

Antibiogram of Bacteria of Public Health Importance in Processed Beef and Chicken Suya Sold in Umuahia, Abia State, Nigeria

Ifediora, A.C*., Edward, K.C and Amaliri, E. D.

Department of Microbiology; Michael Okpara
 University of Agriculture, Umudike, Abia State, Nigeria.

*Corresponding Author: afoma20@yahoo.com

ABSTRACT

The antibiogram of bacteria of public health importance isolated from processed roasted beef and chicken (suya) sold in Umuahia, Abia State was investigated. Thirty samples of beef and chicken suya were bought from three different suya spots in Umuahia. The aerobic bacteria plate count was conducted using the pour plate method for the isolation and enumeration of isolated colonies. Isolates were identified by standard cultural and biochemical tests while antibiotic resistance was determined by Kirby-Bauer disc diffusion method. The total viable bacteria count ranged from 5.2×10^6 to 2.31×10^7 CFU/g. The seven (7) bacterial genera identified were; *Staphylococcus aureus*, *Escherichia coli*, *Enterobacter* spp., *Salmonella* spp., *Shigella* spp., *Proteus* spp. and *Citrobacter* spp. *Escherichia coli* and *Staphylococcus aureus* recorded highest percentage occurrence of 12(40%) and 7(23%) respectively, while *Proteus* spp., and *Citrobacter* spp. had the lowest percentage of occurrence of 1(3.33%) each. These isolates were found to be resistant to a number of popular antibiotics. *Staphylococcus aureus* was susceptible to chloramphenicol and gentamycin but resistant to amoxicillin, erythromycin, ciprofloxacin, streptomycin. The gram-negative bacteria were resistant to all the antibiotics used. The Multiple Antibiotic Resistance Index (MARI) ranged from 0.4 to 0.8 for the organisms. The resistance of most of these isolates to antibiotics highlights the reason for the increasing failure in the treatment of bacterial infections. This study revealed that beef and chicken suya sold in these areas studied were microbiologically unsafe and below acceptable standard for human consumption.

Keywords: Umuahia, Suya, Roasted Beef and Chicken, *E. coli*, *Shigella* spp. Antibiotic Resistance, MAR Index

Introduction

Suya which means roasted or smoked beef or boneless animal meat is a spicy, traditional meat product that is commonly produced by the Hausas in Northern Nigeria (Felagan *et al.*, 2017; Bello and Bello 2022) but has now been introduced to various parts of the country. In Nigeria, “suya” is regarded as a delicacy that transcend socio-economic, cultural, religious, and educational boundaries (Egbebi and Muhammad, 2016; Adesoji *et al.*, 2019).

Meat, according to Giromini and Givens (2023), refers to the flesh of animals consumed as food that provides essential nutrients and also plays a central role in human diets. In the case of *suya*, it is typically prepared from boneless lean cuts of mutton, beef, goat or chicken, which are sliced, spiced, coated with spice mixture produced from groundnut cake (*kuli-kuli*),

Maggi seasoning, salt, ginger and other aromatic spices like black chili pepper, Calabash nutmeg, negro pepper, garlic powder, smoked paprika powder, cayenne pepper, salt and ground onions. After that, the meat with stakes is left to simmer beside a roaring charcoal fire (Wata *et al.*, 2024).

The preparation of *suya* emerged as one of the varieties of preservation techniques for improving the keeping quality and shelf life of meat in order to prevent its spoilage (Ogbonnaya and Imodiboh, 2009; Apata *et al.*, 2013). During roasting, the spiced meat is placed on skewers or a wire mesh over an open charcoal fire and continuously turned to ensure even cooking and browning.

Groundnut oil and additional seasoning are frequently brushed onto the meat throughout the process to enhance tenderness, flavor, and appearance.

This traditional preparation method, though flavorful, often involves open-air handling and exposure, which can contribute to microbial contamination if proper hygiene and processing standards are not maintained (Davis *et al.*, 2022).

Additionally, Suya meat contamination with microorganisms and parasites can occur during exposure on the streets due to the high protein content (Konne *et al.*, 2018). Concerns have been raised about the hygiene of suya meat sold on the streets as there have been sporadic cases of gastroenteritis after the consumption.

The microbial load of meat products increases under favorable conditions such as optimal pH, temperature, moisture, and nutrient availability. *Pseudomonas spp.*, *Bacillus spp.*, *Crude Typhimurium spp.*, *Schwartzella spp.*, *Aeromonas spp.* are usually considered to be the dominant communities in cold meat and poultry packed under aerobic conditions (Odeyemi *et al.*, 2020). Contamination often occurs during slaughtering, evisceration, washing, handling, or through unhygienic equipment, spices, and environmental exposure. With the growing consumption of suya a ready-to-eat meat delicacy there is increased risk of foodborne infections such as gastroenteritis due to improper hygiene and handling by suya processors (Lianou *et al.*, 2017).

This highlights the public health concern associated with microbial contamination of processed beef and chicken suya, especially in developing regions where meat serves as a major protein source. Worthy of note is studies carried out by some researchers implicating suya spices as harboring potential pathogens of public health significance which could give rise to food poisoning outbreak (Bakobie *et al.*, 2017; Amare *et al.*, 2019).

It is also worrisome that some pathogens isolated from suya showed resistance to most commonly prescribed antibiotics thus posing a threat to the management of food borne infections (Bello and Bello, 2020).

This study was carried out to evaluate the bacterial load, the antibiotic resistance and sensitivity patterns of bacterial pathogens associated with beef and chicken suya sold in Umuahia, Abia State.

Materials and Methods

Study Area

This study was conducted in Umuahia North Local Government Area of Abia State, which is geographically located at latitude 5.53°N, longitude 7.49°E and 152 meters elevation above sea level. It is situated in the Eastern Nigeria having a high population density and harbors commercial centers, governmental organizations and academic institutions. The suya samples for this study were drawn from three selected Suya locations namely; Amawom Junction, Orpet Junction and Azikiwe Road suya spots.

Sample Collection

Beef and chicken suya meat samples from each location were aseptically collected into labelled sterile containers. A total of 30 samples were collected for the study; five samples from each suya spot. The samples were immediately taken for analysis at the Microbiology laboratory in Michael Okpara University of Agriculture, Umudike, Abia State and were analyzed within 2 hours of collection.

Microbiological Analysis

Total aerobic bacteria plate count

The total viable aerobic bacteria counts were carried out according to standard procedures. Each suya sample was carefully removed with sterile forceps and about 25g of the sample was weighed using an analytical balance (Model SF-400, India) and aseptically mashed in a sterile laboratory type mortar and pestle. Ten percent of the stock solution was prepared by weighing 10g into 90ml of sterile buffer saline, properly shaken and sieved. A 5-fold serial dilution of each sample was prepared using sterile buffered saline. The serial dilution was made as described by Adeleye *et al.*, 2022).

Isolation and Enumeration of Bacteria

The enumeration of bacteria in the sample was conducted using the pour plate method. An aliquot of 0.1ml from each of the test tubes labelled 10⁵ was collected and inoculated into sterile Petri dishes.

It was allowed to settle; and overlaid with cooled 20 ml of Nutrient Agar and another inoculated plate was overlaid with MacConkey agar respectively. The cultured plates were swirled in all directions for even distribution of the inoculum. Thereafter, the cultured Petri plates were incubated at 37°C for 24 hours. The bacteria colonies which developed on the plates after the incubation were counted using the digital colony counter and expressed as colony forming units per gram (CFU/g) of Suya using the equation below:

$$\text{CFU/ml} = \frac{\text{Number of colonies} \times \text{dilution factor}}{\text{Volume}}$$

Where,

CFU = colony forming unit

Discrete colonies were picked out after morphologically examination and purified by re-streaking on nutrient agar plates. They were then stored on nutrient agar slants at 4°C for further biochemical characterization and identification

Characterization and Identification of Isolates

Identification of different isolated pure cultures was carried out by gram staining and biochemical reactions. These included, catalase, oxidase, Indole, Methyl Red, Voges Proskauer, Citrate Utilization, Motility, and sugar fermentation tests in accordance with standard microbiological methods (Cheesbrough, 2006).

Antibiotic Susceptibility Testing

The antibiotic susceptibility of the isolates was determined on Mueller Hinton (MH) agar using the Kirby-Bauer Disk Diffusion method. The susceptibility of the isolates were tested against Augmentin (Au-30µg), Cotrimoxazole (COT-5µg), Chloramphenicol (C-30µg), Cloxacillin (CXC-5µg) Erythromycin (ERY-15µg), Gentamicin (GEN-10µg), Nalidixic acid (NAL-30µg), Nitrofurantoin (NIT-30µg), Ofloxacin (OFX-5µg) and Tetracycline (T-30µg).

Few colonies of the test organisms were picked with a sterile inoculating loop and suspended in 2ml of sterile saline. The saline tube (inoculum tube) was shaken to create a smooth suspension and the turbidity of the suspension was measured and adjusted to the density of 0.5 McFarland in order to standardize the inoculum size.

The isolate was aseptically streaked with the aid of sterile swab sticks on sterile Mueller Hinton agar plates. The appropriate antimicrobial-impregnated disk was placed on the surface of the agar using sterile forceps and the plates were incubated at 37°C for 24 hours.

Following the incubation of the plates, the zone of inhibition that developed around each disc was measured from underneath each plate with the aid of a ruler and recorded in millimeter (mm). The diameters measured were compared with zone diameter interpretative standards in the updated Disk Diffusion Zone Diameter Chart of Clinical and Laboratory Standards Institutes (CLSI 2021). The comparison was done in order to determine whether an organism was susceptible, intermediate or resistant to the antibiotics it has been tested against. All measurements were made with unaided eye while viewing at the back of the cultured Petri dish. The measured diameter of the inhibition zone included the diameter of the disk.

Determination of Multiple Antibiotic Resistance (MAR) Index

The MAR Index was determined from the result of the antibiotic susceptibility test, MARI was calculated as:

$$\text{MAR Index} = \frac{\text{Number to which organisms are resistant}}{\text{Total number of antibiotics tested}}$$

Results

The results of the total aerobic bacteria count (CFU/g) of beef and chicken suya samples from the different locations are presented in Table 1. A total of 3853 counts were recorded across the 30 samples that were selected. The overall colony forming unit ranged from 5.2×10^6 CFU/g to 2.31×10^7 CFU/g.

Table 2 presents the distribution of the identified isolates from various beef and chicken suya samples analyzed. The number of isolates varied according to samples. In the overall, seven bacteria species were isolated; and they included *Escherichia coli*, *Enterobacter* spp., *Staphylococcus aureus*, *Shigella* spp. *Salmonella* spp.

Citrobacter spp. and *Proteus* spp. *E. coli* had the highest percentage occurrence of 12 (40%), followed by *Staphylococcus aureus* 7(23.33), while *Proteus* spp. 1(3.33) and *Citrobacter* spp. 1(3.33) had the lowest occurrence respectively.

Figure 1 shows the antibiotic susceptibility pattern of the Gram-positive isolate. All isolates of *S. aureus* exhibited 100% resistance to Ciprofloxacin. Figure 2 shows the antibiotic susceptibility pattern of the Gram-negative isolates, antimicrobial agents tested against and as well as the zones of inhibition of the isolate.

While the multiple antibiotics resistance index (MARI) observed in this study are presented in Table 3. MARI = 0.4 to 0.8 was observed among the Gram negative isolates while 0.5 to 0.8 was obtained with gram positive isolates.

Table 1: Aerobic count of chicken and beef suya samples from different locations

Sample	Bacterial Loads (CFU/g) of Suya from the different Locations					
	Beef Suya			Chicken Suya		
	Amawom	Orpet	Azikiwe	Amawom	Orpet	Azikiwe
1	1.42 x 10 ⁷	7.3 x10 ⁶	1.04 x 10 ⁷	9.6 x 10 ⁶	1.56 x 10 ⁷	1.95 x 10 ⁷
2	1.34 x 10 ⁷	8.1 x 10 ⁶	9.9 x 10 ⁶	1.20 x 10 ⁷	1.36 x 10 ⁷	2.31 x 10 ⁷
3	1.58 x 10 ⁷	5.2 x 10 ⁶	9.9 x 10 ⁶	1.28 x 10 ⁷	1.30 x 10 ⁷	1.83 x 10 ⁷
4	1.43 x 10 ⁷	5.4 x 10 ⁶	8.7 x 10 ⁶	1.24 x 10 ⁷	1.58 x 10 ⁷	2.05 x 10 ⁷
5	1.21 x 10 ⁷	6.0 x 10 ⁶	9.2 x 10 ⁶	1.32 x 10 ⁷	1.44 x 10 ⁷	2.16 x 10 ⁷

Table 2: The distribution and percentage occurrence of the Isolates according to samples

Microorganisms Isolated	Beef Suya			Chicken Suya			Total	Occurrence (%)
	Amawom	Orpet	Azikiwe	Amawom	Orpet	Azikiwe		
<i>S. aureus</i>	1	3	-	1	2	-	7	23.33
<i>Enterobacter</i> sp	-	-	-	-	-	2	2	6.67
<i>E. coli</i>	1	3	2	1	1	4	12	40
<i>Shigella</i> spp	-	1	-	-	1	-	2	6.67
<i>Salmonella</i> spp	-	2	-	-	2	1	5	16.67
<i>Proteus</i> spp	-	-	-	1	-	-	1	3.33
<i>Citrobacter</i> spp	-	-	-	-	-	1	1	3.33

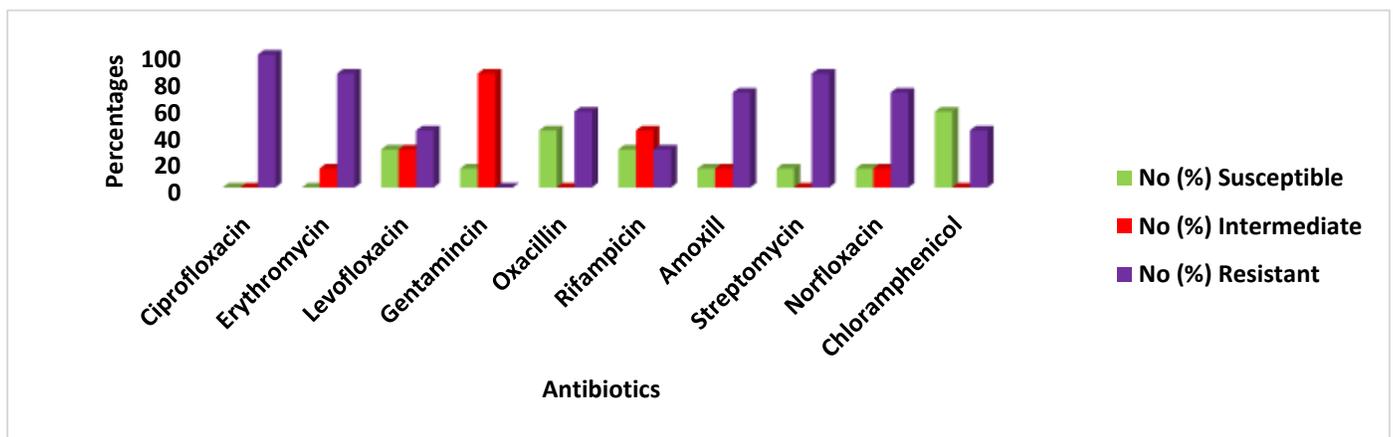


Fig. 1: Antibiotic susceptibility pattern (%) of the Gram-positive bacteria isolated from Suyas

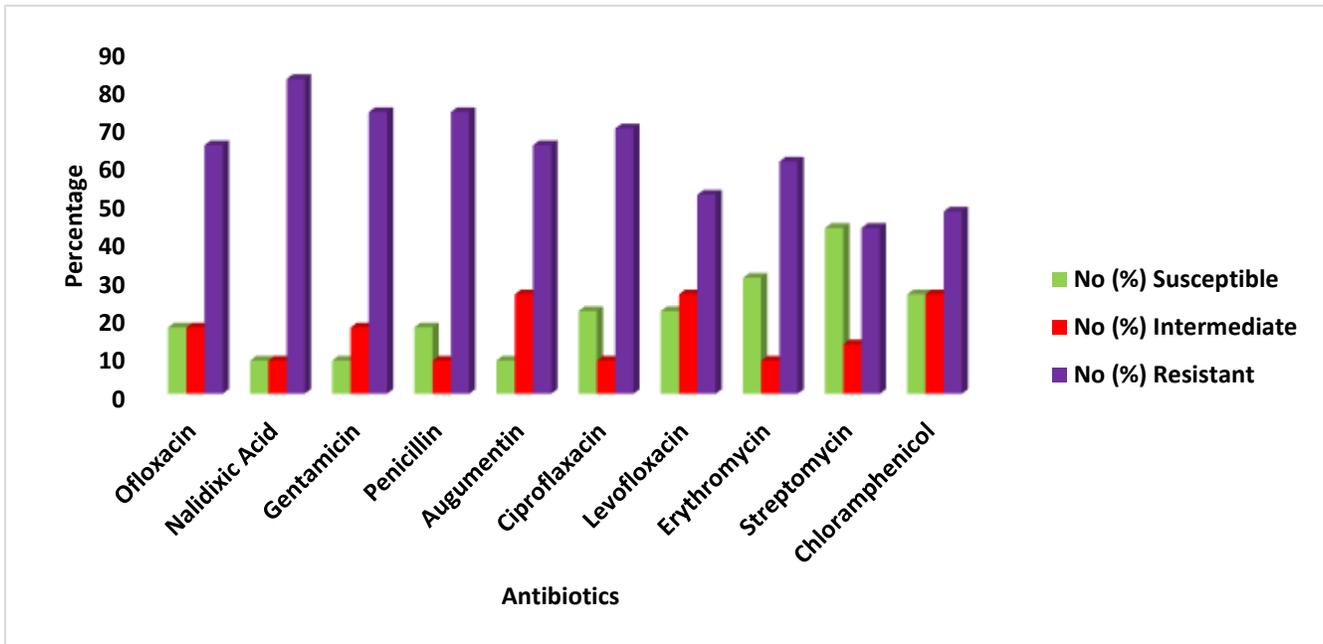


Fig. 2: Antibiotic susceptibility pattern (%) of the Gram-negative bacteria isolated from Suyas

Table 3: MAR Index of the Isolates

Gram Negative Isolates	MAR Index	Gram Positive Isolates	MAR Index
<i>Escherichia coli</i> (EC ₁)	0.5	<i>Staphylococcus aureus</i> (S1)	0.6
<i>Escherichia coli</i> (EC ₂)	0.8	<i>Staphylococcus aureus</i> (S2)	0.6
<i>Escherichia coli</i> (EC ₃)	0.6	<i>Staphylococcus aureus</i> (S3)	0.5
<i>Escherichia coli</i> (EC ₄)	0.7	<i>Staphylococcus aureus</i> (S4)	0.7
<i>Escherichia coli</i> (EC ₅)	0.7	<i>Staphylococcus aureus</i> (S5)	0.8
<i>Escherichia coli</i> (EC ₆)	0.8	<i>Staphylococcus aureus</i> (S6)	0.8
<i>Escherichia coli</i> (EC ₇)	0.5	<i>Staphylococcus aureus</i> (S7)	0.7
<i>Escherichia coli</i> (EC ₈)	0.6		
<i>Escherichia coli</i> (EC ₉)	0.6		
<i>Escherichia coli</i> (EC ₁₀)	0.7		
<i>Escherichia coli</i> (EC ₁₁)	0.7		
<i>Escherichia coli</i> (EC ₁₂)	0.5		
<i>Enterobacter</i> (EN1)	0.4		
<i>Enterobacter</i> (EN2)	0.4		
<i>Shigella</i> (SH1)	0.5		
<i>Shigella</i> (SH1)	0.5		
<i>Salmonella</i> (SA1)	0.6		
<i>Salmonella</i> (SA2)	0.6		
<i>Salmonella</i> (SA3)	0.7		
<i>Salmonella</i> (SA4)	0.6		
<i>Salmonella</i> (SA5)	0.6		
<i>Citrobacter</i> (C1)	0.8		
<i>Proteus</i> (P1)	0.8		

Discussion

The data from this research had a total aerobic plate count values ranging from 5.2×10^6 to 2.31×10^7 CFU/g, this is above the acceptable level by Microbiological Guidelines for Food (for ready-to-eat food in category 1). This finding is suggestive of high level of contamination and underscores environmental and public health concern. However, the values in this study are higher compared with 4.0×10^3 CFU/g to 8.4×10^4 CFU/g reported by Iche and Anyanwu (2022) in Nekede Owerri, Imo State Nigeria but lower compared to 4.0×10^8 to 2.2×10^9 CFU/g reported by Amaeze et al. (2016) in Abuja.

High bacterial counts have been linked to insufficient vendor hygiene and improper handling of meat (Akinyele et al., 2024)). Suya spices have also been implicated as a source of microbial contamination during suya preparation. These spices are mixed in uncovered containers and left exposed to environmental contaminants (Bello and Bello 2022). The high microbial loads of the beef and chicken suya poses a risk of foodborne infection and therefore proper hygiene must be ascertained to ensure safety from infection (Odetokun et al., 2021).

The isolation of different pathogenic microorganisms from both chicken and beef suya calls for concern; more worrisome is the high prevalence of *E. coli*. The organism *E. coli* is a commensal inhabitant of gastrointestinal tract of mammals and causes several infections in both humans and animals. The pathogenic strains often cause severe type of human diarrhea (Ahmed et al., 2021). Infections caused by different pathotypes of *E. coli* are of tremendous public health concern. The isolation of *E. coli* from the Suya samples in this area suggests poor handling of the meat, poor sanitation practices and lack of education among suya sellers which if not addressed might constitute risk for food borne illness (Datok et al., 2021). This is similar to result obtained by Onuorah et al. (2015) who reported *Escherichia coli* (34.3%) as the most frequent organism isolated from suya sold in Awka.

The organism *Enterobacter* spp is an opportunistic bacterium that is found in soil, sewage, water etc. It is known to be widely resistant to most antibiotics including the cephalosporins (Peirano et al., 2018).

The presence of *Staphylococcus aureus* also poses a high risk of food infection. This organism can produce toxins as seen in the case of typhoid toxin in *Salmonella typhi* infection (Chong et al., 2017) which are heat resistant and cannot be destroyed through cooking. The presence of *Proteus species* implies that the meat could have been contaminated with human intestinal normal flora. This organism could also be found in external habitats such as water bodies and soil. It is a gram-negative bacillus which colonizes both the skin and oral mucosa.

Salmonella species and few other microorganisms isolated from the beef Suya meat across the three locations were also isolated in the work done by Konne et al., (2018). Contaminations with these microbes could be as a result of lack of adherence to Hazard Analysis Critical Control Point (HACCP) which is essential for the control of some organisms such as *Salmonella species*, *Escherichia coli* and *Proteus species*. Adherence to this method could reduce the presence of potentially pathogenic microbes in Suya meat through monitoring the hygiene levels of suya personnel and the surrounding environment.

When *Staphylococcus aureus* was tested against some common antibiotics, it was found that the isolate was 100% resistant to ciprofloxacin and high degrees of resistance to erythromycin, streptomycin and norfloxacin. More worrisome is the degree of resistance to oxacillin which a beta lactam antibiotic noted for high antimicrobial activity against *Staphylococcus* spp. This raises serious concerns about treatment options for infections caused by these organisms Likewise, all the isolated strains of gram-negative bacteria were resistant to most of the common antibiotics and this implies that the treatment of the infections they cause may be difficult with the use of these antibiotics. This highlights the reason for the increasing failure in the treatment of bacterial infections in humans.

A striking finding from this study is that each bacterial isolate tested had a MARI value greater than 0.2. Majority had values of 0.5 and above, with several as high as 0.8. This high MARI indicates that all the tested isolates are multi-drug resistant (MDR). They were resistant to a significant proportion of the antibiotics they were tested against.

This is a serious public health concern, as these MDR bacteria can be transmitted directly to consumers through food. The findings from this study are alarmingly consistent with a global body of research on antibiotic resistance in foodborne bacteria, particularly from meat products. A study by Odetokun *et al.* (2020) on ready-to-eat meat (suya, kilishi) in Nigeria reported similarly high MARI values for *E. coli* and *Salmonella* spp., with many isolates showing resistance to critically important antibiotics like beta-lactams and fluoroquinolones.

Research on chicken meat in a study by Velázquez-Ordoñez *et al.* (2021) identified it as a major reservoir for MDR bacteria like *E. coli* and *Salmonella* which directly supports the findings of this present study. Equally, the study of Adzitey *et al.* (2022) on beef and chicken in Ghana reported similarly alarming MARI values for *E. coli* and *S. aureus*, with over 60% of isolates being multi-drug resistant. The high MARI values is of particular concern as MDR bacteria from food animals can transfer their resistance genes to human pathogens, rendering common infections difficult to treat (Founou *et al.*, 2021).

The antibiotic resistance in human might have come as a result of consuming food products which host the resistant bacteria. Most times the resistance is caused by improper administration of antibiotic dose, drug abuse or ignorance of the use of antibiotics. It could be caused by taking the wrong drugs. This often happens when a patient engages in self prescription instead of consulting a physician. Some also prefer cheap and ineffective antibiotic due to poverty. In this case not treating a bacterial infection with the right drug worsens the case.

Conclusion

This study revealed a high bacterial load and the presence of potential pathogens in beef and chicken suya sold in Umuahia. Apparently, this calls for surveillance and monitoring of the microbial safety of roasted and vended foods. The high MAR index obtained in this study is an indication that the general public should be enlightened on the problems associated with inappropriate use of antibiotics which include; therapeutics failure, development of resistance and increased health-care costs.

References

- Adeleye, A. O., Sim, K. M. & Yerima, M. B. (2022). Bacteriological Quality Assessment of Ready-To-Eat Hawked Suya in Dutse Urban, Northwest Nigeria. *Stamford Journal of Microbiology*, 12(1), 25-30.
- Adesoji, A. T., Onuh, J. P., Musa, A. O. & Akinrosoye, P. F. (2019). Bacteriological qualities and antibiogram studies of bacteria from “suya” and smoked fish (*Clarias gariepinus*) in Dutsin-Ma, Katsina State, Nigeria. *Pan African Medical Journal*, 33, 219.
- Adzitey, F., Assoah, B. & Amoako, D. G. (2022). Prevalence and antibiotic resistance of *Escherichia coli* and *Staphylococcus aureus* from beef and chicken in Ghana. *Journal of Food Safety*, 42(1), e12955.
- Ahmed W, et al. 2021. Characterization of enterococci-and ESBL-Producing *Escherichia coli* isolated from milk of bovines with mastitis in Egypt. *Pathogens*, 10 (2), 97.
- Akinyele, H. A., Oluwaseun, A. A., Tunde, A. K., & Oluwaseun, A. C. (2024). Detection and antibiogram of bacterial contaminants n some commonly consumed indigenous street vended foods in Kasua Central Market in Kaduna North, Kaduna State, Nigeria. *Dutse Journal of Pure and Applied Sciences*, 10(1a), 100-110.
- Amaze N., Aboh M. I., Amiohu F. E., Olatunji T. & Oladosu P.(2016). Microbial profile, antibiotic sensitivity and heat resistance of bacterial isolates from commercial roasted beef (suya) in Abuja, Nigeria. *Journal of Phytomedicine and Therapeutic*, 15(2), 22 – 30.
- Amare A, et al. 2019. Bacteriological profile, antimicrobial susceptibility patterns of the isolates among street vended foods and hygienic practice of vendors in Gondar town, Northwest Ethiopia: a cross sectional study. *BMC microbiology*, 19 (1), 1-9.
- Apata E, Kuku I, Apata O & Adeyemi K (2013). Evaluation of Suya (Tsire)-An intermediate moisture meat product in Ogun State, Nigeria. *Journal of food research*, 2 (1), 87-93.

- Bakobie N, Addae, A.S., Duwiejuah, A.B., Cobbina, S.J & Miniyila, S. (2017). Microbial profile of common spices and spice blends used in Tamale, Ghana. *International journal of food contamination*, 4 (1), 1-5.
- Bello, T.K. & Bello, O.O. (2022). Public health implications of antibiotic-resistant bacteria associated with Suya spices in Nigeria. *Journal of Nutrition and Food Security (JNFS)*, 7(3), 340-354.
- Bello, T.K. & Bello, O.O. (2020). Bacteriological safety of suya, a ready-to-eat beef product, and its association with antibiotic-resistant pathogens in Nigeria. *Carpathian Journal of Food Science and Technology, Special*, 12(5), 81-98.
- Chessbrough, M. (2006). District laboratory practice in tropical countries. 2nd ed. London: Cambridge University Press.
- Chong A, Lee S, Yang Y, Song J. (2017). The role of typhoid toxin in *Salmonella typhi* virulence. *Yale Journal Biology and Medicine*, 90(2), 283-290.
- Clinic and Laboratory Standards Institute (CLSI) guidelines for 2021 Performance standard for Antimicrobial Susceptibility Testing; Thirty- One edition Information Supplement. CLSI Document M100-s31. Clinic and Laboratory Standards Institute, Wayne.
- Datok, D.W., Ishaleku, D., Tsaku, P.A., Agya, E.O. & Adoga, M.P. (2021). Multidrug resistance to commonly prescribed antibiotics in *Escherichia coli* isolated from barbecued beef (*Suya*) sold in a Nigerian City. *Pan Afr Med J.*, 19, 39-50.
- Davis, H., Magistrali, A., Butler, G. & Stergiadis, S. (2022). Benefits from fatty acids in organic and grass-fed beef. *Foods*, 11(4), 646.
- Egbebi, O. A. & Muhammad, A. A. (2016). Microbiological analysis of ready-to-eat suya meat sold in Owo, Ondo State. *International Journal of Innovative Biochemistry and Microbiology Research*, 4(2), 11–15.
- Falegan, C. R., Akoja, S. O. & Oyarekua, M. A. (2017). Microbiological assessment of suya (sliced roasted beef) sold in Ado-Ekiti Metropolis, Ekiti State, Nigeria. *MOJ Biology and Medicine*, 2(3), 53-55.
- Founou, L. L., Founou, R. C., & Essack, S. Y. (2021). Antibiotic resistance in the food chain: A developing country-perspective. *Frontiers in Microbiology*, 12, 675-690.
- Giromini, C. & Givens, D. I. (2023). Meat in the diet: Differentiating the benefits and risks of different types of meat. *Foods*, 12(12), 2363.
- Iche, I. & Anyanwu, G.O. (2022). Isolation and characterization of bacteria associated with hawked Suya meat *J. Emerg. Technol. Innov. Res.*, 9 (4), h329 – h341.
- Konne, F. E., Monsi, T. P. & Wokem, G. N. (2018). Bacteriology of suya meat sold in Bonny Local Government Area, Rivers State. *Asian Journal of Medicine and Health*, 10(4), 1-7.
- Lianou, A., Panagou, E. Z. & Nychas, G. J. E. (2017). Meat safety—I: Foodborne pathogens and other biological issues. In: *Lawrie's Meat Science (8th ed., pp. 521–552)*, Woodhead Publishing.
- Odetokun, I. A., Ball, C. & Onwugamba, F. C. (2020). Antimicrobial resistance in food-borne bacteria from ready-to-eat foods in Nigeria: A systematic review and meta-analysis. *Journal of Global Antimicrobial Resistance*, 22, 648-656.
- Odetokun, I. A., Borokinni, B. O., Bakare, S. D., Ghali-Mohammed, I. & Alhaji, N. B. (2021). A cross-sectional survey of consumers' risk perception and hygiene of retail meat: a Nigerian study. *Food Prot. Trends*, 41(3), 274-283.
- Odeyemi. O.A., Alegbeleye, O.O., Strateva, M. & Stratev, D. (2020). Understanding spoilage microbial community and spoilage mechanisms in foods of animal origin. *Compr Rev Food Sci Food Saf*, 19, 311–31.
- Ogbonnaya, C. & Imodiboh, L. I. (2009). Influence of storage conditions on shelf-life of dried beef product (kilishi). *World Journal of Agricultural Sciences*, 5(1), 34-39.
- Onuorah, S. O. I., Odibo, F. & Orji, M. (2015). An assessment of the bacteriological quality of tsire-suya (grilled beef) sold in Awka, Nigeria. *American Journal of Life Science Research*; 3(4), 267-292.

Peirano G, et al. 2018. Genomic epidemiology of global carbapenemase-producing *Enterobacter* spp., 2008–2014. *Emerging infectious diseases*, 24(6), 1010-1019.

Velázquez-Ordoñez, V., Valladares-Carranza, B., & Zamora-Espinosa, J. L. (2021). Antimicrobial resistance in *Escherichia coli* isolated from retail

Chicken meat in Mexico. *Journal of Food Protection*, 84(7), 1178-1185.

Wata, I., Musa, H., Abdullahi, K., Abdullahi, I., Hafsat, S. B. & Adamu, A. M. (2024). Isolation and identification of bacteria from hawked suya meat sold within Katsina Metropolis. *Sahel Journal of Life Sciences (SAJOLS)*, 2(1), 179–184.