Microbial Quality and Public Health Risk Assessment of Ready-to-Eat Suya Meat in Lagos, Nigeria: Prevalence of Pathogenic Bacteria and Implications for Food Safety

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Abstract: Suya, a popular Nigerian skewered meat (pH 5.7–7.2; aw 0.98–0.99), is a low-acid, high-moisture food that is highly susceptible to microbial contamination. Pathogens such as *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus* pose severe public health risks in developing regions, where contaminated meat often serves as a primary transmission pathway. These risks are exacerbated by inadequate preparation and poor hygiene practices. This study assessed the microbiological quality of ready-to-eat Suya sold in Lagos State, Nigeria, and evaluated associated public health risks by identifying prevalent pathogenic bacteria and their contamination levels. Forty Suya samples were collected from vendors across five locations. Selective agars were used to isolate major pathogens, including coliforms, *E. coli*, *Salmonella* spp., *S. aureus*, and *Bacillus cereus*, and to determine their contamination loads. Proximate composition and pH were also measured. All samples contained *B. cereus*, the most frequently isolated bacterium. Mean counts revealed significant contamination: *E. coli* (4.19–4.48 log cfu/g), *S. aureus* (5.31–6.65 log cfu/g), and *Salmonella* spp. (4.17–4.35 log cfu/g). The pH ranged from 6.74 to 8.00. The abundance of pathogenic bacteria highlights inadequate hygiene during preparation and handling, posing substantial risks to consumer health. Ensuring Suya's safety requires strict adherence to Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Point (HACCP) protocols.

Key word: Antimicrobial resistance, *Bacillus cereus*, foodborne pathogens, microbiological contamination, public health safety, suya meat

INTRODUCTION

Meat is a pivotal source of essential nutrients globally, providing nitrogenous compounds, minerals, and vitamins. Its composition includes high moisture (76.78–77.94%), proteins, phospholipids, cholesterol, and fermentable carbohydrates such as glycogen. With a pH range of 5.7–7.2 and water activity (aw) of 0.98–0.99, meat offers an ideal growth medium for diverse microorganisms. Animal-derived foods are therefore classified as high-risk commodities, as they are prone to spoilage through microbial contamination, enzymatic activity, and oxidative reactions (Luning *et al*., 2025). Because bacteria drive much of this deterioration, food hygiene practices are essential (Ovuru *et al.,* 2024).

Suya, a traditional smoked and spiced meat from Northern Nigeria, is a widely consumed delicacy across West Africa. It is typically prepared from cow, ram, or chicken, and may include organ meats such as kidney, liver, and tripe. The meat is finely sliced, marinated in a spice blend containing peanut cake, salt, vegetable oil, and flavourings, and then grilled (Adeyeye *et al.,* 2021; Eke *et al.,* 2012). The marinade, known as *Yaji*, traditionally incorporates the Hausa dehydrated peanut cookie *kulikuli*, along with salt, vegetable oil, and other flavouring agents. The barbecuing process produces a delicacy with numerous regional variations, though Suya remains the most popular form. It is commonly served with dried pepper, Hausa spices, and sliced onions, and is often accompanied by Hausa *Masa* (fermented rice, grain, or corn cakes). Notably, the formulation of *Yaji* lacks a standardised recipe, as ingredient selection is strongly influenced by personal and regional preferences (Okoye *et al.,* 2021).

Coliforms are a type of bacteria that there can be used to indicate the existence of possible pathogens (Collins *et al*., 1989). They are defined by their ability to grow at 35°C with bile salts present and to break down lactose. A lot of people use these organisms to check how clean food and water are, and you can usually find them in the faeces of warm-blooded animals. *Escherichia coli, Salmonella spp., and Staphylococcus aureus* are the primary bacteria that cause foodborne diseases that are very dangerous to public health, especially in poor countries. (Ali *et al.,* 2022; Teniola *et al.,* 2023; Ovuru *et al.,* 2024). Transmission occurs primarily through contaminated food, underscoring the risks associated with meat and meat products. Although many strains are non-virulent, certain variants can acquire pathogenic or toxigenic virulence factors, leading to outbreaks of bacteremia, urinary tract infections, neonatal meningitis, and pneumonia (Szollosi *et al.,* 2020).

Escherichia coli, a Gram-negative, facultative anaerobic, rod-shaped coliform bacterium, primarily inhabits the lower intestine of warm-blooded animals. Although most strains are harmless, pathogenic serotypes such as EPEC and ETEC can cause severe food poisoning and lead to product recalls (Ludwig *et al*., 2020). Non-pathogenic strains contribute to the normal gut microbiota, producing vitamin K_2 and preventing colonization by pathogenic bacteria through mutualistic interactions. *E. coli*, along with other facultative anaerobes, makes up approximately 0.1% of gut microbiota. The faecal–oral route is the main transmission pathway for pathogenic strains (Rivas *et al*., 2015). Colonisation of an infant's gastrointestinal tract within 40 hours of birth, facilitated by exposure to food, water, or handlers, highlights its primary role as a facultative anaerobe in the human gut. Notably, strains that do not acquire virulence-encoding genetic elements remain harmless commensals. This study investigates the contamination and prevalence of key pathogens, including *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, and *Bacillus cereus*, in ready-to-eat Suya, and examines the public health implications for communities where Suya is consumed as a staple food.

MATERIALS AND METHODS

Sample Collection: Forty ready-to-eat (RTE) Suya samples were systematically collected from vendors across five locations in Lagos State, Nigeria: Bariga, Itire, Palm-grove, Ketu, and Ikorodu. Eight samples were obtained per location. Each sample was placed in sterile Ziploc bags and transported under aseptic conditions to the microbiology laboratory for analysis.

Microbiological Analysis

Media and Diluent Preparation: A 3% Tween 80 solution was prepared as the diluent to emulsify samples and neutralize antimicrobial residues. To mitigate chlorine interference, 1 ml of 3% sodium thiosulfate was added per litre of diluent. Agar media were prepared according to manufacturer specifications: Trypticase Soy Agar (Oxoid CM0131), Eosin Methylene Blue Agar (Oxoid CM0069), MacConkey Agar (Oxoid CM0109), and Mannitol Salt Agar (Oxoid CM0085). Media were sterilized at 121°C for 15 minutes, cooled, and dispensed into sterile Petri dishes.

Enumeration of Bacteria: Ten grams of Suya meat were added in 9 ml of Tween 80. Serial dilutions up to 10^{-6} were prepared. The spread plate method (Collins et al., 1989; Teniola & Odunfa, 2002) was employed. Plates were incubated at 37°C for 48 hours. Colonies were enumerated and expressed as colony-forming units per gram (cfu/g). Selective agar plates facilitated presumptive identification: metallic sheen colonies on EMB agar suggested *E. coli*; dark colonies on Salmonella–Shigella agar indicated *Salmonella* spp.; yellow colonies on Mannitol Salt Agar indicated *S. aureus*; pink colonies suggested *B. cereus*.

Isolation and Identification: Distinct colonies were sub-cultured on nutrient agar to obtain pure isolates. Biochemical assays, encompassing Gram staining, catalase, oxidase, citrate, urease, motility, indole, and carbohydrate fermentation, were conducted in accordance with established methods.

(Collins *et al*., 1989; Barrow & Feltham, 2004).

Chemical Analysis: pH was measured using a calibrated pH meter (WPA, India). Proximate composition was determined using AOAC methods (2002; 2023): crude protein (macro-Kjeldahl), crude fat (Soxhlet extraction), ash (muffle furnace at 600°C), crude fibre, and moisture content.

RESULTS

Mean bacterial counts varied by location (Table 1). *E. coli* ranged from 4.19 log cfu/g (Ikorodu) to 4.48 log cfu/g (Ketu). Table 1 revealed that *S. aureus* counts peaked at 6.65 log cfu/g (Ikorodu) and were lowest at 5.31 log cfu/g (Palm-grove). *Salmonella* spp. Ranged from 4.17 log cfu/g (Ikorodu) to 4.35 log cfu/g (Itire). Total viable counts (TVC) were highest in Bariga (7.33 log cfu/g) and lowest in Ketu (6.36 log cfu/g).

Ten bacterial species were identified: *Bacillus cereus*, *Salmonella* spp., *Staphylococcus aureus*, *Klebsiella aerogenes*, *Escherichia coli*, *Proteus mirabilis*, *Enterococcus faecalis*, *Citrobacter farmeri*, *Citrobacter koseri*, and *Kluyvera ascorbate* (Tables 2 and 3). *B. cereus* was consistently isolated from all 40 samples, confirming its prevalence.

Isolates exhibited distinct colonial morphologies (Table 2): *E. coli* (green, smooth colonies), *Salmonella* (black, convex colonies), *B. cereus* (pink, granular colonies), *S. aureus* (yellow, smooth colonies), and others. Biochemical profiles confirmed species identity, with *E. coli* testing positive for indole and lactose fermentation, while *B. cereus* was catalase-positive but indole-negative (Table 3).

Protein content ranged from 28.42% (Palm-grove) to 35.10% (Ketu). Fat content varied between 19.19% (Ketu) and 26.42% (Itire). Ash levels ranged from 1.43% (Bariga) to 2.66% (Palm-grove). Moisture content was highest in Bariga (39.09%) and lowest in Ketu (36.45%) (Table 4).

The pH of Suya samples ranged from 6.74 (Ikorodu) to 8.00 (Palm-grove) (Table 5), indicating a neutral to slightly alkaline environment conducive to bacterial growth.

Table 1: Microbial population (log_{10} cfu/g) of bacterial isolates in ready-to-eat Suya from different Lagos locations

Location	*E. coli*	*S. aureus*	*Salmonella* spp.	*B. cereus*	*Proteus* spp.	TVC
Bariga	4.06 ± 0.03^a	6.13 ± 0.02^d	3.72 ± 0.00^a	3.77 ± 0.02^d	3.48 ± 0.03^a	7.33 ± 0.01^c
Itire	4.22 ± 0.01^b	5.62 ± 0.02^c	4.35 ± 0.02^d	3.48 ± 0.01^b	3.95 ± 0.01^c	6.69 ± 0.01^b
Palm-grove	4.19 ± 0.01^b	5.31 ± 0.02^a	4.14 ± 0.01^{bc}	3.64 ± 0.04^c	4.19 ± 0.01^d	6.37 ± 0.03^a
Ketu	4.88 ± 0.02^d	5.53 ± 0.03^b	4.13 ± 0.03^b	3.20 ± 0.01^a	3.85 ± 0.03^b	6.36 ± 0.01^a
Ikorodu	4.33 ± 0.01^c	6.65 ± 0.05^e	4.17 ± 0.01^c	3.47 ± 0.02^b	3.95 ± 0.02^c	6.69 ± 0.01^b

Keys: Values are mean ± SD of triplicate determinations. Means with the same superscript letter within a column are not significantly different ($p \geq 0.05$). TVC = Total Viable Count

Table 2: Colonial and cellular morphology of bacterial isolates from Suya samples

Isolate	Colony Colour	Surface	Cellular Morphology
Escherichia coli	Green	Smooth, irregular	Short rods, single arrangement
Salmonella spp.	Black	Smooth	Short rods, convex colonies
Bacillus cereus	Pink	Granular, irregular	Short rods
Staphylococcus aureus	Yellow	Smooth	Cocci in clusters
Klebsiella aerogenes	Pink	Slimy	Short rods
Proteus mirabilis	Cream	Smooth	Rod-shaped
Enterococcus faecalis	Cream	Smooth	Spherical cells

Table 3: Biochemical characteristics of bacterial isolates from Suya in Lagos, Nigeria

Bacterial isolates	Biochemical tests										
	Gram Stain	Catalase	Citrate	Urease	Oxidase	Motility	Maltose	Indole	Lactose	Glucose	Sorbitol
Bacillus cereus	+	+	+	–	–	+	+	–	–	+	–
Salmonella spp.	–	+	–	–	–	+	+	–	–	+	+
Staphylococcus aureus	+	+	–	–	–	+	+	–	+	+	–
Klebsiella aerogenes	-	+	+	+	–	+	+	–	+	+	+
Escherichia coli	–	+	–	–	–	+	+	+	+	+	–
Proteus mirabilis	-	+	+	+	–	+	+	–	–	+	–
Enterococcus faecalis	+	–	–	–	–	-	+	–	+	+	–

Keys: + = Positive; – = Negative.

Table 4: Proximate composition of ready-to-eat Suya samples in Lagos, Nigeria

Location	Crude Protein (%)	Crude Fat (%)	Ash (%)	Moisture (%)	Carbohydrate (%)
Bariga	33.42^{c}	24.73^{b}	1.43^{a}	39.09^{d}	1.33^{a}
Ketu	35.10^{d}	19.19^{a}	1.64^{b}	36.45^{a}	7.62^{d}
Itire	30.48^{b}	26.42^{d}	2.40^{c}	38.00^{c}	2.7^{b}
Palmgrove	28.42^{a}	26.29^{c}	2.66^{d}	37.53^{b}	5.1^{c}

Note: Values are the mean. Superscripts indicate statistical differences ($p \leq 0.05$)

Table 5: pH values of Suya samples from locations in Lagos, Nigeria

Location	pH Value
Bariga	7.10 ± 0.01^{c}
Itire	6.80 ± 0.01^{b}
Palm-grove	8.00 ± 0.01^{e}
Ketu	7.60 ± 0.02^{d}
Ikorodu	6.74 ± 0.02^{a}

Note: Values are mean ± SD of triplicate determinations. Superscripts indicate statistical differences ($p < 0.05$).

DISCUSSION

This study demonstrates widespread microbial contamination in RTE Suya sold in Lagos. The consistent isolation of *B. cereus* across all samples highlights its ubiquity and resilience (Table 1). As a spore-forming bacterium, *B. cereus* can survive cooking and produce heat-stable toxins, posing risks of diarrheal and emetic syndromes (Jessberger *et al.,* 2020). Moreover, the existence of these infections frequently correlates with insufficient vendor education and unsanitary procedures, as well as environmental factors such as dust and pest exposure (Mubarak *et al.,* 2025). This widespread contamination of ready-to-eat foods with pathogenic bacteria such as *Bacillus cereus*, *Salmonella* spp., *Shigella* spp., and *Escherichia coli* (Table 1) underscores significant public health concerns due to their potential to cause foodborne illnesses (Ozabor *et al.,* 2023; Onohuean *et al.,* 2025). Such contamination is particularly concerning given that *Salmonella*, *Bacillus*, and *Shigella* are frequently implicated in foodborne outbreaks, necessitating stringent control measures to mitigate public health risks (Njapndounké *et al.,* 2023).

The detection of *Salmonella* spp. in Itire samples (Table 1) suggests inadequate cooking or cross-contamination. *Salmonella* is a leading cause of foodborne illness globally, and its presence in Suya underscores the need for strict hygiene and cooking standards (Soler-Diaz, 2020). Additionally, the identification of *Shigella* species, a prominent cause of severe diarrheal disease, particularly in young children, further exacerbates the public health risk associated with consuming contaminated Suya (Oranusi *et al.,* 2018). Moreover, the isolation of *Escherichia coli* and other coliforms, alongside *Staphylococcus aureus* (Table 1), further indicates potential faecal contamination and poor hygienic practices during handling and preparation, often exceeding the microbial load limits recommended for safe consumption (Njapndounké *et al.,* 2023; Mubarak *et al.,* 2025).

High *S. aureus* counts in Ikorodu samples (Table 1) reflect contamination from food handlers, as the bacterium is commonly found on human skin and mucosa. Its ability to produce enterotoxins and exhibit antibiotic resistance (Mertz *et al.,* 2009; Teniola *et al.,* 2023) raises serious food safety concerns. The proximate composition results indicate that Suya provides a nutrient-rich environment for microbial growth (Table 4). Elevated moisture and protein levels facilitate bacterial proliferation (Table 4), while fat content contributes to flavour but may increase health risks if consumed excessively. High protein and moisture content, coupled with a neutral pH (Table 5), create an ideal substrate for the proliferation of diverse microorganisms, including spoilage bacteria and pathogens (Bello & Bello, 2021). This nutritional profile, coupled with prevalent unsanitary handling practices, elevates the potential for rapid microbial spoilage and the dissemination of foodborne pathogens (Noah, 2020). Enteric bacteria such as *Escherichia coli* were also frequently identified (Table 2 and 3), with *E. coli* being the most prevalent at 47.50% across various street foods, indicating potential faecal contamination from unsanitary water sources used for washing utensils and hands during preparation (Tanyitiku *et al.,* 2025; Mubarak *et al*., 2025). The presence of *Enterobacter aerogenes*, *Serratia rubidaea*, and *Klebsiella pneumoniae* (Table 2 and 3) further emphasises the pervasive nature of faecal–oral contamination in the Suya production chain, underscoring significant public health risks (Bello & Bello, 2021). This issue is further intensified by the fact that numerous Suya processors lack professional training in food preparation, leading to insufficient hygienic practices and a heightened risk of contamination. (Falegan *et al*, 2017). The isolation of *Escherichia coli* and *Enterobacter* spp. in Suya samples, though in lower occurrences, further supports this conclusion, suggesting potential contamination originating from the environment, equipment, or even the spices used in preparation (Falegan *et al.,* 2017). The presence of these diverse bacterial genera, including *Escherichia coli*, *Enterobacter* spp., *Staphylococcus aureus*, and *Bacillus* spp. (Table 1, 2 and 3), aligns with broader reports on microbial contamination in Suya, highlighting persistent food safety challenges in its production and distribution (Falegan *et al*., 2017; Mubarak *et al*., 2025).

Overall, the findings highlight poor hygiene practices among vendors and the absence of standardised food safety protocols. The implementation of GMP and HACCP systems is crucial for reducing contamination and ensuring consumer health safety. This necessitates urgent intervention through comprehensive food safety education for vendors, coupled with regular monitoring and enforcement by regulatory bodies to ensure compliance with established food hygiene standards (Jegede *et al*., 2020; Njapndounké *et al*., 2023). Additionally, regular microbiological surveillance of RTE Suya can provide critical data for identifying contamination hotspots and assessing the effectiveness of implemented control measures (Njapndounké *et al*., 2023; Ibrahim *et al*., 2025).

Furthermore, the observed microbial loads (Table 1) often exceed established public health standards for ready-to-eat foods, necessitating urgent interventions to mitigate potential outbreaks of foodborne illnesses (Njapndounké *et al.,* 2023). These interventions must include comprehensive training for Suya producers on personal hygiene, appropriate handling, and essential control points during processing, in accordance with the identified sources of contamination, including utensils and raw meat. (Edema *et al.,* 2008). Regular monitoring and enforcement of these safety standards by regulatory bodies are also crucial to ensure compliance and reduce the prevalence of pathogenic bacteria such as *Staphylococcus aureus*, *Escherichia coli*, and *Klebsiella pneumoniae* in RTE Suya (Mubarak *et al.,* 2025). Such measures are essential to elevate the safety profile of this popular street-vended meat product, moving it from the current unsatisfactory range to acceptable or even satisfactory limits based on international microbiological standards for ready-to-eat foods (Edema *et al.,* 2008).

CONCLUSION

This study evaluated the microbiological quality of ready-to-eat Suya sold in Lagos, Nigeria, and the results point to clear public-health concerns. All 40 samples collected from five locations showed substantial microbial contamination, suggesting that hygiene lapses during preparation and handling are widespread. Pathogenic organisms were prominent: *Bacillus cereus* appeared in every sample, while *Escherichia coli* (4.19–4.48 log cfu/g), *Staphylococcus aureus* (5.31–6.65 log cfu/g), and *Salmonella* spp. (4.17–4.35 log cfu/g) were consistently detected at levels that exceed acceptable limits for ready-to-eat foods. Ten bacterial species, mostly well-known foodborne pathogens, were identified, including *Klebsiella aerogenes*, *Proteus mirabilis*, *Enterococcus faecalis*, *Citrobacter farmeri*, *Citrobacter koseri*, and *Kluyvera ascorbate*. The Suya samples had pH values between 6.74 and 8.00, a neutral to slightly alkaline range that, combined with the product's high moisture and protein content, supports rapid microbial growth. Taken together, these findings highlight a significant food safety problem. The microbial loads reported here pose a serious risk to consumers and reflect gaps in basic hygiene and handling practices. Strengthened food safety protocols, better vendor training, and more consistent regulatory oversight are urgently needed to reduce the likelihood of foodborne disease linked to Suya in Lagos.

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