



Evaluation of the Antibiotic Resistance Profiles of Bacterial Isolates from Wet and Dry Grinding Machines in Benin City, Nigeria



Ologbosere, Ademola Oluwabunmi^{1*} & Adua, Osaretin²

^{1,2}Department of Microbiology, Faculty of Life Sciences, University of Benin, Benin City, Edo State, Nigeria.

*Corresponding Author Email: oluwabunmi.ologbosere@uniben.edu

ABSTRACT

The contamination of grinding machines with microbes can enable transmission of food pathogens especially in the open markets where the standards of hygiene are minimal. This study aimed to assess the bacteriological quality and antibiotic resistance of the wet and dry grinding machines in selected markets in Benin City, Nigeria. Swab samples of the machines were obtained aseptically and subjected to standard microbiological methods. The total heterotrophic bacterial count ranged from $3.17 \pm 0.28 \times 10^6$ cfu/cm² and $5.10 \pm 0.04 \times 10^6$ cfu/cm² for the dry and wet grinding machines. The highest bacteria count was obtained in the wet grinding machine in Uselu market. The total coliform count varied between $1.16 \pm 0.08 \times 10^6$ cfu/cm and $1.64 \pm 0.20 \times 10^6$ CFU/cm. A total of five bacterial genera were isolated they include *Bacillus* spp., *Klebsiella* spp., *Staphylococcus aureus*, *Enterobacter* spp. and *Citrobacter* spp., with percentages of 26.47%, 23.52%, 20.60%, 17.65% and 11.76%, respectively. Phenotypic virulence test of the bacteria isolates indicated that *Klebsiella* spp., *Citrobacter* spp., *Staphylococcus aureus* and *Enterobacter* spp. had DNase activity. Lipase activity was observed in all isolates except *Enterobacter* spp. The isolated bacteria showed resistance to colistin, cephalexin and tetracycline but sensitive to ciprofloxacin, gentamycin and clindamycin. The multiple antibiotic resistance of the pathogens ranged from 0.50-0.87 CFU/cm². These findings demonstrate that grinding machines serves as reservoir for the transfer of pathogenic and multi-drugs resistance bacteria isolates, emphasizing the need for routine microbial monitoring to reduce the risk of foodborne diseases.

Keywords:

Grinding machines,
Foodborne pathogens,
Multiple antibiotic
Resistance,
Virulence factors,
Market

INTRODUCTION

The safety of food is an important issue for global public health, particularly in developing countries where food processing and vending in the informal sector is the most common (Jaffee and Henson, 2024). In Nigeria, traditional market serves as the center of food preparation and distribution where electric grinding machines are used to pulverize condiments, spices, grains and other foodstuffs such as pepper, tomatoes, egusi, ogbono, crayfish into pastes and powders which are vital in the preparation of meals on daily basis (Azuonwu *et al.*, 2019). These devices are generally manufactured locally and utilized in open markets, while they offer considerable ease, they also constitute a high risk of microbial contamination due to inadequate sanitation and the reuse of these devices without adequate cleaning (Omorodion *et al.*, 2023). Equipment used to process food, such as grinders, can also harbor bacterial growth, which is transferred to the food through a number of mechanisms, including:

residues of previously processed foods that serve as nutrients for organisms; environmental conditions like dust, air particles and the general hygiene of the market that contribute to the introduction of microorganisms; and operator behavior, such as cleaning food contact surfaces after use inadequately or not at all, which further contributes to cross-contamination (Azuonwu *et al.*, 2019).

Such equipment has been isolated with pathogenic and spoilage bacteria, such as *Escherichia coli*, *Staphylococcus aureus*, *Bacillus* spp., *Klebsiella* spp., *Pseudomonas* spp. and *Salmonella* spp. in the Nigerian markets (Azuonwu *et al.*, 2019; Isichei-Ukah *et al.*, 2017). Similar results with blenders used for processing ogbono, okazi, egusi and crayfish in Rivers state recorded high prevalence of *Staphylococcus aureus* and *E. coli*, *Klebsiella* spp. and *Bacillus* spp. (Isichei-Ukah *et al.*, 2017). Other related enteric organisms, such as *Staphylococcus* sp., *Salmonella* sp., *E. coli*, *Bacillus* sp., *Klebsiella* sp., *Aeromonas* sp., *Micrococcus* sp.,

Enterobacter sp., *Shigella* sp., *Proteus* sp., *Citrobacter* sp. and *Serratia* sp. and fungi, such as *Aspergillus niger*, *Fusarium* sp., *Penicillium* sp. and *Saccharomyces* sp. have also been identified in manual and mechanical blenders in local markets in Port Harcourt (Omorodion *et al.*, 2023). Similarly enteric pathogens have also been isolated from grinding machines in Enugu metropolis (Azunwu *et al.*, 2019).

Open markets in Benin City, Edo state, a major urban center in southern Nigeria, have a high population of vendors and small-scale processors who make use of these grinding machines. Although the direct bacteriological evaluation of grinding equipment in the Benin City markets is still inadequate, the research on garri processing in Benin City has revealed that pathogenic microorganisms, such as *Salmonella* sp., *E. coli*, *Aspergillus niger* and *Penicillium chrysogenum* are transferred to the end product using grinding machines and processing facilities (Aghemwenhio *et al.*, 2025). The current research on garri that is being sold in Benin City also points to the persistence of microbial threats posed by the local processing chains (Ehiwario *et al.*, 2025). Research on similar settings in Nigeria has reported a high microbial burden on food processing machinery and contamination has been attributed to improper handling and reuse without disinfection (Yar *et al.*, 2023; Maduka, 2024).

The absence of regulation at various stages of the informal sector also contributes to these problems, as vendors prioritize speed and quantity over standards of hygiene (Omorodion *et al.*, 2023). Bacteriological properties of grinding machines are also worrisome since the processed foods are usually exposed to very little additional heat high enough that even surviving pathogens could be a threat to public health. Diarrheagenic *E. coli*, *Salmonella*, and *Staphylococcus*

aureus were also identified as agents of foodborne diseases causing morbidity in Nigeria, where children, the elderly and immunocompromised persons are high risk population (Mola *et al.*, 2021, Omorodion *et al.*, 2023). Although the use of grinding machines at the market is widespread in Benin City, evidence is lacking on the bacteriological standards of these machines. Data from similar settings have reported continued contamination with pathogens attributed to inadequate cleaning, cross-contamination among different food types, and environmental contamination in congested market places (Azunwu *et al.*, 2019; Omorodion *et al.*, 2023; Aghemwenhio *et al.*, 2025). This type of situation permits organisms to easily be transferred to the subsequently processed foods and may also elevate the incidence of food borne diseases. Sporadic gastroenteritis and outbreaks associated with grinding machines in Nigeria have been attributed to high microbial loads on equipment surfaces, but systematic investigations of grinding machines are not known in the guarded markets of Benin City. The lack of knowledge presents a challenge for an integrated intervention to promote food safety in the informal processing chains.

MATERIALS AND METHODS

Study Area

The research was carried out in Benin City, the capital of Edo State and located within the southern region of Nigeria. Benin City is situated on 6°20'N 6°35'N latitude and between 5°35'E and 5°45'E longitude in the tropical rain forest of southern Nigeria. The sample was collected from two main markets; the New Benin Market and Uselu Market. The markets represent some of the most competitive commercial markets in the city, and are major focal points for the supply of food products for residents and city outskirts.

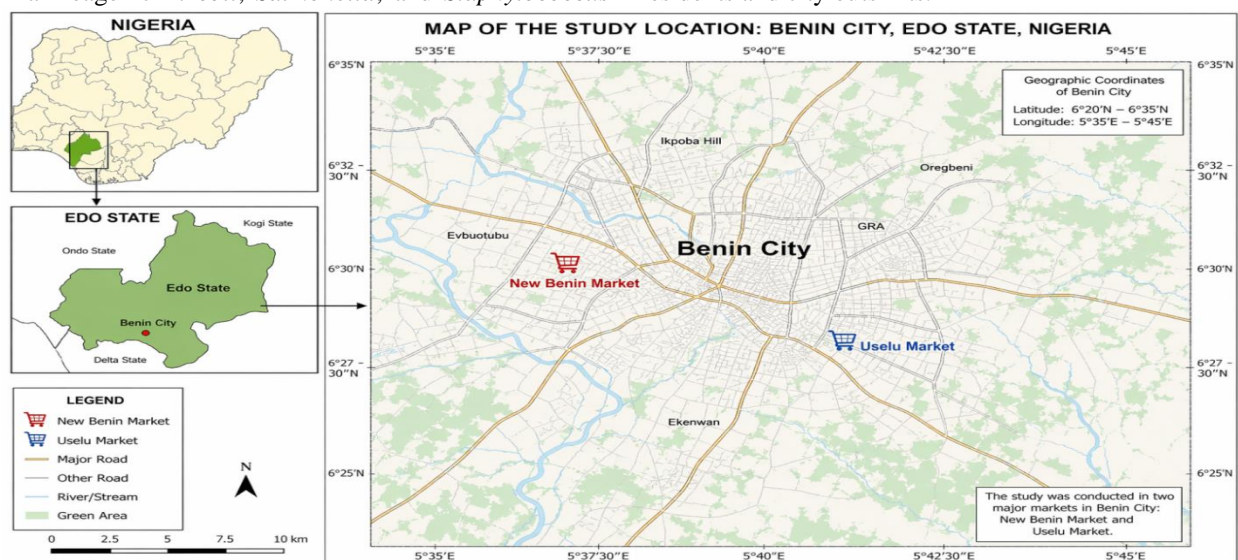


Figure 1: Sample locations of study area

Sample Collection

Twenty (20) swab samples were taken, 10 from New Benin Market (nine wet grinding machines used to grind fresh tomato paste and fresh pepper and one dry grinding machine used to process dry pepper and egusi) and 10 machines from Uselu Market. Targeted in were the critical areas of contact, such as the interior of the grinding chamber, blades, outlet chute, and hopper. Swabs were taken using sterile cotton swabs moistened with 10 mL sterile peptone water (or buffered peptone water). A cross hatching was performed on the surface to be sampled and the area of approximately 5 cm² was swabbed with pressure enough to collect the attached microorganisms. The swab heads were aseptically reinserted into the transport tubes containing peptone water, labeled properly and sent in an ice packed cooler to laboratory within 2-4 h to ensure viability of the microbes.

Isolation of bacteria isolates

Swab tubes were vortexed (30-60s) in the laboratory to obtain microorganisms suspended in a suspension which is the first stock suspension. Serial dilutions were prepared as tenfold conditions to 10⁻⁵ with the help of sterile peptone water. Spread-plates of one milliliter (1 mL) aliquots of proper dilutions were placed on selective and nonselective media, i.e. Nutrient Agar or Plate Count Agar to count total heterotrophic (aerobic mesophilic) bacteria; and Eosin Methylene Blue (EMB) Agar to count total coliform and enteric bacteria. Plates were allowed to incubate in aerobic condition at 37°C and 24- 48 hrs. Sub-culture into fresh media was performed to obtain pure cultures in order to make further identification.

Isolates Identification and Characterization.

Isolates were described in terms of morphology (as colonies: size, color, opaque, consistency, pigmentation, elevation, odor, swarming) and Gram staining. The standard reagents and procedures used to perform biochemical tests included catalase, oxidase, coagulase, indole production, methyl red, Voges-Proskauer, citrate utilization, urease, H₂S production, motility, spore formation and sugar fermentation (glucose, lactose, sucrose, mannitol). Reference schemes used to identify included, in addition to standard tropical microbiology, the Manual of Determinative Bacteriology by Bergey (Cheesbrough, 2006).

Identification of Virulence Factors.

The virulence potential of the bacterial isolates was determined by determining the production of extracellular enzymes including DNase and lipase, the DNase activity was measured using DNase agar. The media was made as provided by the manufacturer and

autoclaved at 121°C to sterilize it in 15 minutes. One poured sterile plates and left to dry. Sterile inoculating loop was used to inoculate the medium surface with test organisms that were then incubated at 37°C of temperature over a period of 24 hours. The plates were then incubated and flooded with 1N hydrochloric acid (HCl). The presence of a clear zone around the colonies was a positive sign of the DNase test that revealed that the organism had the ability to hydrolyze DNA whereas the lack of clear zone indicated a negative outcome. Tributyrin agar was used to determine the production of lipase. The medium was prepared and put into sterile Petri doses. The isolates were placed on the agar bed and incubated at 37°C, 24-48 hours. After incubation, the plates were observed with regards to clear zones around the colonies. Halo presence revealed a presence of lipase activity because of lipid hydrolysis whereas negative result was shown by absence of a clear zone (Cheesbrough, 2006; Cappuccino and Sherman, 2014).

Antibiotic Susceptibility Testing

The standard Kirby-Bauer disk diffusion method on Mueller-Hinton agar (MHA) was used to determine the antibiotic susceptibility pattern of the confirmed Gram positive and negative isolates as per the recommendations of the Clinical and Laboratory Standards Institute (CLSI, 2012). A total of eight antibiotics including: Ciprofloxacin, Erythromycin, Gentamycin, Augmentin, Tetracycline, Rifampicin, Clindamycin, Colistin (Abtek, UK). The bacterial suspension was applied aseptically to the agar plate by 0.1 mL of individually overnight culture, standardized to 0.5 McFarland turbidity using sterile saline. Plates incubated at 37°C for 24 h. The cumulative inhibition zone was recorded and measured to the nearest millimeter and interpreted according to the CLSI.

RESULTS AND DISCUSSION

Table 1 and Table 2 indicate the mean total bacterial counts (THBC) and the mean total coliform counts (CFU/cm²) retrieved in the wet and dry grinding machines in the selected markets within Benin City. The wet grinding machine of Uselu Market ($5.10 \pm 0.04 \times 10^5$ CFU/cm²) had the highest THBC and the wet grinding machine of New Benin Market came in second ($9.22 \pm 0.65 \times 10^4$ CFU/cm²). The dry grinding machine of the New Benin Market recorded the lowest THBC ($3.17 \pm 0.28 \times 10^4$ CFU/cm²). Equally, wet grinding machine of the Uselu Market ($1.64 \pm 0.20 \times 10^3$ CFU/cm²) had the highest mean total coliform and the dry grinding machine of New Benin Market ($1.34 \pm 0.12 \times 10^2$ CFU/cm²) had the lowest total coliform.

Table 1: Mean Total Heterotrophic Bacterial Counts (CFU/cm²) by Market and Machine Type

SAMPLE	Total Heterotrophic Bacterial Counts (CFU/cm ²)
USELU (W)	5.10 ± 0.04
USELU (D)	5.03 ± 0.44
NEW BENIN (W)	9.22 ± 0.65
NEW BENIN (D)	3.17 ± 0.28

Values are represented as mean ± standard error

W = Wet Grinding Machine (fresh tomoto and pepper),

D = Dry Grinding Machine (dry pepper and egusi)

Table 2: Mean Total Coliform Counts (CFU/cm²) by Market and Machine Type

SAMPLE	Total Heterotrophic Bacterial Counts (CFU/cm ²)
USELU (W)	1.64 ± 0.20
USELU (D)	2.68 ± 0.24
NEW BENIN (W)	1.16 ± 0.08
NEW BENIN (D)	1.34 ± 0.12

Values are represented as mean ± standard error

W = Wet Grinding Machine (fresh tomoto and pepper),

D = Dry Grinding Machine (dry pepper and egusi)

Frequency of Occurrence of Bacterial Isolates from Grinding Machines

Figure 1 shows the frequency of occurrence of bacterial isolates recovered from grinding machines in the selected

markets. Five bacterial genera were identified, namely *Klebsiella* spp., *Bacillus* spp., *Citrobacter* spp., *Staphylococcus aureus*, and *Enterobacter* spp. *Bacillus* spp. had the highest frequency of occurrence (26.47%), followed by *Klebsiella* spp. (23.52%) and *Staphylococcus aureus* (20.60%). The least frequently occurring isolate was *Citrobacter* spp (11.76%).

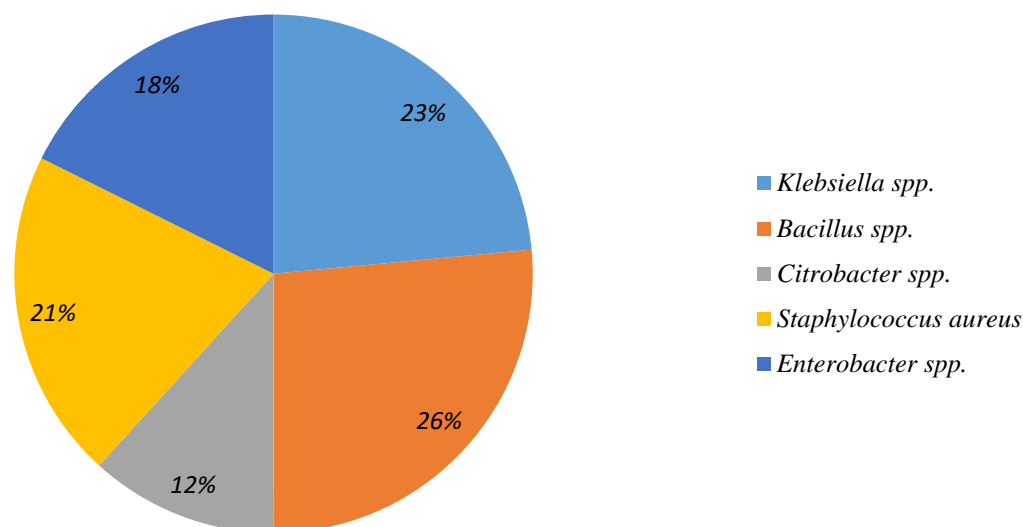


Figure 1: Frequency of Occurrence of Bacterial Isolates from Grinding Machines

Table 3 shows the phenotypic virulence characteristics of the bacterial isolates. The results revealed that most of the isolates demonstrated positive reactions for DNase and lipase activities. However, *Bacillus* spp. showed a negative reaction for DNase activity, while *Enterobacter* spp. tested negative for lipase production.

Table 3: Phenotypic virulence test of the Bacteria isolates

	DNase	Lipase solubility
<i>Klebsiella</i> spp.	+	+
<i>Bacillus</i> spp.	-	+
<i>Citrobacter</i> spp.	+	+
<i>Staphylococcus aureus</i>	+	+
<i>Enterobacter</i> spp.	+	-

*clear zone of inhibition

Antibiotic Susceptibility Patterns and Multiple Antibiotic Resistance (MAR) Indices of Isolates

The results indicated that most of the isolates were resistant to several antibiotics tested. However, *Klebsiella* spp. showed susceptibility to Gentamycin, Clindamycin, and Erythromycin, while *Bacillus* spp., *Citrobacter* spp. and *Staphylococcus aureus* demonstrated susceptibility mainly to Ciprofloxacin. Resistance was commonly observed against Colistin, Cephalexin, Augmentin, and Tetracycline. The multiple antibiotic resistance (MAR) indices of the isolated bacteria are shown in Figure 3. *Bacillus* spp. had the highest MAR index (0.87), followed by *Staphylococcus aureus* (0.75). *Citrobacter* spp. and *Enterobacter* spp. had MAR indices of 0.60, while *Klebsiella* spp. recorded the lowest MAR index (0.50). These values indicate varying levels of antibiotic resistance among the bacterial isolates recovered from the grinding machines.

Table 4: Antibiotics susceptibility pattern of bacteria isolates

ISOLATES	CS	CB	AG	TE	GEN	CD	CIP	E
<i>Klebsiella</i> spp.	R	R	R	S	S	I	R	S
<i>Bacillus</i> spp.	R	R	R	R	R	R	S	R
<i>Citrobacter</i> spp.	R	R	R	I	R	R	S	I
<i>Staphylococcus aureus</i>	R	R	I	R	R	R	S	R
<i>Enterobacter</i> spp.	R	R	R	I	R	R	I	R

Legend: R (resistant) = <10; I (intermediate) = 11-16; S (susceptible) = >17

CIP = Ciprofloxacin, E = Erythromycin, GEN = Gentamycin, AG = Augmentin, TE = Tetracycline, RIF = Rifampicin, CD = Clindamycin, CS = Colistin

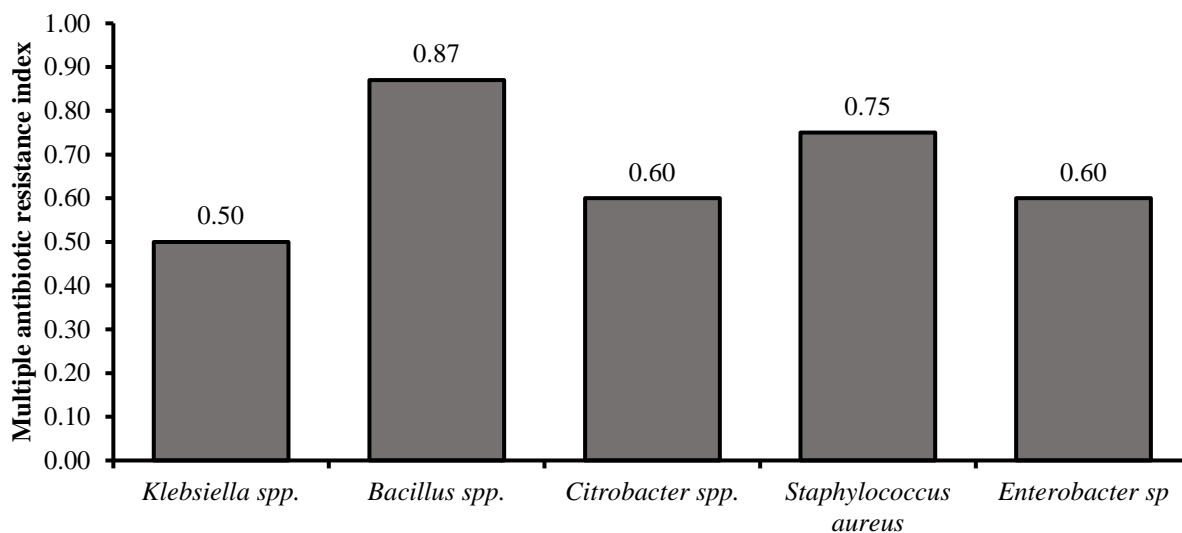


Figure 3: Multiple antibiotics resistance index of the isolated bacteria

The bacteriological quality of grinding machines in the sampled markets in Benin City, Edo State, is also a significant microbial contamination that raises serious concerns of public health. Wet grinding machines (fresh tomato and fresh pepper) were contaminated with total heterotrophic bacterial count (THBC) with maximum count of $5.10 \pm 0.04 \times 10^5$ CFU/cm² in Uselu Market and $9.22 \pm 0.65 \times 10^4$ CFU/cm² in New Benin Market. This high microbial load reflects the development of microorganisms on this moisture effect. Wet grinding introduces water and organic substances such as peppers, spices and grains, into the food debris and creates a nutrient-rich medium that supports the proliferation of bacteria and the production of biofilms. However, the New Benin Market recorded the lowest THBC of the dry grinding machines which processed dry pepper and egusi at a minimum of $3.17 \pm 0.28 \times 10^4$ cfu/cm². This is in line with other similar studies conducted in Nigeria and Ghana which showed higher growth of microbial count in wet milling systems due moisture retention as opposed to dry milling systems (Mola *et al.*, 2021; Omorodion *et al.*, 2023).

The average total coliform counts also indicate risk for fecal contamination, with Uselu Market wet machines having the highest counts ($1.64 \pm 0.20 \times 10^3$ cfu/cm²) and New Benin dry machines having the lowest ($1.34 \pm 0.12 \times 10^2$ cfu/cm²). The occurrence of coliform indicates possible introduction of enteric pathogens, this may be attributable to unhygienic hands of the vendors, water sources employed during cleansing and even dust in the surrounding at the open markets. These levels were found to be above the permissible levels of the sanitary standards on the food-contact surfaces and comparable to the heterotrophic counts on similar equipment in the market. These high levels were found to be above acceptable sanitary levels for food-contact surfaces, but in line with heterotrophic counts on other similar

equipment used in the markets. For instance, in a study by Yar *et al.* (2023) that estimated bacterial count on 55 food milling machines in Asante Mampong Municipal, Ghana reported total mean bacterial count of 1.955×10^5 cfu/ml considered erroneous due to negligent sanitation practices by users. Likewise, the cfu/g of the bacteria recovered from blenders used in the markets of Rivers state, were also between 2.72×10^4 and 1.67×10^6 , highlighting the significance of the leftover food bits in fostering contamination (4). Similar commercial blenders produce heterotrophic counts of 4.2 to 5.1 Log₁₀ cfu/cm² on contact surfaces (3) which supports the view that common market equipment that is not regularly sanitized act as a source of pathogens transfer onto processed foods.

Five bacterial isolates were identified in this study, namely *Bacillus spp.*, *Klebsiella spp.*, *Staphylococcus aureus*, *Enterobacter spp.* Among the isolates, *Bacillus spp.* The most predominant was *Bacillus spp.* (26.47%) followed by *Klebsiella spp.* (23.52%), *Staphylococcus aureus* (20.60%), *Enterobacter spp.* (17.65%) and *Citrobacter spp.* (11.76%) were also obtained. This study was in line with the report of Omorodion *et al.*, who also reported identical bacterial isolates of mechanical and manual blenders from local markets of Port Harcourt, Rivers State (3). Its prevalence may be attributable to the fact that the *Bacillus spp.* has endospores which protect it from desiccation and mechanical damage during milling. The coliforms, *klebsiella spp.* and *Enterobacter spp.* Meanwhile, *Staphylococcus aureus* which is an indicator of contamination by human skin or an individual was also found, and it is tissue cultured that suggests probable infection coming from this human or infected person.

The isolates show pathogenic potential in their phenotypic virulence traits (as illustrated by positive DNase and lipase activities in most strains (except *Bacillus* spp. and *Enterobacter* spp. negative for DNase and lipase respectively). DNase is involved in extracellular degradation of DNA to aid in biofilm dispersal and immune avoidance, whereas lipase supports invasion of tissues and acquisition of nutrients by lipids hydrolysis. Such characteristics increase the ability of the isolates to induce foodborne diseases when transferred to the food items. *Bacillus* spp. and *Staphylococcus aureus* are typical in the isolates and produce toxins (e.g., enterotoxins), which intensifies the threat of gastroenteritis. This type of virulence profile is recorded in studies of food processing equipment; Azuonwu *et al.* (2019) reported toxin-producing *Staphylococcus aureus* and *Bacillus* sp. on Rivers State blenders as direct causes of potential diarrhea, vomiting and cramps. Similar enzyme activities in environmental isolates highlight the impact that dirty grinding surfaces may have on increasing the disease spread especially in undercooked or ready-to consume foods that have been handled in Benin City markets.

The antibiotic susceptibility profiles showed isolates were highly resistant to the antibiotics colistin, cephalexin, augmentin and tetracycline and were only sensitive to the drugs gentamycin (*Klebsiella* spp.), clindamycin, erythromycin (*Klebsiella* spp.) and mainly ciprofloxacin (*Bacillus* spp., *Citrobacter* spp. and *Staphylococcus aureus*). The multiple antibiotic resistance (MAR) indices were also high: *Bacillus* ssp. (0.87), *Staphylococcus aureus* (0.75), *Citrobacter* spp. and *Enterobacter* spp. (0.60) and *Klebsiella* spp. (0.50), indicating an exposure to selective pressures of indiscriminate antibiotics use in human and veterinary medicine. These indices exceed the 0.2 level, which is normally considered as a high-risk source of contamination. The resistance is in line with the review on multidrug resistant bacteria of Nigerian food and beverage (Mensah *et al.*, 2002) and fermented condiment (Onoriode *et al.*, 2021) which showed that Gram-negative isolates were resistant to beta-lactams and tetracyclines and such resistance was plasmid-mediated and disseminated in environment. Omorodion *et al.*, (2023) also observed such high variable resistance in Gram negative isolates in blenders of Port Harcourt to resist augmentin among others, the implication of such could be failure of the treatment, and increased burden on healthcare.

These findings have implications on Edo State beyond equipment hygiene to the larger public health and food safety issues. Common condiments are ground with grinders that people use every day, increasing the possibility of cross contamination and outbreaks of foodborne illness caused by enteric pathogens and toxin

producers. The high MAR indices in our study present a concerning potential for the transfer of the antimicrobial resistance genes to other segments of the food chain, which could pose challenges for clinical treatment in a region with limited surveillance. Improper regulation of the market equipment and practices of operators e.g., the lack of regular cleaning and the shared use, is also a factor that contribute to hazards, just like the case of flour mill in Ghana in which the *Salmonella* spp. and *Shigella* spp were the most frequent (Yar *et al.*, 2023). Similar concerns regarding blenders and grinders have been linked to unhygienic surroundings which harm the survival of pathogens in Nigeria (Isichei-Ukah *et al.*, 2017).

The microbial load, virulence and resistance mechanisms suggest that an enhancement in the level of hygiene, education and regulatory monitoring is warranted to contain dissemination of foodborne disease and (multi)antimicrobial resistance. Such statements are supported by studies from the region, where it is observed that in the absence of systematic intervention, such equipment will be a silent vector of threats to public health.

CONCLUSION

From this study, it was established that grinding machines in Benin City are contaminated with bacteria of public health importance. The presence of moisture in wet grinding machines was responsible for an increased bacterial load. The bacteria identified in this study, such as *Staphylococcus aureus*, *Klebsiella*, *Enterobacter*, *Citrobacter*, and *Bacillus*, have previously been identified as food pathogens. The presence of virulence factors such as DNase and lipase in these bacteria indicates their pathogenic nature. The presence of multiple antibiotic resistance in these bacteria indicates their role in antibiotic resistance. Grinding machines are thus an important source of food pathogens.

CONFLICT OF INTEREST

The authors declare that no known conflict of interest that could have influenced this research exists in this paper.

REFERENCE

Aghemwenhio, I. S., Chukwu, F. O., Ogbedor, V. & Akeem, S. A. (2025). Microbiological identification and characterization of pathogenic bacteria in garri sold within the University of Benin. *Faculty of Natural and Applied Sciences Journal of Applied Biological Science (FNAS-JABS)*, 2(3), 38–44. <https://doi.org/10.63561/jabs.v2i3.931>

- Azuonwu, O., Azuonwu, T. C. & Ndah, M. A. (2019). Isolation and identification of potential high risk pathogens from blenders used in grinding some food stuffs in a local community market in Rivers State: A public health concern. *Journal of Microbiology & Experimentation (JMEN)*, **7**(4), 183–187. <https://doi.org/10.15406/jmen.2019.07.00258>
- Cappuccino, J. G. and Sherman, N. (2014). *Microbiology: A laboratory manual* (10th ed.). Pearson Education Limited, London Press <https://www.amazon.com/Microbiology-Laboratory-James-G-Cappuccino/dp/0321840224>
- Cheesbrough, M. (2006). *District laboratory practice in tropical countries, Part 2* (2nd ed.). Cambridge University Press. New York. <https://doi.org/10.1017/CBO9780511543470>.
- Clinical and Laboratory Standards Institute (CLSI). (2012). *Performance standards for antimicrobial disk susceptibility tests; approved standard* (11th ed.). CLSI document M02-A11. Clinical and Laboratory Standards Institute. (Wayne, PA).
- Ehiwario, N. J., Eromosele, E. O., Orogu, J. O., Okobia, U. B. & Idollo, E. (2025). Bioburden and antibacterial susceptibility pattern of hand manual grinders used in different markets in Ozoro, Delta State. *Tropical Journal of Phytochemistry and Pharmaceutical Sciences (TJPPS)*, **4**(2), 85–91. <https://tjpps.org/index.php/home/article/view/149>
- Isichei-Ukah, B. O. & Imiere, O. D. (2017). Assessment of the impact of processing environment on the microbial quality of garri processing. *Food and Public Health (FPH)*, **7**(4), 91–97. <https://doi.org/10.5923/j.fph.20170704.03>
- Jaffee, S. & Henson, S. (2024). Promoting food safety in the informal markets of low-and middle-income countries: The need for a rethink. *Food Protection Trends*, **44**(5), 376–382.
- Maduka, N. (2024). A review on microorganisms and mycotoxin contamination of selected ‘swallow meals’: Potential health risks to consumers. *Heliyon*, **10**, e15342. <https://doi.org/10.1016/j.heliyon.2024.e15342>
- Mensah, P., Yeboah-Manu, D., Owusu-Darko, K. & Ablordey, A. (2002). Street foods in Accra, Ghana: How safe are they? *Bulletin of the World Health Organization (Bull. WHO)* **80**(7), 546–554.
- Mola, I., Onibokun, A. & Oranusi, S. (2021). Prevalence of multi-drug resistant bacteria associated with foods and drinks in Nigeria (2015-2020): A systematic review. *Italian Journal of Food Safety (IJFS)* **10**(4), 9417. <https://doi.org/10.4081/ijfs.2021.9417>
- Okafor, C. M., Ikegbunam, M. N., Nwachukwu, J. C., Ebenebe, I. N. & Nnanna, J. C. (2020). Prevalence of antibiotic resistant bacteria in Nigerian fermented food condiments. *Journal of Biology and Life Science (JBLS)* **11**(1),110–120. <https://www.macrothink.org/journal/index.php/jbpls/article/view/16383>.
- Omorodion, N. J., Osakuade, F. & Bright, I. (2023). Contaminated condition of commercial blenders and their contact surface in the local market in Port Harcourt, Rivers State Nigeria. *International Journal of Pathology and clinical Research (Int. J. Pathol. Clin. Res)*, **12**(6),19–30. <https://journalijpr.com/index.php/IJPR/article/view/249>
- Onoriode, C., Eruteya, P. O. & Osariemen. (2021). Antibiotic susceptibility of *Staphylococcus aureus* isolated from retailed raw beef at Choba Market, Rivers State. *International Journal of Pathogen Research (IJPR)*, **6**(4), 25–30.
- Yar, D. D., Kwenin, W. K. J., Balali, G. I., Assoah, E., Addy, R. & Francis, G. (2023). Food milling machines are hosts to pathogenic bacteria: A cross-sectional study in the Asante Mampong Municipal, Ghana. *Scientific African (Sci. Afr)*, **20**:e01673 <https://doi.org/10.1016/j.sciaf.2023.e01673>