and 6.11 log10 CFU/g, respectively, with the primary bacteria of concern being predominantly Staphylococcus aureus (Hamat et al., 2019), *followed by Salmonella, V. parahaemolyticus, and L. monocytogenes,* and over 90% tested positive for coliform (Liao et al., 2023). Microbiological test results on fresh vegetable raw materials from 274 samples and RTE vegetables from 92 samples marketed in Tehran, Iran, showed *S. aureus* contamination at 42.3% and 19.6%, respectively (Azimirad *et al*., 2021). The quantity of contaminant bacteria in chicken raw materials for Street-Vended Chicken

Products sold in Nairobi County, Kenya, in 15 samples with 3 repetitions found *Salmonella, E. coli, Campylobacter jejuni,* and *S. aureus* at 6.42 ± 1.64, 6.60 ± 1.25, 8.95 ± 0.94, and 6.92 ± 1.32 log CFU 10/g, respectively (Birgen et al., 2020). Meanwhile, the total bacteria contamination level in tested meat raw materials from Mangaung Metropolitan Municipality, South Africa, averaged 4.8 x 10^5 - 5 x 10^6 CFU/g (Moloi et al., 2021). Contamination test results on raw materials for fish and sago starch used in the production of keropok lekor in Kuala Terengganu and Marang, Malaysial, were ≥ 10^5 CFU/g and ≥ 10^3 CFU/g, respectively (Hamat et al., 2019).

In addition to raw materials, contamination with *S. aureus* in street food processing can originate from factors such as the hygiene of workers' hands and the cleanliness of equipment used in the process (Tasanapak et al., 2023). Out of 650 samples examined, 200 isolates with the most elevated contamination levels were found primarily on food handlers (78%), followed by chopping boards (26%), plates (23%), knives (16%), spoons (13%), and glasses (5%) (Tasanapak et al., 2023). The highest *S. aureus* contamination was due to contact with food handlers hands, knives, and tables used for selling meat in butchery outlets in north-central Nigeria at 48.4% compared to other bacteria (Alimi et al., 2022). Due to the rising incidence of staphylococcal food poisoning outbreaks, efforts to detect *S. aureus* in food handlers in the food processing industry were intensified. A swab test conducted on the hands of 167 workers showed that over 11% tested positive for *S. aureus* (Fernandes et al., 2022). An investigation on contaminant bacteria count on Street-Vended Chicken Products from 15 samples, which was repeated 3 times, showed *Salmonella, E. coli, C. jejuni,* and *S. aureus* by 3:53 ± 2:17, 3:74 ± 1:92, 6:48 ± 0:99, and 4:85 ± 1:00, respectively (Birgen et al., 2020). Subsequently, out of 300 samples from food workers, 125 isolates were identified as *S. aureus* with 42 (33.6%), testing positive for more than one enterotoxins-producing gene (Çakici et al., 2023). Poor personal hygiene practices by food handlers could contribute to the spread of *S. aureus* in street food (Sabry et al., 2017).

Food poisoning by *S. aureus*

Enterotoxigenic *S. aureus* is one of the most common bacteria causing food poisoning worldwide. This bacteria can produce emetic toxins classified in the pyrogenic toxin superantigen family due to the biological activity (Cavaiuolo *et al*., 2023; Kazem & Jarallah, 2022). Street food can be susceptible to the spread of enterotoxigenic *S. aureus* through diverse pathways, including airborne transmission and contamination from processing equipment and food handlers. Earlier investigations showed a prevalence of *S. aureus* carriers, particularly through nasal passages, among food handlers (Çakici *et al*., 2023; EL-Maghraby *et al*., 2018). *S. aureus* exhibits robust resilience on inanimate objects, enabling it to outcompete less resistant microorganisms, even under conditions of elevated temperatures, high osmotic pressure, and relatively low humidity (Fisher et al., 2018; Le et al., 2021). This bacteria can also produce SEs during the storage of platelet concentrates, affecting its safety (Kumar *et al*., 2023). Similarly, food samples testing positive for SEs can potentially cause poisoning when consumed (Alhashimi et al., 2017). Food infection by *S. aureus* occurs through a toxigenic mechanism caused by the production of heat-resistant SEs, commonly found in dairy products such as milk, cheese, and cream, as well as meat and fish (Sirotamarat et al., 2022; Yildirim et al., 2019).

Enterotoxins are low molecular weight proteins resistant to protease enzymes in the stomach and can withstand high temperatures of about 126.7°C for 6.2 minutes (Melo et al., 2020). *S. aureus* can produce various enterotoxins such as SEA-SEE, SEG-SEI, and SER-SET, exhibiting heat resistance at 121°C for 10 minutes (Argudín et al., 2010; Pexara et al., 2018; Tsutsuura et al., 2013). Consequently, these toxins are thermo-persistent, and resistant to elimination through heating processes (Chi et al., 2023). SEs are produced by *S. aureus* during the growth, along with several other virulence factors (Etter, Schelin, et al., 2020). This bacteria generates several types of enterotoxins (Banaszkiewicz et al., 2023). A test on 125 isolates from clinical samples identified the presence of 5 types of enterotoxins (Johora et al., 2021). These types of SEs are in line with those tested on monkey feed causing vomiting reactions by Thomas (2007) showing the emetic activity of SEA, SEB, SEC, SED, and SEE (Johler et al., 2013). The emetic activity of SEs refers to the ability of toxins to induce vomiting symptoms (Lalnunfela,2021), and these 5 types of SEs are then called classical enterotoxins encoded by the genes SEA, SEB, SEC, SED, and SEE (Nguyen Do et al., 2020) (Schwendimann *et a*l., 2021). Subsequently, new types of enterotoxin genes, including SEj, SEl, SEq, SEm, and SEr, have also been identified in *S. aureus* isolates from various sources (Hu, 2016). SEs can act as superantigens, leading to T-cell activation for cytokinin production leading to multisystem failure (Chung, 2023; Johler et al., 2013). Poisoning symptoms usually manifest 1-7 hours after consuming food contaminated with SEs, leading to vomiting, diarrhea, nausea, fatigue, abdominal cramps, pain, headaches, and, in severe cases, death. Immediate hospital treatment is essential in such situations (Etter, Schelin, et al., 2020; Le et al., 2021; H. na Li et al., 2023). The regulation of SEs expression is also associated with accessory gene regulators (Agr) and environmental factors such as temperature, pH, and the presence of specific sugars. Different temperature and pH levels have been found to influence enterotoxin synthesis by *S. aureus* (Hunt et al., 2014). Temperature is a key factor in stimulating SEA and SEB expression with high expression at 30°C (Li et al., 2023). Enterotoxin synthesis in milk medium is achieved after entering the stationary growth phase at 18-66 hours. Optimal synthesis occurs at pH 6.5 and a temperature of 37^0 C for SEC (Hunt et al., 2014). Meanwhile, synthesis for SEA is achieved after the 7-log CFU/ml growth phase, starting at a minimum of 1-2 hours of incubation at 37^0 C (Tsutsuura et al., 2013).

Foodborne infection by *S. aureus*

S. aureus is a major cause of clinical infection, resulting in over 100,000 cases of bacteremia each year in the United States and 434 foodborne outbreaks in the European Union. This bacteria is a pathogenic zoonosis responsible for various infectious diseases characterized by septicemia and sepsis (Crombé et al., 2013; Song et al., 2015; Zhang et al., 2018). Subsequently, it is commonly found worldwide as the causative agent of diseases ranging from sinusitis, respiratory tract infections, and skin infections to myocarditis, endocarditis, osteomyelitis, pneumonia, urinary tract infections, and other soft tissue infections in the human body (Cheung et al., 2021; Guo et al., 2021; Jang et al., 2021; Rahimi et al., 2016).

Cases of localized skin infections may often resolve on their own but can serve as entry points for *S. aureus* into deeper tissues and the bloodstream (Yarovoy et al., 2019). This bacteria can cause various types of invasive infections, but not everyone colonized by it will experience symptoms. Approximately 30% of the human population permanently colonized by *S. aureus* in the nasal passages may not show any symptoms (Bitschar *et al*., 2020; Etter, Corti, et al., 2020; Laux et a*l*., 2019). This bacteria was previously considered an extracellular pathogen, but increasing evidence supports *S. aureus* as an intracellular pathogen capable of infecting, replicating, and persisting in host cells to evade bactericidal immune attacks and antibiotic treatments (Casadevall & Fang, 2020; Jin et al., 2023; Soe et al., 2021). *S. aureus* induces diseases through diverse mechanisms, including the capacity to survive inside cells, infect epithelial cells, evade host immunity, and replicate in host cells (Jin et al., 2023; Wilson et al., 2011). This bacteria produces toxins and virulence factors that damage host cells and inhibit adaptive immunity (Jang et al., 2021).

Biofilm formation is one of the most significant virulence mechanisms in the attachment of staphylococcal strains to living or non-living surfaces and resistance to antibiotics. It is the term used to describe the complex structure formed by bacteria, such as *S. aureus*, on surfaces. Biofilm production by *S. aureus* has been identified in various environments, including dairy processing settings (Ramachandran et al., 2023; Vargová et al., 2023).

The capability to produce biofilm varies among different strains, with some exhibiting a higher biofilm-forming ability than others (Alonso et al., 2021). Vargova (2023) stated that *S. aureus* is the most commonly found pathogen in milk and on surfaces. In all tested strains, the bacteria count required for biofilm formation is >5 Log10 CFU/cm^2, except for the reference strain. *S. aureus* isolates show superior biofilm production compared to the reference strain in the first 3 hours. This biofilm on milking equipment poses a persistent contamination source (Vargová et al., 2023), and has been associated with chronic infections such as infective endocarditis and is believed to contribute to *S. aureus* ability to cause persistent infections (Alonso et al., 2021; Yee et al., 2022).

Certain strains identified as culprits behind mastitis in cows possess the capability to generate a dense extracellular polysaccharide layer, also known as slime or biofilm. This layer is deemed a virulence factor because it aids in the adherence of bacteria to mammary epithelial cells and shields them from opsonization and phagocytosis (Dubravka et al., 2010). Biofilm formation also leads to bacteria attachment on the surfaces of inanimate objects such as implant medical devices, causing infections impacting patients' morbidity and mortality (Bimanand et al., 2018). Furthermore, it is a sophisticated and intricately organized assemblage of stationary bacteria developed on either living or non-living surfaces, encased within a self-generated extracellular matrix comprising exopolysaccharides, proteins, and DNA. (Gowrishankar et al., 2012; Neopane et al., 2018; Salamandane et al., 2021). The extracellular polysaccharide produced by *S. aureus* is known as polysaccharide intercellular adhesin (PIA) or poly-β (1-6)-N-acetylglucosamine (PNAG). This polysaccharide functions in adhesion and provides protection against antibiotics (Karygianni et al., 2020; Parastan et al., 2020). Most research identified the icaA, D, B, and C operons, responsible for producing PIA, as the primary mechanism for biofilm formation (Bimanand, 2017). The test of *S. aureus* producing biofilm from various food samples with a total of 97 isolates showed that 72% tested positive for biofilm-encoding genes icaABCD, clfA/B, cidA, and fib (Chen et al., 2020).

CONCLUSION

Based on the explanation that has been given, the following conclusions can be drawn regarding the microbiological hazards of the contaminant bacterium *S. aureus* found in various snack foods in developing countries:

1. *S. aureus* is the most common commensal bacterium that causes foodborne intoxication and foodborne infection cases transmitted through food in various countries worldwide, especially in developing countries.
2. *S. aureus* is frequently found in street food in developing countries such as Bangladesh, Nigeria, Malaysia, India, Cambodia, Pakistan, and South Africa.
3. The sources of *S. aureus* contamination in street food originate from raw materials used in food processing, water, ice as a chilling medium, processing equipment, and the hygiene of food handlers.
4. Most *S. aureus* strains discovered can produce five types of heat-resistant enterotoxins (SEA, SEB, SEC, SED, and SEE), leading to various cases of poisoning due to consuming contaminated food.
5. In addition to producing staphylococcal enterotoxins, *S. aureus* was found to be primarily capable of producing biofilms associated with various cases of infection and causing antibiotic resistance properties that can jeopardize the disease healing process.

Continuous assessment of various types of *S. aureus* found in food is necessary to develop preventive measures, food processing strategies, and disease mitigation efforts.

REFERENCES

1. Akinnola OO, Williams AN, Oniha MI, Ogunleye BO. Nasal carriage of *Staphylococcus aureus* and associated risk factors among food handlers in a Nigerian University. J Pure Appl Microbiol. 2022;16(4):2507-2513. https://doi.org/10.22207/JPAM.16.4.10
2. Alhashimi HMM, Ahmed MM, Mustafa JM. Nasal carriage of enterotoxigenic *Staphylococcus aureus* among food handlers in Kerbala city. Karbala Int J Mod Sci. 2017;3(2):69-74. https://doi.org/10.1016/j.kijoms.2017.02.003

3. Alimi BA, Lawal R, Odetunde ON. Food safety and microbiological hazards associated with retail meat at butchery outlets in north-central Nigeria. Food Control. 2022;139:109061. https://doi.org/10.1016/j.foodcont.2022.109061
4. Alonso B, Pérez-Granda MJ, Latorre MC, Sánchez-Carrillo C, Bouza E, Muñoz P, Guembe M. Production of biofilm by *Staphylococcus aureus*: Association with infective endocarditis? Enferm Infecc Microbiol Clin. 2021;40:418-422. https://doi.org/10.1016/j.eimc.2021.03.012
5. Amare A, Worku T, Ashagirie B, Adugna M, Getaneh A, Dagnew M. Bacteriological profile, antimicrobial susceptibility patterns of the isolates among street vended foods and hygienic practice of vendors in Gondar town, Northwest Ethiopia: A cross sectional study. BMC Microbiol. 2019;19(1):1-9. https://doi.org/10.1186/s12866-019-1509-4
6. Ansari S, Abro SH, Tanweer AJ, Sethar A, Abbas G, Ansari S, Kamboh AA. Evaluation of bacterial contamination from raw and cooked fish, mutton and beef sold by local vendors in Hyderabad, Pakistan. J Anim Health Prod. 2022;10(4):431-437. https://doi.org/10.17582/journal.jahp/2022/10.4.431.437
7. Argudín MÁ, Mendoza MC, Rodicio MR. Food poisoning and *Staphylococcus aureus* enterotoxins. Toxins. 2010;2(7):1751-1773. https://doi.org/10.3390/toxins2071751
8. Asiegbu CV, Lebelo SL, Tabit FT. Microbial quality of ready-to-eat street vended food groups sold in the Johannesburg metropolis, South Africa. J Food Qual Hazards Control. 2020;7(1):18-26. https://doi.org/10.18502/JFQHC.7.1.2448
9. Avila-Novoa MG, Solis-Velazquez OA, Guerrero-Medina PJ, González-Gómez JP, González-Torres B, Velázquez-Suárez NY, Martínez-Chávez L, Martínez-Gonzáles NE, De la Cruz-Color L, Ibarra-Velázquez LM, Cardona-López MA, Robles-García MÁ, Gutiérrez-Lomelí M. Genetic and compositional analysis of biofilm formed by *Staphylococcus aureus* isolated from food contact surfaces. Front Microbiol. 2022;13:1-12. https://doi.org/10.3389/fmicb.2022.1001700
10. Ayamah A, Sylverken AA, Ofori LA. Microbial load and antibiotic resistance of Escherichia coli and *Staphylococcus aureus* isolated from ready-to-eat (RTE) Khebab Sold on a university campus and its environs in Ghana. J Food Qual. 2021;2021:8622903. https://doi.org/10.1155/2021/8622903
11. Azimirad M, Nadalian B, Alavifard H, Negahdar Panirani S, Mahdigholi Vand Bonab S, Azimirad F, Gholami F, Jabbari P, Yadegar A, Busani L, Asadzadeh Aghdaei H, Zali MR. Microbiological survey and occurrence of bacterial foodborne pathogens in raw and ready-to-eat green leafy vegetables marketed in Tehran, Iran. Int J Hyg Environ Health. 2021;237:113824. https://doi.org/10.1016/j.ijheh.2021.113824
12. Ballah FM, Islam S, Rana L, Ullah A, Ferdous FB, Neloy FH, Ievy S, Sobur A, Rahman AMMT. Virulence determinants and methicillin resistance in biofilm-forming *Staphylococcus aureus* from various food sources in Bangladesh. Antibiotics (Basel). 2022;11(11):1666. https://doi.org/10.3390/antibiotics11111666
13. Banaszkiewicz S, Tabiś A, Wałecki B, Łyżwińska K, Bystroń J, Bania J. spa Types and Staphylococcal Enterotoxin production of *Staphylococcus aureus* isolated from wild boar. Microb Ecol. 2023;86(3):2184-2191. https://doi.org/10.1007/s00248-023-02236-4

14. Banna MH, Kundu S, Brazendale K, Ahinkorah BO, Disu TR, Seidu AA, Okyere J, Khan MSI. Knowledge and awareness about food safety, foodborne diseases, and microbial hazards: A cross-sectional study among Bangladeshi consumers of street-vended foods. Food Control. 2022;134:108718. https://doi.org/10.1016/j.foodcont.2021.108718
15. Bellia C, Bacarella S, Ingrassia M. Interactions between street food and food safety topics in the scientific literature—A bibliometric analysis with science mapping. Foods. 2022;11(6). https://doi.org/10.3390/foods11060789
16. Bencardino D, Amagliani G, Brandi G. Carriage of *Staphylococcus aureus* among food handlers: An ongoing challenge in public health. Food Control. 2021;130:108362. https://doi.org/10.1016/j.foodcont.2021.108362

17. Bimanand L, Taherikalani M, Jalilian FA, Sadeghifard N, Ghafourian S, Mahdavi Z, Mohamadi S, Sayehmiri K, Hematian A, Pakzad I. Association between biofilm production, adhesion genes and drugs resistance in different SCCmec types of methicillin resistant *Staphylococcus aureus* strains isolated from several major hospitals of Iran. Iran J Basic Med Sci. 2018;21(4):400-403. https://doi.org/10.22038/ijbms.2018.19378.5132
18. Bintsis T. Foodborne pathogens. AIMS Microbiol. 2017;3(3):529-563. https://doi.org/10.3934/microbiol.2017.3.529
19. Birgen BJ, Njue LG, Kaindi DM, Ogutu FO, Owade JO. Determinants of microbial contamination of street-vended chicken products sold in Nairobi County, Kenya. Int J Food Sci. 2020;2020:2746492. https://doi.org/10.1155/2020/2746492
20. Bitschar K, Staudenmaier L, Klink L, Focken J, Sauer B, Fehrenbacher B, Herster F, Bittner Z, Bleul L, Schaller M, Wolz C, Weber ANR, Peschel A, Schittek B. *Staphylococcus aureus* skin colonization is enhanced by the interaction of neutrophil extracellular traps with keratinocytes. J Invest Dermatol. 2020;140(5):1054-1065.e4. https://doi.org/10.1016/j.jid.2019.10.017
21. Çakici N, Demirel Zorba NN, Akali A. Carriage of Enterotoxigenic *Staphylococcus aureus* and hygiene practices of food workers. J Basic Clin Health Sci. 2023;7(2):618-627. https://doi.org/10.30621/jbachs.1137869
22. Casadevall A, Fang FC. The intracellular pathogen concept. Mol Microbiol. 2020;113(3):541-545. https://doi.org/10.1111/mmi.14421
23. Cavaiuolo M, Lefebvre D, Mutel I, Vingadassalon N, Merda D, Hennekinne JA, Nia Y. First report of enterotoxigenic Staphylococcus argenteus as a foodborne pathogen. Int J Food Microbiol. 2023;394:110182. https://doi.org/10.1016/j.ijfoodmicro.2023.110182
24. Chen Q, Xie S, Lou X, Cheng S, Liu X, Zheng W, Zheng Z, Wang H. Biofilm formation and prevalence of adhesion genes among *Staphylococcus aureus* isolates from different food sources. Microbiol Open. 2020;9(1):1-11. https://doi.org/10.1002/mbo3.946
25. Cheung GYC, Bae JS, Otto M. Pathogenicity and virulence of Staphylococcus aureus. Virulence. 2021;12(1):547-569. https://doi.org/10.1080/21505594.2021.1878688
26. Chi SI, Yousuf B, Paredes C, Bearne J, McDonald C, Ramirez-Arcos S. Proof of concept for detection of staphylococcal enterotoxins in platelet concentrates as a novel safety mitigation strategy. Vox Sang. 2023;118(7):543-550. https://doi.org/10.1111/vox.13440
27. Chung KF. *Staphylococcus aureus* enterotoxin-specific IgE sensitization in severe eosinophilic asthma phenotype. Allergy Asthma Immunol Res. 2023;15(2):119-121. https://doi.org/10.4168/aair.2023.15.2.119
28. Crombé F, Angeles Argudín M, Vanderhaeghen W, Hermans K, Haesebrouck F, Butaye P. Transmission dynamics of methicillin-resistant *Staphylococcus aureus* in pigs. Front Microbiol. 2013;4:57. https://doi.org/10.3389/fmicb.2013.00057
29. Das, A., Rume, F. I., Ansari, W. K., Alam, M. N., Islam, M. R., Dutta, P. K., & Anower, A. K. M. M. (2019). Assessment of bacterial contamination levels on the surface of the bovine carcasses at slaughterhouses of Barishal city in Bangladesh. J. Vet. Med. OH Res., 1(2), 231–245. https://doi.org/10.36111/jvmohr.2019.1(2).0014
30. Derakhshan, S., Navidinia, M., & Haghi, F. (2021). Antibiotic susceptibility of human-associated *Staphylococcus aureus* and its relation to agr typing, virulence genes, and biofilm formation. BMC Infectious Diseases, 21(1), 1–10. https://doi.org/10.1186/s12879-021-06307-0
31. Dubravka, M., Lazić, S., Branka, V., Jelena, P., Bugarski, D., & Zorica, Š. (2010). Slime production and biofilm forming ability by *Staphylococcus aureus* bovine mastitis isolates. Acta Veterinaria, 60(2–3), 217–226. https://doi.org/10.2298/AVB1003321
32. EL-Maghraby, M., Hassan, M., Hassanin, F., & Shawky, N. (2018). Street vended meat products as potential sources of Staphylococcus aureus. Benha Veterinary Medical Journal, 35(1), 197–202. https://doi.org/10.21608/bvmj.2018.38364
33. Erdoğan, M., & Pamuk, Ş. (2020). Microbial contamination in food, food-handlers' hands and surfaces and evaluation of contamination sources by the similarity between isolates.

Ankara Universitesi Veteriner Fakultesi Dergisi, 67(1), 73–79. https://doi.org/10.33988/auvfd.599367

34. Etter, D., Corti, S., Spirig, S., Cernela, N., Stephan, R., & Johler, S. (2020). *Staphylococcus aureus* population structure and genomic profiles in asymptomatic carriers in Switzerland. Frontiers in Microbiology, 11, 1–7. https://doi.org/10.3389/fmicb.2020.01289
35. Etter, D., Schelin, J., Schuppler, M., & Johler, S. (2020). Staphylococcal Enterotoxin C—An Update on SEC Variants, Their Structure and Properties, and Their Role in Foodborne Intoxications. Toxins, 12(9). https://doi.org/10.3390/toxins12090584
36. FAO/WHO. (2023). A Guide to World Food Safety Day 2023: Food standards save lives. https://www.who.int/campaigns/world-food-safety-day/2023
37. Fei, Y., Ali, A., Mohammad, M., & Jin, T. (2022). Commensal bacteria augment *Staphylococcus aureus* septic arthritis in a dose-dependent manner. Frontiers in Cellular and Infection Microbiology, 12, 942457. https://doi.org/10.3389/fcimb.2022.942457
38. Fernandes, A., Ramos, C., Monteiro, V., Santos, J., & Fernandes, P. (2022). Virulence potential and antibiotic susceptibility of *S. aureus* strains isolated from food handlers. Microorganisms, 10(11), 2155. https://doi.org/10.3390/microorganisms10112155
39. Fisher, E. L., Otto, M., & Cheung, G. Y. C. (2018). Basis of virulence in enterotoxin-mediated staphylococcal food poisoning. Frontiers in Microbiology, 9, 1–18. https://doi.org/10.3389/fmicb.2018.00436
40. FSIN and Global Network Against Food Crises. (2023). 2023 Global Report on Food Crises. 1–213. https://www.fsinplatform.org/global-report-food-crises-2023
41. Ghabbour, R., Awad, A., & Younis, G. (2022). Genetic characterization and antimicrobial-resistant profiles of *Staphylococcus aureus* isolated from different food sources. Biocontrol Science, 27(2), 87–97. https://doi.org/10.4265/bio.27.87
42. Gowrishankar, S., Duncun Mosioma, N., & Karutha Pandian, S. (2012). Coral-associated bacteria as a promising antibiofilm agent against methicillin-resistant and -susceptible *Staphylococcus aureus* biofilms. Evidence-Based Complementary and Alternative Medicine, 2012. https://doi.org/10.1155/2012/862374
43. Guo, J., Mao, K., Yuan, Z., Qin, Z., Xu, T., Bateni, S. M., Zhao, Y., & Ye, C. (2021). Global food security assessment during 1961–2019. Sustainability (Switzerland), 13(24). https://doi.org/10.3390/su132414005
44. Haghi, F., Zeighami, H., Hajiloo, Z., Torabi, N., & Derakhshan, S. (2021). High frequency of enterotoxin encoding genes of *Staphylococcus aureus* isolated from food and clinical samples. Journal of Health, Population and Nutrition, 40(1), 1–6. https://doi.org/10.1186/s41043-021-00246-x
45. Hamat, H. W., Lani, M. N., Hamzah, Y., Alias, R., & Hassan, Z. (2019). Microbiological assessment of keropok lekor production in Kuala Terengganu and Marang, Malaysia. Asian Journal of Agriculture and Biology, 7(1), 74–85.
46. Hu, W. D. (2016). Distribution of food-borne *Staphylococcus aureus* enterotoxin genes. Genetics and Molecular Research, 15(1), 1–9. https://doi.org/10.4238/gmr.15016084
47. Hunt, K., Butler, F., & Jordan, K. (2014). Factors affecting staphylococcal enterotoxin C bovine production in milk. International Dairy Journal, 39(1), 41–46. https://doi.org/10.1016/j.idairyj.2014.05.001
48. Ibrahim, H. (2020). Isolation and identification of microorganisms from street vended ready-to-eat foods in Gombe Metropolis, Nigeria. UMYU Journal of Microbiology Research (UJMR), 5(2), 26–32. https://doi.org/10.47430/ujmr.2052.004
49. Jahan, M., Rahman, M., Rahman, M., Sikder, T., Uson-Lopez, R. A., Selim, A. S. M., Saito, T., & Kurasaki, M. (2018). Microbiological safety of street-vended foods in Bangladesh. Journal Fur Verbraucherschutz Und Lebensmittelsicherheit, 13(3), 257–269. https://doi.org/10.1007/s00003-018-1174-9
50. Jang, K. O., Lee, Y. W., Kim, H., & Chung, D. K. (2021). Complement inactivation strategy of *Staphylococcus aureus* using decay- accelerating factor and the response of

infected HaCaT cells. International Journal of Molecular Sciences, 22(8). https://doi.org/10.3390/ijms22084015

51. Jin, Q., Xie, X., Zhai, Y., & Zhang, H. (2023). Mechanisms of folate metabolism-related substances affecting *Staphylococcus aureus* infection. International Journal of Medical Microbiology, 313(2), 151577. https://doi.org/10.1016/j.ijmm.2023.151577
52. Johler, S., Tichaczek-Dischinger, P. S., Rau, J., Sihto, H. M., Lehner, A., Adam, M., & Stephan, R. (2013). Outbreak of staphylococcal food poisoning due to sea-producing Staphylococcus aureus. Foodborne Pathogens and Disease, 10(9), 777–781. https://doi.org/10.1089/fpd.2013.1503
53. Jores, D., Arif, M. T., & Rahman, M. M. (2018). Factors associated with food hygiene practices among street food vendors in Padawan, Sarawak. Borneo Journal of Resource Science and Technology, 8(1), 56–65. https://doi.org/10.33736/bjrst.824.2018
54. Karygianni L, Ren Z, Koo H, Thurnheer T. Biofilm matrixome: Extracellular components in structured microbial communities. Trends Microbiol. 2020; 28(8): 668-681. https://doi.org/10.1016/j.tim.2020.03.016
55. Kazem EM, Jarallah EM. Molecular detection of *Staphylococcus aureus* enterotoxin genes. Int J Health Sci. 2022; 6(July): 6004-6019. https://doi.org/10.53730/ijhs.v6ns4.11018
56. Kumar P, Bansal P, Garg VK, Sangwan S, Dhama K, Chandran D, Bhatia GK, Gupta B, Tuli HS. In silico targeting enterotoxin from *Staphylococcus aureus* with selected flavonoids: Hope for the discovery of natural anti-mastitis agents. J Exp Biol Agric Sci. 2023; 11(1): 132-139. https://doi.org/10.18006/2023.11(1).132.139
57. Lalnunfela J, Lalmuanpuia E, Motina DD, GL. Molecular detection of Staphylococcal enterotoxin C (SEC) and Staphylococcal enterotoxin D (SED) from the cattle nares in Aizawl, Mizoram (India). Int J Curr Microbiol Appl Sci. 2021; 10(2): 1250-1253. https://doi.org/10.20546/ijcmas.2021.1002.147
58. Laux C, Peschel A, Krismer B. *Staphylococcus aureus* colonization of the human nose and interaction with other microbiome members. Gram-Positive Pathogens. 2019; 2: 723-730. https://doi.org/10.1128/9781683670131.ch45
59. Le HHT, Dalsgaard A, Andersen PS, Nguyen HM, Ta YT, Nguyen TT. Large-scale *Staphylococcus aureus* foodborne disease poisoning outbreak among primary school children. Microbiol Res. 2021; 12(1): 43-52. https://doi.org/10.3390/MICROBIOLRES12010005
60. Li HN, Kang ZD, Wang T, Li T, Yang YG, Zhou W, Yuan F. Effect of environmental factors on expression of staphylococcal enterotoxin genes. Environ Sci Pollut Res. 2023; 30(50): 108694-108705. https://doi.org/10.1007/s11356-023-29412-w
61. Li P, Yin R, Cheng J, Lin J. Bacterial biofilm formation on biomaterials and approaches to its treatment and prevention. Int J Mol Sci. 2023; 24(14). https://doi.org/10.3390/ijms241411680
62. Liao X, Shen W, Wang Y, Bai L, Ding T. Microbial contamination, community diversity and cross-contamination risk of food-contact ice. Food Res Int. 2023; 164(June 2022): 112335. https://doi.org/10.1016/j.foodres.2022.112335
63. Long J, Du G, Chen J, Xie C, Xu J, Yuan J. Bacteria and poisonous plants/fungi were the primary causative hazards of foodborne disease outbreaks: A five-year survey from Guangzhou, Guangdong. Int J Food Microbiol. 2023; 400(September 2022): 110264. https://doi.org/10.1016/j.ijfoodmicro.2023.110264
64. Loukieh M, Mouannes E, Abou Jaoudeh C, Hanna Wakim L, Fancello F, Zeidan M. Street foods in Beirut city: An assessment of the food safety practices and of the microbiological quality. J Food Saf. 2018; 38(8): 12455. https://doi.org/10.1016/j.sjbs.2023.103653
65. Mahdi NB. Prevalence of Panton-Valentine leukocidin and toxic shock syndrome toxin-1 genes in methicillin-resistant *Staphylococcus aureus* isolated from nose of restaurant

workers in Kirkuk city. J Adv Pharm Technol Res. 2023; 14(1): 34-38. https://doi.org/10.4103/japtr.japtr_508_22
66. Martins DM, Cardoso EM, Capellari L, Botelho LAB, Ferreira FA. Detection of *Staphylococcus aureus* from nares of elderly living in a Brazilian nursing home. Diagn Microbiol Infect Dis. 2024; 108(1). https://doi.org/10.1016/j.diagmicrobio.2023.116089
67. Mehta HD. Bacteriological analysis and hygiene of street food panipuri: A case study of Morbi City-Gujarat, India. Indian J Pure Appl Biosci. 2020; 8(4): 313-317. https://doi.org/10.18782/2582-2845.8224
68. Melo FD, Sfaciotte RAP, Dalmina KA, Wildemann P, Parussolo L, Wosiacki SR, Da Costa UM, Ferraz SM. Enterotoxigenic potential of Staphylococcus spp. isolates recovered from raw milk and artisanal cheese. An Acad Bras Cienc. 2020; 92(3): 1-7. https://doi.org/10.1590/0001-3765202020180925
69. Moloi M, Lenetha GG, Malebo NJ. Microbial levels on street foods and food preparation surfaces in Mangaung Metropolitan Municipality. Health SA. 2021; 26: 1-7. https://doi.org/10.4102/hsag.v26i0.1407
70. Nawawee NSM, Bakar NFA, Zulfakar SS. Microbiological safety of street-vended beverages in Chow Kit, Kuala Lumpur. Int J Environ Res Public Health. 2019; 16(22). https://doi.org/10.3390/ijerph16224463
71. Neopane P, Nepal HP, Shrestha R, Uehara O, Abiko Y. In vitro biofilm formation by *Staphylococcus aureus* isolated from wounds of hospital-admitted patients and their association with antimicrobial resistance. Int J Gen Med. 2018; 11: 25-32. https://doi.org/10.2147/IJGM.S153268
72. Nethathe B, Matsheketsheke PA, Mashau ME, Ramashia SE. Microbial safety of ready-to-eat food sold by retailers in Thohoyandou, Limpopo province, South Africa. Cogent Food Agric. 2023; 9(1). https://doi.org/10.1080/23311932.2023.2185965
73. Nguyen Do P, Dang Thuy L, Le Thi MH, Tran Thi T, Nguyen Thi NB, Quach Kim N. Prevalence of classical Staphylococcal enterotoxin genes of *Staphylococcus aureus* isolated from ready-to-eat food in Ho Chi Minh City, Vietnam. Heavy Metals and Arsenic Concentrations in Water, Agricultural Soil, and Rice in Ngan Son District, Bac Kan Province, Vietnam. 2020; 3(4): 9-15. https://doi.org/10.47866/2615-9252/vjfc.1755
74. Nwachukwu MO, Azorji JN, Onyebuagu PC, Nnadozie RIA, Izundu MI. Microbiological quality of food sold in different grades of mobile food vendors and canteens in Owerri Metropolis. Int J Pathogen Res. 2020; February: 12-21. https://doi.org/10.9734/ijpr/2020/v4i430118
75. Osalumhense OS, Izevbuwa OE. Microbiological assessment of ready-to-eat food from selected street vending food locations in Ikpoba-Okha Local Government Area of Edo State. Bacterial Empire. 2021; 4(1): 20-24. https://doi.org/10.36547/be.2021.4.1.20-24
76. Pal M. Staphylococcus aureus: A major pathogen of food poisoning. Nutr Food Process. 2022; 5(1): 01-03. https://doi.org/10.31579/2637-8914/074
77. Parastan R, Kargar M, Solhjoo K, Kafilzadeh F. *Staphylococcus aureus* biofilms: Structures, antibiotic resistance, inhibition, and vaccines. Gene Rep. 2020; 20(May). https://doi.org/10.1016/j.genrep.2020.100739
78. Pexara A, Bourriel A, Govaris A. Review article Ανασκόπηση *Staphylococcus aureus* and Staphylococcal enterotoxins. J Hellenic Vet Med Soc. 2018; 61(4): 316-322
79. Rosales PA, Linnemann AR, Luning PA. (2023). Food safety knowledge, self-reported hygiene practices, and street food vendors' perceptions of current hygiene facilities and services - An Ecuadorean case. Food Control, 144(April 2022), 109377. https://doi.org/10.1016/j.foodcont.2022.109377
80. Proctor RA. (2021). Have we outlived the concept of commensalism for Staphylococcus aureus? Clinical Infectious Diseases, 73(1), E267–E269. https://doi.org/10.1093/cid/ciaa1431
81. Rahimi F, Katouli M, Karimi S. (2016). Biofilm production among methicillin resistant *Staphylococcus aureus* strains isolated from catheterized patients with urinary tract

infection. Microbial Pathogenesis, 98, 69–76. https://doi.org/10.1016/j.micpath.2016.06.031

82. Ramachandran G, Alharbi NS, Chackaravarthy G, Kanisha Chelliah C, Rajivgandhi G, Maruthupandy M, Quero F, Natesan M, Li WJ. (2023). Chitosan/silver nanocomposites enhanced the biofilm eradication in biofilm forming Gram positive *S. aureus*. Journal of King Saud University - Science, 35(4), 102597. https://doi.org/10.1016/j.jksus.2023.102597
83. Rashed EY, Zaid BA. (2022). Detection of some virulence factors and antibiotic resistance of *Staphylococcus aureus* isolated from food source. International Journal of Health Sciences, 6(May), 6839–6847. https://doi.org/10.53730/ijhs.v6ns4.10310
84. Rortana C, Nguyen-Viet H, Tum S, Unger F, Boqvist S, Dang-Xuan S, Koam S, Grace D, Osbjer K, Heng T, Sarim S, Phirum O, Sophia R, Lindahl JF. (2021). Prevalence of salmonella spp. and *Staphylococcus aureus* in chicken meat and pork from Cambodian markets. Pathogens, 10(5), 1–17. https://doi.org/10.3390/pathogens10050556
85. Sabry MA, Abdel-Moein KA, Hamza DA, Abdel-Twaab T. (2017). Enterotoxigenic Staphylococcus aureus: sources and strategy for control in food outlets. Journal Fur Verbraucherschutz Und Lebensmittelsicherheit, 12(4), 335–339. https://doi.org/10.1007/s00003-017-1120-2
86. Salamandane A, Silva AC, Brito L, Malfeito-Ferreira M. (2021). Microbiological assessment of street foods at the point of sale in Maputo (Mozambique). Food Quality and Safety, 5, 1–9. https://doi.org/10.1093/fqsafe/fyaa030
87. Schwendimann L, Merda D, Berger T, Denayer S, Feraudet-Tarisse C, Kläui AJ, Messio S, Mistou MY, Nia Y, Hennekinne JA, Grabera HU. (2021). Staphylococcal enterotoxin gene cluster: Prediction of enterotoxin (SEG and SEI) production and of the source of food poisoning on the basis of vSaβ typing. Applied and Environmental Microbiology, 87(5), 1–15. https://doi.org/10.1128/AEM.02662-20
88. Sharma A, Gangopadhyay S, Agarwal JK, Kumar A, Ingole KV. (2021). Hand contamination among food handlers: A study on the assessment of food handlers in canteen of various hospitals in Solapur City, Maharashtra. Journal of Pure and Applied Microbiology, 15(3), 1536–1546. https://doi.org/10.22207/JPAM.15.3.48
89. Shin K, Yun Y, Yi S, Lee HG, Cho JC, Suh K Do, Lee J, Park J. (2013). Biofilm-forming ability of *Staphylococcus aureus* strains isolated from human skin. Journal of Dermatological Science, 71(2), 130–137. https://doi.org/10.1016/j.jdermsci.2013.04.004
90. Siddabathuni A. (2019). Bacteriological analysis of ready-to-serve foods from a South Indian City: A potential source for drug resistant pathogens. Journal of Microbiology and Infectious Diseases, 9(July 2018), 83–89. https://doi.org/10.5799/jmid.574601
91. Sirotamarat P, Hinjoy S, Chuxnum T, Wongkumma A, Somboonna N, Nuanualsuwan S. (2022). Quantitative risk assessment of staphylococcal enterotoxin A (SEA) in pork in metropolitan Bangkok, Thailand. Lwt, 168(August), 113942. https://doi.org/10.1016/j.lwt.2022.113942
92. Sivakumar M, Dubal ZB, Kumar A, Bhilegaonkar K, Vinodh Kumar OR, Kumar S, Kadwalia A, Shagufta B, Grace MR, Ramees TP, Dwivedi A. (2019). Virulent methicillin resistant *Staphylococcus aureus* (MRSA) in street vended foods. Journal of Food Science and Technology, 56(3), 1116–1126. https://doi.org/10.1007/s13197-019-03572-5
93. Soe YM, Bedoui S, Stinear TP, Hachani A. (2021). Intracellular *Staphylococcus aureus* and host cell death pathways. Cellular Microbiology, 23(5). https://doi.org/10.1111/cmi.13317
94. Song M, Bai Y, Xu J, Carter MQ, Shi C, Shi X. (2015). Genetic diversity and virulence potential of *Staphylococcus aureus* isolates from raw and processed food commodities in Shanghai. International Journal of Food Microbiology, 195, 1–8. https://doi.org/10.1016/j.ijfoodmicro.2014.11.020

95. Sonune NA. (2022). Assessment of bacteriological quality of street food and their antibiotic profiling. SAR Journal of Pathology and Microbiology, 3(4), 39–45. https://doi.org/10.36346/sarjpm.2022.v03i04.001
96. Tahaei SAS, Stájer A, Barrak I, Ostorházi E, Szabó D, Gajdács M. (2021). Correlation between biofilm-formation and the antibiotic resistant phenotype in *Staphylococcus aureus* isolates: A laboratory-based study in Hungary and a review of the literature. Infection and Drug Resistance, 14, 1155–1168. https://doi.org/10.2147/IDR.S303992
97. Tasanapak K, Kucharoenphaibul S, Wongwigkarn J, Sitthisak S, Thummeepak R, Chaibenjawong P, Chatdumrong W, Nimanussornkul K. (2023). Prevalence and virulence genes of *Staphylococcus aureus* from food contact surfaces in Thai restaurants. PeerJ, 11, 1–15. https://doi.org/10.7717/peerj.15824
98. Tiengtip R. (2020). Original Article Anisakis spp. Parasites and Staphylococcus aureus, Bacillus cereus in Sushi and sashimi from Thammasat University (Rangsit Campus) Area Restaurants. 20(4), 307–316.
99. Todd E. (2020). Food-borne disease prevention and risk assessment. International Journal of Environmental Research and Public Health, 17(14), 1–13. https://doi.org/10.3390/ijerph17145129
100. Tropea A. (2022). Microbial contamination and public health: An overview. International Journal of Environmental Research and Public Health, 19(12). https://doi.org/10.3390/ijerph19127441
101. Tshipamba ME, Lubanza N, Adetunji MC, Mwanza M. (2018). Molecular characterization and antibiotic resistance of foodborne pathogens in street-vended ready-to-eat meat sold in South Africa. Journal of Food Protection, 81(12), 1963–1972. https://doi.org/10.4315/0362-028X.JFP-18-069
102. Tsutsuura S, Shimamura Y, Murata M. (2013). Temperature dependence of the production of staphylococcal enterotoxin A by Staphylococcus aureus. Bioscience, Biotechnology and Biochemistry, 77(1), 30–37. https://doi.org/10.1271/bbb.120391
103. Vargová M, Zigo F, Výrostková J, Farkašová Z, Rehan IF. (2023). Biofilm-producing ability of *Staphylococcus aureus* obtained from surfaces and milk of mastitic cows. Veterinary Sciences, 10(6). https://doi.org/10.3390/vetsci10060386
104. Wan Y, Wang X, Zhang P, Zhang M, Kou M, Shi C, Peng X, Wang X. (2021). Control of foodborne *Staphylococcus aureus* by shikonin, a natural extract. Foods, 10(12). https://doi.org/10.3390/foods10122954
105. Wilson J, Guy R, Elgohari S, Sheridan E, Davies J, Lamagni T, Pearson A. (2011). Trends in sources of meticillin-resistant *Staphylococcus aureus* (MRSA) bacteraemia: Data from the national mandatory surveillance of MRSA bacteraemia in England, 2006-2009. Journal of Hospital Infection, 79(3), 211–217. https://doi.org/10.1016/j.jhin.2011.05.013
106. Yarovoy JY, Monte AA, Knepper BC, Young HL. (2019). Epidemiology of community-onset *Staphylococcus aureus* bacteremia. Western Journal of Emergency Medicine, 20(3), 438–442. https://doi.org/10.5811/westjem.2019.2.41939
107. Yee R, Yuan Y, Tarff A, Brayton C, Gour N, Feng J, Zhang Y. (2022). Eradication of *Staphylococcus aureus* biofilm infection by persister drug combination. Antibiotics, 11(10). https://doi.org/10.3390/antibiotics11101278
108. Yildirim T, Sadati F, Kocaman B, SİRİKEN B. (2019). *Staphylococcus aureus* and Staphylococcal enterotoxin detection in raw milk and cheese origin coagulase positive isolates. International Journal of Science Letters, 1(1), 30–41. https://doi.org/10.38058/ijsl.596007
109. Zhang Y, Xu D, Shi L, Cai R, Li C, Yan H. (2018). Association between agr type, virulence factors, biofilm formation and antibiotic resistance of *Staphylococcus aureus* isolates from pork production. Frontiers in Microbiology, 9(JUL), 1–12. https://doi.org/10.3389/fmicb.2018.01876

110. Zheng Y, Gracia A, Hu L. (2023). Predicting foodborne disease outbreaks with food safety certifications: econometric and machine learning analyses. Journal of Food Protection, 86(9), 100136. https://doi.org/10.1016/j.jfp.2023.100136