Research Article

Microbial Quality of Ready-To-Eat Shrimps from Three Selected Markets in Ibadan

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Abstract | The microbial load of shrimps and related products are not frequently checked in Nigeria, and consumers are unaware of the risk of ready-to-eat (RTE) shrimps purchased in Ibadan seafood markets. Therefore, this study determined the microbial quality of ready-to-eat shrimps from three major seafood markets in Ibadan. Ready-to-eat shrimps were collected from 80 outlets at the three major seafood markets in Ibadan (50 from Bodija, 15 from Alesinloye and 15 from Eleyele) and checked for microbial presence, microbial counts, and antibiotic sensitivity patterns of the isolated bacteria. The mean total bacterial and coliform counts were 6.40 log CFU/g and 6.24 log CFU/g, respectively. The total bacterial count was significantly lower in ready-to-eat shrimps sourced from Alesinloye [6.29 (6.24 – 6.33) log CFU/g] compared to those from Eleyele [6.43 (6.40 – 6.46) log CFU/g] and Bodija [6.43 (6.41 – 6.46) log CFU/g]. Of the 80 ready-to-eat shrimps samples, *Escherichia coli* was isolated from 52 (65.5%), *Salmonella* spp. from 68(85.0%), *Shigella* spp. from 52(65.5%), *Bacillus* spp. from 52(65.5%), *Staphylococcus aureus* from 56 (70.0%) and *Staphylococcus epiderdimis* from 43 (53.8%) samples. All the *Salmonella* and *Shigella* isolates were sensitive to ceftazidime, cefuroxime, ofloxacin, and ciprofloxacin but resistant to gentamicin, cefixime, augmentin, and nitrofurantoin. This study concluded that ready-to-eat shrimps in Ibadan are not safe, wholesome and fit for human consumption because of the high loads of bacteria. The bacterial and fungal organisms isolated from the shrimps indicate contamination from personnel and the environment.

Keywords | Seafood products; Microbial count; Antimicrobial sensitivity; Ready-to-eat shrimps; Quality

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INTRODUCTION

A significant proportion of the world's food supply and income is contributed by seafood. Over the past 50 years, annual global consumption of seafood products per capita has more than doubled, from almost 10 kg in 1960 to over 20 kg in 2014 (FAO, 2016b). Seafood is a significant portion of a healthy diet. Seafood has high-quality protein and other indispensable nutrients with low saturated fatty acids and high Omega-3 fatty acids (Kakara et al., 2016). As a good protein source, seafood accounts for 14–16% of the animal-sourced protein consumed worldwide by over one billion people (Tidwell and Allan, 2012; Viglia et al., 2022).

The American Heart Association recommends consuming two servings of fish and shellfish per week to prevent coronary heart disease. Also, the United States Food and Drug Administration recommends that pregnant women or breastfeeding mothers consume 2 to 3 servings per week. They also suggest that children eat 1 to 2 servings per week at two years of age to promote development and growth (Centre for Disease Control and Prevention, 2018). However, seafood consumption is a potential source of human exposure to pathogenic microbes.

Infections of seafood can be due to pathogens, including parasites, viruses, and bacteria. These pathogens may have entered the food from different sources, such as production, harvesting, processing or transport to food handlers, including the consumers. In addition, these agents can be obtained from one of three sources: faecal contamination of the aquatic environment, the natural aquatic environment, and during the processing and preparation at homes, restaurants, retail stores, or industries. Similarly, a significant proportion of most food-borne diseases and outbreaks is caused by seafood allergy, which in sensitive people might be fatal (Mu et al., 1997; Heinitz et al., 2000; Fatma et al., 2006).

People most often find shrimps in marketplaces either frozen, uncooked or as products that have been cooked. In addition to fresh and prepared products, a ready-to-eat (RTE) product provides the consumer with a more convenient option. Ready-to-eat shrimp is a unique kind of primary domestic product made by specific communities of people and then sold in public places, such as supermarkets and traditional markets, to customers for immediate consumption. The current market trends demonstrate a fast-expanding demand for convenience items that are both ready-to-cook and ready-to-serve. The sophisticated consumer abroad, as well as the urban consumer at home, demand new type of value added, hygienically prepared, nutritious and attractively packed products (Gopakumar, 1997; Mohanbabu et al., 2008).

On the other hand, RTE goods provide a management challenge to the food safety authority in their ability to constantly monitor the foods' quality and preparation (Jeyasanta et al., 2019). The appropriate handling of shrimp from the time it is captured and the time it is delivered to the consumer is an essential component in assuring the quality of the final product. This process ensures that the shrimp stays in good condition and is free of contaminants. Shrimp quality can also be affected by factors such as sanitation standards, the manner of handling, the amount of time held, and the temperature. As a result of the high degree of perishability of these foods, a drop in quality can arise very quickly after the catch (Dewi et al., 2011). Additionally, the presence of bacterial pathogens and the microbial load in seafood are essential indicators of the item's quality and the potential threat to consumer health. (Rosmini et al., 2004; Mhango et al., 2010; Hosen and Afrose, 2019). Therefore, the screening of commercial marine fish for pathogenic microorganisms (bacteria, viruses and fungi) is of paramount importance (Geetha et al., 2014).

In addition, antibiotic administration to fish is a common practice in most aquaculture farms in the tropics. The World Health Organization has accepted 14 drugs, including seven antimicrobial agents (sulfadiazine/trimethoprim, oxytetracycline, flumequine, sarafloxacin, oxolinic acid, florfenicol and amoxicillin) employed in aquaculture. Also, two antibiotics used for human antibacterial therapies (fluoroquinolones and tetracyclines) are still approved for treating shrimp (Cabello, 2006). These antibiotics have been used in various production, processing, and value-addition chain settings across Nigeria. However, surveillance studies of antibiotics and antibiotic-resistant bacteria to ensure the wholesomeness of seafood and maintain human health and safety are limited in Nigeria.

However, the microbial load of shrimp and related products is not frequently monitored in Nigeria. As a result, consumers are unaware of the risk of ready-to-eat seafood purchased in Ibadan seafood markets. Also, there is a need to identify the critical control point in the distribution chain of shrimps and its products using the Hazard Analysis Critical Control Points (HACCP) principle. This study, therefore, aims to determine the microbial quality of ready-to-eat shrimps available in Ibadan. Precisely, this study will (i) determine the microbial quality of ready-to-eat shrimps sold in selected markets in Ibadan; (ii) identify the microbial content associated with ready-to-eat shrimps commonly consumed by people in Ibadan; (iii) determine the susceptibility pattern of the isolates identified.

MATERIALS AND METHODS

Study Location

This study was carried out including three selected markets (Alesinloye, Eleyele and Bodija) in Ibadan, Nigeria, with longitude 7° 2' and 7° 40' E and latitudes 3° 35' and 4° 10' N. A total of 80 ready-to-eat (RTE) shrimp samples were purchased from three selected markets in Ibadan (Figure 1) as follows; Aleshinloye (n=15), Eleyele (n=15), and Bodija (n=50). The shrimp (ready-to-eat) were sourced directly from the markets that public consumers often patronise. The retail vendors were randomly selected at the different markets. All collected samples had their exoskeletons intact.

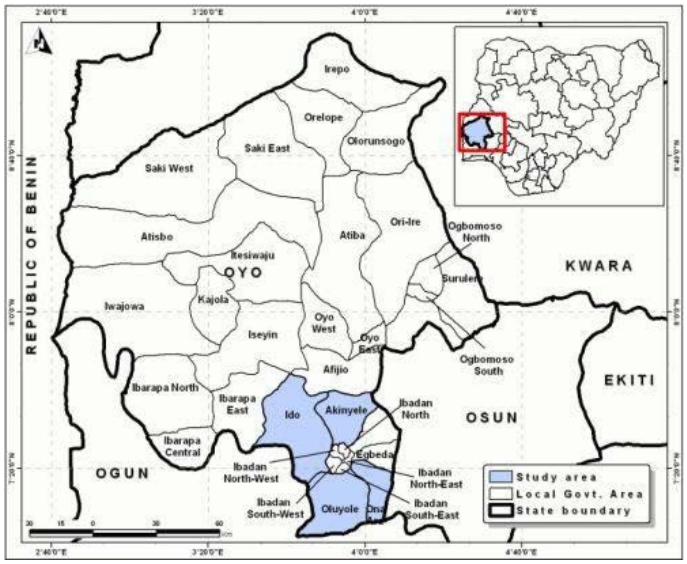

Figure 1: Map showing the selected local government area of Ibadan

Sample Collection and Preparation

A total of eighty (80) samples of unbranded Ready–To–Eat shrimp were purchased from three open markets in Ibadan (50 from Bodija, 15 from Alesinloye and 15 from Eleyele). These were fried samples with no information on the ingredients or recipe used. During collection, all the shrimp samples were packed into individual sterile polythene bags and placed on ice packs. These samples were transported to the Food and Meat Hygiene Laboratory, Department of Veterinary Public Health and Preventive Medicine, the University of Ibadan, for microbiological studies. The samples were immediately processed for microbial quality assessment. The shrimps were then aseptically blended, homogenised using a sterile waring laboratory blender, and kept in sterile sampling bottles. For each sample, 25g was suspended in 225ml of buffered Peptone water, homogenised using a stomacher (Laboratory Blender), inoculated in different media, and incubated at 37°C for 24-48 hours. In addition, an aliquot of 0.1ml of the pre-enrichment broth was inoculated onto each of the prepared Agar Plates.

Microbial Isolation and Purification of Isolates

Bacterial and Fungal Isolation: A modified method of bacterial and fungal isolation by Kusumaningrum & Zainurib, (2015), was adopted. The homogenates were diluted one at a time, and each successive dilution was used to inoculate the culture. Nutrient agar was used for the Total Aerobic Plate Count, Sabouraud Dextrose Agar was used for the fungal count, Mannitol Salt agar was used for the isolation of *Staphylococcus aureus*, Eosin Methylene Blue agar was used for the coliform count, Bacillus cereus medium and Xylose Lysine Deoxyribose agar were used for the bacterial count, and so on. Agar plate preparations (for isolation of Shigella and Salmonella). The homogenates were diluted serially from 10^{-3} to 10^{-5} times, and 0.2 millilitres of each dilution was used to inoculate media plates consisting of Nutrient agar (to determine the total number of aerobic plate counts) and MacConkay agar (to determine the total number of coliform counts).

After each incubation period at 37°C for 24–48 hours, colony counts were obtained from plates containing the proper dilutions. For easy identification, the cultural aspects of the colonies were also documented. After the incubation period, the number of colonies was determined using a colony counter. Finally, a total count was given regarding colony-forming units (CFU) per gramme of material, abbreviated as CFU/g. By repeatedly subculturing the isolates on the proper medium, pure cultures of the isolates were acquired for characterisation. The morphological properties of the colonies, microscopy, and the results of several biochemical tests, such as the sugar fermentation test, the oxidase test, the indole test, and the catalase test, were used to make a preliminary determination of the identity of the bacterial isolates.

Fungal Identification: The distinct mycelia section from each isolate on sabouraud dextrose agar based on colour, pigment production were cut using a sterile mounted lancet blade and placed on a clean glass slide, teased and moistened. A drop of Lactophenol Cotton Blue (LCB) was added (Kusumaningrum & Zainurib, 2015), and a cover slip was placed to be viewed at different magnifications using a light microscope.

Bacterial Identification: The identification methods by Buchanan & Gibbons, (1985); Garrity et al. (2004); Krieg et al. (2004) were employed in this study. Briefly, all the isolates were primarily identified from their staining reactions using Gram's technique. Further test conducted were biochemical studies which employed Catalase test, Indole test, Oxidase test, Sugar fermentation test and Triple sugar test.

Antibiotic Sensitivity Tests

The antibiotic sensitivity tests were performed using the Kirby-Bauer method (Disc Diffusion Technique) with reference to the Clinical and Laboratory Standards Institute (CLSI, 2012). The sensitivity discs were specifically designed and contained appropriate concentrations of different Gram-positive antibiotics; ceftazidime(30µg), cefuroxime(30µg), gentamicin(10µg), ceftriaxone(30µg), erythromycin(5µg), cloxacillin(5µg), ofloxacin(5µg), augmentin(30µg). And Gram-negative antibiotics; ceftazidime(30µg), cefuroxime(30µg), gentamicin(10µg), cefixime(5µg), ofloxacin(5µg), augmentin(30µg), nitrofurantoin(300µg), and ciproflaxaciline(5µg).

Pure isolates were closely streaked onto the surface of Muller –Hinton Agar plates. The plates were then incubated at 37°C for 18-24 hours. Following incubation, they were observed for the inhibition zone surrounding each disc.

Statistical analysis

Bacterial counts were measured in colony-forming units using two different dilutions (10^{-3} and 10^{-5}), the average of which was used for the final analysis. Bacterial counts were $\log_{10}$ transformed (because they were positively skewed) to make them approximately normally distributed during analysis. Total bacterial and coliform counts were presented as mean (95% Confidence Interval) and compared by location. Bacterial and fungal isolates were presented as proportions and their corresponding 95% confidence interval (CI). The isolated organisms' proportions were compared by location and presented as bar charts with 95% CI error bars. The statistical significance was set at a 2-tailed p-value of 0.05 or less. Data analysis was done with STATA version 14.2 for Windows (StataCorp, College Station, TX, USA).

RESULTS

Total bacterial and coliform counts

The mean total bacterial and coliform counts were 6.40 log CFU/g and 6.24 log CFU/g, respectively. However, the total bacterial count was significantly lower in ready-to-eat shrimp sourced from Alesinloye [6.29 (6.24 – 6.33) log CFU/g] compared to those from Eleyele [6.43 (6.40 – 6.46) log cfu/g] and Bodija [6.43 (6.41 – 6.46) log CFU/g]. Similarly, the total coliform count was significantly lower in ready to eat shrimp obtained from Alesinloye [6.14 (6.07 – 6.21) log CFU/g] compared to those from Eleyele [6.25 (6.21 – 6.30) log CFU/g] and Bodija [6.27 (6.23 – 6.31) log CFU/g] (Table 1).

Table 1: Total bacteria and coliform counts (log CFU/g) from ready-to-eat shrimp in Ibadan

Locations	Total bacteria count (95%CI) *	Total coliform count (95%CI) *
Eleyele	6.43 (6.40 – 6.46) [b]	6.25 (6.21 – 6.30) [b]
Alesinloye	6.29 (6.24 – 6.33) [a]	6.14 (6.07 – 6.21) [a]
Bodija	6.43 (6.41 – 6.46) [b]	6.27 (6.23 – 6.31) [b]
Total/average	6.40 (6.38 – 6.43)	6.24 (6.22 – 6.27)

*Log CFU/ml; Values with different superscripts in the same column differ significantly ($p < 0.05$)

Prevalence of bacterial organisms isolated from ready to eat shrimp in Ibadan

Of the 80 ready-to-eat shrimps sampled for the study, *E. coli* was isolated from 52 (65.5%), *Salmonella* spp. from 68 (85.0%), *Shigella* spp. from 52(65.5%), *Bacillus* spp. from 52(65.5%), *Staphylococcus aureus* from 56 (70.0%) and *Staphylococcus epidermidis* from 43 (53.8%) (Table 2).

Table 2: Proportion of bacteria organisms isolated from ready to eat Shrimp in Ibadan

Organisms	No. Isolated (%)	95% CI
E. coli	52 (65.5)	53.5 - 75.3
Salmonella spp.	68 (85.0)	75.2 - 92.0
Shigella spp.	52 (65.5)	53.5 - 75.3
Bacillus spp.	52 (65.5)	53.5 - 75.3
Staphylococcus aureus	56 (70.0)	58.7 - 79.7
Staphylococus epiderdimis	43 (53.8)	42.2 - 65.0

Prevalence of fungal organisms isolated from ready to eat shrimp in Ibadan

The prevalence of fungal organisms isolated from ready-to-eat shrimp is presented in Table 3. The most and least frequently isolated fungi were *Rhizopus* spp. (70.0%, 95% CI: 58.7% – 79.7%) and *Trichophyton* spp. (12.5%, 95% CI: 6.2% – 21.8%) respectively. Other pathogenic fungi isolated were *Aspergillus Niger* (50.0%, 95% CI: 38.6% – 61.4%), *Aspergillus fumigatus* (38.8%, 95% CI: 28.1% – 50.3%), *Aspergillus flavus* (25.0%, 95% CI: 16.0% – 35.9%), *Penicillium* spp. (20.0%, 95% CI: 11.9% – 30.4%), *Candida* spp. (16.3%, 95% CI: 9.0% – 26.2%) and *Mucor* spp. (28.8%, 95% CI: 19.2% – 40.0%) (Table 3).

Table 3: Proportion of fungal organisms isolated from ready to eat Shrimp in Ibadan

Organisms	No. Isolated (%)	95% CI
Aspergillus niger	40 (50.0)	38.6 - 61.4
Aspergillus fumigatus	31 (38.8)	28.1 - 50.3
Aspergillus flavus	20 (25.0)	16.0 - 35.9
Penicillum spp.	16 (20.0)	11.9 - 30.4
Rhizopus spp.	56 (70.0)	58.7 - 79.7
Trichophytum spp.	10 (12.5)	6.2 - 21.8
Candida spp.	13 (16.3)	9.0 - 26.2
Mucor spp.	23 (28.8)	19.2 - 40.0

Prevalence of bacterial organisms isolated from ready to eat shrimp by location

Figures 2-4 compared the proportion by location of some gram-negative and gram-positive bacteria isolated from ready-to-eat shrimp. The proportions of *Shigella* spp., *Salmonella* spp., *E. coli*, *Bacillus* spp., *Staphylococcus aureus,* and *Staphylococcus epidermidis* isolated from ready to eat shrimp did not differ significantly by location ($p > 0.05$). However, the percentage of *E. coli and Salmonella* spp. isolated was highest in shrimp sourced from Eleyele (80.0% and 86.7%, respectively), followed by Bodija (62.0% and 86.0%, respectively) and Alesinloye (60.0% and 80.0%, respective-

ly) (Fig. 2). For *Shigella* spp., the highest isolation proportion was observed in Alesinloye followed by Bodija and Eleyele, while *Bacillus* spp. the proportion isolated was the same in Eleyele and Alesinloye (73.3%) but higher than in Bodija (60.0%). For *Staphylococcus aureus*, the proportion isolated from shrimp was highest in Bodija (74.0%), followed by Eleyele (66.7%) and Alesinloye (60.0%), while for *Staphylococcus epidermidis* prevalence was highest in Eleyele (73.3%), followed by Alesinloye (53.3%) and Bodija (48.0%).

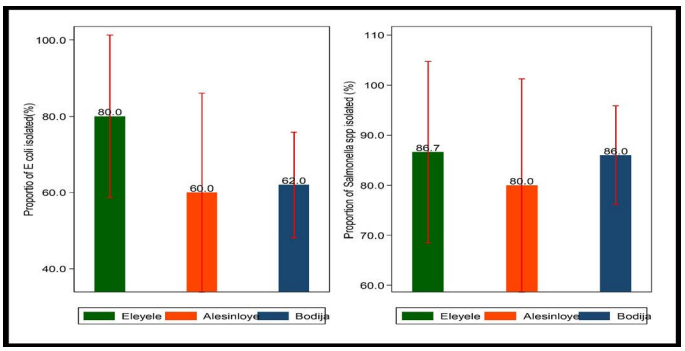

Figure 2: Proportion of *E. coli* and *Salmonella* spp. isolated from ready to eat Shrimp in Ibadan

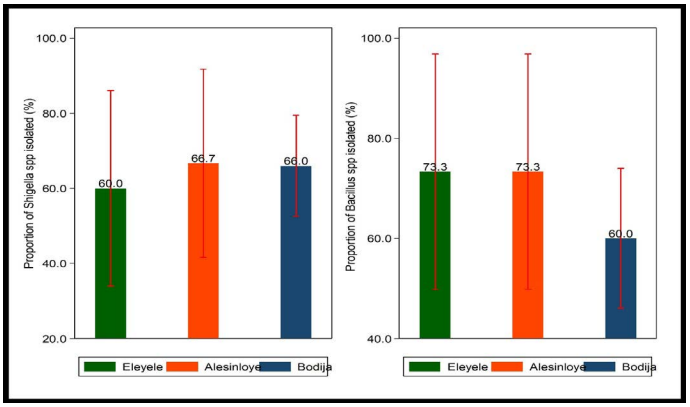

Figure 3: Proportion of *Shigella* spp. and *Bacillus* spp. isolated from ready to eat Shrimp in Ibadan

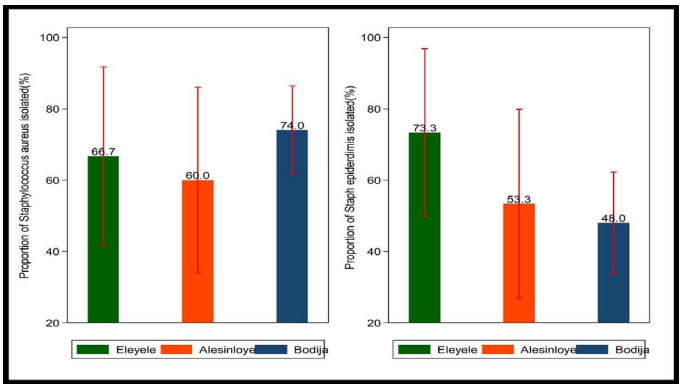

Figure 4: Proportion of *Staphylococcus aureus* and *Staphylococcus epidermis* isolated from ready to eat Shrimp in Ibadan

Prevalence of fungal organisms isolated from ready to eat shrimp by location

Figures 5 -8 compared the proportion by location of some fungi isolated from ready-to-eat shrimp. The proportions of *Rhizopus* spp., *Trichophytum* spp., *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus flavus*, *Penicillum* spp., *Candida* spp. and *Mucor* spp. isolated from ready-to-eat shrimp was not significantly different by location ($p > 0.05$). However, the proportion of *Aspergillus niger* and *Aspergillus fumigatus* isolated was highest in Bodija (54.0% & 42.0%), respectively. The ratio of *Penicillium* spp. isolated was the same in all three locations (20.0%), while the isolation rate for *Aspergillus flavus* was highest in Alesinloye (33.3%). For *Rhizopus* spp., the proportion of isolation was the same in Eleyele and Alesinloye (33.3%) but higher than in Bodija (24.0%) while for *Trichophyton* spp., it was highest and lowest in Bodija (14.0%) and Alesinloye (6.7%), respectively.

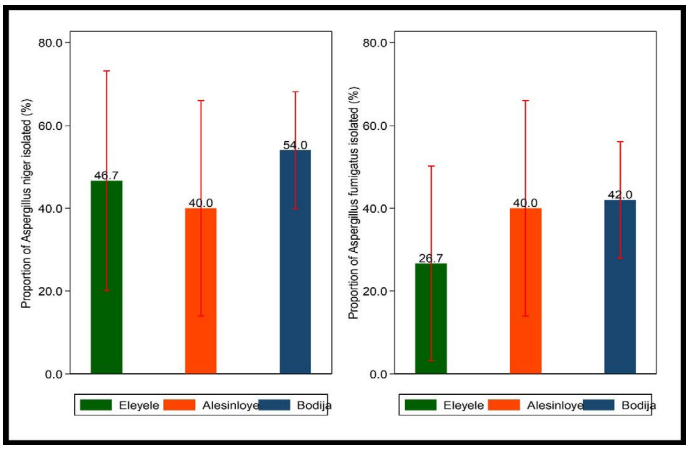

Figure 5: Proportion of *Aspergillus niger* and *Aspergillus fumigatus* isolated from ready to eat Shrimp in Ibadan

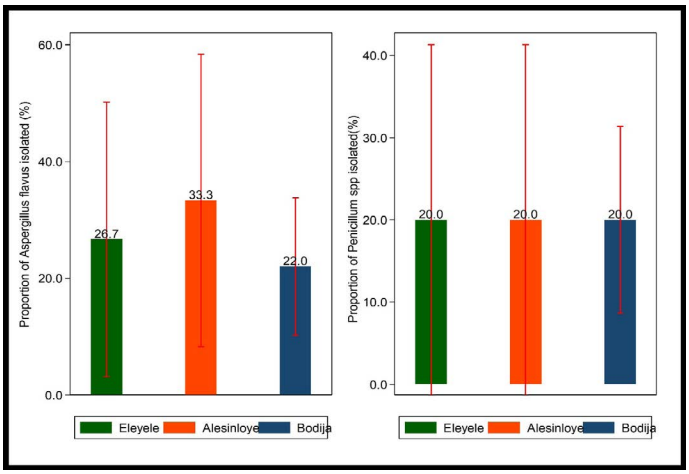

Figure 6: Proportion of *Aspergillus flavus* and *Penicillium* spp. isolated from ready to eat Shrimp in Ibadan

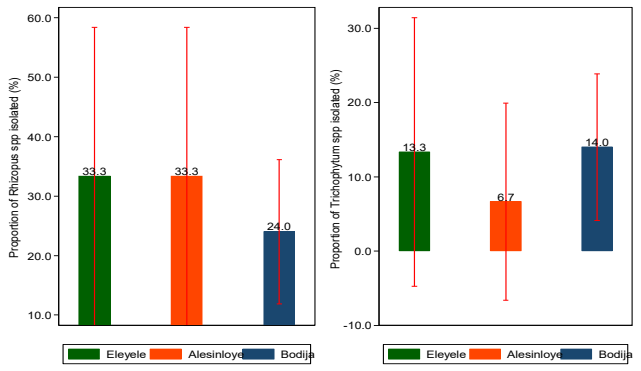

Figure 7: Proportion of *Rhizopus* spp. and *Trichocytum* spp. isolated from ready to eat Shrimp in Ibadan

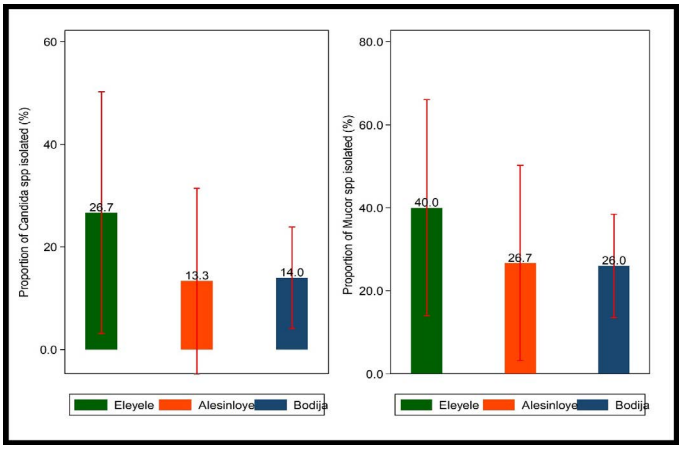

Figure 8: Proportion of *Candida albicans* and *Mucor* spp. isolated from ready to eat Shrimp in Ibadan

Antibiotic sensitivity test results

All the Salmonella and Shigella isolates were sensitive to ceftazidime, cefuroxime, ofloxacin, and ciprofloxacin but resistant to gentamicin, cefixime, augmentin, and nitrofurantoin. All Bacillus isolates were sensitive to gentamicin, erythromycin, and ofloxacin but resistant to ceftazidime, cefuroxime, ceftriaxone, cloxacin, and augmentin. All *Staphylococcus aureus* isolates were sensitive to gentamicin, ceftriaxone, erythromycin, and cloxacin but resistant to ceftazidime, cefuroxime, ofloxacin and augmentin. In contrast, *Staphylococcus epidermidis* isolates were sensitive to ceftazidime, gentamicin, ceftriaxone, and erythromycin but resistant to cefuroxime, cloxacin, ofloxacin, and augmentine. *E. coli* was sensitive to ciprofloxacin, ofloxacin, ceftazidime, and cefuroxime but resistant to, cefixime, gentamycin, augmentin, and nitrofurantoin (Figure 9).

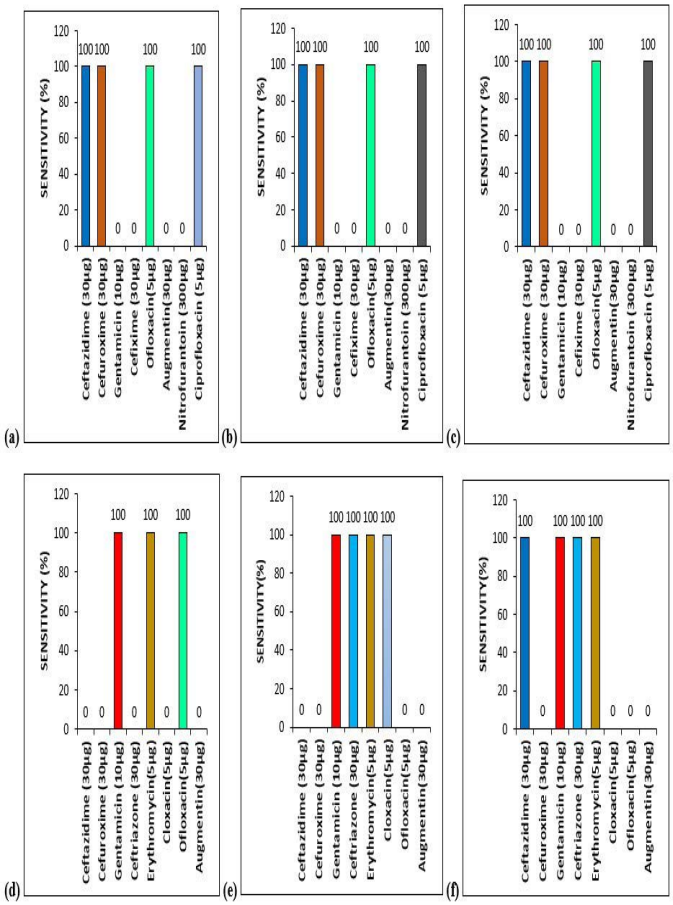

Figure 9: Antibiotic sensitivity pattern of (a) *E. coli*; (b) *Salmonella* spp.; (c) *Shigella* spp.; (d) *Bacillus* spp.; (e) *Staphylococcus aureus*; and (f) *Staphylococcus epidermis*

DISCUSSION

The mean total bacterial count of 6.40 log CFU/g and coliform count of 6.24 log CFU/g, reported in this study, are higher than the minimum permissible limit of the International Commission on Microbiological Specification for Foods (2005). This result suggested a maximum microbial count of less than 5.0 log CFU/g and a coliform level of less than 2.0 log CFU/g of shellfish for consumer safety. Our values in this study were also considerably higher than those obtained by Oranusi and Nubi, (2016), who found microbial counts ranging from 4.11 to 5.75 log CFU/g from ready-to-eat shrimp was selected from three vending sites along Lagos-Shagamu expressway. Ehigiator et al., (2008) also obtained values ranging from 2.03 to 5.08 log CFU/g in prawns from Ovie River in Edo State.

The extremely high counts might result from pollutants from shrimp flora that were not eliminated by the processing methods, or they could be due to post-process contamination that originated from the processing environment, water, utensils, and food employees (Chukwu et al., 2013). The discovery of coliforms in the shrimp samples

suggests that the items may have been tainted with animal or human faeces, which might be a probable explanation for their contamination. Coliforms are considered indicator organisms because the presence of these organisms suggests that other intestinal pathogens could also be present. Because the samples are frequently packaged and organised with bare hands in white cellophane or hawked in tiny bowls for clients using forks or toothpicks to select, contamination with coliforms might be caused by the staff (food processors and vendors). The water used for processing and cleaning utensils is another potential source of coliform contamination in samples (Reilly et al., 2007; Zambuchini et al., 2008). The market environment at Bodija, Aleshinloye, and Eleyele could contribute to coliform contamination. Also, animals in their flocks are a typical scene in these markets as the animals are moved to nearby markets for sale. Therefore, the practical application of sound and hygienic shrimp-processing practices and HACCP is essential to prevent contamination from coliform.

The bacteria isolated from ready-to-eat shrimp in this study were *Bacillus* spp., *Shigella* spp., *Salmonella* spp., *E. coli*, *Staphylococcus aureus* and *Staphylococcus epidermidis*. In contrast, the fungal organisms isolated were *Rhizopus* spp. and *Trichophytum* spp., *Aspergillus fumigatus, Aspergillus flavus, Penicillium* spp., *Candida* spp. and *Mucor* spp. The presence of *Staphylococcus aureus* and *S. epidermidis in* the shrimp selected for this study indicates the possible contamination of the samples from personnel because both organisms are found in the normal flora of humans. Furthermore, shrimp samples could have been cross-contaminated from equipment and contact surfaces. Enterotoxin-producing strains of *S. aureus* are known to cause food poisoning (Le Loir et al., 2003; Oranusi et al., 2007). There is, therefore, a need to control ready-to-eat shrimp from *S. aureus* contamination. In addition, the presence of entero-bacterial organisms, such as *Salmonellae* and *E. coli* showed that some of the shrimp samples were contaminated by faeces (Oranusi et al., 2007). *Salmonellae* are the infectious organisms that cause salmonellosis, which is frequently linked to the intake of foods and drinks that have been contaminated (Heinitz et al., 2000; Phan et al., 2005). The presence of *E. coli* in some of the shrimps is evidence that the shrimps were contaminated with faeces and may affect the consumer's health. Evidence shows that the pathogenic strains of *E. coli*, notably *E. coli* O157: H7, are responsible for outbreaks of food-borne infections (CDC, 2014). Over the past few years, there has been a significant increase in focus placed on the production, processing, packing, transportation, and storage of food. Because of this, foods can get contaminated with infectious or toxigenic bacteria if they are not produced and kept in the appropriate circumstances and/or if any damage occurs. As a result, they can become a source of disease transmission to humans. In Brazil, staphylococcal food poisoning epidemics have been observed and examined for several years (Carmo, 1995).

It is well-established that certain fungal species produce spores and are widespread environmental contaminants; this could be why those spores were found in the shrimp samples. Most *Bacillus* and fungal species are either food spoilage organisms or opportunistic pathogens. Therefore, they need to be controlled to reduce the likelihood of engaging in activities that result in food spoilage. Mycotoxins are known to be produced by fungi such as Aspergillus species when favourable conditions are present; these mycotoxins are a concern in ready-to-eat foods. Shrimp should not be taken lightly because these products are stored for days before being sold. In addition, these products are nutritionally rich enough to support the proliferation of these fungi in growth and possibly the production of mycotoxins. Particularly in the immunocompromised population, certain species of Rhizopus and Mucor have been linked to acting as opportunistic agents that cause infections (Kirk et al., 2008). Mycotoxins are known to be produced by certain species of fungi, such as *Aspergillus*. Moreover, *A. flavus* is a species that produces aflatoxin, which has been linked to human carcinogenicity, mutagenicity, and teratogenicity (Zhang et al., 2015). The fungus, *A. fumigatus,* is the most common pathogen that causes infections in humans, followed by the bacteria *A. flavus*, *A. niger*, *A. terreus*, and *A. nidulans* (Morgan et al., 2005).

According to Adebayo-Tayo and Okpo (2010), the occurrence of *Penicillium sp.* and *Aspergillus sp.* could be because, during storage, the shellfish, such as the shrimp samples, are susceptible to reabsorb moisture from the environment, which then supports the growth of microorganisms in addition to the contamination during processing and handling. Therefore, the occurrence of indicators and other organisms investigated in this study is of particular concern. Also, the greatest threat associated with shrimp used for food preparation, eating purposes and other human consumption may be due to contamination by human excrement (Okonko et al., 2009). Therefore, it is essential to do microbiological testing on shrimp and other types of seafood before they are prepared and packed for human consumption to lessen the risk of infection (Fagade et al., 2005).

Most organisms discovered on these shrimps are the microbes often found in soil and water. But an organism, *S. aureus*, found in shrimp, is a pathogenic organism that is important to public health. The pathogens isolated in this current study are comparable to the microorganisms reported by Olawale et al. (2005). They found nine bacterial genera and two fungal genera in a study that was very similar to this one, which included *E. coli* and *S. auerus*. The

findings of this study are in agreement with the findings of Adesokan et al. (2005), who reported the presence of *E. coli* and *Bacillus sp.* among other organisms, and Bankole et al. (2004); Bankole et al. (2005), who reported the presence of *S. aureus*, *S. epidermidis*, *Bacillus sp.*, *E. coli*, *Shigella sp.*, *Salmonella sp.*, and *A. flavus*. The finding that the organisms *Bacillus sp.* and *A. flavus* were present in the contamination of some non-carbonated orange drinks is comparable to the findings that Fagade et al. (2005) obtained from a study on the microbiological qualities of certain non-carbonated orange drinks. In that study, the researchers found that the same organisms were present in the contamination of the drinks.

The presence of *Bacillus* spp. *and Aspergillus flavus* in this shrimp sample is also comparable with Ehigiator et al. (2014) in a study of bacteria and fungi load of raw processed shrimp from different meat shops in the Benin metropolis. According to the findings of the study, the same organisms were present. It was discovered that locally smoked prawns had microorganisms that were either pathogenic, cause food poisoning or deterioration, or are of epidemiological importance.

Antimicrobial resistance is a worldwide public health concern that has drawn attention in the recent time. Existence of antibiotic resistance amongst the bacterial isolates may have public health implication in shrimp consumers. While the bacterial isolates from the shrimps were multidrug resistant, the resistance of the isolates to antibiotics could be explained by the possibility of the massive use of these compounds in aquaculture, several of which are non-biodegradable (Gufe et al., 2019). This study also revealed the effectiveness of the existing and readily available drugs to control both gram-positive and gram-negative bacterial pathogens in aquaculture. However, there is need to be aware of the potential hazards of indiscriminate use of drugs in aquaculture systems, which has been largely reported (Okocha et al., 2018).

CONCLUSION

This study demonstrated the presence of highly pathogenic agents such as *Salmonella* and *Shigella* species in ready-to-eat shrimps samples from Ibadan. The mean total bacterial and coliform counts were 6.40 log CFU/g and 6.24 log CFU/g, respectively. This study concluded that ready-to-eat shrimps in Ibadan are not safe, wholesome and fit for human consumption because of the high loads of bacteria. The bacterial and fungal organisms isolated from the shrimps indicate contamination from personnel and the environment. The isolated multidrug resistant bacteria pose high risk to human, animal, and the environment. Strict rules and monitoring activities combined with food safety training for stakeholders on various aspects of good hygiene practices are recommended.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

NOVELTY STATEMENT

The study provided current data on the microbial load of shrimps which is not routinely checked in Ibadan.

AUTHORS CONTRIBUTION

Olufemi Bolarinwa Adedeji conceived, designed and supervised the study; Blessing Ndenum Peter performed the research, analysed and interpreted the data; Reuben Chukwuka Okocha and Ekemini Moses Okon analysed and interpreted the data, writing - review and editing.

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