Review

Impact of sporadic reporting of poultry *Salmonella* serovars from selected developing countries

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Abstract

This review documents the sporadic reporting of poultry *Salmonella* serovars in South Africa, Egypt, Indonesia, India, and Romania, five countries selected based on the importance of their distribution in different regions of the world and their cumulative significant population size of 1.6 billion. South Africa reported contamination of its poultry carcasses by *S.* Hadar, *S.* Blockley, *S.* Irumu, and *S.* Anatum. Results from Egypt showed that *S.* Enteritidis and *S.* Typhimurium were predominant in poultry along with other non-typhoid strains, namely *S.* Infantis, *S.* Kentucky, *S.* Tsevie, *S.* Chiredzi, and *S.* Heidelberg. In Indonesia, the isolation of *Salmonella* Typhi was the main focus, while other serovars included *S.* Kentucky, *S.* Typhimurium, and *S.* Paratyhi C. In India, *S.* Bareilly was predominant compared to *S.* Enteritidis, *S.* Typhimurium, *S.* Paratyphi B, *S.* Cerro, *S.* Mbandaka, *S.* Molade, *S.* Kottbus, and *S.* Gallinarum. Romania reported two *Salmonella* serovars in poultry that affect humans, namely *S.* Enteritidis and *S.* Typhimurium, and other non-typhoid strains including *S.* Infantis, *S.* Derby, *S.* Colindale, *S.* Rissen, *S.* Ruzizi, *S.* Virchow, *S.* Brandenburg, *S.* Bredeney, *S.* Muenchen, *S.* Kortrijk, and *S.* Calabar. The results showed the spread of different serovars of *Salmonella* in those five developing countries, which is alarming and emphasizes the urgent need for the World Health Organization Global Foodborne Infections Network (WHO-GFN) to expand its activities to include more strategic participation and partnership with most developing countries in order to protect poultry and humans from the serious health impact of salmonellosis.

Key words: Developing countries; poultry *Salmonella* serovars.

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Introduction

Salmonella are the most common causes of foodborne illness worldwide [1]. The two foods that are most commonly associated with *Salmonella* food illness are eggs and poultry meat [2-4]. More than 2,500 serovars of *Salmonella* have been identified, with many commonly infecting poultry and humans. The frequency patterns of predominant serovars in each country is challenged with a shift in prevalence due to globalization, especially linked to livestock trade, international travel, and human migration [5-7].

Meager *Salmonella* control programs in most developing countries, and the presence of vigorous globalization, will challenge other countries with new serovars that could potentially be multidrug resistant [8] and could disseminate throughout the food chain [8,9]. The participation of different countries depends upon a number of factors, such as availability of financial and human resources, and also willingness to participate in and support initiatives of the Global Foodborne Infections Network (GFN). The World Health Organization (WHO) program is now known as the GFN [11,12]. The countries that are involved with national and regional projects of the WHO-GFN include fewer than 10 out of a total of 196 independent countries worldwide. The lack of active GFN projects and initiatives in many developing countries has resulted in underreporting of S*almonella* serovars in humans and other food sources that are supposed to be included in the web-based country data bank (CDB) [11]. This present global situation urges the need to build a hypothesis that compiling sporadic data on poultry *Salmonella* serovars from selected developing countries could highlight the importance of the chicken reservoir as a potential source of *Salmonella* infection to humans.

The purpose of this review was to compile sporadic recent reports about the *Salmonella* serovars isolated from poultry and their derived products in five selected developing countries that represent, cumulatively, around 22.2% of the 7.2 billion people of the world. The global public health significance of the sporadic reporting of poultry *Salmonella* serovars, documented by developing countries, is highlighted.

Methodology

Significant inclusion of the five selected developing countries

The significance of inclusion of the five selected developing countries in this study lies in their geographic distributions in different regions of the world that represent major trafficking of people and poultry products. The populations of the included developing countries range from 0.05–0.25 billion people, and cover countries in Africa, Asia, and Europe. Poultry contributes significantly as a major food source consumed by a total of 1.6 billion people inhabiting these five selected developing countries. The selected countries are South Africa (located at the southern tip of Africa), Egypt (with one part in Africa and the other part in Asia), Indonesia (located in the Asian continent), India (located in the southern region of Asia), and Romania (located in southeastern central Europe, and joined the European Union in 2007).

Population and poultry product consumption

The total egg and poultry meat production in the world is 65×10^3 and 103×10^6 tons, respectively. The highest consumption of eggs per capita per year is in Romania (13.6 kg) (population of 20 million), while the lowest is in Egypt and India (3.0 kg) (populations of 84 million and 1.2 billion, respectively). Indonesian and South African populations have a moderate consumption of eggs of 4.5 and 6.6 kg, respectively (populations of 246 and 53 million, respectively). The pattern of poultry meat consumption is different from that of eggs in the five countries. The highest consumption of poultry meat is in South Africa (24.5 kg/capita/year), while the lowest is in India (2.7 kg/capita/year). The data from the other three countries lie in between, with the following figures in a decreasing order of consumption: Romania (10.0 kg/capita), Indonesia (6.1 kg/capita), and Egypt (5.9 kg/capita) [13,14].

Sporadic reporting of Salmonella serovars

The absence of controlled reporting of *Salmonella* serovars through the WHO-GFN program in these five selected developing countries [15] inspired the compilation of data on the sporadic reporting of *Salmonella* serovars in poultry. The 2014 regional centers of GFN are only present in six countries: Thailand (Faculty of Veterinary Science of Chulalongkorn University, Bangkok), Argentina (The National Institutes and Laboratories of Health, Buenos Aires), Mexico (The Autonomous University of Yucatan, represented by the Faculty of Veterinary Medicine, Merida, Yucatan), Poland (National Institute of Hygiene in Warsaw), Cameroon (Institute Pasteur Yaoundé), and Costa Rica (Costa Rica Nutrition and Health Research and Training Institute, San José). Unfortunately, none of these six centers of the WHO-GFN reported the serovar distribution in the five selected countries included in this study, due to the lack of routine national surveillance and scarcity of data in these countries.

Results and Discussion

The following is the compilation of reports related to *Salmonella* serovars present in poultry of the five developing countries.

South Africa

The presence of *Salmonella* in raw chicken carcasses in South Africa has not been extensively investigated. The first report from South Africa included an examination of fewer than 10 samples of raw poultry for isolation of *Salmonella* [16,17]. The results of such studies are not by any means considered representative of the overall situation of *Salmonella* prevalence in the poultry of South Africa. The other study by van Nierop *et al.* in 2005 [18] included a larger sample of 99 raw chicken carcasses (fresh and frozen) collected from butcheries, supermarkets, and street vendors. The percentages of *Salmonella*-contaminated chicken samples were found in chicken carcasses fresh from butcheries (53.3%), frozen from butcheries (64.7%), fresh from supermarkets (43.8%), and fresh from street vendors (50.0%). The level of contamination in the abovementioned chicken carcasses is alarming, as it provides a potential reservoir for infecting human consumers. The four most commonly detected *Salmonella* serovars in the contaminated chicken carcasses in decreasing order of frequency were *S.* Hadar, *S.* Blockley, *S.* Irumu, and *S.* Anatum. The following serovars were also detected in equal frequency: *S.* Reading, *S.* Virchow, *S.* Schwarzengrund, *S.* Westhampton, *S.* Typhimurium, *S.* Derby, and *S.* Heidelberg. It is worth noting that the invasive non-typhi *Salmonella* (NTS) results in a case fatality percentage, among hospitalized patients in Africa, equivalent to 4.4%–27.0% for children [19-22] and 22%–47% for adults [23-25]. Unfortunately, a routine national surveillance of the distribution of *Salmonella* serovars in poultry of South Africa, and their potential effects on humans in this country, are absent.

Egypt

Egypt is another developing country that lacks routine *Salmonella* surveillance of chicken flocks. The sporadic cases of salmonellosis in Egypt were first reported by Ammar *et al.* in 2010 [26], who documented the isolation of *Salmonella* Enteritidis from chickens and other sources in Dakhlia governorate, and incriminated these sources as possible reservoirs for infection in hospitalized patients. Another report from Egypt described the development of a diagnostic-restriction enzyme and plasmid profile analysis of *S.* Typhimurium recovered from Egyptian poultry farms [27]. The numbers of plasmids in the tested poultry isolates of *S.* Typhimurium were one to six. One plasmid, with a molecular size of 11,425 bp, was common to all isolates. This study aimed to use a plasmid marker in future epidemiologic targeted surveillance of *S.* Typhimurium distribution in poultry farms.

Another report by Rabie *et al.* in 2012 [28] documented a *Salmonella* food illness outbreak in humans, associated with *Salmonella* recovered from consumed poultry products. The samples included in this study were 50 chickens with diarrhea, 50 pieces of raw frozen chicken meat, and 30 patients with symptoms of food poisoning. The common *Salmonella* serovars isolated from different poultry samples and from the affected humans were *S.* Enteritidis and *S.* Typhimurium. This was confirmed by multiplex polymerase chain reaction (PCR) amplification of poultry and human *Salmonella* isolates, showing the same size of specific bands on the gel.

An excellent report on *Salmonella* serovar distribution on broiler farms of Kalubia governate in Egypt was documented by Abd- El-Ghany *et al.* in 2012 [29]. This study included 1,073 samples collected from 293 broilers. The samples included cloacal swabs, gall bladders, yolk sacs, spleens, and livers. The frequency of *Salmonella* serovars recovered from the broiler flocks were *S.* Enteritidis (37.25%), *S.* Typhimurium (29.41%), S. Infantis (19.6%), *S*. Kentucky (7.84%), *S*. Tsevie (3.92%), and *S.* Chiredzi (1.96%). The prevalence of *S*. Enteritidis and *S*. Typhimurium in broiler flocks of Kalubia governate of Egypt requires drastic measures for their control, since the two serovars are known for their potential to cause severe foodborne illness in humans [30,31].

El- Safey in 2013 [32] focused on the isolation of *S.* Heidelberg from foods. A total of 200 samples were collected in Cairo and Assuit cities from chicken, beef, milk, kushary (traditional Egyptian food), and sausage. *S.* Heidelberg was recovered from 15% of chicken samples, 5% of beef samples, 2.5% of milk samples, 2.5% of kushary samples, and 10% of sausage samples. The chicken seemed to be the main source of this serovar. This is in agreement with what was reported by Hennessy *et al.* in 2004 [33], indicating that poultry is the main source of *S.* Heidelberg contamination. *S. enterica* serovar Heidelberg is the third most common cause of human infections in the USA, after *S*. Typhimurium, and it contributes to about 7% of all of the deaths caused by *Salmonella* [33-35].

Another work was performed in the vicinity of Assiut in Egypt, reporting the detection of *S.* Typhimurium in retail chicken meat and giblets [36]. This work included the examination of *Salmonella* in 100 samples of frozen raw chicken meat, livers, and hearts. *S.* Typhimurium was detected in 44% of chicken meat samples, 40% of liver samples, and 48% of heart samples. This high frequency of detection of *S*. Typhimurium in chicken carcasses and giblets is alarming, and is a threatening reservoir for this serovar that may have adverse effects on the health of Egyptian consumers.

Indonesia

The incidence of typhoid in Indonesia is high and alarming (148.7 per 100,000 persons/year) [37]. More than 90% of the world morbidity by typhoid occurs in Asia alone [38]. For this reason, the research work in Indonesia has been devoted towards the development of a rapid PCR technique to detect *S.* Typhi, avoiding the lengthy classical methods of isolation, biochemical testing, and serology [39].

In 2012, another targeted surveillance of *Salmonella* was documented in Indonesia; 125 samples were examined for *Salmonella* isolation and serovar typing [40]. The 125 samples included 40 samples of chicken cuts. The results indicated a high unacceptable percentage of *Salmonella* contamination in the examined chicken cuts collected from open markets (52.5%) as well as from supermarkets (50%). The identified serovars in the chicken cuts, collected from the open market, in decreasing order of frequency, were *S*. Kentucky, *S*. Typhimurium, and *S*. Paratyphi C. However, the only two serovars recovered from the chicken cuts collected from supermarkets were *S*. Kentucky and *S*. Typhimurium, in equal frequencies.

These pilot studies in Indonesia indicated the significance of *Salmonella* presence in high frequencies in poultry products, which may act as possible reservoirs of these organisms to a large size of consumers in this country. The lack of routine surveillance of *Salmonella* serovar distribution in Indonesian poultry is a threat to the population's health, and to visitors from different parts of the world.

India

This developing country is more aware of the *Salmonella* problem, as shown from its published articles in this area. The National Salmonella and Escherichia Center in India implemented routine monitoring of *Salmonella* serovars, and shares its isolates with different scientists in India for further investigations. An earlier study by Ganguli in 1958 [41] revealed the importance of *S.* Bareilly as a human pathogen. Majumdar and Singh in 1973 [42] pursued the work on this predominant serovar, developing a phage-typing system for it, helping later to implement an epidemiology for tracing this serovar across the country [43]. This system was further developed by Singh *et al.* in 1988 [44]; 637 strains of *S.* Bareilly were provided to these research works by the National Salmonella and Escherichia Center in Kasauli, India, collected from different parts of India between 1959 and 1989. This effective cooperation helped these researchers to study the distribution of the phage types of this serovar across India, including isolates recovered from poultry and sheep products.

During the period 1990–1991, 3,222 *Salmonella* isolates were serotyped, revealing 53 different serovars. These isolates were recovered from humans, poultry, other animals, reptiles, birds, and other sources [45]. Another interesting study was conducted by Murugkar *et al.* in 2005 [46], analyzing poultry and human samples for *Salmonella*. The percent positive samples for *Salmonella* included human stool (20.5%) and poultry cloacal swabs (14.7%). Three *Salmonella* serovars were common between poultry and humans, resulting in same pattern of decreasing frequency; these serovars were *S.* Typhimurium, *S.* Enteritidis, and *S*. Paratyphi B. This work added more supporting evidence of poultry being the reservoir of *Salmonella* serovars that are shared by humans.

Suresh *et al*. in 2011 [47] reported the prevalence and distribution of *Salmonella* serovars in marketed broiler chickens and processing environment in Coimbatore, a city in southern India. This work included 214 samples of broiler chickens and 311 environmental samples from cages. *Salmonella* was found in chicken cloacae (1.4%) and chicken crops (6.9%). The range of contamination of cage samples was between 0 and 16.67%. The predominant serovar was *S.* Enteritidis; the other less prevalent serovars were *S.* Bareilly, *S.* Cerro, *S.* Mbandaka, and *S.* Molade. Singh *et al*. in 2013 [48] reported the prevalence of *Salmonella* serovars in chickens from north India. One *Salmonella* serovar, *S. Kottbus*, was recovered from eggs, feces of chicken, and cloacae *S.* Kottbus. Another serovar, *S. Typhimurium*, was common to eggs and cloacae. Rajagopal and Mini in 2013 [49] reported an outbreak of salmonellosis in three different poultry farms in Kerala, India. The *Salmonella* serovar that caused the outbreak on all the surveyed farms was *S.* Gallinarum.

Last but not least, a prevalence of *Salmonella* in pigs and chicken broilers in Tarai region of Uttarakh and in India was documented in correspondence by Kumar *et al.* in 2014 [50].

This work involved the isolation of *Salmonella* from a total of 343 fecal samples of poultry and pigs, and from 100 tissue samples of broilers. The study was performed between January 2011 and July 2012. The total prevalence of *Salmonella* in poultry was 12.28% (8.4% of cloacal samples and 22.0% of tissue samples). The detected poultry serovars, in decreasing order of frequency, were *S*. Typhimurium, *S*. Enteritidis, and *S*. Gallinarum.

Romania

Romania has a population of around 20 million, with the highest consumption of eggs per capita and the second-highest consumption of poultry meat per capita, compared to the four other developing countries included in this study. It is located in the southwestern central Europe, and became a member in the European Union (EU) in 2007. This merging with the EU presented a sensitive situation to food safety of Romania due to the pressure that the regulatory agencies in Romania were put under from the EU to permit Romanian poultry products to enter the whole EU market.

The first study on *Salmonella* in poultry and pigs of all the regions of Romania was performed in 2011, four years after Romania joined the EU. Unfortunately, the publication came three years after the conclusion of the work [51]. The study was conducted on 650 samples of chicken and pork meat collected from production sites and retail markets. A total of 149 *Salmonella* isolates were recovered, of which 22.92% were contaminated with *Salmonella*: 48 pork isolates (32.21% of positive samples), and 101 chicken isolates (67.78% of positive samples). Thirteen serovars were identified in this surveillance, including, in decreasing order of frequency, *S.* Infantis (70.87%), *S.* Typhimurium (18.45%), *S.* Derby (14.56%), *S.* Colindale (13.59%), *S.* Rissen (5.83%), *S.* Ruzizi (4.85%), *S.* Virchow (4.85%), *S.* Brandenburg (3.88%), *S.* Bredeney (3.88%), *S.* Muenchen (0.97%), *S.* Hortrijk (0.97%), *S.* Enteritidis (0.97%), and *S.* Calabar (0.97%). The recovery of *S.* Typhimurium and *S.* Enteritidis, two serovars with known pathogenicity in human hosts, encourages the implementation of strict rules on poultry and pork products containing these two pathogenic serovars.

In 2013, the president of the Union of Poultry Breeders in Romania declared that poultry flocks in this country are routinely monitored for *Salmonella*, and that all legal measures are taken in case of an outbreak. This regulation is enforced in all EU countries. At present, the Romanian Union of Poultry Breeders controls around 550 farms across the country; only 15 farms are the major producers of 60% of the country's chicken meat [52].

The transformation of Romania from a developing country to a developed EU member country has helped it to build proper laboratories and to implement routine monitoring of *Salmonella* serovars, enabling it to take rapid action once *Salmonella* is detected in foods, before consumers are affected. The 2013 incident of *Salmonella* contamination of poultry products in Romania did not result in any food illness to consumers, due to the rapid intervention of the responsible Romanian authorities who adopted the EU food safety regulations.

Conclusions

This review focused on the sporadic nature of targeted surveillance for *Salmonella* serovars in poultry in South Africa, Egypt, Indonesia, and India, and the conversion towards EU regulations for routine *Salmonella* surveillance in Romania. Routine surveillance of poultry farms for *Salmonella* and rapid intervention will drastically improve global food safety and security, while the sporadic nature of targeted surveillance will miss the diagnosis of this zoonotic pathogen in many areas of the poultry sector, including breeders, hatcheries, commercial layers, broilers, slaughterhouses, and chicken processing plants. The absence of controlled routine reporting of *Salmonella* serovars in these five selected developing countries is expected to lead to more illness related to consumption of non-monitored poultry products that could be contaminated with *Salmonella*.

It is recommended that the WHO-GFN expand its capacity-building program in the promotion of integrated, laboratory-based surveillance and intersectoral collaboration among the veterinary and food-related disciplines and human health worldwide. This indispensable expansion should include more strategic participation and partnership of developed countries in the WHO-GFN program, for the sake of improving the livelihood of animals and the safety of human consumers.

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