IJMAAS International Journal of Microbiology and Applied Sciences
ISSN 1115-4004 Volume 5 issue 3 Sept - Dec, 2026 Research Article

Occurrence of *Salmonella* and *Aspergillus* species in Street-Vended Suya within Port Harcourt Metropolis, Rivers State, Nigeria

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ABSTRACT

Suya is widely consumed in Nigeria despite microbiological safety concerns. This study examined the occurrence of *Salmonella* and *Aspergillus* species in street vended suya sold within Port Harcourt Metropolis, Rivers State, Nigeria. A total of 45 samples were collected from GRA, Mgbuoba and Iwofe and subjected to microbiological analysis using standard techniques. The virulence characteristics of the Salmonella isolates were determined using hemolysis and biofilm formation was assessed using the Congo red method. Data obtained from study showed that the mean Salmonella counts for GRA, Mgbuoba and Iwofe were $(8.30\pm1.80)\times10^3$, $(1.0\pm0.13)\times10^3$ and $(1.24\pm2.40)\times10^4$, (CFU/g), respectively. The mean Aspergillus counts for GRA, Mgbuoba and Iwofe were $(2.0\pm0.04)\times10^2$, $(8.2\pm0.40)\times10^3$, and $(3.9\pm0.39)\times10^3$, (CFU/g), respectively. It was observed that 12 samples has *Salmonella* giving an overall prevalence of 26.7%, 10 samples have *Aspergillus* giving an overall prevalence of 22.2%. Virulence assessment revealed that Gamma hemolysis predominated (58.3%), followed by beta hemolysis (33%), alpha (8.3%), while 58.3% of the *Salmonella* isolates were biofilm positive. The occurrence of *Salmonella* and *Aspergillus* demonstrate that street vended Suya may represent a medium for exposure to bacterial and fungal hazards. The findings highlight the importance of food safety concerns for consumers. Strengthening hygiene practices, food safety surveillance and public awareness programmes is therefore necessary to reduce microbial contamination of street vended Suya.

Keywords: *Salmonella, Aspergillus*, suya, biofilm, food safety.

Introduction

Suya is a popular Nigerian street food, made from thinly sliced pieces of meat (usually beef, chicken, or goat meat) that are marinated in a mixture of spices, peanut oil, and other ingredients, then grilled over an open flame (Okonkwo et al., 2012). Suya is prepared from boneless meat of animals (Abdullahi et al., 2004). The meat is thinly sliced and usually served with dried pepper mixture of spices mix and additives which make up Suya marinade (called yaji in Hausa language) and the spice mix and served with it (Ugwuja et al., 2009). There is no standard recipe to produce the complex mixture of spices and additives which makeup the Suya and the spice mix served with it (Akpamu et al., 2011). Suya is mostly sold in the evening hours with only very few vendors selling during the day.

However, due to its method of preparation and conditions in which its sold, Suya is often exposed to environmental contaminants, which can compromise its safety and quality (Akinlola et al., 2021).

Studies indicate that contamination can arise from various sources, including handling by vendors, poor hygiene practices, and exposure to dust and flies during processing and sale (Chukwuma et al., 2017). Similarly, (Wilson et al., 2022) reported that ready to eat Suya is susceptible to microbial contamination during processing, handling and vending.

Environmental contamination from road side traffic emissions, dirty processing tools, polluted water, and low grade spices can introduce toxic heavy metals into the ready to eat meat (Oyewole et al., 2024).

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Several organisms have been associated with contaminated including species of *Salmonella, E. coli, Staphylococcus aureus* and *Aspergillus* (Omotoso et al*.,* 2023). Among the bacterial contaminants associated with meat and meat products, *Salmonella* species are of particular public health importance. The organism is commonly associated with foods of animal origin including meat, poultry, eggs and dairy products (Silva et al., 2011; Carstens et al., 2019). Human infection typically occurs through the consumption of contaminated food or water and may result in salmonellosis, a disease characterized by diarrhoea, fever, abdominal cramps, vomiting and other gastrointestinal disorders (Ehuwa et al., 2021). The recovery of Salmonella from ready to eat foods is therefore considered an important indicator of food safety failure and inadequate hygienic practices.

Salmonella is an important food borne pathogen of public health concern because of its ability to survive in foods and cause gastrointestinal infections following consumption of contaminated food. Its pathogenicity is associated with a range of virulence attributes that facilitate adhesion, colonization, invasion and persistence within the host (Jajere, 2019). Virulence associated traits such as hemolytic activity and biofilm formation are important phenotypic markers that enhance bacterial survival and pathogenicity. Hemolysis refers to the ability of bacterial cells to lyse red blood cells. Biofilm formation is another important characteristic that contributes to the persistence of *Salmonella* in food environments. Through biofilm formation, bacterial cells adhere to surfaces and become embedded in an extracellular matrix, thereby enhancing their ability to survive environmental stresses and resist removal during cleaning and food-handling processes (Wang et al., 2023). This characteristic is particularly important in ready to eat foods because persistent *Salmonella* on food contact surfaces may serve as a continuing source of contamination.

Fungal contamination is another important food safety issue associated with ready-to-eat foods. Species belonging to the genus *Aspergillus* are among the most common fungi found in food products and food processing environments. Members of the genus are widely distributed in nature and can grow under diverse environmental conditions (Geiser, 2009; Hawksworth, 2011).

Certain *Aspergillus* species such as *A. flavus, A. fumigatus* and *A. niger* have frequently been isolated from foods and food ingredients, particularly spices and dried food materials (Pitt & Hocking, 2009). Their occurrence in food products is often associated with poor handling practices, environmental exposure and inadequate storage conditions.

Consuming contaminated Suya can lead to food borne illness including gastroenteritis, diarrhea, and vomiting. Food borne illnesses can result in economic losses, including medical expenses, loss productivity, and damage to the food industry. Suya related food borne illness can be significant public health concern, particularly in areas with poor sanitation and hygiene practices (Asomugha et al*.,* 2021).

This study was therefore carried out to investigate the Occurrence of *Salmonella* and *Aspergillus* species in street vended Suya meat within Port Harcourt Metropolis.

Materials and Methods

Study Area

This study was carried out in Port Harcourt Metropolis. Port Harcourt Metropolis is the capital city of Rivers State. The Suya samples were collected from three different locations in Port Harcourt Metropolis, Rivers State, Nigeria. These locations include Government Residential Area (GRA), Mgbuoba and Iwofe with the following coordinates latitude 4°49’16’’N Longitude 7°0’4’’E, Latitude 4°51’9’’N Longitude 6°58’30’’ E, Latitude 4°50’15’’N Longitude 6°59’15’’E respectively.

Study Design and Sampling Technique

The study was conducted using a descriptive cross-sectional design. Due to the small number of Suya vendors in the study area that limits the application of Yamane's and Cochran / Standard Proportion Formula, a convenience sampling technique was adopted, involving all available street Suya vendors across the selected locations. The proportion of vendors was stratified to achieve uniformity a cross the different study locations.

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Sample Collection

A total of 45 samples was used for this study, 5 samples each were collected randomly from three locations and sampled at monthly intervals for three months. The Suya samples were collected, appropriately labeled, and individually wrapped in sterile aluminum foil and transported to Rivers State University's Microbiology lab for examination.

Isolation and Enumeration of Microorganisms

The bacteria and fungi pathogen were isolated from vended suya meat following the ten fold serial dilution. This was done by weighing Twenty five grams of each suya and transferred into 225 mL of sterile distilled water. The ten-fold serial dilution was prepared and 0.1 mL aliquots were inoculated onto *Salmonella-Shigella* agar (SSA) and Sabouraud Dextrose Agar (SDA) for bacterial and fungal isolation, respectively. The cultured samples were incubated at 37℃ for 24 hours and 7 days with respect to bacteria and fungi species respectively. Colonies were enumerated and expressed as CFU/g.

Characterization of Isolates

Bacterial isolates were characterized by colony morphology, Gram staining, motility, catalase, oxidase, indole, citrate utilization, methyl red, Voges Proskauer and sugar fermentation tests. Fungal isolates were characterized using macroscopic and microscopic features.

Virulence Assessment

The virulence associated characteristics of *Salmonella* isolates were assessed using hemolysis and biofilm formation assays. The techniques used were as reported by (Robinson et al., 2023). Haemolytic activity was categorized as Alpha hemolysis (partial hemolysis) Beta hemolysis (complete hemolysis) or gamma hemolysis (no hemolysis), while Biofilm formation was assessed using the Congo red method.

Statistical Analysis

Data were expressed as mean ± standard deviation. Analysis of variance (ANOVA) was used to determine differences among sampling locations, with statistical significance set at $P < 0.05$.

Results

The population of *Salmonella* isolated from the vended Suya meat samples from the various locations is shown in Table 1. Results showed that the mean *Salmonella* counts for GRA, Mbuogba and Iwofe were $(8.30\pm1.80) \times 10^3$, $(1.0\pm0.13) \times 10^3$, and $(1.24\pm2.40) \times 10^4$, CFU/g, respectively. The result showed that the vended Suya meat from Iwofe$(1.24\pm2.40)\times10^4$ CFU/g, had the highest *Salmonella* count followed by the vended Suya meat from GRA $(8.30\pm1.80)\times10^3$ CFU/g, while the least *Salmonella* count in vended Suya meat was recorded in the Mbuogba location $(1.0\pm0.13) \times 10^3$CFU/g.

Table 1: *Salmonella* Count in Vended Suya Meat

Isolate Code	Location of Suya Spot and *Salmonella* Count ($\times10^4$ CFU/g)		
	GRA	Mgbuoba	Iwofe
1	4.05	0.33	0.00
2	0.00	0.06	0.00
3	0.10	0.10	0.70
4	0.01	0.00	5.50
5	0.00	0.02	0.00
Mean ± SD	0.83 ± 1.80	0.10 ± 0.13	1.24 ± 2.40
P-value		0.5893	

Results also showed that the *Aspergillus* counts of the vended Suya meat for GRA, Mbuogba and Iwofe were $(2.00\pm0.04) \times 10^2$ CFU/g, $(8.2\pm0.40) \times10^3$ CFU/g, and $(3.9\pm0.39) \times 10^3$ CFU/g, respectively. Samples from Mbuogba had the highest *Aspergillus* count $(8.2\pm0.40) \times 10^3$CFU/g, followed by samples from Iwofe $(3.9\pm0.39) \times 10^3$CFU/g. Vended Suya at the GRA location had the lowest *Aspergillus* count $(2.00\pm0.04) \times 10^2$CFU/g as shown in Table 2.

Table 2: *Aspergillus* Count in Vended Suya Meat

Isolate Code	Location of Suya Spot and *Aspergillus* Count ($\times10^4$ CFU/g)		
	GRA	Mgbuoba	Iwofe
1	0.00	0.10	0.55
2	0.00	1.00	0.00
3	0.00	1.00	0.20
4	0.10	1.00	1.00
5	0.00	1.00	0.20
Mean ± SD	0.02 ± 0.04	0.82 ± 0.40	0.39 ± 0.39
P-value		0.0076	

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Statistical analysis revealed no significant difference in the mean values from the *Salmonella* count ($P>0.05$) as seen in Table 1. However, a significant difference was seen from the *Aspergillus* count ($P<0.05$) as shown in Table 2.

The data obtained on the prevalence of the Isolates revealed that *Salmonella* was isolated from 12 samples giving an overall prevalence of 26.7%, The highest location specific prevalence was recorded in Mgbuoba (40.0%), followed by GRA (26.7%) and Iwofe (13.3%). while *Aspergillus* was isolated from 10 samples giving an overall prevalence of 22.2%.

The highest location specific prevalence was recorded in Iwofe (33.3%), followed by Mgbuoba (26.7%) and GRA (6.7%). The prevalence of *Salmonella* and *Aspergillus* in the vended Suya meat samples is shown in Table 3.

Table 3: Prevalence of Isolates from the Vended Suya Meat

Sample Location	Prevalence of Isolates (%)	
	Salmonella	***Aspergillus***
GRA	26.7	6.7
Mgbuoba	40	26.7
Iwofe	13.3	33.3
Overall	26.7	22.2

The results on the virulence potentials of isolates based on hemolysis and biofilm on the isolates: The data obtained on the hemolytic activity of the *Salmonella* isolates revealed gamma hemolysis was the predominant hemolytic pattern, occurring in 58.3% of the isolates, followed by beta hemolysis with occurred in 33.3% of the isolates, while alpha hemolysis was observed in 8.3% of the isolates.

Furthermore, biofilm production was detected in 58.3% of the *Salmonella* isolates. The distribution of the hemolytic patterns and biofilm producing isolates is seen in Table 4.

Table 4: Haemolysis and Biofilm Result of *Salmonella* Isolates from Vended Suya Meat

Isolate code	Alpha (α)	Beta (β)	Gamma (γ)	Biofilm
1	-	-	+	-
2	-	-	+	-
3	-	+	-	-
4	-	+	-	+
5	+	-	-	-
6	-	-	+	+
7	-	-	+	+
8	-	+	-	-
9	-	+	-	+
10	-	-	+	+
11	-	-	+	+
12	-	-	+	+
Total (%)	**1(8.3)**	**4(33.3)**	**7(58.3)**	**7(58.3)**

Discussion

The occurrence of *Salmonella* from ready to eat Suya in this study demonstrates that microbiological hazards can persist in a food that has already undergone roasting. This is important because the principal food safety concern with ready-to-eat foods is not necessarily the contamination of raw ingredients alone, but the possibility that microorganisms may survive inadequate processing or be reintroduced during handling, seasoning, storage and sale. The population of *Salmonella* in suya meat in this study varied across the different sellers and locations.

The results obtained from this study are lower than the *Salmonella* count of suya in Maiduguri reported by (Ogbonna et al., 2012). Similarly, Manyi et al. (2014) reported a mean *Salmonella* count in Suya that ranged from 6.92×10^4CFU/g to undetectable.

Differences between studies may reflect variation in sampling locations, sample handling, processing practices, storage conditions and environmental exposure. Similarly, (Konne et al., 2018), noted that microbial contamination of Suya can occur through air, human handlers, equipments, water, papers, and utensils.

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The overall prevalence of 26.7% obtained in this study further demonstrates the occurrence of *Salmonella* in the suya sold within the study area.

This prevalence was higher than the 17.0% reported by (Konne et al., 2018) among suya vendors in Bonny and considerably higher than the 2.1% reported by (Orpin et al., 2019) in Katsina State. The relatively higher prevalence observed in the present study may indicate increased exposure of finished products to contamination sources such as processing equipment, contaminated water, packaging materials, food handlers and environmental aerosols. Beyond occurrence, the pathogenic potential of the recovered *Salmonella* isolates is of particular importance. Assessment of hemolytic activity revealed the predominance of gamma hemolysis among the isolates, followed by beta and alpha hemolysis respectively. The detection of beta hemolytic isolates is especially significant because beta hemolysis is generally associated with complete lysis of red blood cells and is often considered an indicator of enhanced virulence potential.

Biofilm formation was detected in 58.3% of the *Salmonella* isolates. This finding is significant because biofilms contribute substantially to bacterial persistence within food processing environments. Biofilm producing bacteria possess the ability to attach to food-contact surfaces and become embedded within an extracellular polymeric matrix, which provides protection against environmental stress and cleaning procedures (Wang et al., 2023). The high proportion of biofilm forming isolates observed in this study suggests the possibility of persistent contamination sources within the suya production and vending chain. Contaminated knives, trays, tables, skewers and cutting boards may act as reservoirs from which bacteria are continuously transferred to processed meat products.

Fungal contamination was also evident in the suya samples analyzed. The recovery of *Aspergillus* species from all sampled locations demonstrates that fungal contamination represents an additional food safety challenge associated with street vended suya. The significantly higher counts observed in some locations suggest that environmental conditions may influence the extent of fungal contamination.The variation may reflect differences in environmental exposure, storage conditions, moisture and handling after roasting. The overall prevalence of 22.2% recorded in this study confirms that fungal contamination is common among suya sold within the study area.

Similar findings have been reported by (Mohammed et al*.,* 2017) and (Chukwura et al., 2004), who isolated *Aspergillus* species from suya samples obtained in Minna and Awka, respectively. The recurrent isolation of these fungi from suya across different regions of Nigeria suggests that fungal contamination may represent a widespread challenge in the production and sale of this ready to eat product.

The identification of *A. flavus, A. fumigatus* and *A. niger* has important public health implications. The identification of species such as *Aspergillus flavus* is of particular concern because some strains are capable of producing aflatoxins, which are associated with chronic health effects including hepatotoxicity, immunosuppression and hepatocellular carcinoma (Bennett & Klich, 2003; Van Egmond et al., 2007).

Similarly, *A. fumigatus* is an opportunistic pathogen capable of causing aspergillosis, particularly among immunocompromised individuals. The occurrence of these fungi in ready to eat suya therefore suggests not only a risk of food spoilage but also a potential threat to consumer health. The recovery of potentially toxigenic fungal species highlights the need for continuous monitoring of fungal contaminants in street-vended foods.

The detection of both bacterial and fungal contaminants in the analyzed suya samples suggests that contamination may arise from multiple sources throughout the production chain.The occurrence of potentially pathogenic *Salmonella* species and toxigenic *Aspergillus* species in suya indicates the potential for food borne disease transmission within the population. Such contamination may contribute to increased healthcare costs, reduced productivity and diminished consumer confidence in street vended foods.

Furthermore, the detection of virulence associated characteristics among some *Salmonella* isolates suggests that contamination is not limited to the presence of microorganisms alone but also involves strains capable of persistence and pathogenicity.

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These observations emphasize the need for routine microbiological surveillance, improved vendor education and stricter enforcement of food safety regulations.

Consequently, strengthening hygiene practices throughout the suya production chain remains essential for reducing microbial contamination and improving consumer safety.

The study contributes directly to Sustainable Development Goal 2 (Zero Hunger) through the promotion of safe and nutritious food, Sustainable Development Goal 3 (Good Health and Well-being) through the reduction of foodborne disease risks, and Sustainable Development Goal 12 (Responsible Consumption and Production) through advocacy for safer food handling, processing and vending practices. Ultimately, ensuring the microbiological safety of street vended suya is essential for protecting public health and promoting sustainable urban food systems.

Conclusion

The study has established the presence of *Salmonella* and *Aspergillus* species in street vended Suya meat within Port Harcourt Metropolis, indicating microbial contamination of the Suya. These organisms are known to be associated with frequent food borne and opportunistic infections with *Salmonella enterica* associated with salmonellosis and *Aspergillus* species associated with aspergillosis particularly among susceptible individuals. The detection of these microbial contaminants in street vended Suya highlights the potential health risk consumers are exposed to and suggests that the level of risk may vary across different locations within Port Harcourt Metropolis.

The virulence characteristics revealed that gamma hemolysis predominated among the *Salmonella* isolates, whereas a few isolates exhibited beta hemolysis, suggesting the presence of strains with pathogenic potential that may pose a health risks to prospective consumers.

Furthermore, the presence of biofilm producing isolates suggests the presence of strains with enhanced pathogenic and environmental persistence potentials. Biofilm formation may facilitate survival of the organism in food processing environments, increase its ability to colonize host tissues and contribute to the transmission of infection through contaminated street vended Suya within Port Harcourt Metropolis.

This present study highlights the public health significance of microbial contamination in street vended Suya and emphasize the need for continuous Public health surveillance, improved hygiene practices during processing and vending, and strengthened food safety monitoring programmes within Port Harcourt Metropolis.

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