J. of Family and Society Research 3 (1), June 2024, pp. 68 – 79

JFSR

# Qualitative and Quantitative Analysis of Microbes in Locally Fermented Food Condiments Sold in a Selected Market in Enugu State

***Nwobi, C.A.[1], Owoh, N.P.[1], Oguejiofor, O.M.[1], & Eze, D.[1]**
[1]Department of Home Science and Management,
University of Nigeria, Nsukka

***Correspondence**: chibundo.okonkwo@unn.edu.ng

**Abstract**

The microbiological assessment of three commonly consumed Nigerian fermented food condiments, ogiri (*Ricinus communis*), ukpaka (*Pentaclethra macrophylla*), and okpei (*Parkia biglobosa*), sourced from different vendors in Nkwo-Ibagwa market, Nsukka, was conducted to ascertain their quality. The objectives of the study were to identify microbial contaminants and their total viable count, compare the total viable count of microorganisms, isolate and identify the Gram's characteristics of the microorganisms in the samples using established protocols. Descriptive statistics (mean and standard deviation) and ANOVA were used to analyze the data. The findings revealed the presence of fermentative bacteria such as *Bacillus coagulance, Bacillus subtilis, Micrococcus varians, Bacillus licheniformis, Lactobacillus fermenti, Lactobacillus caesi*, and *Micrococcus luteus*. Pathogenic bacteria including *Pseudomonas aeruginosa, Escherichia coli, Staphylococcus saprophyticus, Staphylococcus aureus,* and *Klbsiellaoxytoca* were also detected. Notably, ogiri and ukpaka samples had both gram-positive and gram-negative microorganisms, whereas only gram-positive microorganisms were found in okpei samples. The total bacterial counts ranged from 1.5 x $10^6$cfu/g to 1.2 x $10^9$cfu/g, with ogiri exhibiting the highest total coliform count and okpei the lowest. There was a significantly different mean total viable count of microbes in okpei (4.1x$10^6$cfu/g) compared to ogiri (6.6x$10^8$cfu/g) and ukpaka (3.8x$10^8$cfu/g). The study highlights the potential health risks, including poisoning and gastroenteritis, faced by consumers of these condiments. Consequently, it advocates for enhanced hygiene practices among processors and traders to mitigate cross-contamination and ensure consumer safety.

**Keywords:** Fermentation, Fermented foods, Condiments, Fermented food condiments, Microbiological quality

## Introduction

Fermentation is viewed as one of the oldest and most cost-effective techniques for producing and preserving foods in developing countries (Chukwu et al., 2019). It is defined as the extensive growth of microorganisms on a suitable medium, often with the aim of generating specific chemical products such as enzymes, vaccines, antibiotics, or various food products or additives (Ramesh & Joshi, 2014). This process takes place without the presence of oxygen, and is facilitated by microorganisms like yeast and bacteria. Fermented foods are defined as delectable products, derived from both raw or heat-treated materials, and whose distinct properties are acquired through microbial processes (Ogunshe & Olasubga, 2008). These foods hold considerable significance as they not only provide, but also preserve substantial quantities of nutritious food items, presenting a diverse array of flavours, aromas and textures that contribute to the enrichment of the human diet (Osho et al., 2010). Nigeria, specifically, boasts of a wide variety of indigenous staple foods suitable for fermentation, many of which serve as essential condiments in household food preparations.

Condiments refer to edible substances which are added to foods to impart a specific flavor, enhance existing flavors, and in certain cultural contexts, complement the dish (Chukwu et al., 2019). They can be derived from both plant and animal sources, utilizing processes in which microorganisms actively participate in altering the physical, nutritional and sensory properties of the initial ingredients. Typically, local condiments are prepared through traditional methods involving uncontrolled solid substrate fermentation leading to extensive breakdown of proteins and carbohydrates. These local condiments, often produced from fermented vegetable protein, are typically presented as oily pastes with distinctive ammonical scent (Isu & Ofuya, 2000). In Nigeria, these local condiments are integral to food preparation, serving as flavour enhancers to impart pleasant aroma to soups, sauces and other traditional dishes. Additionally, these local condiments serve as rich sources of protein, essential amino acids, lipids, carbohydrates, fatty acids and vitamins (Olasupo, 2006). Among the most widely recognized indigenous fermented condiments available in local markets in Nsukka are ogiri, ukpaka and okpei.

Ogiri is a local condiment derived from melon or castor seed oil (*Ricinus communis*) belonging to the family of Euphorbiaceae. It undergoes a fermentation process where bacteria and fungi breakdown the proteins and carbohydrates in the seeds. This process yields a paste-like substance characterized by a strong aroma and nutty flavour, typically wrapped in plantain or banana leaves (Achi, 2005). In Nigerian cuisine, Ogiri is widely utilized to impart flavor and fragrance to soups and various dishes, particularly in the eastern and southern regions, where it features prominently in recipes such as ofeakwu (Banga soup), ofeonuogbu (bitter leaf soup), and ofeoha (oha soup).The production techniques for Ogiri are deeply rooted in Nigerian tradition, with methods varying across regions and specific ingredient choices.Besides its flavor-enhancing properties, ogiri boasts significant nutritional value, being a rich source of protein, fiber, essential amino acids, vitamins, and minerals. Recent years have witnessed a surge in interest regarding Ogiri, with some studies (Irobi et al., 2000; Ibeabuchi et al., 2014; Ahaotu et al., 2020; Okwunodulu et al., 2020) suggesting its potential as a functional food offering health benefits such as antimicrobial and antioxidant properties.

Ukpaka, a ready-to-eat condiment, is produced by fermenting African oil bean seeds (*Pentaclethra macrophylla*), a specie of the Fabacae family. Predominantly consumed by the Igbo people of southeastern Nigeria, it serves as a protein rich delicacy typically produced in households as a small-scale family enterprise, leading to variations in production methods and resulting in non-uniform products (Ogueke et al., 2010). Ukpaka is commonly enjoyed with various local dishes such as tapioca (Abacha), different yam, cocoyam, and pigeon pea dishes. It serves as an affordable protein source, particularly for those whose staple diets are deficient in protein (Obeta, 2008) and is reported to be rich in fats and carbohydrates (Odoemelam & Nwokedi, 2005). During the fermentation process of ukpaka, bacteria such as *Bacillius subtilis, B.micrococcus* and *B. lactobacillius* significantly alter the product nutritionally, biochemically and oganoleptically and are often introduced through air, water, utensils or handlers themselves (Ogueke & Aririata, 2004).

Okpei is another locally fermented food condiment derived from locust bean seed (*Parkia biglobosa*) and is known by various indigenous names such as iru (Yoruba), okpehe (Idoma) and kiriya (Hausa) (Ogunshe et al., 2007). It is commonly utilized across Nigeria by Igbo, Yoruba, and Middle Belt indigenous populations to enhance the flavor of soups and various local dishes (Gberikon et al., 2015). It is a good source of protein, thus offers a cost-effective option for individuals with limited income and can help address protein-energy malnutrition and essential fatty acid deficiencies (Oguntoyinbo et al., 2001). Okpei is used in the preparation of a wide range of dishes including soups like ofeoyi, egusi, ogbono and okro soups; sauces such as local tomato sauce, vegetable sauce; and local dishes such as yam, potato, plantain pottage and local jollof rice. Similar to ogiri and ukpaka, the primary organisms involved in okpei fermentation predominantly the Bacillus species, including *B. subtilis, B. pumilus, B. licheniformis* and *B. megaterium* (Oguntoyibo et al., 2010; Geberikon et al., 2015). Although these three fermented condiments have not been implicated in food poisoning, the absence of standardized sanitary and quality control measures during household production in Nsukka Local Government Area raises concern, prompting the need for microbial quality assessments.

Microbial quality of food refers to the absence or limited presence of harmful microorganisms, such as pathogens and spoilage organisms, in a food product (Springer, 2005). It constitutes a crucial aspect of food safety, ensuring that the food is safe for consumption and has an extended shelf life. Microbial quality is commonly evaluated through microbiological analysis, employing techniques to detect and quantify microorganisms within a food sample. Investigating the microbial quality of locally fermented foods is essential to ensure that the food products are of a high quality, and are safe for consumption. The selection of Nkwo-Ibagwa market for this study stems from its significance as a central trading hub for these condiments, which are integral in the traditional cuisine of the region.

**Objectives of the study:** The broad objective of the study was to determine the microbiological quality of three locally fermented food condiments sold in Nkwo-Ibagwa market in Nsukka, Enugu State. Specifically, the study sought to:

1. identify the microbial contaminants and their total viable count in samples of ogiri, ukpaka and okpei sold in Nkwo-Ibagwa market in Nsukka, Enugu State;
2. compare the total viable count (microbial load) of microorganisms in the samples of ogiri, ukpaka and okpei and;
3. isolate and identify gram characteristics of microorganisms in the different samples.

## Materials and Methods

***Sample procurement*:** The samples were procured fromNkwo-Ibagwa market located in Enugu State, Nigeria. It is situated in the Ibagwa-Ani community, which is part of the Nsukka Local Government Area of Enugu State. A total of 15 packaged samples, 5 samples each of okpei, ukpaka and ogiri were randomly purchased from different sellers in the market. They were labelled accordingly and transported immediately in an ice chest to the laboratory for analysis.

***Sample cultivation*:** The samples were transferred onto oven-dried, sterile agar plates and streaked using a sterile inoculating wire loop. After a 10-minute standing period, the plates were incubated at specific temperatures (35°C for 48 hours on glucose-enriched agar plates and 25°C for 72 hours on sabourauds dextrose agar plates). Observations were made after the initial 48-

hour and 72-hour incubation periods, followed by additional incubation for another 48 hours for further assessment.

***Determination of the original cell population (Total Viable Count: TVC) of the microbes:*** The surface viable count method was used to determine the original cell population. 1g of the samples were weighed and suspended in 10ml of sterile water, then allowed to stand for 15 minutes with agitation at intervals. Serial dilutions were prepared using the 10-fold serial dilution techniques as described by American Public Health Association [APHA] (1985). The oven dried sterile glucose enriched agar plate was divided into 8 equal parts, and labeled and a portion of each dilution was plated onto it. The plates were incubated at 35°C for 48 hours, and colonies were counted to determine the dilution yielding countable colonies. Mean colony counts per drop were calculated from the observed growth on the plates.

***Identification of bacteria isolates*:** Each colony was then isolated and transferred onto oven-dried sterile agar plates using a sterile inoculating wire loop. The plates were then incubated overnight at 35°C. Following the incubation period, the culture plates were examined for purity of the isolates. The bacteria isolates were identified based on colonial morphology like color of hyphae, shape and texture. The method of Foyowo (2017) was used for the microscopic examination of the bacteria isolates using the wet mount technique. The observed characteristics were compared with the characteristics of reference organisms according to Cooper (1995).

***Statistical analysis*:** Data generated from the study was coded into Statistical Product for Service Solution (SPSS version 23). Descriptive statistics (mean and standard deviation) was used to analyze the data. The level of significance was determined using one way analysis of variance (ANOVA) and accepted at $p \leq 0.05$. Duncan's New Multiple Range test was used to separate means for each parameter.

## Results

### Presence of and total viable count (microbial load) of microorganisms in the samples

Table 1 shows the presence of microbiological contaminants as well as the microbial load of each sample. The result shows that all the 15 samples had growth of various microorganisms on 0.5% W/V Glucose enriched agar. Furthermore, the total viable count of ogiri samples ranges from $1.2 \times 10^9$ cfu/g to $9.5 \times 10^8$ cfu/g. The microbial load of ukpaka samples ranges from $2.0 \times 10^8$ cfu/g to $6.5 \times 10^8$cfu/g. The total viable count of microorganisms in the okpei samples ranges from $1.5 \times 10^6$cfu/g to $8.0 \times 10^6$cfu/g.

**Table 1: Presence of and total viable count (microbial load) of microorganisms in the samples**

| Sample | Growth on 0.5% W/V Glucose Enriched Agar | Total viable count (cfu/g) |
|---|---|---|
| **Ogiri 1** | Positive | 400000000 ≅ $4.0 \times 10^8$ |
| **Ogiri 2** | Positive | 950000000 ≅ $9.5 \times 10^8$ |
| **Ogiri 3** | Positive | 550000000 ≅ $5.5 \times 10^8$ |
| **Ogiri 4** | Positive | 1200000000 ≅ $1.2 \times 10^9$ |
| **Ogiri 5** | Positive | 200000000 ≅ $2.0 \times 10^8$ |
| **Ukpaka 1** | Positive | 250000000 ≅ $2.5 \times 10^8$ |
| **Ukpaka 2** | Positive | 350000000 ≅ $3.5 \times 10^8$ |
| **Ukpaka 3** | Positive | 650000000 ≅ $6.5 \times 10^8$ |
| **Ukpaka 4** | Positive | 450000000 ≅ $4.5 \times 10^8$ |
| **Ukpaka 5** | Positive | 200000000 ≅ $2.0 \times 10^8$ |
| **Okpei 1** | Positive | 4000000 ≅ $4.0 \times 10^6$ |
| **Okpei 2** | Positive | 1500000 ≅ $1.5 \times 10^6$ |
| **Okpei 3** | Positive | 8000000 ≅ $8.0 \times 10^6$ |
| **Okpei 4** | Positive | 4500000 ≅ $4.5 \times 10^6$ |
| **Okpei 5** | Positive | 2500000 ≅ $2.5 \times 10^6$ |

**Comparison of the total viable count (microbial load) of the condiments**

Table 2 shows the significant difference between the microbial loads of ogiri, okpei and ukpaka samples. From the table, okpei ($4.1x10^6$cfu/g) differed significantly (p = 0.006) from ogiri and ukpaka. However, the mean tvc of microbes in ogiri ($6.6x10^8$cfu/g) and ukpaka ($3.8x10^8$cfu/g) were comparable (p = 0.11).

**Table 2: Comparison of the total viable count (microbial load) of the different condiments**

| Samples | Mean TVC (cfu/g) |
|---|---|
| **Ogiri** | $660000000^b$± 408350339.80 |
| **Ukpaka** | $380000000^b$ ± 178885438.20 |
| **Okpei** | $4100000^a$ ± 2484954.72 |

Values = mean ± standard deviation. Means with the same superscripts are comparable at p ≤ 0.05 while means with different superscript are significantly different at p ≤ 0.05.

**Gram characteristics of microorganisms in samples of the food condiments**

Table 3 shows the gram character of the microorganisms present in the samples. Both gram positive and gram-negative microorganisms were present in the ogiri samples when gram stained. A similar pattern was also observed in the ukpaka samples. In the okpei samples, all microorganisms were gram positive when gram stained. The table also presents the microorganisms identified in each of the samples. From the table, *Bacillus coagulance, Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Bacillus licheniformis, Lactobacillus fermenti and Lactobacillus casei* were isolated and identified in different samples of ogiri. The microorganisms identified in samples of ukpaka include *Escherichia coli, Micrococus luteus, Lactobacillus fermenti, Micrococcus varians, Staphylococcus saprophyticus, Klebsiella oxytoca, Bacillus subtilis and Lactobacillus casei*. Similarly, *Bacillus subtilis, Lactobacillus fermenti, Staphylococcus aureus and Micrococcus varians* were isolated and identified in different samples of okpei.

**Table 3: Gram characteristics of microorganisms in samples of the food condiments**

| Sample | Gram's character | Isolate identified |
|---|---|---|
| **Ogiri 1** | Positive, negative | *Bacillus coagulance, Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Bacillus licheniformis* |
| **Ogiri 2** | Positive, negative | *Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Lactobacillus fermenti* |
| **Ogiri 3** | Positive, negative | *Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Lactobacillus casei, Lactobacillus fermenti,* |
| **Ogiri 4** | Positive | *Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Lactobacillus fermenti* |
| **Ogiri 5** | Positive, negative | *Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Lactobacillus fermenti* |
| **Ukpaka 1** | Positive, negative | *Escherichia coli, Micrococcus luteus, Lactobacillus fermenti* |
| **Ukpaka 2** | Positive, negative | *Escherichia coli, Micrococcus varians, Lactobacillus fermenti, Staphylococcus saprophyticus, Klebsiella oxytoca* |
| **Ukpaka 3** | Positive, negative | *Micrococcus varians, Lactobacillus fermenti, Klebsiella oxytoca* |
| **Ukpaka 4** | Positive, negative | *Escherichia coli, Micrococcus varians, Lactobacillus fermenti, Staphylococcus saprophyticus, Klebsiella oxytoca* |
| **Ukpaka 5** | Positive, negative | *Bacillus subtilis, Micrococcus varians, Lactobacillus casei, Staphylococcus saprophyticus, Klebsiella oxytoca* |

| | | |
|---|---|---|
| **Okpei 1** | Positive | *Bacillus subtilis, Lactobacillus fermenti, Staphylococcus aureus,* |
| **Okpei 2** | Positive | *Micrococcus varians, Lactobacillus fermenti, Staphylococcus aureus* |
| **Okpei 3** | Positive | *Bacillus subtilis, Lactobacillus fermenti, Staphylococcus aureus* |
| **Okpei 4** | Positive | *Bacillus subtilis, Micrococcus varians, Staphylococcus aureus* |
| **Okpei 5** | Positive | *Micrococcus varians, Lactobacillus fermenti, Staphylococcus aureus* |

**Discussion of findings**

The findings of this study revealed the presence of microorganisms in each sample of ogiri, ukpaka and okpei sold in Nkwo-Ibagwa market in Nsukka. This outcome is anticipated, given that these condiments undergo fermentation, a process reliant on the presence of microorganisms. The present study revealed varying levels of microbial presence in samples of ogiri, ukpaka and okpei. The lowest total viable count of microorganisms was observed in ogiri4 while ogiri2 had the highest. Sample Ukpaka3 and Ukpaka5 exhibited the highest and lowest total viable counts respectively within the Ukpaka samples. Sample Okpei2 and Okpei3 had the lowest and highest total viable counts in okpei samples.

The microbial load of a food product reflects the quantity of microorganisms present within that product, typically measured as colony-forming units per gram (cfu/g). It is an important hygiene indicator that may give information about the overall microbiological status of food products. These microorganisms may have contaminated the condiments at any stage, ranging from production up to the point of sale. Comparatively, the total microbiota counts observed in these condiments exceeded those reported by Fowoyo (2017), whose study recorded microbial counts ranging from $9.5 \times 10^5$ to $1.8 \times 10^6$ cfu/g. It is noteworthy that microbial counts serve as an indicator solely for the microbiological quality of a food product and there are no universally binding standards governing the quality of products of this type. Thus, following the criteria outlined by Lepcka et al. (2022), the food condiments analyzed in this study were categorized as unsatisfactory due to their total viable count of organisms exceeding $10^6$cfu/g.

The microbial load in okpei sample was significantly lower compared to ogiri and ukpaka. This suggests that okpei might be less prone to spoilage and may have a longer shelf-life. The result is expected given that okpei has lower moisture content than the others as it is usually sundried after production. A lower microbial load indicates a lower risk of contamination by harmful bacteria, which can reduce the risk foodborne illness. Thus, consumers of okpei may face fewer health risks related to microbial contamination. The microbial loads of ogiri and ukpaka are comparable, indicating similar levels of microbial activity in the products. These two condiments are usually wrapped in leaves or stored in plastic bags after production. Thus, the higher microbial load indicates improper handling or/and storage which can pose potential health risk to the consumer.

Gram positive bacteria are characterized by thick cell walls which provide them with protection against antibiotics and other potentially harmful substances. On the other hand, gram negative bacteria have thinner cell walls and are more susceptible to antibiotic destruction. This study identified microorganisms exhibiting either gram-positive or gram-negative characteristics. This simply implies that the gram-positive microorganisms may present challenges in antibiotic treatment in cases of infection due to their resistance or reduced susceptibility, whereas gram-negative microorganisms are typically more susceptible to antibiotics. Thus, consumption of food contaminated with any of these microorganisms can result in varying degrees of difficulty in treatment. This finding is in line with the observations of Ogunshe & Olasugba (2008) who noted that gram-negative bacteria isolated in their study have been implicated in acute bacterial diarrheas and food poisoning incidents.

The microorganisms identified in this study included *Bacillus coagulance, Bacillus subtilis, Pseudomonas aeruginosa, Micrococcus varians, Micrococcus luteus, Bacillus licheniformis, Lactobacillus fermenti, Lactobacillus casei, E.coli, Staphylococcus aureus, Staphylococcus saprophyticus and Klebsiella oxytoca*. This finding is in line with that of Fowoyo (2017). According to Enujiugha (2009), *Bacillus* species are commonly associated with the fermentation process of locust bean seeds used in the production of okpei. *Bacillus* species produce protease enzymes, which play a key role in the breakdown of proteins, contributing to the texture and flavor of fermented foods (Fowoyo, 2017). It is worthy to note that *Bacillus subtilis* is recognized a Generally Regarded as Safe (GRAS) organism by the Food and Drug Administration, and is commonly found in the human gut, with humans likely to exhibit resistance to its effects.

While the bacillus strains identified in this study were deemed safe for human consumption, they may pose potential side effects to the consumer. Enujiugha (2009) reported that *B. coagulance* can lead to stomach upset, bloating or gas, while *B. licheniformis* may cause vomiting, diarrhea and abdominal cramps when consumed in high numbers ($10^6 - 10^8$). These symptoms typically manifest within 2 to 14 hours after consumption and may persist for up to 24 hours. *B. licheniformis* produces heat-resistant toxins called lichenysin, which remain unaffected by cooking or the host's digestive system. In line with the study, Dodd et al. (2017) noted that diseases associated with *B. substilis* exhibit rapid onset, occurring within ten minutes to fourteen hours, with symptoms resolving within 1.5 to 8 hours. Common symptoms include vomiting, diarrhea accompanied by abdominal cramps, nausea and headaches. Additionally, *B. substilis* produces an enzyme called subtilism, which when consumed in high quantities, may trigger allergic reactions.

*Pseudomonas aeruginosa,* a gram-negative bacterium commonly found in water, soil, plant and animal tissues, is recognized as an opportunist human pathogen which possesses the ability to cause severe acute and chronic life-threatening infections such as meningitis, otitis media, urinary tract infections and pneumonia. In this study, *Pseudomonas aeruginosa* was isolated in ogiri samples, a condiment often wrapped in layers of leaves prior to sale. Hence, contamination of this condiment may have occurred through the leaves used for wrapping, water utilized during sample preparation or via contact with surfaces, equipment or the handler themselves. This finding is consistent with the observations of Gao et al. (2023), who similarly identified *Pseudomonas aeruginosa* as a common food spoilage bacterium, noting its ability to proliferate even at low temperatures and its frequent involvement in foodborne infections. Consequently, the practice of refrigerating ogiri contaminated with this bacterium in an attempt to inhibit its growth may prove ineffective. Moreover, *Pseudomonas aeruginosa* has been isolated from various food items in prior studies conducted by Xu et al. (2019), Li et al. (2020), Erhirhie et al. (2020), and Ezemba et al. (2022). Recent research has also highlighted the antibiotic resistance of *Pseudomonas aeruginosa* strains, particularly against

Ceftazidime, Cefepime and Tobramycin (Xie et al., 2017; Liu et al., 2018). This emphasizes the importance of monitoring and addressing microbial contamination in food products to mitigate health risks posed by antibiotic-resistant pathogens like *Pseudomonas aeruginosa.*

*Micrrococcusvarians and Micrococcus luteus,* both gram-positive cocci bacteria commonly utilized in food fermentation, are generally recognized as GRAS and are renowned for enhancing the colour and flavour profiles of fermented food products. The findings of this study indicate the widespread presence of *Micrococcus varians* across nearly all examined samples, with *Micrococcus luteus* detected in a single sample of ukpaka. This finding aligns with reports by Fowoyo (2017). Despite their GRAS status, both *M. varians*and *M. luteus* are implicated as food spoilers, diminishing the shelf-life of food products. Additionally, *M. luteus* has been associated with opportunistic pathogenicity, contributing to various health ailments including septic arthritis, prosthetic valve endocarditis, and recurrent bacteraemia, pneumonia in acute leukaemia patients, and catheter-related infections in pulmonary arterial hypertension patients. Nuñez (2014) emphasizes the importance of recognizing *M. luteus* not solely as a contaminant but also potential pathogen necessitating therapeutic interventions.

*Lactobacillus* species such as *Lactobacillus fermenti and Lactobacillus casei* are gram-positive bacteria identified in this study which demonstrated varying prevalence among the samples evaluated, with *Lactobacillus fermenti*detected in 12 out of 15 samples and *Lactobacillus casei* in 2 out of 15 samples. This aligns with the findings reported by Ogunshe and Olasugba (2008). *Lactobacillus fermenti,* as the name implies, plays a pivotal role in the fermentation of food products while *Lactobacilluscasei* contributes to both fermentation and ripening processes. Despite being generally regarded as safe, these bacteria may induce gastrointestinal discomfort, including gas, stomach upset or diarrhea when consumed above $10^9$ colony-forming units. Additionally, individuals with allergies may experience adverse reactions such as skin rash, hives, swelling, dizziness and difficult breathing upon ingestion.

Staphylococcus species, gram-positive bacteria belonging to the Staphylococcaceae family were also identified in this study, comprising *Staphylococcus saprophyticus* and *Staphylococcus aureus. Staphylococcus saprophyticus* was identified in three samples of ukpaka while *Staphylococcus aureus* was present in four samples of okpei. These bacteria are commonly spread because of poor hygiene and sanitary practices. Notable, *S. aureus* is usually found in the nasal cavity of humans and contaminates food substances when infected droplets are dispersed through sneezing or coughing. According to Bush and Schmidt (2023), *Staphylococcus aureus* portrays a significant concern among staphylococcal bacteria, posing a considerable risk of food poisoning that is often resistant to treatment with certain antibiotics. The Center for Disease Control and Prevention (2023) has pointed out the ability of *Staphylococcusaureus* to proliferate in foods and reproduce heat-resistant toxins, rendering them capable of causing illness even after cooking. While the bacterium itself can be destroyed by heat, the toxins are not and still possess the ability to cause illness after heating. Symptoms of food poisoning from this bacterium manifest within 30 minutes of consuming food and subside within 24 hours. It is worth to note that antibiotic treatment is ineffective against illnesses caused by *staphylococcusaureus* because the toxins produced are not susceptible to antibiotic action.

The results of the study have also identified *Klebsiella oxytoca*and *Escherichia coli* in four and three samples of ukpaka, respectively. The detection of these potential pathogens emphasizes the associated risks linked with consuming this condiment and underscores the necessity of stringent control measures. Ukpaka is commonly consumed without heat treatment rendering it susceptible to microbial contamination. *Klebsiella oxytoca*is a gram-negative bacterium that occurs in the nasal cavity of humans and animals and can contaminate food products through contact with contaminated surfaces, equipment, and poor hygienic practices. Consumption of foods contaminated by *Klebsiellaoxytoca* may result in foodborne illnesses including nausea, abdominal cramps and vomiting, dehydration, and fatigue. *Escherichiacoli,* also a gram-negative bacterium originating from fecal matter, was likewise detected in ukpaka samples. The presence of *E. coli* in this food condiment is an indication of poor hygiene conditions and inadequate sanitary practices among the handlers. While most strains of *E. coli* are harmless, certain strains can cause severe food poisoning. According to the World Health Organization [WHO] (2018), symptoms of *E. coli* infection may include diarrhea (potentially bloody diarrhea in severe cases), fever and vomiting, lasting from three days to eight days, with most patients fully recovered by the tenth day. However, such infections may be life threatening to children and the elderly. The absence of *Klebsiella oxytoca and Escherichia coli* in samples of Okpei and Ogiri is noteworthy and commendable suggesting better hygiene practices or inherent differences in processing methods compared to ukpaka.

**Conclusion**

The study qualitatively and quantitatively analyzed microbes in locally fermented food condiments sold in a selected market in Enugu state. All fifteen samples showed microbial growth on 0.5%W/V glucose-enriched agar, and the microbial counts exceeded acceptable limits, indicating unsatisfactory microbiological quality according to established criteria. The microbial load in okpei sample was significantly lower than those of ogiri and ukpaka, indicating a lower risk of contamination by harmful bacteria.Ogiri samples contained both gram-positive and gram-negative microorganisms, including *Bacillus coagulans,* and *Pseudomonas aeruginosa*). Ukpaka samples also contained both gram-positive and gram-negative microorganisms, such as *Escherichia coli* and *Lactobacillus fermenti*.Okpei samples had only gram-positive microorganisms, including *Bacillus subtilis* and *Staphylococcus aureus*. Gram-positive bacteria have thick cell walls that protect them from antibiotics and other harmful substances while gram-negative bacteria have thinner cell walls, making them more vulnerable to antibiotics. The presence of pathogenic bacteria such as*Staphylococcus aureus* and *Escherichia coli* in some samples highlights the need for improved hygiene practices and sanitary measures throughout the food production chain. The potential health risks associated with these pathogens, including severe foodborne illnesses, highlight the importance of stringent quality control measures to safeguard consumer health.

**Recommendations**

The following recommendations were made based on the findings of this study.

1. Producers and sellers of okpei, ogiri, and ukpaka should be encouraged to implement strict hygienic practices during the production, packaging, and storage of these condiments. This includes proper hand washing, sanitizing equipment and storage containers, and maintaining a clean and controlled environment.

2. Regular testing and monitoring of samples for microbial contamination to help identify potential issues and take corrective measures. This will help in ensuring their safety and quality.
3. Collaboration among researchers, producers, farmers, and vendors should be encouraged to improve the overall quality and safety standards of locally fermented food condiments. This collaboration will ensure that stakeholders can collectively work towards implementing best practices and innovative solutions to address food safety concerns.
4. Local health authorities and public health agencies in Nsukka, Enugu State should play a crucial role in ensuring food safety within the community. They should enforce adherence to regulations, conduct regular random inspections, and provide training programmes aimed at enhancing hygiene practices of condiment producers and vendors. This will immensely contribute to the prevention of foodborne illnesses and the promotion of public health.

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