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Review Article

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Biological Hazards Associated with Chicken Meat: A Review

Abdallah F.A. Mahmoud, Mohamed A.M. Hussein, Eman A.A. Mohamed, Wageh S. Darwish*

Department of Food Hygiene, Safety and Technology, Faculty of Veterinary Medicine, Zagazig University, El-Zeraah str. 114; 44519-Zagazig, Egypt

***Correspondence**
Corresponding author: Wageh S. Darwish
E-mail address: wagehdarwish@gmail.com

Abstract

Chicken meat and meat products are considered as significant sources of high quality animal derived protein, essential amino acids, minerals, and vitamins. Besides, chicken meat is regarded as alternative cheap source of protein compared with the red meat. However, chicken meat can be contaminated with a vast array of microorganisms, and subsequently it can be implicated in many biological hazards such as bacterial food poisoning. The latter can be divided into bacterial foodborne infections including *E. coli*, *Salmonella* spp., *Campylobacter* spp., *Listeria monocytogenes*, *Shiegella* spp., and *Yersinia* spp. Bacterial foodborne intoxication including *Staphylococcus aureus*, and *Clostridium botulinum*. The third class of the bacterial food poisoning is foodborne toxicoinfection which involves *Clostridium perfringens*, and *Bacillus cereus*. This review threw the light on the current scenario of the contamination of the poultry meat with some bacterial hazards in Egypt and worldwide. Besides, the public health significance of such hazards was also discussed.

KEYWORDS
Biological hazards, Chicken meat, Egypt, Worldwide

Introduction

Because they are nutritious, delicious, and affordable, chicken meat and meat products such as liver, gizzards, chicken burgers, luncheon meat, and frankfurters are important sources of protein, energy, vitamins, and minerals around the world (Darwish *et al*., 2018; Morshdy *et al*., 2021a). However, due to cross-contamination of chicken meat from the environment or the food chain, chicken products may pose a risk. To enhance human growth and health, chicken meat provides a considerable part of microelements like as copper, iron, zinc, calcium, phosphorus, and cobalt. Besides, vitamins such as vitamin B group can also be provided when chicken meat is consumed (El Bayomi *et al*., 2018).

Biological hazards include bacteria, viruses, fungi, and parasites. Such hazards might contaminate edible parts of the chicken and subsequently find their way to the human body when such parts are consumed leading to the onset of food poisoning. The latter Bacterial food poisoning is subdivided into 3 sections including: Bacterial foodborne infections, which include *E. coli*, *Salmonella* spp., *Campylobacter* spp., *Listeria monocytogenes*, *Shiegella* spp., and *Yersinia* spp. Bacterial foodborne intoxication that caused by *Staphylococcus aureus* (*S. aureus*) and *Clostridium botulinum*. Foodborne toxicoinfection, which involves *Clostridium perfringens* and *Bacillus cereus* (*B. cereus*), is the third type of the bacterial food poisoning (Alsayeqh *et al*., 2021).

Such microorganisms can contaminate chicken meat via many sources which can be divided into extrinsic sources such as feathers, contaminated animal feed, contaminated equipment (knives, cutting boards, and processing machines), contaminated water used for washing of the poultry carcasses, operators' hands, and clothes, dropping of the bird carcass to the ground of the slaughterhouse or the butcher shop. Intrinsic sources might contribute to the contamination of the poultry carcasses such sources include cutting of the intestinal tract or the proventriculus during evisceration, overscalding of the poultry carcasses, migration of the microorganisms from the intestine to other organs of the bird during slaughtering. The processing procedure can also lead to meat product contamination due to raw materials, spices, and water utilized during the packing process (Darwish *et al*., 2022).

This review spotted the light on the bacterial hazards (*Salmonella* spp., *S. aureus*, and *B. cereus*) associated with the consumption of chicken meat and their potential adverse health effects.

Salmonella spp.

In Turkey, researchers used two phenotyping approaches to look for *Salmonella* spp. in 150 chicken meat samples: classic culture technique (CCT) and immunomagnetic separation (IMS). In order to authenticate the isolates at the molecular level, the *invA* gene was found in these isolates. The presence of *invA*, class 1 (*Cls1*) integrons, and integrase (*Int1*) genes was demonstrated by PCR, and antibiotic resistance of the isolated *Salmonella* spp. strains was determined by disc diffusion. *Salmonella* spp. were discovered in a total of 64 (42.66%) chicken flesh samples after combining the culture and PCR data. The contamination percentage in carcasses was higher (53.33%, n = 75) than in meat portions (32%, n = 75). When the results of regular culture were

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compared to the IMS approach, the IMS (n = 54) clearly outperformed the CCT (n = 38). Resistance to vancomycin, tetracycline, streptomycin, or nalidixic acid was reported to be extremely high (89.28%). Trimethoprim-sulfamethoxazole resistance was found in 32.14% of the patients. Resistance to gentamicin, chloramphenicol, ampicillin, and ceftriaxone was found to be quite low (8.33%). Resistance to at least four antibiotics was found in 92.85% of the isolates. Cls1 and Int1 integrons were found in 80.95% and 95.23% of the isolates, respectively. However, Int1 was only found in 15.47% of the cases (n = 13) (Siriken *et al*., 2015).

In Bangladesh, Parvin *et al*. (2020) assessed the incidence of *Salmonella* harboring extended-spectrum -lactamase (ESBL) and their antibiotic resistance pattern in 113 domestic frozen chicken meat samples purchased from supermarkets in five divisional megacities. The study also looked for β-lactamase- and plasmid-mediated quinolone resistance-encoding genes. *Salmonella* was detected in all samples using selective media and a PCR assay. Disc diffusion tests were used to determine antimicrobial susceptibility, while double-disk synergy testing was used to screen for ESBLs. Multiplex PCR was used to identify resistance genes. 65.5% of the samples tested positive for *Salmonella* spp., and 58.1% of these isolates produced ESBL. The entire isolates tested positive for multidrug resistance (MDR): 40.5% were resistant to all three to five and six to eight antimicrobial classes; 17.6% were resistant to all antimicrobial classes. Resistance to oxytetracycline was found to be 100%, followed by trimethoprim-sulfamethoxazole (89.2%), tetracycline (86.5%), nalidixic acid (83.8%), amoxicillin (74.3%), and pefloxacin (70.3%). Notably, 48.6% of the isolates tested positive for imipenem resistance. One isolate (1.4%) was likely highly drug resistant. All of the isolates tested positive for the bla_{TEM} gene, 2.7% tested positive for $bla_{CTX-M-1}$, and 20.3% tested positive for bla_{NDM-1}. The *qnrA* and *qnrS* genes were found in 4.1 and 6.8% of people, respectively. This study found ESBL-producing *Salmonella* in frozen chicken meat in Bangladesh, putting more responsibility on food processors and policymakers to assure food safety.

In Japan, *Salmonella* was isolated from 143 samples (59.6%), and the most common serovars detected were Infantis (77/240, 32.1%) and Schwarzengrund (56/240, 23.3%). Previous studies only reported *S.* Schwarzengrund contamination of grill chickens in western Japan; however, in the current study, *S.* Schwarzengrund was isolated from meat produced in eastern Japan-20% (12/60) in the C prefecture to 36.4% (8/22) in the Y prefecture-suggesting that *S.* Schwarzengrund-contaminated areas have expanded towards eastern Japan (Ishihara *et al*., 2020). Besides, in Japan also low-temperature and long-time (LT-LT) cooking, commonly known as sous vide cooking, is a method of cooking meat in heated water at a relatively low temperature of roughly 60°C. This cooking method has grown in popularity, and low-temperature cookers for home use are now available on the market. However, if any pathogenic bacteria persist after LT-LT cooking, they could cause infection and foodborne diseases. As a result, the goal of this study was to find the best LT-LT cooking methods for chicken by measuring temperature changes and investigating bacteria in LT-LT-cooked chicken meat. Temperatures were recorded at the surface and in the centres of 300 g single- and double-layer samples at predetermined cooking temperatures of 60 and 65°C. The surface required 5 to 14 minutes to reach 50°C, the centre of the single-layer sample 25 minutes, and the centre of the double-layer sample 33 to 35 minutes. The surface of single-layer chicken meat reached 50°C the fastest, followed by the centre of single-layer and double-layer chicken meat ($P < 0.05$). Colour changes in the meat and heating of the meat were noticed all the way to the interior when the meat was LT-LT cooked at 60 and 65°C for 60 minutes. *Campylobacter jejuni*, *Salmonella* O7, and *Listeria monocytogenes* were inoculated into chicken breasts and cooked at 60 and 65°C for 15, 30, 60, 90, and 120 minutes. *C. jejuni* survived cooking for up to 30 minutes, *Salmonella* O7 survived cooking for up to 60 minutes at 60°C and 30 minutes at 65°C, and *L. monocytogenes* survived cooking for up to 90 minutes at 60°C and 60 minutes at 65°C. Thus, LT-LT cooking for 120 minutes at 60°C and 90 minutes at 65°C is indicated to prevent infection and illness caused by the three investigated bacteria species (Shimojima *et al*., 2022).

In the republic of Korea, searched the various characteristics of *Salmonella* spp. isolated from raw chicken meats accessible in Korean markets. The information gathered, such as the food source of isolation, sampling information, serotype, pathogenicity, and genetic profile including sequence type, was entered into a database for future comparative study of the strains isolated from the traceback inquiry samples. We tested 113 domestically distributed chicken meat samples for *Salmonella* spp. infection in order to characterize serotype, pathogenicity, and gene sequences. Using pulsed-field gel electrophoresis (PFGE) and multilocus sequence typing (MLST), phylogenetic analysis was performed on 24 strains (21.2%) of *Salmonella* isolated from 113 commercially available chicken meats and by-products. Serotyping of *Salmonella* spp. isolated revealed S. Enteritidis in 11 strains (45.8%), *S.* Virchow in 6 strains. *S.* Montevideo was found in two strains (8.3%), *S.* Bsilla in two strains (8.3%), S. Bareilly in one (4.2%), S. Dessau in one (4.2%), and *S.* Albany in one (4.2%). The genetic association revealed that 24 isolated strains were categorized into 18 clusters with genetic similarity ranging from 64.4-100%. Eleven isolated S. Enteritidis strains were separated into nine genotypes with 74.4% sequence identity, while the most distantly related S. Virchow strain was grouped into five genotypes with 85.9% identity. The MLST analysis revealed that the *Salmonella* spp. recovered from domestic chicken sold in Chungcheong Province belonged to ST 11 and 16, which differed from the genotype of *Salmonella* isolated from imported chicken (Koh *et al*., 2022).

In Egypt, chicken meat, which could be a healthy and nutritious food, has been implicated as a source of *Salmonella* typhimurium, which has a high potential to cause human salmonellosis. The purpose of this study was to determine the prevalence of multidrug resistant *S.* typhimurium in chicken flesh as well as the effects of essential oils on its viability. A total of 300 chicken meat and product samples were streaked on XLD agar plates, and the isolates were identified using biochemical and serological assays. Ten S. typhimurium isolates were serotyped and tested for sensitivity to 14 antimicrobials using a single diffusion method. Eight isolates (80%) demonstrated multiple antimicrobial resistance (MAR) for three or more antimicrobials, with an average MAR score of 0.4857 (Morshdy *et al*., 2021b). Furthermore, Habashy *et al*. (2021) reported that *Salmonella* spp. isolation rates were 33.3% and 16.6%, respectively, from chicken breast and thigh retailed in Egypt. *S.* Typhimurium, *S.* Enteritidis, *S.* Kentucky, and *S.* Anatum were discovered as *Salmonella* serotypes. S. Typhimurium recovered from breast and thigh muscles at rates of 23.33% and 13.33%, respectively, followed by *S.* Enteritidis (3.33% each). In addition, *Salmonella* Typhimurium isolates included the hilA and stn genes. Besides, *Salmonella* spp. could only be isolated from chicken burger and fillet at 10% and 23.33%, respectively, according to Morshdy *et al*. (2023).

Staphylococcus aureus

In Japan, Phenotypic and genotypic approaches were used to characterize two isolates of mecA-positive methicillin-resis-

tant *Staphylococcus aureus* (MRSA) from retail raw chicken flesh. One isolate exhibited the human biovar, coagulase type III, phage group I III, the absence of enterotoxins and TSST-1 production, and resistance to PCG/ABPC/EM/GM/KM. The other isolate exhibited the human biovar, coagulase type III, phage group III, enterotoxin C and TSST-1 production, and resistance to PCG/ABPC/CEZ. The biotyping results show that the two isolates had human *S. aureus* features. They also carried SCCmec type IV, which is common in community-acquired MRSA isolates (Kitai *et al*., 2005).

In Iran, from January 2011 to March 2012, 360 fresh raw chicken meats were collected from 133 chicken shops in Isfahan, Iran, to detect virulence factors and investigate antibiotic susceptibility of *Staphylococcus aureus*. The isolates of *Staph. aureus* were identified using culture and phenotypic methods. The PCR tests were designed using specialized primers to detect *Staph. aureus* pathogenicity and antibiotic resistance genes. The antibiotic susceptibility of *Staph. aureus* isolated from chicken flesh samples was tested using the agar disc diffusion method. In this survey, 101 of 360 samples (28.05%) were positive for *Staphylococcus*. According to our findings, 82 (22.77%) of 360 samples tested positive for *Staph. aureus*, and 96.34% had X-region and 76.92% had fibrinogen clumping factor A. 63.41% had staphylococcal coagulase virulence genes, 26.82% had IgG binding area, and no sample carried the toxic shock syndrome toxin-1 gene. Methicillin had the greatest antibiotic-resistant genes (82.92%), whereas macrolides had the lowest (34.14%) among *Staph. aureus*-positive samples. In *Staph. aureus* isolates, tetracycline showed the greatest resistance profile (97.56%), followed by methicillin (75.6), sulfamethoxazole (31.7%), trimethoprim (31.7%), streptomycin (31.7%), gentamicin (29.26%), enrofloxacin (28.04%), ampicillin (26.82%), chloramphenicol (20.73%), and cephalothin (17. Statistical analysis revealed that the presence of several virulence and antibiotic resistance genes in *Staph. aureus* isolated from chicken meat samples differed significantly (Momtaz *et al*., 2013)

In Cambodia, Between October 2018 and August 2019, 52 traditional markets and 6 supermarkets in 25 provinces of Cambodia were sampled. In all, 532 samples were collected, including chicken flesh and pork (n = 408, 204 of each), as well as chicken and pork cutting board swabs (n = 124, 62 of each). *Salmonella* spp. and *S. aureus* were found in all samples; colony-forming units per gramme (CFU/g) of coagulase-positive Staphylococci (CPS) were counted, and a subset of samples was further tested for the most likely number (MPN, n = 136) of *Salmonella*. *Salmonella* spp. and *S. aureus* were found in 42.1% (224/532) and 29.1% (155/532) of samples, respectively, with 14.7% (78/532) of samples having both bacteria. *Salmonella* spp. were found in 42.6% of chicken meat samples. It was 41.9% on the chicken cutting board, 45.1% on the pork cutting board, and 30.6% on the pork cutting board. Chicken meat exhibited a considerably (p-value 0.05) greater prevalence of *S. aureus* than chicken cutting board (17.7%), pork 28.9%, and pork cutting board 11.3%. The mean MPN-*Salmonella* concentration was 10.6 MPN/g in chicken samples and 11.1 MPN/g in pork samples. In chicken and pork samples, the average Log CFU/g of CPS was 2.6 and 2.5, respectively. According to the findings, chicken meat and pork in Cambodia were extensively infected with *Salmonella* spp. and *S. aureus*, posing health concerns to consumers. Improving hygiene for safer meat in Cambodian markets requires immediate intervention.

In Egypt, Darwish *et al*. (2018) demonstrated that chicken giblets and wastewater samples are potential sources of methicillin-resistant *S. aureus* (MRSA) and heat-resistant staphylococcal enterotoxins transmission to humans. Furthermore, the isolated MRSA exhibited varying degrees of antibiotic resistance. As a result, strict cleanliness measures should be followed while preparing chicken items for human consumption, including giblets. Furthermore, before serving to people, chicken meat and giblets must be thoroughly cooked. Besides, Abolghait *et al*. (2020) mentioned that methicillin-resistant *Staphylococcus aureus* (MRSA) causes a variety of difficult-to-treat illnesses as well as staphylococcal food poisoning (SFP). The purpose of this study was to look at the prevalence and enterotoxigenicity of MRSA in grill chicken meat and giblets. 5.5% (8/144) of the samples tested positive for *mecA* positive/*mecC* negative *MRSA*, with staphylococcal levels of around 10^2 colony forming units (CFU)/g in breast, thigh, and gizzard samples and approximately 3.3 10^3 CFU/g in frozen liver samples. The staphylococcal enterotoxin B (*seb*) gene was found in the majority of MRSA isolates (75%, 6/8). MRSA isolates commenced SEB synthesis in experimentally contaminated chicken livers within 24 hours of storage at temperatures above 8°C, according to reverse transcription-PCR (RT-PCR). When the MRSA levels reached 7.3 103, SEB was maximally generated at 24 °C. According to Habashy *et al*. (2021), the percentage of *S. aureus* isolated from the studied hens' breast and thigh muscles was 23.3% and 26.6%, respectively. In *S. aureus* isolates, the enterotoxin genes (sea and see) and the *mecA* gene were found. Besides, Morshdy *et al*. (2023) discovered that *S. aureus* was isolated from 22% of the chicken meat products tested. *S. aureus* was identified from the chicken burger, fillet, luncheon, nuggets, and panne at 33.33%, 36.66%, 13.33%, 6.66%, and 20%, respectively.

Bacillus cereus

In USA, *Bacillus cereus* was detected in samples of five chicken meat items purchased from retail outlets. Breaded, fully cooked, frozen nuggets (NUGGETS); fully cooked, frozen, white-meat fajita-style strips (STRIPS); raw, refrigerated, boneless, skinless, marinated breast fillets (FILLETS); and raw, refrigerated, cut-up, tray-pack bone-in parts (PARTS), either split breasts or thighs. On three different days (n = 60), four packages of each item were obtained. Frozen and refrigerated items were stored overnight in their respective conditions before being opened aseptically and a total of 25 g of tissue was extracted from different parts inside a package. For 18 hours, the 25-g samples were enriched in 225 ml of Trypticase soy-polymixin broth for 18 to 24 h at 30 degrees C and then plated on mannitol-egg yolk-polymixin agar and incubated for 18 to 24 h at 30 degrees C. *B. cereus* was found in 27 of the 60 total samples. NUGGETS were 11 of 12 positive; TENDERS were 8 of 12 positive; STRIPS were 6 of 12 positive; FILLETS were 0 of 12 positive; and PARTS were 2 of 12 positive. PCR was used to look for the presence of the toxin-encoding genes bceT, nheABC, hblACD, and cytK in isolates. *B. cereus* organisms were found on four of the five retail poultry products evaluated in this investigation, with the highest rates seen on the three fully cooked items, particularly the two breaded items. All of the strains obtained had the gene(s) for at least one of the toxins, but none of them had the cytK gene (Smith *et al*., 2004).

In Australia, *Bacillus cereus* illness may be underreported because few people seek medical assistance due to the mild nature and brief duration of symptoms. As a result, nothing is known about the presence and concentration of this bacterium in retail food products. A total of 1263 retail food products were tested for *B. cereus* using the spread plate technique on polymyxin pyruvate egg yolk mannitol bromothymol blue agar, with a limit of detection of log(10) 2.0 cfu/g. *Bacillus cereus* was not found in skim milk powder, sandwiches, sushi, fresh beef mince, tortillas, or shelf stable stir-fry sauces tested. *Bacillus cereus* was found in the following foods: 1 of 63 uncooked pizza bases, log(10) 2

cfu/g, cooked pizza (8 of 175, log(10) 3.4 cfu/g), cooked meat pies (7 of 157, log(10) 2.2 cfu/g), cooked sausage rolls (5 of 153, log(10) 2.6 cfu/g), processed meats (1 of 350, log(10) 3.3 cfu/g) and raw diced chicken (3 of 55, log(10) 4.3 cfu/g). Because of the multiple elements that may introduce spores into the foods, composite food products tend to have more positive detection samples (Eglezos *et al*., 2010).

Potential adverse health effects

Consumption of chicken meat contaminated with *Salmonella* spp., *Bacillus cereus*, and enterotoxins of *S. aureus* lead to food poisoning. Symptoms of foodborne infection due to *Salmonella* spp. include fever, diarrhea, abdominal pain, and vomiting with an incubation period of 12 to 24 hours. Symptoms of *S. aureus* foodborne intoxication include salivation, nausea, vomiting, diarrhea, loss of appetite, severe abdominal cramps, subnormal temperature or no fever with short incubation period of 1 to 6 hours depending on the dose of the ingested enterotoxin and the involved age group of the consumers. Symptoms of *B. cereus* foodborne toxicoinfection depends on the type of the toxin produced as there are diarrheal or emetic forms. The diarrheal form is characterized by the watery diarrhea and abdominal cramps with an incubation period of 6-15 hrs. While the emetic form is characterized by vomiting, and nausea with an incubation period of 30 minutes to 6 h (Darwish *et al*., 2022).

CONCLUSION

Chicken meat and meat products are considered as potential sources of bacteria causing food poisoning, therefore the following measure are highly recommended: Proper cooking of foods (minimum to pasteurization temperature and time, such as 71.7°C for 15 seconds), proper cooling to 3 or 4°C or freezing, if not used within 2 h), prevention of cross-contamination of ready-to-eat food with a raw food through cutting boards, equipment, utensils and hands. Besides, use of proper sanitation and personal hygiene, not handling a food while sick and proper reheating a food refrigerated for a long time.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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