

# Effect of Traditional and Modern Cooking Methods on the Microbial and Physicochemical Quality of Jollof Rice

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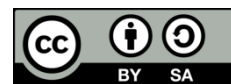
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## ABSTRACT

Jollof rice is a popular West African dish, but its microbiological and physicochemical quality can be compromised by cooking methods. This study investigated the effect of traditional and modern cooking methods on the microbiological and physicochemical quality of Jollof rice sold around University of Port Harcourt. 20 samples of Jollof rice were collected from vendors, cooked using with firewood and gas cooker. Microbiological analysis and physicochemical analysis were conducted using standard methods. Microbiological analysis revealed that firewood cooked Jollof rice had higher total heterotrophic bacteria count ( $3.7 \times 10^4$  CFU/g to  $4.5 \times 10^4$  CFU/g), exceeding stipulated standards. It was also observed that gas cooked Jollof rice had higher fungal count ( $1.4 \times 10^3$  CFU/g to  $8 \times 10^3$  CFU/g) was within stipulated microbiological standard. Firewood-cooked Jollof rice had higher microbial counts compared to gas cooked Jollof rice. Five bacteria species: *Bacillus subtilis*, (18.75%); *Klebsiella sp*, (12.5%); *Bacillus cereus*, (18.75%); *Staphylococcus aureus*, (43.75%); and *Proteus mirabilis*, (6.25%) and three fungi species: *Aspergillus niger*, (57.1%); *Fusarium sp*, (14.3%) and *Penicillium sp*, (28.6%) were isolated. Physicochemical analysis showed that firewood cooked Jollof rice had higher values in; Ash, fibre, lipid and moisture content compared to gas-cooked Jollof rice. Gas-cooked Jollof rice had better physicochemical properties, including lower pH and higher protein content. This study concludes that Traditional cooking methods (firewood) may compromise the microbiological and physicochemical quality of Jollof rice, while modern methods (gas) produce safer and more nutritious products. This study highlights the importance of adopting safe cooking practices to ensure food safety and quality. It is recommended to adopt modern cooking methods (gas) to ensure food safety and quality.

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## 1. INTRODUCTION

Jollof rice, a well-loved and iconic dish in West Africa, has become a symbol of culinary tradition, culture, and pride in countries such as Nigeria, Ghana, Senegal, and Sierra Leone [1]. It is typically prepared with rice, tomatoes, onions, and a variety of spices, often accompanied by chicken, fish, or meat [2][3]. Cooking methods can significantly impact the quality and safety of Jollof rice. Given its widespread popularity, ensuring Jollof rice's safety and nutritional quality is paramount, particularly in regions where foodborne diseases are a major public health concern. While the dish's ingredients play a crucial role in its flavor and nutritional value, the cooking method can significantly impact both its microbiological safety and physicochemical properties [4][5].

Cooking methods can significantly impact the quality and safety of Jollof rice. Traditional cooking methods, such as firewood cooking, are still widely used in many parts of West Africa, while modern

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methods like gas cooking are becoming increasingly popular [6]-[9]. Two prevalent cooking methods in many parts of West Africa are firewood cooking and gas cooking, each with its unique characteristics, advantages, and drawbacks. Firewood cooking, which is traditional in rural areas, relies on burning wood to generate heat. It is widely used due to its availability and low cost, particularly in low-income communities [10][11]. However, firewood cooking has been associated with several health, environmental, and safety concerns. In contrast, gas cooking is considered a modern and cleaner alternative, widely adopted in urban areas where liquefied petroleum gas (LPG) is accessible [12]. Gas stoves provide a more consistent and controlled heat source, which is crucial for ensuring proper cooking and preventing microbial contamination in food [13].

The method of cooking influences the microbiological quality of food by determining the degree of heat applied to inactivate harmful microorganisms. Cooking is essential for destroying pathogenic microorganisms such as *Salmonella* spp., *Bacillus cereus*, and *Escherichia coli*, which are commonly found in improperly cooked or stored foods [14][15]. However, the effectiveness of the cooking process depends on the ability to maintain an appropriate and consistent temperature. Firewood cooking, due to its reliance on open flames and natural materials, often results in uneven heat distribution, which may leave parts of the food undercooked. This can increase the risk of microbial contamination and foodborne illnesses [16]. Additionally, the exposure of food to smoke from firewood cooking can introduce harmful substances, such as polycyclic aromatic hydrocarbons (PAHs), which have been linked to carcinogenic effects [17][18].

On the other hand, gas cooking offers more precise temperature control, which allows for the thorough cooking of food, reducing the likelihood of microbial contamination [19]. Studies have shown that foods cooked with gas are less likely to harbor pathogens due to the consistent heat provided by gas stoves [20]. In addition to microbial safety, the method of cooking also affects the physicochemical properties of food, including its pH, moisture content, and nutrient retention. These properties are essential for maintaining the food's nutritional quality and sensory attributes, such as texture, flavor, and appearance.

Moisture content is a critical factor in food safety, as high moisture levels can promote the growth of microorganisms [21]-[23]. Foods with high moisture content, such as rice, are particularly susceptible to microbial spoilage if not cooked or stored correctly [24]. Firewood cooking, due to its variability in temperature, may result in uneven moisture retention in the food, potentially creating pockets of undercooked rice that could support the growth of bacteria. In contrast, gas cooking, with its more controlled heat, can help achieve a uniform moisture content in the rice, ensuring better microbial safety.

The pH of food also influences its microbiological stability. Foods with a low pH (acidic) are generally less susceptible to microbial growth [25][26]. In contrast, foods with a higher pH (neutral or alkaline) can support the growth of spoilage organisms and pathogens [27]. Cooking methods can affect the pH of food, either by causing chemical changes during heating or by influencing moisture loss. For instance, prolonged cooking over firewood can result in excessive drying and concentration of acids, which may alter the pH of the food. Gas cooking, with its ability to cook food quickly and evenly, may help preserve the natural pH balance of the dish.

Furthermore, cooking methods can have a significant impact on nutrient retention. Prolonged exposure to high temperatures, especially in methods like firewood cooking, can lead to the degradation of heat-sensitive nutrients such as vitamins and antioxidants. Gas cooking helps preserve the nutrient content of food better than firewood cooking, primarily due to its shorter cooking times and more consistent heat application. In dishes like Jollof rice, which contain a mix of vegetables, spices, and sometimes meat or fish, preserving these nutrients is essential for maintaining the dish's nutritional value.

The environmental and health concerns associated with firewood cooking have also been a growing topic of discussion. Firewood combustion releases harmful pollutants into the air, including particulate matter (PM<sub>2.5</sub>) and carbon monoxide (CO), which contribute to indoor air pollution [28][29].

Despite the benefits of gas cooking, its adoption in many rural areas remains limited due to economic barriers, including the high cost of gas and gas stoves and inadequate infrastructure for gas distribution. Firewood, being readily available and inexpensive, continues to be the primary cooking fuel for many households, even though it poses significant health and environmental risks. This creates a need to examine the impact of firewood cooking on food safety and to explore strategies for promoting the transition to cleaner cooking technologies. The microbiological and physicochemical quality of Jollof rice is influenced by the method of cooking. Firewood cooking, while economically viable for many households, poses risks to food safety due to inconsistent heat control and potential exposure to harmful smoke.

On the other hand, gas cooking offers better control over temperature and is associated with safer food handling practices. This study aims to explore these differences in greater detail by analyzing the microbial load and physicochemical properties of Jollof rice prepared using firewood and gas cooking methods. Focusing on traditional and modern cooking methods is crucial for improving nutrition, health, and food safety.

The study provides insights into how cooking practices affect food safety and quality, with potential implications for public health, nutrition, and environmental sustainability in regions where both cooking methods are widely used.

Firewood cooking and gas cooking may have different effects on the microbiological and physicochemical quality of Jollof rice. Firewood cooking involves exposing food to smoke and potentially harmful compounds, while gas cooking uses a controlled flame and may produce fewer pollutants. Jollof rice can be contaminated with microorganisms such as bacteria, viruses, and parasites, posing health risks to consumers [30]. Cooking methods can influence the microbiological quality of Jollof rice. Jollof rice cooked with charcoal had higher bacterial counts than Jollof rice cooked with gas. However, there is limited research on the specific effects of these cooking methods on Jollof rice. To investigate the effects of firewood and gas cooking on Jollof rice's microbiological and physicochemical quality.

## 2. METHOD

A total of 20 samples of Jollof rice were collected from food vendors in the University of Port Harcourt, Choba, Rivers State campus. The food samples included ten roadside vendors who practice traditional cooking methods and ten restaurants that practice modern cooking methods. The samples were immediately transported to the Food Microbiology Research laboratory at the University of Port Harcourt, Department of Microbiology, Port Harcourt, Rivers State.

### 2.1. Microbiological Analysis of Jollof Rice

#### 2.1.1. Sample preparation

Ten (10) grams of each Jollof rice sample was mixed with 90 ml of normal saline, and serial dilutions of each sample homogenate were made to  $10^{-6}$  dilutions.

#### 2.1.2. Serial dilution and inoculation

The isolation and enumeration of microbes were performed using serial dilution of all the samples carried out in up to  $10^{-6}$  in normal saline. Samples were plated in duplicates using spread plate methods. 0.1ml of dilution factor  $10^{-1}$  to  $10^{-6}$  of the samples were pipetted into petri dishes containing Plate count agar for total bacteria count, Mannitol salt agar for total staphylococcus counts and Potato dextrose agar for total fungi count well spread and were incubated at  $37^{\circ}\text{C}$  for 24 – 48 hrs and 3 to 5 days for total fungi count hours. The total colony-forming unit (CFU/ml) was recorded after incubation.

#### 2.1.3. Isolation and preparation of a pure colony

Using a sterile wire loop, a random colony was picked from each culture and subculture on a freshly prepared sterile nutrient agar and incubated for 24 hours for the bacteria. In contrast, potato dextrose agar was used to incubate fungi for 5 days to obtain a pure colony [31][32]. Bacterial isolates were identified using standard biochemical tests as described by Chesbrough (2006).

#### 2.1.4. Fungal isolation and identification

The fungal isolates were identified microscopically and macroscopically. Slide preparation of the fungi isolates was made and stained with lactophenol cotton. Cover glasses were placed over them and examined under the microscope [33]-[35].

#### 2.1.5. Physicochemical Analysis of Jollof rice meal prepared via different cooking methods

Proximate composition, moisture, ash, and protein content of the samples in triplicate were determined by the analysis methods of the Association of Official Analytical Chemists procedure [36][37]. The Soxhlet extraction method determined the fat content, while the carbohydrate was determined by difference.  $\text{Carbohydrate} = 100 - (\text{moisture} + \text{ash} + \text{fibre} + \text{protein} + \text{fat})$ .

The samples (2.0 g) were digested with nitric and perchloric acids ( $\text{HNO}_3 / \text{HClO}_4$ : 4:1, v/v) in the presence of hydrogen peroxide in a fume cupboard until a colourless solution was obtained. The solution was poured into standard flask and made up to 50 mL with distilled water. The solution was taken for mineral determination using Atomic Absorption Spectrophotometer.

## 3. RESULTS AND DISCUSSION

### 3.1. Total Heterotrophic Bacteria Count of the Jollof Rice Samples

The Total Heterotrophic Bacteria count of the different samples is presented in Figure and the table shows the growth of heterotrophic bacteria in Firewood-cooked Jollof rice and Gas-cooked Jollof rice. The heterotrophic bacteria count of Firewood-cooked Jollof rice ranged from  $3.9 \times 10^3$  CFU/g to  $4.3 \times 10^3$  CFU/g,

while Gas-cooked Jollof rice ranged from  $1.4 \times 10^3$  CFU/g to  $3.2 \times 10^3$  CFU/g. The results showed that the total heterotrophic bacteria count of the samples differed with that Firewood cooked Jollof rice having the highest count.

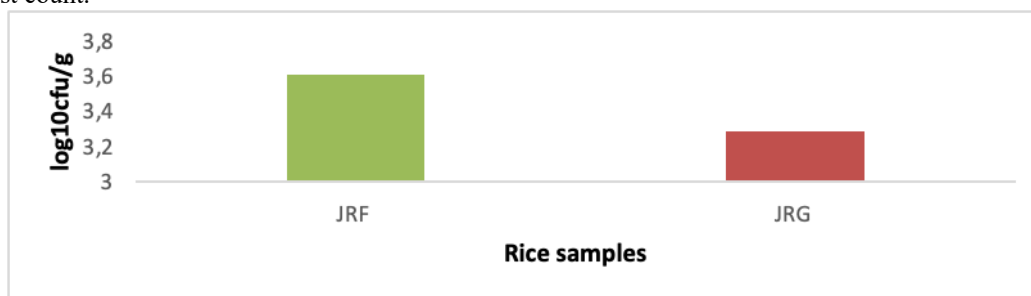


Figure 1. Bar chart of total heterotrophic bacteria counts of firewood-cooked and gas-cooked jollof rice  
Keys: JRF = Jollof Rice Prepared using Firewood, JRG = Jollof Rice Prepared using Gas cooker.

### 3.2. Total Staphylococcal Counts of Jollof Rice Samples

The total staphylococcal count of the different samples is presented in Figure 4.2. The table shows the growth of Staphylococcal bacteria in Firewood-cooked jollof rice and Gas-cooked jollof rice. The total staphylococcal count of Firewood-cooked jollof rice ranged from  $1.2 \times 10^3$  CFU/g to  $1.75 \times 10^4$  CFU/g, while Gas-cooked jollof rice ranged from  $1.8 \times 10^3$  CFU/g to  $7 \times 10^3$  CFU/g. The results showed that the staphylococcal count of the Firewood cooked jollof rice had the highest Staphylococcal count.

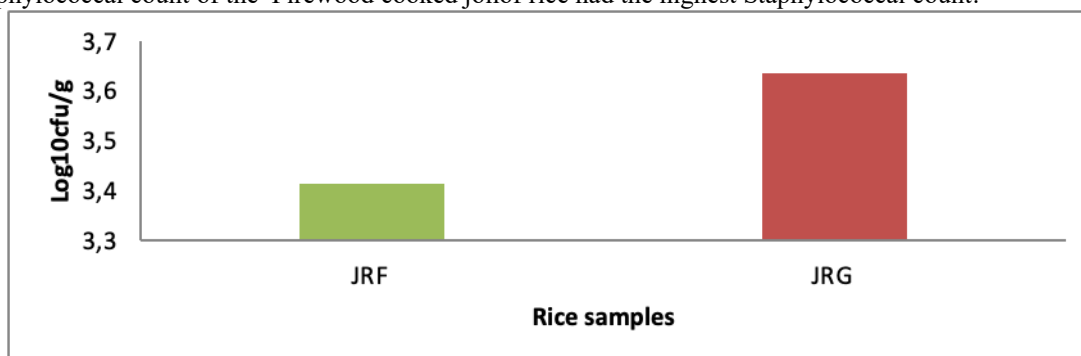


Figure 2. Bar chart of the mean total staphylococcus of Firewood Cooked and Gas Cooked Jollof Rice  
Keys: JRF = Jollof Rice Prepared using Firewood, JRG = Jollof Rice Prepared using Gas cooker

### 3.3. Total Coliform Counts of Jollof Rice Samples

The total coliform count of the different samples is presented graphically in Figure 3. The table shows the growth of coliform bacteria in Firewood cooked jollof rice and Gas cooked jollof rice. The total coliform count of Firewood-cooked jollof rice ranged from  $1.2 \times 10^3$  CFU/g to  $2.2 \times 10^3$  CFU/g, while in Gas-cooked jollof rice, no coliform growth was detected per 1g of sample. This does not imply the absence of coliforms in Jollof rice prepared using Gas, just that it was not detected per 1 gram.

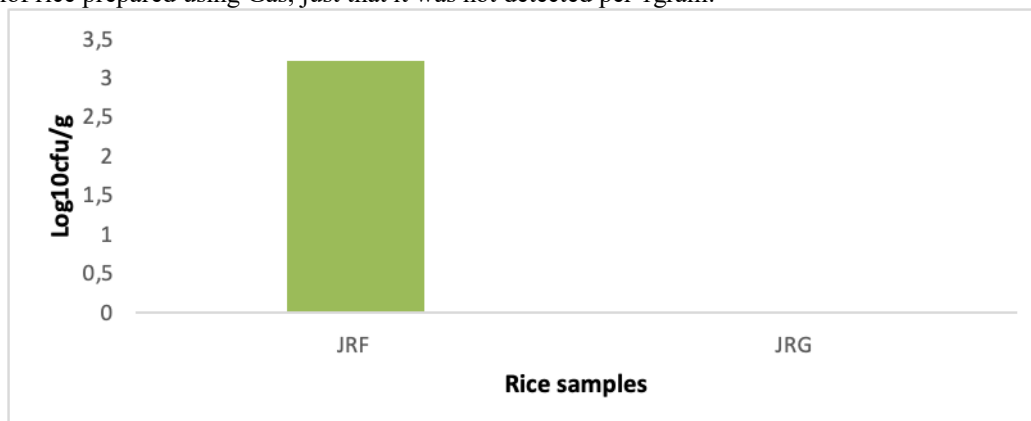


Figure 3. Bar chart of the mean total coliform counts of gas-cooked and firewood-cooked Jollof rice.  
Keys: JRF = Jollof Rice Prepared using Firewood, JRG = Jollof Rice Prepared using Gas cooker

### 3.4. Total Fungi Count of Jollof Rice Samples

The total Fungi count of the different samples is presented graphically in Figure 4, and the table shows the growth of fungi in Firewood-cooked jollof rice and Gas-cooked jollof rice. The total fungi count of Firewood-cooked jollof rice ranged from  $1.7 \times 10^3$  CFU/g to  $2.4 \times 10^3$  CFU/g, while Gas-cooked jollof rice ranged from  $2 \times 10^3$  CFU/g to  $8 \times 10^3$  CFU/g.

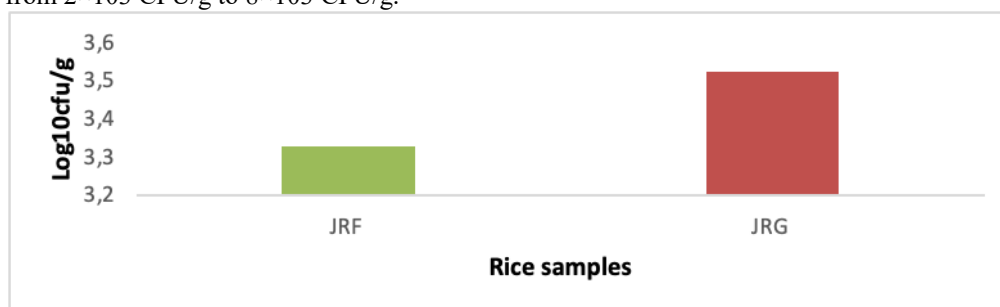


Figure 4. Bar Chart of Mean Total Fungi Count of the Firewood cooked and gas cooked Jollof Rice  
Keys: JRF = Jollof Rice Prepared using Firewood, JRG = Jollof Rice Prepared using Gas cooker

Table 1. Frequency of Occurrence Bacteria in the Jollof Rice Samples

Isolated organisms	Firewood-Cooked Jollof rice		Gas-Cooked Jollof rice	
	Frequency of occurrence	Percentage occurrence (%)	Frequency of occurrence	Percentage occurrence (%)
<i>Bacillus subtilis</i>	2	18.2	1	20
<i>Staphylococcus aureus</i>	4	36.3	3	60
<i>Bacillus cereus</i>	2	18.2	1	20
<i>Klebsiella pneumoniae</i>	2	18.2	-	-
<i>Proteus sp</i>	1	9.1	-	-
Total	11	100	5	100

Table 2. Frequency of Occurrence of Fungi in the Jollof Rice Samples

Isolated organisms	Firewood-Cooked Jollof rice		Gas-Cooked Jollof rice	
	Frequency of occurrence	Percentage occurrence (%)	Frequency of occurrence	Percentage occurrence (%)
<i>Aspergillus niger</i>	2	60	2	70
<i>Penicillium sp</i>	1	20	1	30
<i>Fusarium sp</i>	1	20	-	-
Total	4	100	3	100

### 3.5. Proximate and mineral composition of gas and firewood-cooked jollof rice

Table 3 specifies the average of the proximate analysis of firewood-cooked jollof rice and gas-cooked jollof rice. Jollof rice prepared using firewood had an ash percentage of 1.42%, while jollof rice cooked with gas had an ash percentage of 1.28%. The percentage of moisture in jollof rice prepared using gas was higher than that of Jollof rice prepared using firewood, with gas having 69.46% moisture content compared to jollof cooked with firewood, with a Percentage of 61.34% moisture content. The crude fiber and crude protein of firewood-cooked jollof were 0.62% and 6.71% respectively, while those of gas-cooked jollof had an average of 0.57% and 5.83% respectively. Gas-cooked jollof rice had an average of 19.57%, and firewood-cooked jollof rice had 26.07%. Table 4 presents the average mineral analysis of the Firewood-cooked jollof rice and Gas-cooked jollof rice. The iron, zinc, magnesium, and calcium content of jollof rice cooked with firewood in mg/100g was 3.71934, 1.87674, 28.18501, and 47.19167, respectively. In contrast, gas-cooked jollof rice had its iron, zinc, magnesium, and calcium in mg/100g to be 3.05728, 1.40296, 24.18647, and 38.94058, respectively. The jollof rice cooked with gas had an average pH of 5.70, while that cooked with firewood had a lower average pH reading of 5.63.

Table 3. Mean Proximate Composition of the Jollof Rice Samples

SAMPLE CODE	% MOISTURE	% ASH	% FIBRE	% PROTEIN	% LIPID	% CARBOHYDRATE
JRF	69.46	1.42	0.62	5.83	2.84	26.07
JRG	61.34	1.28	0.57	6.71	2.29	19.57

Keys: JRF = Jollof Rice Prepared using Firewood, JRG = Jollof Rice Prepared using Gas cooker

Table 4. Mean Mineral Composition and pH of the Jollof Rice Samples

SAMPLE CODE	Iron ( mg/100g)	Zinc ( mg/100g)	Magnesium (mg/100g)	Calcium (mg/100g)	pH
JRF	3.71	1.87	28.18	47.19	5.6
JRG	3.05	1.40	24.18	38.94	5.7

Keys: JRF = Jollof Rice Prepared using Firewood, JRG = Jollof Rice Prepared using Gas cooker

### 3.6. Microbial quality of the Gas-cooked and Firewood-cooked Jollof rice

Food is an essential part of our lives, and access to good quality food has been a human's main endeavor from the earliest days of human existence. Safety of food is a basic requirement of food quality. This study investigated the effect of traditional and modern cooking methods on the microbial and physicochemical quality of Jollof rice sold around the University of Port-Harcourt.

The total heterotrophic count of the different samples is presented in Figure 1. The heterotrophic bacteria count of Jollof rice prepared using Firewood or open fire and Jollof rice prepared using Gas cooker ranged from  $3.7 \times 10^3$  CFU/g to  $2.8 \times 10^3$  CFU/g and  $1.5 \times 10^3$  CFU/g to  $3.2 \times 10^3$  CFU/g, respectively. This is in line with the early report of Chijioke et al. (2023), who worked on the examination of Jollof rice served in some restaurants in Bonny Island, reporting  $3.0 \times 10^3$  CFU/g to  $7.0 \times 10^4$  CFU/g of total heterotrophic bacteria. This study is consistent with a few meals that were ready to eat and found that the overall number of bacteria ranged from  $2.0 \times 10^4$  CFU/g to  $1.2 \times 10^6$  CFU/g. According to standards, the maximum count of heterotrophic bacteria that can be present in food should not be more than 100 colony forming units per gram. The number of heterotrophic bacteria in these foods meets the established threshold.

The International Commission for Microbiological Specification for Foods states that ready-to-eat foods like Jollof rice with a plate count between  $0-10^3$  is acceptable, between  $10^4-10^5$  is tolerable, and  $10^6$  and above is unacceptable.

The total staphylococcal count of the different samples is presented in Figure 2 of Firewood-cooked jollof rice and Gas-cooked jollof rice. The total staphylococcal count of Firewood-cooked jollof rice and Gas-cooked jollof rice ranged from  $1.4 \times 10^3$  CFU/g to  $1.75 \times 10^4$  CFU/g and  $1.8 \times 10^3$  CFU/g to  $7 \times 10^3$  CFU/g, respectively. This is in line with the early report of Chijioke et al. (2023), who worked on the examination of Jollof rice served in some restaurants in Bonny Island, reported a total staphylococcal count for Jollof rice between  $1.3 \times 10^4$  cfu/g and  $1.0 \times 10^3$  cfu/g. This present study differs from those who noted that the total staphylococcal count for jollof rice sold in cafeteria C was  $6.0 \times 10^5$  CFU/g, and in cafeteria E it was  $1.5 \times 10^5$  CFU/g. The acceptable level of *Staphylococcus aureus* in ready-to-eat food is below  $10^3$  colony-forming units per gram (CFU/g)

The total coliform count of the different samples is presented in Figure 3. The total coliform count of Firewood cooked jollof rice and Gas cooked jollof rice ranged from  $1.2 \times 10^3$  CFU/g to  $2.2 \times 10^3$  CFU/g and  $0.0 \times 10^3$  CFU/g to  $0.0 \times 10^3$  CFU/g, respectively. The study observed that the total heterotrophic count, staphylococcal count, and coliform count of the Jollof rice prepared using Firewood were higher than those of Jollof rice cooked with Gas. There was no coliform detected per 10g of sample of the gas-cooked jollof rice. The result of this study is the evaluation of bacteria associated with ready to eat rice in the Niger Delta South-South Nigeria. In this study, the high microbial count observed in Firewood-cooked Jollof rice could be because of exposure to air in an environment that has questionable conditions, which could have led to microbial contamination. The International Microbiological Standard recommends a bacterial count limit of less than  $10^4$  CFU/g for ready-to-eat foods. The bacteria count (total heterotrophic bacteria count, total staphylococcus counts, and total coliform count) in this present study is below the International Microbiological Standard. The presence of coliform count in the Jollof rice prepared using Firewood could be a public health risk to the consumers, even at a low count. The high microbial density can be accounted for by a poor and unhygienic processing environment, poor running water for washing and dilution.

The total fungi count of Jollof rice prepared using Firewood and Jollof rice prepared using Gas cooker ranged from  $1.7 \times 10^3$  CFU/g to  $2.5 \times 10^3$  CFU/g and  $1.4 \times 10^3$  CFU/g to  $8 \times 10^3$  CFU/g respectively. The total fungal count ranged from  $1.4 \times 10^4$  to  $3 \times 10^5$  CFU/g obtained from Jollof rice sold at Bukateria in Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. Based on the World Health Organization/ Food and Agricultural Organization which categorized certain foods as unsatisfactory, hence, all the examined samples (Firewood cooked rice and Gas cooker rice) purchased from shops within and around University of Port Harcourt, River state are considered safe for human consumption because the total fungal count did not exceed the standard threshold of  $10^4$  CFU.

According to other investigations conducted in Nigeria, fungi have reportedly been isolated from jollof rice that is ready to consume. The presence of fungi in the samples could be due to improper storage, which caused the foodstuffs to become damp, allowing the fungi to grow in the ready-to-eat food sold in the

university community. Aflatoxin, a key metabolite produced by fungi, has been shown to be extremely harmful to humans as well as all domestic and laboratory animals. The exposure to the atmosphere where environmental conditions are questionable and the carelessness of vendors could also influence the microbiological quality of the food. The results from shops within and around the University of Port Harcourt showed that five bacterial genera were isolated, including *Bacillus subtilis*, *Bacillus cereus*, *Klebsiella species*, *Staphylococcus species*, and *Proteus species*. The percentage of bacteria occurrence in firewood-cooked jollof rice and gas-cooked jollof rice includes *Bacillus subtilis* (18.2%) and (20%). *Klebsiella species* (18.2%) and (60%). *Staphylococcus species* (36.3%) and (40%). *Bacillus cereus* (18.2%) and (40%). *Proteus species* (9.1%) and (2.44%), respectively.

*Staphylococcus species* (36.3%) in Firewood cooked jollof rice and (60%) in Gas cooked jollof rice have the highest percentage occurrence, while *Proteus species* (9.1%) in Firewood cooked jollof rice and (2.44%) in Gas cooked jollof rice have the least percentage occurrence. *Bacillus cereus* (12.8%) as the highest percentage occurrence followed by *Escherichia coli* (8.5%) which is very different from this present study. Since *Staphylococcus species* normally inhabit human skin and nasal passages, human interaction is the main cause of their presence in food products. This is indicative of the vendors' inadequate hygiene practices. The presence of *Staphylococcus aureus* is certainly concerning for public health. Because they produce heat-stable enterotoxins in direct proportion to their inoculum level, most strains of *Staphylococcus aureus* are known to be harmful.

A total of three (3) fungi species was identified and their percentage occurrence are *Aspergillus niger* (57.1%), *Penicillium species* (28.6%) and *Fusarium species* (14.3%) were identified. *Aspergillus niger* has the highest percentage occurrence of (57.1%), followed by *Penicillium species* (28.6%) while *Fusarium species* has the least percentage occurrence of (14.3%) each. This present study is quite different from those who reported similar fungi species, but *Aspergillus candidus* (40%) has the highest percentage occurrence. This result should be a public health concern because some species of *Aspergillus* could produce aflatoxins and mycotoxins. *Staphylococcus aureus* in the food samples indicates inadequate management and handling practices, which must have resulted in possible cross-contamination during dishwashing. *Staphylococcus aureus* is a common skin bacterium. When a hand is occasionally used to dish food, it is always possible for the hand—which may not be protected or sterilized—to transfer bacteria into the food. Another situation is when a food vendor or customer talks about the unfinished meal that is out in the open, introducing *Staphylococcus aureus*, a common oral flora. Because *Staphylococcus aureus* has been linked to foodborne illnesses, its presence in the food sales area is therefore indicative of a possible health risk.

A toxin that causes disease and may be eliminated by heat is produced when *Staphylococcus species* are allowed to develop in food. This toxin is heat-stable. These organisms can cause mild to severe cholera, typhoid, and diarrhea symptoms. Because of its capacity to produce spores that are resilient to extreme environmental conditions, *Bacillus species* were isolated from the Jollof rice samples, and this could be attributed to the ability of *Bacillus species* to form spores resistant to harsh environmental conditions. In the current investigation, the presence of the conventional indicator bacterium *Klebsiella species* (fecal coliform) suggests that enteric pathogens may be present in the examined samples. The samples' presence of coliforms suggests fecal contamination, which may result from contaminated ingredients, preparation, or cross-contamination, contaminated ingredients, preparation or from the food handlers.

The isolated *Proteus species* is typically found in the human intestinal tract and is the most common urinary tract pathogen in clinical settings. Food handlers' unsanitary practices are the cause of its occurrence in food samples. It belongs to the gram-negative rod family Enterobacteriaceae, which can ferment glucose. Additionally, *Proteus mirabilis* exhibits hemolytic activity on blood agar. It has peritrichous flagella, is motile, and frequently forms fimbriae.

Due to their capacity to produce spores, some fungi are the most prevalent environmental contaminants; this may be connected to their presence in food samples. Numerous ready-to-eat foods, including Jollof rice, have been linked to them. *Aspergillus species* are known to produce harmful mycotoxins in the right circumstances. Therefore, care must be taken when they are present in food.

Infections attributable to *Penicillium species* include rhino-cerebral mucormycosis, genitourinary, mucocutaneous, gastrointestinal, pulmonary, and disseminated infections. The origin of the fungal genera isolated from Jollof rice may be attributed to airborne particles in the surrounding environment during the processes of dishing and serving. Food quality encompasses intricate attributes of food that dictate its worth or acceptability to consumers. The results of this investigation indicate that the microbiological contamination in firewood-cooked jollof rice was more than that in gas-cooked jollof rice. The elevated microbiological levels in the firewood-cooked jollof rice may stem from the vendor's negligence and unsanitary methods; therefore, it is vital to uphold stringent hygiene standards to prevent microbial contamination.

### 3.7. Physicochemical quality of the Jollof rice samples

The physicochemical results of the samples are represented in Tables 2 and 3. The pH of Gas-cooked jollof rice and Firewood-cooked jollof rice ranged from 5.50 to 5.83 and 5.52 to 5.70, respectively. It is observed from the results that the pH of the Firewood-cooked Jollof rice samples was mostly higher than the Gas-cooked Jollof rice samples. Gas cooking helps consistent pH level while fire wood cooking involves direct and smoke which can introduce more acidic compound into the jollof rice, The difference in pH could be as a result of longer cooking time and higher temperature which can break down acidic compounds of the food components thereby altering pH and this not quite in line with.

The proximate content of Firewood-cooked jollof rice and Gas-cooked jollof rice is presented in Table 2. The moisture content of Firewood cooked jollof rice and Gas-cooked jollof rice is 69.46% and 61.34% respectively.

The shelf life of foods is mostly determined by their moisture content. Foods with lower moisture content have a longer shelf life and a lower water activity, but foods with higher moisture content are more susceptible to microbial activity and spoiling. Furthermore, foods with a high moisture content have lower concentrations of other nutrients, whereas foods with a low moisture content have higher concentrations of other nutrients. All of my samples have moisture contents higher than 50%, meaning that improper storage will make them extremely perishable due to microbial activity. The ash content of Firewood-cooked jollof rice and Gas-cooked jollof rice ranged from 1.42% and 1.28% respectively. The ash content result obtained in this study does not align with the European Union Food Safety Authority standard of 2-5 % ash content for ready-to-eat foods. Ash content measures the total amount of minerals present within a food sample; therefore, an increase in its level may be attributed to the deposition of wood ash from the firewood. The lipid content of Firewood-cooked jollof rice was 2.84% and Gas-cooked jollof rice was 2.29%. The difference in the lipid contents between the samples could result from moisture retention in the firewood-cooked Jollof rice, which could also lead to oil retention.

Protein in food is an essential nutrient needed by the body to repair worn-out tissues, make hormones, enzymes and synthesize the cells of the immune system. The body utilizes protein as a source of energy. The protein content of Firewood-cooked jollof rice and Gas-cooked jollof rice was 6.71% and 5.83% respectively. There was an increase in protein content of Firewood-cooked Jollof rice, which could be because of the longer cooking time and variable temperature, which may lead to excess protein extraction, and the slightly reduced protein content noticed in the Gas-cooked Jollof rice could be because of shorter cooking time and even temperature. The carbohydrate content of the samples, Firewood cooked jollof rice and Gas cooked jollof rice, were (26.07%) and (19.57%) respectively. The fibre content of Firewood-cooked jollof rice was 0.62%, and Gas-cooked jollof rice was 0.57%. Firewood-cooked jollof rice has the highest fibre content compared to gas-cooked jollof rice, and this could be due to longer cooking time and variable temperature, which may facilitate fibre extraction.

The mineral composition of the samples is presented in Table 3. The calcium content of Firewood-cooked jollof rice was 47.2mg/100g, and Gas-cooked jollof rice was 38.9mg/100g. The Zinc content of firewood-cooked jollof rice was (1.87mg/100g), and gas-cooked jollof rice was (1.4mg/100g). The Iron content of firewood-cooked jollof rice was (3.7mg/100g), and gas-cooked jollof rice was (3.0mg/100g). The magnesium content of Firewood-cooked jollof rice was (28mg/100g), and Gas-cooked jollof rice was (24mg/100g). The significant difference in the mineral (Iron, Zinc, calcium, and magnesium) contents is due to different cooking temperatures and times, which may affect mineral extraction and retention, and it can also result from the firewood deposition.

## 4. CONCLUSION

The findings of this study revealed that Traditional cooking methods (firewood) compromise the microbiological and physicochemical quality of Jollof rice, while modern methods (gas) produce safer and more nutritious products. This study highlights the importance of adopting safe cooking practices to ensure food safety and quality.

It is recommended to adopt modern cooking methods (gas) to ensure food safety and quality. Food vendors should maintain proper hygiene and handling practices. There should be regular monitoring of microbiological and physicochemical quality of street foods. There should be public education on safe cooking practices and food handling.

## REFERENCES

- [1] S. Nani, "The West African Social Media "Jollof Rice War"", *Global Perspectives on Soft Power Management in Business*, pp. 443-459, 2023. <https://doi.org/10.4018/979-8-3693-0250-7.ch023>
- [2] B. Babayemi and O. Adepoju, "Dietary Fibre and Micronutrient Potential of Underutilized Green Leafy Vegetable Sprinkles on Selected Foods", *Journal of Applied Sciences and Environmental Management*, vol. 24, no. 8, pp. 1391-1396, 2020. <https://doi.org/10.4314/jasem.v24i8.13>

- [3] S. Kushitor, "Food Availability and Food Habits Among Ghanaians: Tracking the Dietary Transition in Ghana", *Nutrition and Health*, vol. 29, no. 1, pp. 157-166, 2021. <https://doi.org/10.1177/02601060211066707>
- [4] L. Zhonggui, W. Ho, K. Rafael, Y. Xie, J. Hu, & K. Yan, "Habitual Tendency, Cooking Methods, and Development of Food Choices Behavior", *World Journal of Advanced Research and Reviews*, vol. 19, no. 3, pp. 632-639, 2023. <https://doi.org/10.30574/wjarr.2023.19.3.1854>
- [5] M. Lopes, G. Silva, & B. Tagliapietra, "Impact of Cooking Methods on the Availability of Nutrients in Foods of Plant Origin", *Disciplinarum Scientia - Ciências Da Saúde*, vol. 25, no. 1, pp. 25-40, 2024. <https://doi.org/10.37777/dscs.v25n1-003>
- [6] T. Tumpunuvatr and W. Jittanit, "Quality Improvement of Refrigerated Ready-to-Eat Cooked Brown Rice by Adding Gellan Gum and Trehalose with Ohmic Heating Compared to Conventional Cooking Method", *Journal of Food Processing and Preservation*, vol. 46, no. 4, 2022. <https://doi.org/10.1111/jfpp.16443>
- [7] A. Lerma-Aguilera, S. Pérez-Burillo, B. Navajas-Porras, E. León, S. Ruiz, S. Pastoriza et al., "Effects of Different Foods and Cooking Methods on the Gut Microbiota: An In Vitro Approach", *Frontiers in Microbiology*, vol. 14, 2024. <https://doi.org/10.3389/fmicb.2023.1334623>
- [8] A. Kowalska and L. Manning, "Food Safety Governance and Guardianship: The Role of the Private Sector in Addressing the EU Ethylene Oxide Incident", *Foods*, vol. 11, no. 2, pp. 204, 2022. <https://doi.org/10.3390/foods11020204>
- [9] J. Yang, S. Shu, P. Wang, G. Li, H. Wang, W. Wuet et al., "Effect of Cooking Methods on Flavor Profiles of Xuanwei Ham: Analytical Insights into Aromatic Composition and Sensory Attributes", *Food Chemistry: X*, vol. 23, pp. 101713, 2024. <https://doi.org/10.1016/j.fochx.2024.101713>
- [10] S. Gurung, A. Tamang, J. Chettri, & A. Rai, "Firewood Extraction Patterns and Preferred Species in Mamlay Watershed in Sikkim Himalaya, India: A Household Model of Three Categories Based on Socioeconomic Status", *Ecology, Environment and Conservation*, vol. 30, no. Suppl, pp. S167-S178, 2024. <https://doi.org/10.53550/eec.2024.v30i06s.025>
- [11] P. Chirwa, C. Ham, S. Maphiri, & M. Balmer, "Bioenergy Use and Food Preparation Practices of Two Communities in the Eastern Cape Province of South Africa", *Journal of Energy in Southern Africa*, vol. 21, no. 4, pp. 26-31, 2010. <http://dx.doi.org/10.17159/2413-3051/2010/v21i4a3260>
- [12] G. Shen, M. Hays, K. Smith, C. Williams, J. Faircloth, & J. Jetter, "Evaluating the Performance of Household Liquefied Petroleum Gas Cookstoves", *Environmental Science & Technology*, vol. 52, no. 2, pp. 904-915, 2018. <https://doi.org/10.1021/acs.est.7b05155>
- [13] W. Li, D. Lai, L. Mou, X. Zhou, & K. Yuan, "Research Status and Development Trend of Household Gas Stoves", *Academic Journal of Science and Technology*, vol. 9, no. 3, pp. 20-24, 2024. <https://doi.org/10.54097/g0v23264>
- [14] R. Yongyod, P. Phusomya, & P. Chopjitt, "Microbiological Quality and Sanitation of Food Stalls and Drinking Water Vending Machines", *Environment and Natural Resources Journal*, vol. 21, no. 4, pp. 1-10, 2023. <https://doi.org/10.32526/enrj/21/20230014>
- [15] M. Mukelabai, K. Wijayantha, & R. Blanchard, "Hydrogen for Cooking: A Review of Cooking Technologies, Renewable Hydrogen Systems and Techno-Economics", *Sustainability*, vol. 14, no. 24, pp. 16964, 2022. <https://doi.org/10.3390/su142416964>
- [16] S. Hong, Y. Shen, & Y. Li, "Physicochemical and Functional Properties of Texturized Vegetable Proteins and Cooked Patty Textures: Comprehensive Characterization and Correlation Analysis", *Foods*, vol. 11, no. 17, pp. 2619, 2022. <https://doi.org/10.3390/foods11172619>
- [17] M. Bwala and T. Imam, "Contamination of Polycyclic Aromatic Hydrocarbons (PAHs) on Processed Food: A Review", *Archives of Ecotoxicology*, vol. 5, no. 2, pp. 61-65, 2023. <http://dx.doi.org/10.36547/ae.2023.5.2.61-65>
- [18] H. Aliyu, G. Obiochi, J. Samaila, & K. Benjamin, "Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in *Clarias gariepinus* and *Tilapia zillii* Smoked using Charcoal and Gas Smoking Kilns in Benue State", *Asian Science Bulletin*, vol. 2, no. 3, pp. 242-248, 2024. <https://doi.org/10.3923/asb.2024.242.248>
- [19] M. Rodríguez-Ayala, H. Sandoval-Insausti, A. Bayán-Bravo, J. Banegas, C. Donat-Vargas, R. Ortolá et al., "Cooking Methods and Their Relationship with Anthropometrics and Cardiovascular Risk Factors among Older Spanish Adults", *Nutrients*, vol. 14, no. 16, pp. 3426, 2022. <https://doi.org/10.3390/nu14163426>
- [20] Y. Jung, H. Kim, D. Kim, B. Joo, J. Jhoo, & A. Jang, "Physicochemical Properties and Volatile Organic Compounds of Dairy Beef Round Subjected to Various Cooking Methods", *Food Science of Animal Resources*, vol. 43, no. 5, pp. 767-791, 2023. <https://doi.org/10.5851/kosfa.2023.e35>
- [21] M. Owureku-Asare, I. Oduro, F. Saalia, C. Tortoe, J. Ampah, & R. Ambrose, "Drying Characteristics and Microbiological Quality Assessment of Solar-Dried Tomato", *International Journal of Food Science*, vol. 2022, pp. 1-13, 2022. <https://doi.org/10.1155/2022/2352327>
- [22] N. Vanqa, V. Mshayisa, & M. Basitere, "Proximate, Physicochemical, Techno-Functional and Antioxidant Properties of Three Edible Insect (*Gonimbrasia belina*, *Hermetia illucens* and *Macrotermes subhyllanus*) Flours", *Foods*, vol. 11, no. 7, pp. 976, 2022. <https://doi.org/10.3390/foods11070976>
- [23] J. Barnes, H. Whaley, K. Ross, & J. Smith, "Defining Food Safety Inspection", *International Journal of Environmental Research and Public Health*, vol. 19, no. 2, pp. 789, 2022. <https://doi.org/10.3390/ijerph19020789>
- [24] M. Compaoré, S. Kpoda, R. Bazie, M. Ouedraogo, M. Valian, M. Gampene et al., "Microbiological Quality Assessment of Five Common Foods Sold at Different Points of Sale in Burkina-Faso", *Plos One*, vol. 17, no. 4, pp. e0258435, 2022. <https://doi.org/10.1371/journal.pone.0258435>

- [25] R. Jesús, A. Gutiérrez-Ibáñez, I. Puebla, N. GARCÍA, M. Siclán, & L. ROMERO, "Microbiological Quality and Presence of Enteropathogenic Bacteria in Orange Juice Sold in Popular Markets", *Food Science and Technology*, vol. 42, 2022. <https://doi.org/10.1590/fst.09621>
- [26] M. Ali, M. Hashish, & M. Fekry, "Microbiological Quality of Some Packed and Unpacked Bread Products in Alexandria, Egypt", *Journal of the Egyptian Public Health Association*, vol. 98, no. 1, 2023. <https://doi.org/10.1186/s42506-023-00141-9>
- [27] K. Ekpo, G. Osseyi, J. Dossou, & V. Ahyi, "Comparative Study of the Physicochemical and Microbiological Quality of Liquid, Freeze-Dried, Hot Air-Dried, and Pasteurized Quail Eggs Produced in Benin", *International Journal of Food Science*, vol. 2022, pp. 1-8, 2022. <https://doi.org/10.1155/2022/1991659>
- [28] L. Sun and B. Singer, "Cooking Methods and Kitchen Ventilation Availability, Usage, Perceived Performance and Potential in Canadian Homes", *Journal of Exposure Science & Environmental Epidemiology*, vol. 33, no. 3, pp. 439-447, 2023. <https://doi.org/10.1038/s41370-023-00543-z>
- [29] S. Erhan, C. Proestos, S. Manoharadas, & F. Öz, "Effect of Different Cooking Methods on Selected Quality Criteria and Polycyclic Aromatic Hydrocarbon Content of Cultivated Mushrooms (*Agaricus bisporus*)", *International Journal of Food Science & Technology*, vol. 58, no. 11, pp. 5689-5700, 2023. <https://doi.org/10.1111/ijfs.16666>
- [30] R. Amaich, S. Lairini, M. Fadil, M. Benboubker, R. Bouslamti, S. Amrani et al., "Microbiological Profile and Hygienic Quality of Foodstuffs Marketed in Collective Catering in Central Morocco", *International Journal of Food Science*, vol. 2023, pp. 1-13, 2023. <https://doi.org/10.1155/2023/2820506>
- [31] D. Myemba, G. Bwire, & R. Sangeda, "Microbiological Quality of Selected Local and Imported Non-Sterile Pharmaceutical Products in Dar es Salaam, Tanzania", *Infection and Drug Resistance*, vol. Volume 15, pp. 2021-2034, 2022. <https://doi.org/10.2147/idr.s355331>
- [32] S. Isanovic, S. Constantinides, E. Frongillo, S. Bhandari, S. Samin, E. Kenney et al., "How Perspectives on Food Safety", *Current Developments in Nutrition*, vol. 7, no. 1, pp. 100015, 2023. <https://doi.org/10.1016/j.cdnut.2022.100015>
- [33] C. Zawani, M. Nor-Khaizura, N. Mahyudin, M. Ismail-Fitry, & N. Nirmal, "Microbiological and Sensorial Quality of Beef Meat (*Longissimus dorsi*) Marinated with Cinnamon Extract and Stored at Various Temperatures", *Foods*, vol. 11, no. 24, pp. 3971, 2022. <https://doi.org/10.3390/foods11243971>
- [34] S. Tilahun, M. Alemu, M. Tsegaw, & N. Berhane, "Morphological and Molecular Diversity of Ginger (*Zingiber officinale* Roscoe) Pathogenic Fungi in Chilga District, North Gondar, Ethiopia", *Frontiers in Fungal Biology*, vol. 2, 2022. <https://doi.org/10.3389/ffunb.2021.765737>
- [35] A. Abdul-Rahaman, S. Irtwange, K. Aloho, B. Barau, & S. Pareek, "Isolation, Identification, and Polymerase Chain Reaction Analysis of Pathogenic Fungi in Sweet Orange (*Citrus sinensis* L.) Fruits during Storage", *ACS Agricultural Science & Technology*, vol. 3, no. 9, pp. 805-811, 2023. <https://doi.org/10.1021/acscagcitech.3c00164>
- [36] Ş. Milea, N. Condurache, I. Simionov, Ş. Petrea, M. Călmuc, V. Calmuc et al., "Effects of Cooking Methods and Co-ingested Foods on Mercury Bioaccessibility in Pontic Shad (*Alosa immaculata*)", *Current Research in Food Science*, vol. 7, pp. 100599, 2023. <https://doi.org/10.1016/j.crf.2023.100599>
- [37] S. Verma, P. Ganesan, P. Kishore, S. Remya, C. Mohan, P. Padmavathy et al., "Effects of Different Cooking Methods on the Proximate Composition and Physical Properties of Brown Shrimp (*Metapenaeus dobsonii*) During Cooking and Freezing Cycle", *Food Science and Technology International*, vol. 30, no. 6, pp. 517-526, 2023. <https://doi.org/10.1177/10820132231166972>