Asian Journal of Research in Infectious Diseases

Volume 15, Issue 10, Page 36-46, 2024; Article no.AJRID.122202
ISSN: 2582-3221

Prevalence of Non-typhoidal Salmonella Species in Food and Stool Samples in Port Harcourt, Rivers State, Nigeria

Emmanuel Valentine Edamkue [a*], Ollor Amba Ollor [a] and Tombari Pius Monsi [a]

[a] Department of Medical Microbiology, Faculty of Medical Laboratory Science, Rivers State University, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ajrid/2024/v15i10380

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122202

Original Research Article

Received: 01/07/2024
Accepted: 02/09/2024
Published: 13/09/2024

ABSTRACT

Aim: To assess the prevalence of Non-Typhoidal *Salmonella* spp isolated from food and stool samples in Port Harcourt.
Study Design: This was a cross-sectional study with simple randomized sampling.
Methodology: In this study, 210 stool samples and 210 food samples collected from December 2022 to November 2023 were tested for *Salmonella* using standard bacteriological and biochemical tests. The *Salmonella* species were isolated from the samples using *Salmonella*-Shigella agar (SSA), and Bismuth Sulfite Agar (BSA) after pre-enrichment and enrichment methods had been

**Corresponding author: E-mail: edamkuee@gmail.com;*

Cite as: *Edamkue, Emmanuel Valentine, Ollor Amba Ollor, and Tombari Pius Monsi. 2024. "Prevalence of Non-Typhoidal Salmonella Species in Food and Stool Samples in Port Harcourt, Rivers State, Nigeria". Asian Journal of Research in Infectious Diseases 15 (10):36-46. https://doi.org/10.9734/ajrid/2024/v15i10380.*

carried out using peptone water and Selenite F Broth after which biochemical tests were carried out for further identification. Data collected was analyzed with Graph pad prism version 8.

Results: The prevalence and distribution of *Salmonella* were presented in frequencies and percentages with all analysis done at a 95% confidence interval and *P*-values less than .05 were considered significant. From chi-square analysis there was a 3.3% prevalence rate in food samples in comparison to stool samples that had a 2.4% prevalence (*P* value = .56). A higher prevalence was also reported in the female subjects (3.7%) compared to the male subjects (1.0%) (*P* value = .19). There was a statistically significant difference in relation to the age groups with the 'above 50' and '0 – 10' age groups having a higher prevalence (11.1% and 10% respectively) compared to other age groups (*P* value = .02). For the food samples, samples in the chicken category had the highest prevalence (8.7%) (*P* value = 0.11).

Conclusion: This study reports a relatively lower prevalence of Non-Typhoidal *Salmonella* species at 2.9% with the age, education and occupation of the subjects being significantly associated (*P* value < .05) with the prevalence of the infection. Health promotion and appropriate surveillance system should be put in place to continually reduce the burden of this disease.

Keywords: Non-typhoidal; prevalence; salmonella; salmonellosis; microbiology.

1. INTRODUCTION

Foodborne infections cause enormous suffering, affecting 10% of the world's population and 33 million deaths per year [1]. There are several variables that lead to foodborne infections and illnesses caused by *Salmonella* species. *Salmonella* belongs to the *Enterobacteriaceae* family which is a gram-negative bacterium with rod-like morphology (bacillus). *Salmonella bongori* and *enterica* are the two species of *Salmonella* that are currently recognized. There are more than 2,600 serotypes in the six subspecies of *S. enterica* [2], which is the type species. The serovars, or mosaic combinations of surface O and H antigens, are what distinguish *Salmonella* enterica from its around 2600 closely related species. There are two types of *Salmonella* infections: typhoid and non-typhoidal, which are distinguished by their distinct pathogenic characteristics. Non-typhoidal *Salmonella* infections typically resolve on their own, whereas typhoidal *Salmonella* infections have the potential to cause fatal systemic infections [3]. Public health and food safety are seriously threatened by the advent of pathogenic *Salmonella enterica* serovar Typhimurium (*S*. Typhimurium), particularly when it comes to multiple antibiotic resistance (AR).

When bacteria penetrate intestinal epithelial cells and avoid the stomach acid barrier, an NTS infection results, causing inflammation. This eventually causes ulcers, diarrhea, and the death of mucous cells. In those with compromised immune systems and neonates in particular, the infection may lead to an invasive NTS (iNTS) systemic infection if it continues and spreads throughout the intestines [4,5]. iNTS infections are the most common cause of morbidity and death in impoverished nations, accounting for nearly 680,000 fatalities and 3.4 million cases globally [5]. Despite being a serious public health concern, the pathogenesis of NTS infection is still unclear [6].

The two most prevalent serotypes that cause human NTS infections are *S*. Typhimurium and *S*. Enteritidis, according to the US and European Food Safety Authority (EFSA). Nevertheless, it has also been demonstrated that several common serotypes, including Newport, Javiana, Infantis, and monophasic Typhimurium, are pathogenic [7,8]. Animals are the primary source of NTS, and the main way that it spreads to people is through food. Numerous domestic and wild animals, such as pigs, cattle, poultry, rodents, wild birds, pets, and exotic animals [9], can harbor *Salmonella* and act as reservoirs. Geographical location, economic variables, cultural and food production techniques, and geographic location all influence the prevalence in various food models, which differ between countries and regions [7]. One of the main causes of NTS infections in people is pigs. Many nations, including the majority of Europe and the US, view them as a primary source of salmonellosis. This is due to the fact that throughout the production chain, pigs frequently carry and spread the virus asymptomatically. Thus, the main sources of the Typhimurium serovar are pigs and pork meat [7,10]. Poultry can spread *Salmonella* by both horizontal and vertical pathways because they can pick up different serovars of the bacteria, frequently

without showing any symptoms. Egg and chicken consumption are associated with Serovar Enteritidis [11,12]. 37.1% of *S*. Enteritidis isolates in Europe were discovered in laying hens and eggs, whereas 57.2% were discovered in broiler chicks and their meat [13]. Other serovars, such as Weltevreden and Anatum, were frequently found in shellfish and cattle, respectively [14]. It is acknowledged that the Weltevreden serovar poses a serious threat to public health, especially in China's coastal areas [15].

In many places in sub-Saharan Africa, nontyphoidal *Salmonella* are the primary cause of bacteremia where they can also result in meningitis or localized infections frequently without any recent or ongoing diarrhea [16]. A total of 422,000 (78.9%) illnesses and 66,500 (85.9%) fatalities from the anticipated 535,000 nontyphoidal *Salmonella* illnesses and 77,500 deaths in 2017 occurred in sub-Saharan African nations [17,18]. Most illnesses affect people under the age of five. A higher risk applies to those who are malnourished or immunocompromised, such as those who have recently contracted malaria or HIV [19].

In Nigeria, the burden of NTS was 325,731 cases with a total of 1043 human fatalities, and 37,321 disability-adjusted life years (DALYs), using 2020 as the reference point. The price tag on human infection was $473,982,068. The estimated overall loss in poultry, including the direct value of animal loss, was $456,905,311 [20]. In other to better understand the epidemiology of Salmonellosis in the region and to direct the adequate care and preventive measures for this disease, this study was aimed at investigating the prevalence of non-typhoidal *Salmonella* species in Port Harcourt, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

Samples for this study were collected from different locations in Port Harcourt, Rivers State, in the oil rich Niger Delta, southern Nigeria. Bulk of the stool samples were collected from Rivers State University Teaching Hospital (RSUTH) and University of Port Harcourt Teaching Hospital (UPTH), others were collected from medical laboratories and identified individuals presenting with gastroenteritis in the Port Harcourt metropolis. Food samples were collected from different fast-food outlets, local 'mama put' and street-hawked food in the study area. Port Harcourt is located between latitude 4°49´27" N and longitude 7°2´1 " E. The study area has an estimated population of 3,480,101 with a land area of 369 km^2

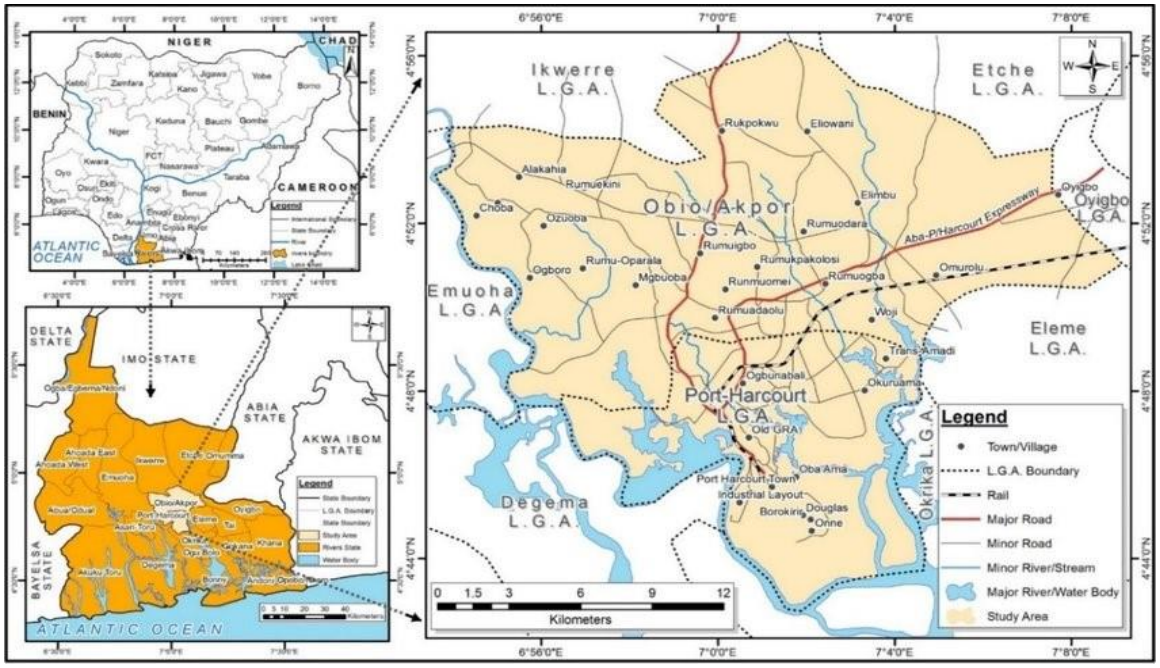

Fig. 1. Map of Port Harcourt in Rivers State of Nigeria
https://www.researchgate.net/figure/Map-of-Port-Harcourt-metropolis-Abio-Akpor-and-Port-Harcourt-LGAs_fig1_343946150

2.2 Study Design

The investigations were carried out using a cross-sectional study design with simple randomized sampling technique. The study was undertaken from December 2022 to November 2023.

2.3 Study Population and Sample Size Determination

The study population comprised patients presenting with gastroenteritis, patients with bacteriologically confirmed *Salmonella* infection and those presenting stool to the laboratory for examination. Different food vendors were sampled in the course of this study. The sample size of 210 for food samples and 210 for stool samples were obtained using a sample size calculator for prevalence studies [21] based on the expected prevalence of *Salmonella* species in stool as reported by Akinyemi et al. [22] which revealed a prevalence of 16.3%.

2.4 Inclusion and Exclusion Criteria

An indication of the signs and symptoms of Salmonellosis such as diarrhea, stomach cramps, fever, nausea, vomiting, chills, headache, blood in stool, etc., as well as willingness to provide informed consent were the basis for inclusion in the study while patients already undergoing antibiotic therapy and those who didn't give consent were excluded from participating in the study. Spoilt and raw food were excluded from this study while street-vended and food sold in restaurants were included in this study.

2.5 Data Collection

A questionnaire was developed and given to subjects to obtain sociodemographic and other vital information. The questionnaire comprised of two sections; the first section assessed sociodemographic characteristics while the second assessed other risk factors. Anonymity was maintained by using serial numbers.

2.6 Specimen Collection and Processing

Two hundred and ten (210) stool samples were collected in sterile well-labelled universal bottles and placed in sterile ziploc bags and taken immediately to the microbiology laboratory for analysis. Subjects were given proper guidance for collecting the stool samples. Where delay was inevitable, samples were stored in the refrigerator at 4°C. Two hundred and 10 (210) food samples were collected in sterile containers to avoid contamination. Six different food categories (Sea food, n = 35; Chicken, n = 35; Beef and Pork, n = 35, Dairy products, n = 35, Vegetable and fruit, n = 35, Grains, n= 35) were sampled. The food samples were food that was commonly consumed in Port Harcourt metropolis.

2.6.1 Stool culture

Stool samples were inoculated into freshly prepared Selenite F Broth and incubated at 37°C for 18 – 24 hours. The overnight culture was sub-cultured unto *Salmonella-Shigella* Agar (SSA) and Bismuth Sulfite Agar (BSA) and incubated for 18-24 hours at 35 – 37°C. Transparent colonies with black centers on SS agar and colonies with metallic sheen and black center on BSA were identified as presumptive *Salmonella.*

2.6.2 Food culture

Salmonella was isolated based on standard protocols [23]. A 1:10 dilution of each food sample was made by weighing 10g of the food sample and grinding it using a small pestle and mortar before homogenization with 90ml peptone water. The homogenate was then incubated at 37℃ for 24 hours. Following incubation, 1ml of the culture was transferred aseptically into 10 ml of sterile Selenite F Broth, mixed and then incubated at 37℃ for 24 hours. Following incubation, a loop-full of each culture was streaked unto the surface of recently prepared *Salmonella-Shigella* Agar (SSA) and Bismuth Sulfite Agar (BSA) and incubated at 37℃ for 24 to 48 hours and examined for the presence of *Salmonella* colonies.

2.6.3 Biochemical identification

The biochemical characterization performed was based on standard techniques [23]. Suspected *Salmonella* colonies were picked from the agar plates and inoculated into the following Biochemical test tubes for confirmation; Triple Sugar Iron (TSI) test (Presumptive *Salmonella* colonies gave reactions typical of *Salmonella* by showing Alkaline/Acid with or without gas and hydrogen sulfide on TSI), Urease test (Presumptive *Salmonella* colonies were Urease negative), and Indole test (Presumptive *Salmonella* colonies gave negative Indole

reaction). Colonies which gave all the reactions typical of *Salmonella* were kept in Nutrient Agar slants until further characterized

2.7 Data Analyses

Raw data was collected using Microsoft excel and descriptive and inferential statistics were conducted using Graph pad prism version 8. Chi-square was utilized to identify statistically significant relationships between the prevalence of Salmonellosis and sociodemographic characteristics. The level of significance was defined as $P < .05$ at a 95% confidence interval.

3. RESULTS

3.1 Socio-demographics of the Study Participants

A total of 210 subjects aged between 4 to 69 (mean age = 29.8 years) were enrolled in this study. Most of the subjects were between the ages of 11 – 30 years (56.67 %), mostly females (50.95%), mostly students (48.10%), and had at least a tertiary school education (60%). Most of the subjects were residing in the Obio/Akpor local government area (57.14%) and were Christians (84.76%) (Fig. 2).

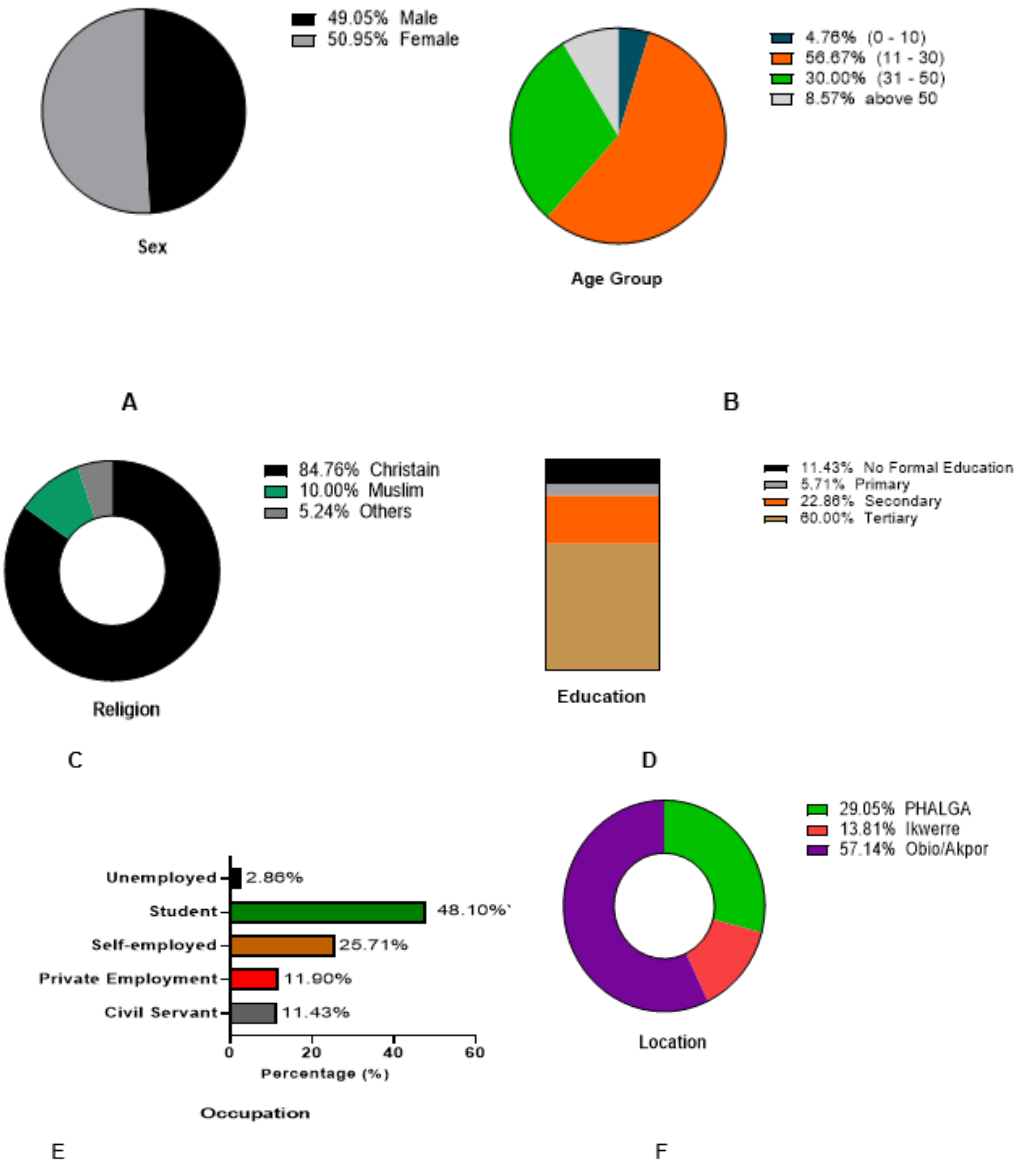

Fig. 2. Sociodemographic characteristics of the stool-sampled population: A) Sex B) Age C) Religion D) Education E) Occupation F) Location

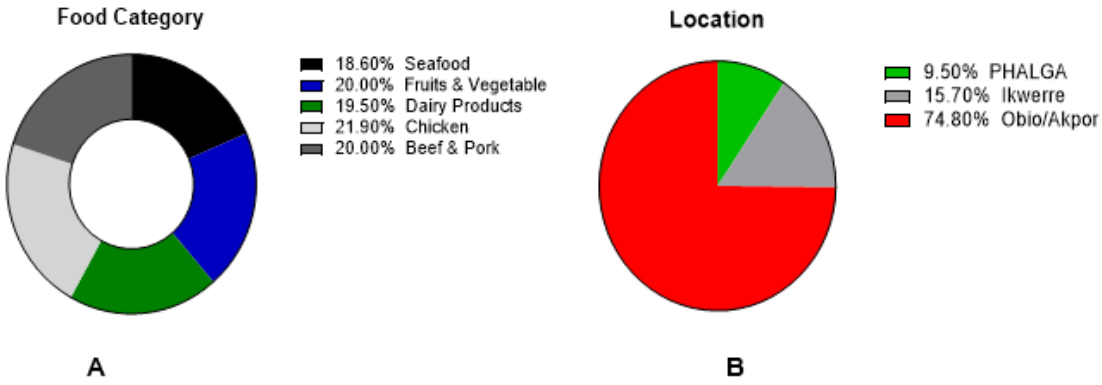

Fig. 3. Food Sample Characteristics: A) Food Categories B) Location of Food Source

3.1.1 Prevalence of non-typhoidal *Salmonella* species

A total of 420 samples (210 stool and 210 food) were collected and tested for the presence or absence of *Salmonella* species. *Salmonella* was isolated from 12 (2.9%) of all samples tested. Of the 420 samples, 210 were stool samples from subjects in Port Harcourt metropolis of which five samples (2.4%) were confirmed to be *Salmonella* spp. and 210 were for food samples of which seven samples (3.3%) were confirmed to be *Salmonella* spp. positive by conventional microbiology method (Table 1).

3.1.2 Prevalence of non-typhoidal *Salmonella* species in stool samples by sociodemographic characteristics

The Female subjects had a higher prevalence of 3 (3.7%) in comparison to their male counterpart, 1 (1.0%). Prevalence of *Salmonella* species for '0 – 10', '11 – 30', '31 – 50' and 'above 50' age groups were 1 (10%), 1 (0.8%), 1 (1.6%), and 2 (11.1%) respectively and was statistically significant (P = .02). The prevalence according to occupation were 0 (0%) for civil servants, 0 (0%) for the privately employed, 2 (3.7%) for self-employed, 1 (0.9%) for students and 2 (33%) for unemployed (P < .0001). Prevalence of *Salmonella* species for 'No formal education', Primary, Secondary, and Tertiary education were 2 (8.3%), 1 (8.3%), 2 (4.2%), and 0 (0%) respectively and was statistically significant (P < .03). For religion, Christian subjects had the highest prevalence 5 (2.8%) while Muslims and others were both 0 (0%). A similar case was observed in terms of location with Obio/Akpor having the highest prevalence with 5 (4.2%) while Ikwerre and PHALGA had 0 (0%) (Table 2).

3.1.3 Prevalence of non-typhoidal *Salmonella* species in food samples

Two hundred and ten food samples (fruits & vegetables, Sea food, Dairy Products, Beef & Pork, and Chicken) were collected for culture with food in the chicken category having the highest prevalence with 4 (8.7%) followed by Seafood with 2 (5.1%), Dairy products with 1 (2.4%) while food in Beef and Pork category and Fruits and Vegetables both had 0 (0%). For the location, food collected from Obio/Akpor had a prevalence of 7 (4.5%) while Ikwerre and PHALGA had 0 (0%) each (Table 3).

3.1.4 Prevalence of *Salmonella* species by month

The stool and food samples were collected during the same period (December 2022 to November 2023). There were more positive samples for the stool samples during the month of March (2) with February, April and June having 1 each. Fig. 3. and for Food samples, there were more positive samples in the months of January, March and April (two each) while February had one positive sample. Fig 3.

Table 1. Prevalence of Non-Typhoidal *Salmonella* in Stool and Food Samples

Variable	Positive (%)	Negative (%)	Total (%)	X^2	Df	*P*-value
Food	7 (3.3)	203 (96.7)	210 (100)			
Stool	5 (2.4)	205 (97.6)	210 (100)			
Total	12 (2.9)	408 (97.1)	420 (100)	.3431	1	.56

Table 2. Prevalence of *Salmonella species* in Stool by Sociodemographic Characteristics

Variable	Positive (%)	Negative (%)	Total (%)	X^2	Df	p-*value*
Sex						
Male	1 (1.0)	102 (99.0)	103 (100)			
Female	4 (3.7)	103 (96.3)	33 (100)	0.729	1	.19
Total	**5 (2.4)**	**205 (97.6)**	**210 (100)**			
Age Group						
(0 – 10)	1 (10.0)	22 (91.7)	10 (100)			
(11 – 30)	1 (0.8)	118 (99.2)	119 (100)			
(31 – 50)	1 (1.6)	62 (98.4)	63 (100)	9.786	3	.02*
(above 50)	2 (11.1)	16 (88.9)	18 (100)			
Total	**5 (2.4)**	**205 (97.6)**	**210 (100)**			
Education						
NFE	2 (8.3)	22 (91.7)	24 (100)			
Primary	1 (8.3)	11 (91.7)	24 (100)			
Secondary	2 (4.2)	46 (95.8)	48 (100)	9.220	3	.03*
Tertiary	0 (0)	126 (100)	126 (100)			
Total	**5 (2.4)**	**205 (97.6)**	**210 (100)**			
Occupation						
Civil Servant	0 (0)	24 (100)	24 (100)			
Privately Employed	0 (0)	25 (100)	25 (100)			
Self-Employed	2 (3.7)	52 (96.3)	54 (100)	27.17	4	<.0001*
Student	1 (1.0)	100 (99.0)	101 (100)			
Unemployed	2 (33.0)	4 (67.0)	6 (100)			
Total	**5 (2.4)**	**205 (97.6)**	**210 (100)**			
Religion						
Christian	5 (2.8)	173 (97.2)	173 (100)			
Muslim	0 (0)	21 (100)	21 (100)	0.9208	3	.63
Others	0 (0)	11 (100)	11 (100)			
Total	**5 (2.4)**	**205 (97.6)**	**210 (100)**			
Location						
Obio/Akpor	5 (4.2)	115 (95.8)	120 (100)			
Ikwerre	0 (0)	29 (100)	29 (100)	3.841	2	.15
PHALGA	0 (0)	61 (100)	61 (100)			
Total	**5 (2.4)**	**205 (97.6)**	**210 (100)**			

Table 3. Prevalence of *Salmonella* in Food Samples and Sociodemographic Characteristics

Variable	Positive (%)	Negative (%)	Total (%)	X^2	Df	p-*value*
Location						
Obio/Akpor	7 (4.5)	150 (95.5)	157 (100)			
Ikwerre	0 (0)	33 (100)	33 (100)	2.536	2	.28
PHALGA	0 (0)	20 (100)	20 (100)			
Total	**7 (3.3)**	**203 (96.7)**	**210 (100)**			
Food Category						
Beef & Pork	0 (0)	42 (100)	42 (100)			
Chicken	4 (8.7)	42 (91.3)	46 (100)			
Dairy Products	1 (2.4)	40 (97.6)	41 (100)	7.493	4	.11
Fruits & Vegetable	0 (0)	42 (100)	42 (100)			
Seafood	2 (5.1)	37 (94.9)	39 (100)			
Total	**7 (3.3)**	**203 (93.7)**	**210 (100)**			

** Statistical significance P < .05; Values in parenthesis = percentages*

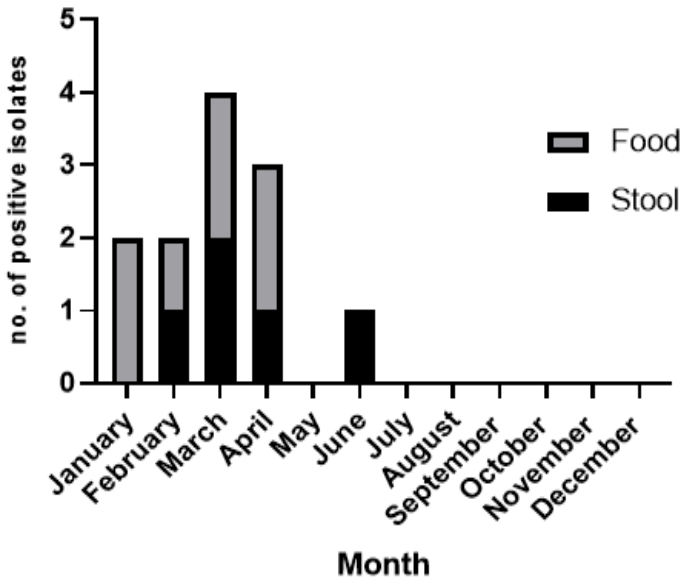

Fig. 4. Positive *Salmonella* samples by month

4. DISCUSSION

Salmonella infection is very common in developing countries especially the non-typhoidal species. The common vehicle of transmission is via food. The present study investigated the prevalence of non-Typhoidal *Salmonella* in food sources and human stools using different parameters such as seasons, sociodemographic factors and type of sample (clinical and non-clinical). Four hundred and twenty (420) samples yielded 12 (2.9%) *Salmonella* isolates. *Salmonella* was positive in 5 (2.4%) of human samples (stool) and 7 (3.3%) of food samples. This higher prevalence in food samples in comparison to stool samples is in accordance with a study carried out by Ndu et al. [24] who also reported a higher prevalence in food samples. This may be due to the fact that animals from which food are gotten is the main reservoir for *Salmonella* and an immuno-competent human body can fight off *Salmonella* infections easily. The prevalence rate from food sources reported in this study is lower than that reported by Ndu et al. [24] with 8.2% from ready-to-eat food samples. A similar study on isolation of *Salmonella* from raw beef and chicken used in Abuja fast-food restaurants by Bawa et al*.* [25] reported a prevalence of 1.5% which is lower than that reported in the present study. Konne et al*.* [26] showed Salmonella species was the second most prevalent pathogen in roasted beef with a prevalence of 17% which is much higher than that obtained in this study. This difference in prevalence may be due to the location of sampling with restaurant's food likely to be more hygienic compared to road-side food.

The prevalence in human (stool) samples in this study is higher than that reported by Akinyemi et al. [22] that demonstrated a 0.9% prevalence in humans living in Lagos. A similar study by Aworh et al. [27] on rare serovars of non-typhoidal *Salmonella* in abattoir workers reported a prevalence of 4.2% which is higher than the prevalence rate in humans gotten in the present study. This variance in prevalence rates may be due to differences in sample sizes, the unsanitary nature of abattoirs and cattle in the abattoirs have been implicated as a likely source in the transmission of non-typhoidal *Salmonella* to humans.

Previous studies have suggested possibility of association between age and infection [28]. The age groups with the highest prevalence were the '0 – 10' age group with a 10% prevalence and 'above 50' age group with 11.1% prevalence and the difference was statistically significant compared to other age groups (*P* value = .02). These findings are consistent with a study by Zaidenstein et al. [29] who reported a significant difference in Israeli patients <10 and ≥60 years old. This may be due to the underdeveloped immune system in the '0 – 10' age group and the weakened immune system in the 'above 50' age group. The females had a higher prevalence (3.7%) compared to the male (1%). This is consistent with the findings of Kebede et al. [30] that reported a higher *Salmonella* prevalence

among female diarrheic patients in Ethiopia. In terms of educational status, there was a higher prevalence in subjects with non-formal education (8.3%) and those with only primary education with a significant difference compared to those in other groups (*P* value < .03). This may be due lack of knowledge on proper food handling. Also, there was a significant difference in prevalence between the occupational classes with the unemployed (33%) having the highest prevalence while the civil servants and privately employed had a zero percent (0%) prevalence. This may be down to accessibility to properly cooked food and also due to the fact that those in the unemployed category were also children less than 5 years and adults older than 65 years both of which do not have a suitable immune system to fight off infections. In terms of religion, the Christians had the highest prevalence but there was no significant difference in comparison to other religions.

The months with the highest prevalence were between January and June with March (14.3%) having the highest prevalence for the stool isolates and April (25%) having the highest prevalence for food isolates. This may be due to the warm nature of these months in Nigeria and warmer weather create ideal conditions for *Salmonella* to grow [31]. In terms of location, the Obio/Akpor had a higher prevalence rate in both stool and food samples compared to the two other local governments, but the difference was not statistically significant. For the food samples, food in the chicken category had the highest prevalence (8.7%) compared to other food category which were beef & pork (0%), dairy products (2.4%), fruits & vegetables (0%) and seafood (5.1%). This was in line with a study carried out by Sudhanthirakodi who also reported a higher prevalence in chicken [32].

5. CONCLUSION

The present study shows that the prevalence of non-typhoidal *Salmonella* was 2.9%, with the age, educational background and occupation of the status being significantly associated (*P* < .05) with the prevalence of the infection. It also demonstrated that this pathogenic bacterium is found more commonly in food (3.3%) especially in chicken (8.7%) in comparison to stool (2.4%). The study also shows that the infection is more common during the months of January to June which are the warmest months in Nigeria. Health campaigns should be carried out to enlighten the populace about the risks involved in the prevalence of this infection so as to reduce its burden.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

CONSENT AND ETHICAL APPROVAL

Ethical approval was obtained from Rivers State Health Research Ethical Committee with REC number RSUTH/REC/202319 before commencement of this study. Verbal and written (questionnaire) consent were also obtained from patient before samples were collected.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ghazy A, Nyarku R, Faraj R, Bentum K, Woube Y, Williams M, Alocilja E, Abebe W. Gold Nanoparticle-Based Plasmonic Detection of Escherichia Coli, Salmonella Enterica, Campylobacter Jejuni, and Listeria Monocytogenes from Bovine Fecal Samples. Microorganisms. 2024;12:1069.
2. Ryan MP, O'Dwyer J, Adley CC. Evaluation of the Complex Nomenclature of the Clinically and Veterinary Significant Pathogen Salmonella. BioMed Research International. 2017:3782182. DOI: 10.1155/2017/3782182.
3. Gal-Mor O, Boyle EC and Grassl GA. Same species, different diseases: how and why typhoidal and non-typhoidal Salmonella enterica serovars differ. Front Microbiol. 2014;5(391).
4. Uzairue LI, Shittu OB, Ojo OE, Obuotor TM, Olanipekun G, Ajose T, Arogbonlo R, Medugu N, Ebruke B, Obaro SK. Antimicrobial resistance and virulence genes of invasive Salmonella Enterica from children with bacteremia in north-central Nigeria. SAGE Open Med. 2023; 11.
5. Abebe E. Gugsa G, Ahmed M. Review on major food-borne zoonotic bacterial pathogens. J. Trop. Med. 2020;2020: 1–19.

6. Daigle F. Special Issue Salmonella: pathogenesis and host restriction. Microorganisms. 2021;9(325).
7. National Enteric Disease Surveillance: Salmonella Annual Report, 2016; Centers for Disease Control and Prevention: Atlanta, GA, USA; 2016.
8. European Food Safety Authority and European Centre for Disease Prevention and Control (EFSA and ECDC). The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2017. EFSA J. 2018;16.
9. Galán-Relaño Á, Valero DA, Huerta LB, Gómez-Gascón L, Mena Rodríguez MÁ, Carrasco JE, Pérez RF, Astorga-Márquez RJ. Salmonella and Salmonellosis: An Update on Public Health Implications and Control Strategies. Animals. 2023;13: 3666.
10. World Health Organization. WHO Estimates of the Global Burden of Foodborne Diseases: Foodborne Disease Burden Epidemiology Reference Group 2007–2015; World Health Organization: Geneva, Switzerland; 2015.
11. Bonardi S. Salmonella in the pork production chain and its impact on human health in the European Union. Epidemiol. Infect. 2017;145:1513–1526.
12. Uelze L, Bloch A, Borowiak M, Grobbel M, Deneke C, Fischer M, Malorny B, Pietsch M, Simon S, Szabó I, et al. What WGS reveals about Salmonella enterica Subsp. Enterica in Wildlife in Germany. Microorganisms. 2021;9(1911).
13. Aung KT, Khor WC, Ong KH, Tan WL, Wong ZN, Oh JQ, Wong WK, Tan BZY, Maiwald M, Tee NWS, et al. Characterisation of Salmonella Enteritidis ST11 and ST1925 associated with human intestinal and extra-intestinal infections in Singapore. Int. J. Environ. Res. Public. Health. 2022;19:5671.
14. European Food Safety Authority and European Centre for Disease Prevention and Control (EFSA and ECDC). The European Union Summary Report on Trends and Sources of Zoonoses, Zoonotic Agents and Food-borne Outbreaks in 2017. EFSA J. 2018;16.
15. Ferrari RG, Rosario DKA, Cunha-Neto A, Mano SB, Figueiredo EES, Conte-Junior CA. Worldwide epidemiology of Salmonella serovars in animal-based foods: A meta-analysis. Appl. Environ. Microbiol. 2019;85.
16. Makendi C, Page AJ, Wren BW, Le Thi-Phuong T, Clare S, Hale C, Goulding D, Klemm EJ, Pickard D, Okoro C, et al. A phylogenetic and phenotypic analysis of Salmonella Enterica serovar Weltevreden, an emerging agent of diarrheal disease in tropical regions. PLoS Negl. Trop. Dis. 2016;10.
17. Marchello CS, Dale AP, Pisharody S, Rubach MP, Crump JA. Prevalence of community-onset bloodstream infections among hospitalized patients in Africa and Asia: A systematic review and meta-analysis. Antimicrob Agents Chemother. 2019;64.
18. Nemhauser JB. (Ed.) CDC Yellow Book 2024: Health Information for International Travel; Oxford University Press: New York, NY, USA, 2023.
19. GBD 2017 Non-Typhoidal Salmonella Invasive Disease Collaborators. The global burden of non-typhoidal Salmonella invasive disease: A systematic analysis for the global burden of disease study 2017. Lancet Infect Dis. 2019;19:1312–1324.
20. Sanni AO, Onyango J, Rota AF, Mikecz O, Usman A, Pica Ciamarra U, Fasina FO. Underestimated economic and social burdens of non-Typhoidal Salmonella infections: The One Health perspective from Nigeria. One Health. 2023;19(16).
21. Naing L, Winn T, Nordin R. Practical issues in calculating the sample size for prevalent studies. Arch Orofacial Sci. 2006;1.
22. Akinyemi KO, Bamiro BS, and Coker AO. Salmonellosis in Lagos, Nigeria: incidence of Plasmodium falciparum-associated co-infection, patterns of antimicrobial resistance, and emergence of reduced susceptibility to fluoroquinolones. J Health Popul Nutr. 2007;25(3),351.
23. O´Hara C. Manual and automated instrumentation for identification of Enterobacteriaceae and other aerobic gram-negative bacilli. Clin Micro Rev. 2005;18(1): 147-162.
24. Ndu FI, Ollor OA, Nwokah GE, and Wachukwu CK. Prevalence and Antimicrobial Susceptibility of Salmonella spp Isolated from Ready-to-eat foods and Food Handlers in Port Harcourt Metropolis, Nigeria. J Adv Micro. 2022;22(9):85–96.
25. Bawa S, Kwaga J, Lawan K, and Bawa S. Isolation of Salmonella from raw beef and chicken used in fast food restaurants in

Abuja, Nigeria. PAMJ – One Health. 2020;3.
Available:https://doi.org/10.11604/pamj-oh.2020.3.13.24264.

26. Konne E., Monsi TP, Wokem GN. Bacteriology of Suya Meat Sold in Bonny Local Government Area, Rivers State. Asian Journal of Medicine and Health. 2018;10(4):1-7.
Available:https://doi.org/10.9734/AJMAH/2018/34160
27. Aworh MK, Nilsson P, Egyir B, Owusu FA, Hendriksen RS. Rare serovars of non-typhoidal Salmonella enterica isolated from humans, beef cattle and abattoir environments in Nigeria. PLoS One. 2024;19(1).
28. Amala SE, Karibi-Botoye R, Nwokah EG, Monsi TP. Prevalence of Asymptomatic Bacteriuria in Pregnancy and Urinary Tract Infection in Non-pregnant Symptomatic Women. American Journal of Biomedical Sciences. 2021;13(4):172-183.
DOI: 10.5099/aj210400172
29. Zaidenstein R, Peretz C, Nissan I, Reisfeld A, Yaron S, Agmon V, Weinberger M. The epidemiology of extraintestinal non-typhoid Salmonella in Israel: the effects of patients' age and sex. Eur J Clin Microbiol Infect Dis. 2010;29(9):1103-1109.
DOI: 10.1007/s10096-010-0968-1.
30. Kebede R, Alemayehu H, Mehdin G, and Eguale T. Non-typhoidal Salmonella and their antimicrobial susceptibility among diarrheic patients attending private hospitals in Addis Ababa, Ethiopia. Bio Res Int. 2021;1-8.
31. Billah MM and Rahman S. Salmonella in the environment: A review on ecology, antimicrobial resistance, seafood contaminations, and human health implications. J Haz Mat Adv. 2024;13.
Doi: 10.1016/j.hazadv.2024.100407.
32. Sudhanthirakodi S. Non-typhoidal Salmonella isolates from livestock and food samples, Kolkata, India. J Microbil Infect Dis. 2016;6(3):113-120.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122202