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Review Article

Role of egg in food born salmonellosis: A public health issue

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Introduction

Food borne diseases are a serious concern as public health issue in the food industry. *Salmonella* organisms are most frequently isolated bacterial agents of food borne disease outbreaks especially from poultry and are of significant public health concern[1]. Due to its significant morbidity and mortality rates salmonellosis causes risks to human health and economic loss[2]. Eggs are among the most nutritious foods on earth and can be part of a healthy diet. Chicken is the most important bird to produce eggs for human consumption around the world, and eggs are unique well-balanced source of nutrients in the human diet[3]. Unbroken, clean, fresh eggs may contain bacteria that can cause food-borne illness. While the number of eggs affected is quite small, there have been cases of food- borne illness in the last years. To be safe, eggs must be properly handled, refrigerated, and cooked[4]. *Salmonella* organisms are Gram negative, facultative anaerobic, non-spore forming, rod shaped bacilli belonging to the family *Enterobacteriaceae*.

The genus *Salmonella* was named after Daniel E. Salmon who first reported the isolation of *Salmonella* from a pig in 1885 and named the organisms *Bacterium* choleraesuis[5]. *Salmonella* genus consists of two species, *Salmonella enterica* and *Salmonella bongori*. S. *enterica* is divided into six subspecies: S. *enterica* subsp. *enterica*, S. e*nterica* subsp. salamae, S. *enteric* subsp. arizonae, S. *enterica* subsp. diarizonae, S. enteric subsp. houtenae and S. enterica subsp. Indica[6]. The antigenic formulae of *Salmonella* serovars are listed in a document called White-Kauffmann-Le minor scheme, based on which Salmonella strains are serologically classified[7]. There are more than 2500 different *Salmonella* serotypes and all are considered potentially pathogenic to human[8]. Most common cause of egg related to non-typhoidal salmonellosis is S. Enteritidis and S. Typhimurium[9]. But in developing countries, S. Typhi and S. Paratyphi causes Enteric fever and gastroenteritis and these serotypes are transmitted to the community through egg from unhygienic practice of farm handlers[10]. Therefore, the objective of this review is to show the egg related salmonellosis from the perspective of public health and to forward recommendation based on conclusion.

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Poultry as a source of salmonellosis

In recent years public health problems associated with salmonellosis were of poultry origin[11]. Poultry and eggs are considered as most important reservoirs from which *Salmonella* is passed through the food chain and ultimately transmitted to humans[12]. The levels of this pathogen in poultry can vary depending on country, production system and the specific control measures in place[13]. *Salmonella* can contaminate eggs on the shell or internally, but the egg shells are much more frequently contaminated than the white/yolk. The emergence of S. Enteritidis as the leading cause of human salmonellosis in many countries was attributed to this serotypes unusual ability to colonize the ovarian tissue of hens and be present within the contents of intact shell eggs [14].*Salmonella* is able to remain viable in frozen products as well as foods stored at high temperatures for long periods, due to their marked ability to persist in a wide range of varying environmental conditions[15].

Transmission of *Salmonella* through egg

There are two possible routes of bacterial contamination of egg shell and egg contents: either vertically or horizontally.

Transovarian or vertical transmission

In vertical transmission, *Salmonella* are introduced from infected reproductive tissue to eggs prior to shell formation [16]. Salmonella serotypes associated with poultry reproductive tissues that are of public health concern include *Salmonella* Enteritidis, Salmonella Typhimurium and *Salmonella* Heidelberg. Among the different serotypes, *Salmonella* Enteritidis may be better able to achieve invasion, and as a consequence, may be found more frequently in reproductive tissues [17,18].

Horizontal transmission

Horizontal transmission is usually from fecal contamination on the egg shell. It also includes contamination through environmental vectors, such as farm handlers, pets and rodents[4].

Transmission to human

Human salmonellosis is generally foodborne and is contracted through consumption of contaminated food of animal origin such as meat, milk, poultry and eggs. Recently, egg and egg products are the important source of salmonellosis[1]. Unhygienic practice of farm handlers even home-made egg foods can cause salmonellosis due to ingestion of undercooked egg[10].

Pathogenesis

In human the bacteria travel to the stomach and pass to the intestine, where they invade the cells, causing diarrhoea to their infected host body. *Salmonella* pathogenicity Island (SPI1) function is required for the initial stages of salmonellosis, i.e. the entry of *Salmonella* into nonphagocytic cells by triggering invasion and the penetration of the gastrointestinal epithelium. Furthermore, SPI1 function is required for the onset of diarrheal symptoms during localized gastrointestinal infections. The function of SPI2 is required for later stages of the infection, i.e. systemic spread and the colonization of host organs. The role of SPI2 for survival and replication in host phagocytes appears to be essential for this phase of pathogenesis[19].

In gastro-enteritis, infiltration of polymorphonuclear leukocyte (PMN) confines *Salmonella* infection to gastrointestinal (GI) tract. This response appears to depend on the induction of IL-8, a strong neutrophil chemotactic factor which is secreted by the intestinal cells as a result of *Salmonella* colonization and translocation of bacterial protein into host cell cytoplasm. The degranulation and release of toxic substances by neutrophil may result in damage to the intestinal mucosa causing the inflammatory diarrhoea in nontyphoidal salmonellosis and the strong inflammatory response prevents the spread beyond the GI tract [20].

In enteric fever (typhoid and paratyphoid) there is infiltration of mononuclear cells into small intestinal mucosa. The *Salmonella* disseminate before they multiply to high enough levels to stimulate a strong inflammatory response so the initial symptoms are only low grade fever and constipation. First *Salmonella* is transported from gut to mesenteric lymphnode and multiply there, then through thoracic duct it enters in circulation and causes primary bacterimia. Then it infects different reticulo-endithelial organs such as liver, bone marrow, different lymphnode including payer's patches, multiplying in those organs and re-enters in circulation and causes secondary bacterimia. Fever and other signs and symptoms develop during this phase. Finally, the bacteria may persist in gallbladder and rarely in kidney and causes chronic carrier state from where it may shed usually in stool and occasionally in urine[21].

Clinical manifestation of salmonellosis

In human disease, the clinical pattern of salmonellosis can be divided into four disease patterns namely enteric fever, gastroenteritis, bacteremia and other complications of nontyphoidal salmonellosis as well as chronic carrier state [22].

Enteric fever

Salmonella Typhi causes typhoid fever whereas Paratyphi A, B and C cause paratyphoid fever with symptoms which are milder and a mortality rate that is lower than *Salmonella* Typhi[22]. Both serotypes are solely human pathogens. Infection occurs due to ingestion of raw egg or undercooked egg product contaminated with human waste[23]. Symptoms are headache, chills, cough, sweating, myalgia, malaise and arthalgia. Gastrointestinal symptoms include anorexia, abdominal pain, nausea, vomiting, and diarrhea more commonly than constipation. Physical findings include coated tongue, rose spot, rash, splenomegaly, bradycardia and abdominal tenderness. Up to 10% of untreated patients with typhoid fever excrete *Salmonella* Typhi in the feces for up to 3 months and 1-5% develop chronic asymptomatic carrier, shedding *Salmonella* Typhi in either urine or stool for >1 year [20].

Gastroenteritis

Nontyphoidal salmonellosis or enterocolitis is caused by at least 150 *Salmonella* serotypes with Salmonella Typhimurium and *Salmonella* Enteritidis being the most common serotypes in the United States. Infection always occurs via ingestion of egg contaminated with poultry feed or poultry dropping rather than human waste[22]. Symptoms of non-typhoidal infection (*Salmonella* Enteritidis and *Salmonella* Typhimurium) commonly observed are diarrhea, headache, abdominal pain, nausea, fever and vomiting[13, 23].

Epidemiology

WHO's Food borne Disease Burden Epidemiology Reference Group (FERG) shows that from 2010, there were an estimated 582 million cases of 22 different food borne enteric diseases, among them *Salmonella* were the main enteric disease agent responsible for most deaths[24]. It is estimated that in the U.S. *Salmonella* transmission through contaminated egg shell or egg products results in 48 million cases of salmonellosis and costs $ 365 million annually[11]. A more accurate figure of salmonellosis is difficult to determine because normally only large outbreaks are investigated whereas sporadic cases are

under-reported[25]. Typhoid fever is endemic throughout Africa and Asia as well as persists in the Middle East, some eastern and southern European countries and central and South America[22].

Detection techniques for *Salmonella* in eggs

Conventional culture methods used for the isolation of *Salmonella* from eggs include, nonselective pre-enrichment followed by selective enrichment and plating on selective and differential agars. Suspect colonies are then confirmed biochemically and serologically. These methods are time consuming and take approximately 4-7 days[26]. Since *Salmonella* are closely related to both public and animal health, more rapid and sensitive methods for the identification for the identification of this bacterium are required[26].

Rapid detection methods

The detection of antibodies to *Salmonella* by EIA offers a sensitive and cost-effective method. The PCR tests have been successfully applied to detect a number of food borne pathogens, including *Salmonella*, from a range of foodstuffs[27].

Detection of carrier state

The current gold standard method to detect for carriers is stool culture. This is not only tedious and costly; it also has a low sensitivity. Multiple bacteriological examinations of stools are also necessary to make a reliable diagnosis due to intermittent or light fecal excreters among carriers. Different serological test like detection of IgG and IgA against Vi-antigen in blood are developed for diagnosis of carrier state by ELISA or RIA. Various studies were revealed that IgG is the primary indicator for carriers. But IgA can be found in both the acute and carrier state[28, 29,30].

Antibiotic susceptibility pattern of *Salmonella*/ different treatment pattern of salmonellosis

Most of the *Salmonella* serotypes are sensitive to ciprofloxacin, ceftriaxone, choramphenicol, amphicillin, cotrimoxazole and azithromycin[20]. Recently Multi drug resistance *Salmonella* Typhi (MDRST) are resistant to amphicillin, cotrimoxazole and chloramphenicol[31]. With the emergence of MDRST, quinolone such as ciprofloxacin has gained the importance for the treatment of enteric fever for the last several years[32]. But now it becomes almost ineffective. At present ceftriaxone is the most effective drug for enteric fever[33]. Azithromycin has also been effective in some case. Ciprofloxacin 750mg twice daily for 14 days is the treatment of choice in *Salmonella* carrier state. Cholecystectomy may be indicated in treatment failure cases having gall stones or nonfunctioning gallbladder. *Salmonella* gastroenteritis is self limiting disease and usually needs no antibiotics[31,34].

Bangladesh scenario

Bangladesh is one of the developing country in the world, but rich in poultry industry as other neighbor country like India and Pakistan. Several studies were done regarding prevalence of Salmonella from egg collected from poultry and market. *Salmonella* was prevalent in a wide range (8%-12%) from egg in Dhaka city[26,35]. Another study revealed the contamination rate of different serotype of *Salmonella* in 4.47% of market eggs and 6.66% of poultry eggs. Of them, most of the identified *Salmonella* serotype was S. Enteritidis [36]. Prevalence rate of *Salmonella* is 83% in poultry eggs in different market of Savar area[37]. Contamination mainly by moist environment of market and poultry house, poultry feeds, unhygienic practice of farm handlers and surrounding environment 4. Another study was done to detect the Salmonella contamination rate from poultry feeds, where 71.43% *Salmonella* was detected from poultry feeds from different market in Savar area[38].

Public health significance of salmonellosis

Salmonellosis is an important global public health problem causing substantial morbidity and thus also has a significant economic impact. Although most infections cause mild to moderate self-limited disease, serious infections leading to deaths do occur[39]. In spite of the improvement in hygiene, food processing, education of food handlers and information to the consumers, foodborne diseases still dominate as the most important public health problem in most countries [40].This has significant implication in the developing countries like Bangladesh where poultry industry is the fastest growing segments[41]. Salmonella is mostly transmitted to humans, through contaminated food and water. In hospitals, person to person transmission may also happen. Cross contamination can occur in farm houses as well as during handling of poultry products[42]. Salmonella can also leads to severe condition like sepsis and death especially in infants and immunocompromised adults[43]. Other than gastroenteritis, *Salmonella* may also cause extra intestinal infection like meningitis, osteomyelitis, arthritis, pneumonia, cholecystitis, peritonitis, pyelonephritis, endocarditis, pericarditis, vasculitis and chronic condition like aseptic arthritis and Reiter's syndrome[44]. The predominant serovars of Salmonella, having public health importance are mainly S. Enteritidis and S. Typhimurium 1. Recent concern in public health point of view is antibiotic resistant serotypes[45]. The WHO observed an alarming rate increment of resistant *Salmonella* strains due to the abusive use of antibiotics in poultry farm[46]. The horizontal transmission of virulence genes in multidrug resistant *Salmonella* strains can increase virulence and invasiveness and it cause high mortality rates[47].

Conclusion

Eggs associated salmonellosis is an important public health problem in the world. We have to consider some of the points that eggs offered for sale must be free of feces, dirt and stains. Premises and equipment for handling and storage of eggs must be maintained in a sanitized state fit for the production of food for human consumption. Egg farms and retail markets must be regularly visited by field inspectors to monitor poultry feed, egg quality. Continuous monitoring and control methodologies, which should be applied in poultry farms for the control of spread and eradication of this pathogen, where possible, are strongly recommended. Efforts including critical control point programs in food production are needed to reduce the incidence of *Salmonella* in food. Consumers-awareness efforts would protect public health from food borne Salmonellosis.

Conflict of interests

There is no conflict of interests among authors regarding the publication of this paper.

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