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Impact of Different Thermal processing Techniques (Boiling and Frying) On the Microbial Safety and Nutritional Value of Meat

Omorodion, Nnenna J.P[1] Morakinyo, Titilayo E[2]
[1, 2] Department of Microbiology, University of Port Harcourt, PMB 5323 Rivers State, Nigeria.
***Corresponding author:** Omorodion, Nnenna J.P

Abstract

This study investigates the microbial contamination and physicochemical properties of beef and chicken subjected different processing techniques. Meat samples were purchased from Choba market in Port Harcourt, and were prepared for uniformity in size and composition. Microbial analysis was conducted using standard methods. The THBC ranged from 6.60×10^3 to 2.50×10^4 CFU/g in boiled meat and 1.20×10^4 to 2.40×10^6 CFU/g in fried samples, while TFC values ranged for boiled samples, the log CFU/g values ranged from 0.90 to 1.82 log CFU/g, for fried samples, the log CFU/g values ranged from 1.08 to 1.82 log CFU/g. from 8.00 to 16.00 CFU/g in boiled and 12.00 to 36.00 CFU/g in fried samples. The TCC and TSC were also measured, showing significant levels of coliforms and Staphylococci in both meat types. Bacteria isolated from the meat samples Bacillus sp, Staphylococcus sp, Micrococcus sp, Enterococcus sp, Escherichia coli and Proteus sp while fungi isolated include. Proximate composition showed that fried beef and chicken had higher crude lipid and carbohydrate contents, whereas boiled beef and chicken exhibited higher moisture and crude protein percentages. The results of this study indicate that frying reduces microbial contamination more effectively due to higher temperatures but results in increased lipid and carbohydrate content. Boiling, however, preserves more moisture, protein, and minerals, highlighting the need for optimized cooking methods to balance microbial safety and nutritional retention.
Keywords: Microbial contamination, physicochemical quality, beef meat,chicken meat and processing techniques.

Introduction

Across many cultures, meat is an essential part of the human diet. Its high-quality protein composition, which includes all the essential amino acids required for tissue growth, repair, and general maintenance, accounts for its nutritional relevance. Meat and other animal proteins are regarded as complete proteins, which makes them better than the majority of plant-based proteins. Furthermore, meat offers vital micronutrients that are important for many physiological functions, such as iron, zinc, selenium, and a variety of B vitamins. For example, the heme type of iron found in meat is easier for the body to absorb than non-heme iron found in plants (Hurrell & Egli, 2010). Additionally, only present in animal food, vitamin B12 is essential for the production of red blood cells and neurological function (Watanabe, 2007).

However, despite meat's nutritional advantages, there are serious issues with food safety. Because of its natural moisture and nutrient content, meat provides an ideal environment for the growth of harmful microbes. Meat can become contaminated during slaughter, processing, and handling by pathogens such as *Salmonella*, *Escherichia coli*, *Listeria monocytogenes*, and *Campylobacter*. If the meat is not cooked enough, this can pose serious health hazards (Mead et al., 1999). A serious public health concern, foodborne infections associated with these bacteria can cause outbreaks, hospitalizations, and in extreme situations, even death. Therefore, in order to eradicate these viruses and guarantee the safety of meat for human consumption, appropriate cooking techniques are crucial.

Due to its excellent nutritional value, low fat content, and low cholesterol, chicken meat and products are generally very popular food commodities worldwide (Gordana et al. 2018). In many nations, the consumption of chicken meat has been continuously rising over the past few decades. While processed meat is defined as "meat that has been transformed through salting, curing, fermentation, smoking, or other processes to enhance flavor or improve preservation, mainly including pork or beef," red meat is defined as "unprocessed mammalian muscle meat, including beef, veal, pork, lamb, mutton, horse, and goat meat" (Bouvard et al., 2015).

Meat is frequently prepared using thermal processing methods like boiling and frying, which are crucial in determining the finished product's safety and nutritional value. Meat is boiled by immersing it in water and boiling it at a temperature of about 100°C. Because the high temperature denatures bacteria' proteins and kills them, this approach effectively reduces microbial contamination. Furthermore, some flavoring molecules might be eliminated, which could affect the cooked meat's sensory appeal.In contrast, frying entails cooking meat at significantly higher temperatures—typically between 170°C and 190°C—in heated oil. This technique improves the meat's flavor profile and gives it a desired crispy texture, which appeals to a wide range of consumers. One of the old-fashioned ways to prepare meat is to fry it. The popularity of deep-fried foods can be attributed to the meat products' development of a crunchy flavor and appealing color during the frying process. Zhang and associates (2012). However, after being fried, meat products contain a lot of oil. Consuming a lot of oil is linked to a number of negative health outcomes and may increase the risk of developing conditions like cancer, atherosclerosis, and hypertension. Sahoo et al., 2021; Grootveld et al., 2022.Furthermore, a number of chemical reactions, including the Maillard reaction, the oxidative degradation protein, and the oil oxidation reaction, take place in the matrix of frying meat products during the frying process. However, frying also raises health and nutritional issues (Estévez, 2011). In addition to causing the formation of toxic substances like trans fats, heterocyclic amines (HCAs), and polycyclic aromatic hydrocarbons (PAHs), the high temperatures can destroy heat-sensitive nutrients like some B vitamins. Furthermore, frying increases the meat's fat content, which may not be ideal for your health. Hazardous compounds like trans fatty acids (TFAs), acrylamide (AA), polycyclic aromatic hydrocarbons (PAHs), and heterocyclic amines (HCAs) are produced as a result of these chemical reactions and end up in fried meat products. Lu et al. (2017), Lee et al., (2020).

The influence of cooking methods on meat's nutritional and microbial quality has been a topic of extensive research, with mixed results. For instance, some studies have reported that boiling preserves meat's tenderness and retains essential amino acids better, while others suggest that frying enhances certain fat-soluble vitamins but significantly increases the caloric content (Chio et al.,2016). Understanding these effects is crucial for optimizing cooking methods that balance nutritional benefits and food safety. While boiling and frying are popular methods, each has distinct advantages and drawbacks that can influence the quality of the final product. Boiling, which cooks meat in water at 100°C, may effectively reduce microbial load but result in the loss of essential water-soluble nutrients, such as certain vitamins and minerals Choi et al.,(2016).On the other hand, frying, which cooks meat at high temperatures in oil, enhances flavor and texture but introduces unhealthy fats and may compromise nutrient integrity due to the formation of harmful compounds like heterocyclic amines (HCAs) and trans fats. Lee et al.,(2020). The aim of this study is to investigate the impact of different cooking methods (boiling & frying) on the microbial safety and nutritional value of meat.

MATERIALS AND METHODS

Collection of Samples

30 Fresh meat samples, (beef and chicken), were purchased at Choba market from five different sellers of beef and chicken meat and were brought from each seller and placed in clean properly labeled bags and transported to the laboratory. The samples were cooked/fried and weighed.

Sample Preparation

Two thermal processing techniques were applied:
a. **Boiling**: Meat samples were cooked in boiling water until they reached an internal temperature of 74°C (165°F), which was verified using a food thermometer, adhering to the United States Department of Agriculture (USDA) guidelines.
b. **Frying**: Meat samples were fried in a preheated frying pan with vegetable oil until they reached the safe internal temperature of 74°C (165°F), as measured with a thermometer.

Microbiological Analysis of the Samples

25g of the meat sample was homogenized in a stomacher for 2-3 minutes, and was added into 225ml of peptone water. This becomes the stock solution and is labelled as dilution 10-1. (APHA 2001). Serial dilution of samples was to achieve a reduction in the microbial population in the samples, stock solution was further diluted by pipetting 1ml of the stock into 9ml of normal saline contained in a test tube to get dilution 10^{-2} and was further diluted up to dilution 10^{-6}.

Total Heterotrophic Bacteria Count (THBC)

0.1ml aliquot of the inoculum was collected from 10^{-2} and 10^{-3} for beef and chicken using a sterile syringe and inoculated in a plate count agar (PCA) surface. The inoculum was spread evenly with a sterile hockey stick. Plates were incubated at 37ºc for 24hrs. After that, colonies were counted in order to obtain colony forming units (CFU) per ml of the sample. Distinct colonies were picked and streaked on freshly prepared nutrient agar medium go obtain pure culture after 24hours of incubation at 37ºc. The pure culture was gram stained for microscopic examination and biochemical tests for characterization and identification of the isolates.

Total Staphylococcus Count

0.1ml of sample from 10^{-1} and 10^{-2} dilutions from the different meat samples and were dispensed into sterile petri dishes containing 20ml of mannitol salt agar (MSA) and then incubated at 37°C for 24 hours.

Total Coliform Count (TCC)

0.1ml of sample from 10-^{1} and 10-^{2} dilutions from the different meat samples and were dispensed into sterile petri dishes containing 20ml of MacConkey agar. The inoculum was spread gently round the plate to ensure even distribution of inoculum and then allowed to solidify and incubated at 37°C for 24 hours.

Total Fungi Count (TFC)

An aliquot (0.1ml) of dilutions 10^{-1} to 10^{-4} of the samples were aseptically transferred into Petri dishes with freshly prepared potato dextrose agar (PDA) labelled with fresh labelled potato dextrose agar. Culture plates were incubated at 30ºc for 24h. After incubation, the fungal colonies were manually counted on the culture plates and the results were expressed in colony forming units per milliliter (CFU/ml) as described by Maduka et al., (2021).

Characterization and Identification of the Fungal Isolates

The fungal isolates will be identified and described using microscopic features and colonial morphology. The mycelia of the fungal isolates will be examined under a microscope at x40 objectives using lactophenol cotton blue stain in order to ascertain their microscopic morphology. Under a microscope, the morphology of the fungal isolates will be compared to reference standards as described by Geo et al. 2013).

Characterization and Identification of the Bacterial Isolates

Based on their cultural and morphological traits, the bacterial isolates from the samples were described and presumed to be identified. Gram staining, a motility test, and biochemical tests, such as those for catalase, oxidase, citrate, urease, coagulase, and indole, were then performed using the procedures outlined by Cheesbrough (2002).

Proximate Analysis

Nutritional content, including carbohydrates, proteins, ash, fiber, and lipids, was analysed to determine the meat's chemical composition as described by Osakue et al., (2016)

Data Analysis

Data collected were statistically analyzed using tests such as

ANOVA. Comparisons were made to assess microbial safety and physicochemical properties across different cooking methods. Statistical software was used to determine significant differences, and results were presented in an appropriate format for interpretation

RESULTS

Microbial Counts of the Meat Samples

Figures 1-8 illustrate the microbial counts of beef and chicken samples subjected to different cooking methods (boiling and frying). The y-axis represents the log CFU/g, while the x-axis represents the sample type (beef or chicken). The bars represent the boiled and fried samples. These figures provide a visual comparison of the microbial loads of the samples, allowing for an assessment of the effects of cooking methods on microbial safety

Total Heterotrophic Bacteria Count (THBC)

Figure 1 and Figure .2 shows the Mean total heterotrophic bacteria count (THBC) of boiled and fried beef and chicken samples. The Figures reveals that boiling significantly reduced the THBC in both beef and chicken samples, with log CFU/g values ranging from 2.60 to 3.43 for beef and 2.13 to 4.04 for chicken. In contrast, frying resulted in lower THBC values, with log CFU/g values ranging from 1.38 to 2.12 for beef and 1.43 to 4.78 for chicken.

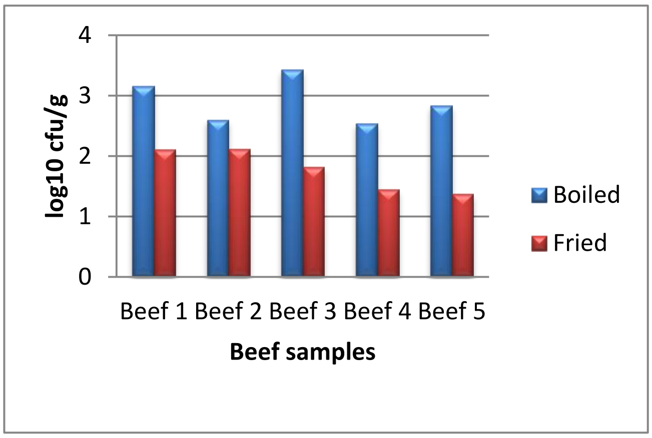

Figure 1 **Mean Total Heterotrophic Bacteria Count for Beef Samples**

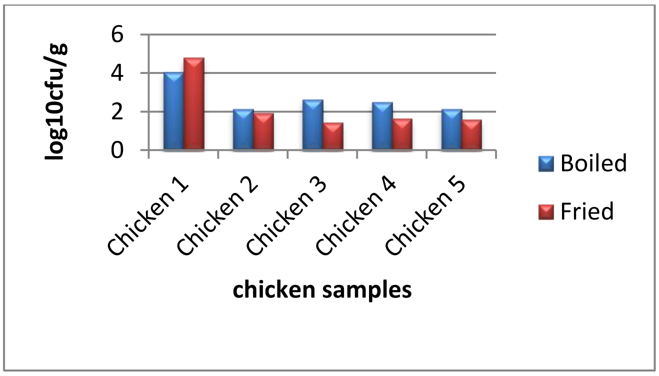

Figure 2 Mean Total Heterotrophic Bacteria Count for Chicken Samples

Total Fungi Count (TFC)

Figures .3 and 4 show the Mean total fungal count (TFC) of boiled and fried beef and chicken samples. The graph indicates that boiling resulted in relatively low TFC values, with log CFU/g values ranging from log CFU/g 0.90 to log CFU/g 1.20 for beef and log CFU/g 1.26 to log CFU/g 1.82 for chicken. Frying also yielded low TFC values, with log CFU/g values ranging from log CFU/g 1.08 to log CFU/g 1.56 for beef and log CFU/g 1.28 to log CFU/g 1.82 for chicken.

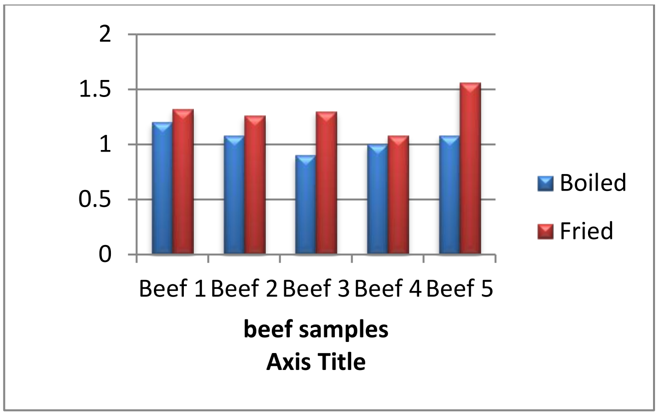

Figure 3 **Mean Total Fungi Count for Beef Samples**

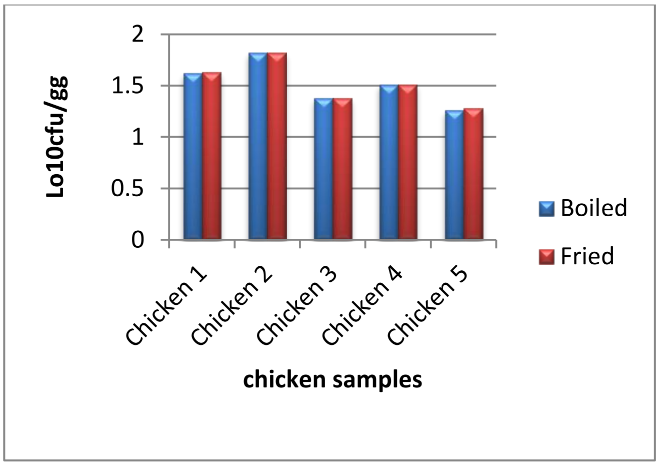

Figure 4 **Mean Total Fungi Count for Chicken Samples**

Total Coliform Counts (TCC)

Figures 5 and 6 show the Mean Total Coliform Count (TCC) of boiled and fried meat samples. The graph reveals that boiling significantly reduced the TCC in both beef and chicken samples, with log CFU/g values ranging from 3.00 to 3.38 for beef and 4.02 to 4.81 for chicken. In contrast, frying resulted in lower TCC values, with log CFU/g values ranging from 3.00 to 3.55 for beef and 3.20 to 3.73 for chicken.

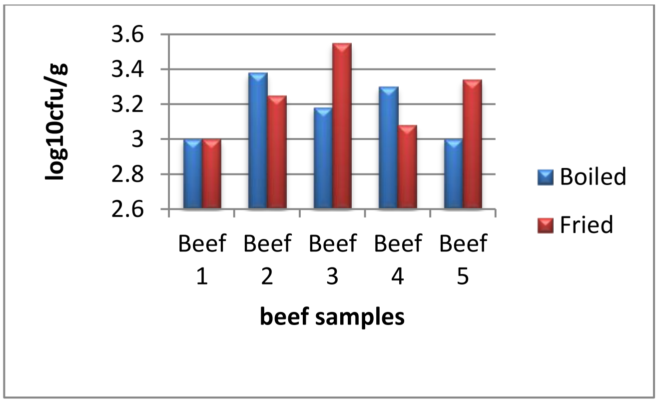

Figure 5 **Mean Total Coliform Counts for Beef Samples**

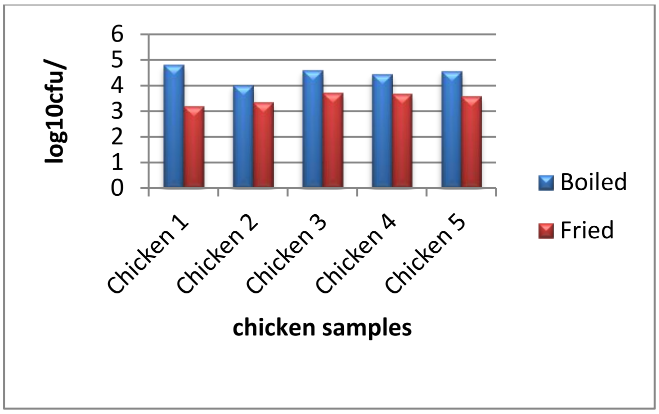

Figure 6 Mean Total Coliform Counts for chicken Samples

Total Staphylococcus Counts (TSC)

Figures 7 and 8 shows the Mean total Staphylococcus count (TSC) of boiled and fried beef and chicken samples. The graph indicates that boiling resulted in relatively low TSC values, with log CFU/g values ranging from log CFU/g 3.30 to log CFU/g 4.21 for beef and log CFU/g 3.66 to log CFU/g 3.98 for chicken. Frying also yielded low TSC values, with log CFU/g values ranging from log CFU/g 2.90 to log CFU/g 4.21 for beef and log CFU/g 2.95 to log CFU/g 3.34 for chicken.

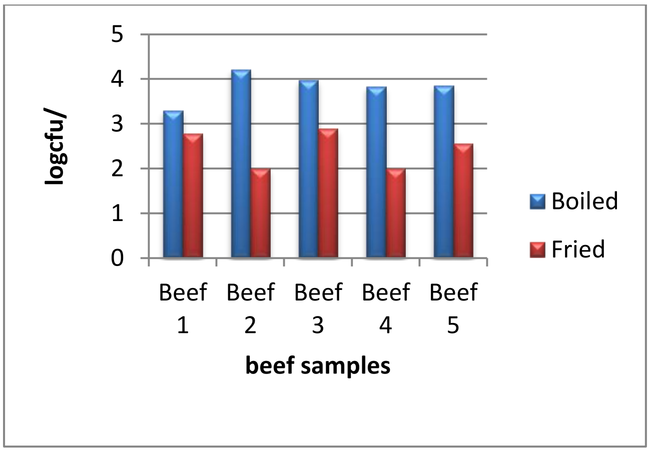

Figure 7 Mean Total *Staphylococcus* Counts for Beef Samples

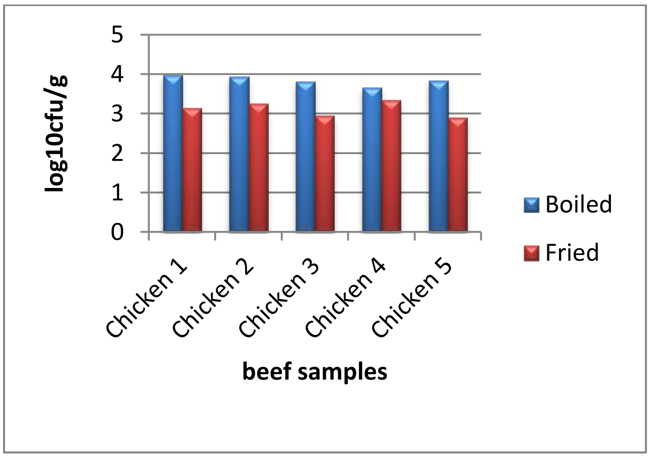

Figure 8 Mean Total Staphylococcus Counts for Chicken Samples

Table 1 Frequency of Occurrence of Bacteria in Beef and Chicken Samples

Isolates	**Beef**		**Chicken**	
	Frequency of Occurrence	**Percentage of Occurrence (%)**	**Frequency of Occurrence**	**Percentage of Occurrence (%)**
Bacillus sp.	**8**	**34**	**9**	**29.0**
Staphylococcus sp.	**7**	**30.4**	**5.00**	**16.1**
Micrococcus sp.	**4**	**17.4**	**10**	**32.3**
Enterobacter sp.	**-**	**-**	**2**	**6.5**
Escherichia coli.	**2**	**8.7**	**4**	**12.9**
Proteus sp.	**2**	**8.7**	**1**	**3.2**
Total	**23**	**100**	**31**	**100**

Table 2 Frequency of Occurrence of Fungi in Beef and Chicken Samples

Isolates	Beef		Chicken	
	Frequency of Occurrence	Percentage of Occurrence (%)	Frequency of Occurrence	Percentage of Occurrence (%)
Aspergillus flavus	5	23.8	3	13
Aspergillus niger	4	19.0	4	17.4
Mucor sp.	3	14.3	3	13
Penicillium sp.	5	23.8	5	21.7
Fusarium	-	-	4	17.4

sp.				
Rhizopus stolonifer	2	9.5	2	8.7
Botrytus cinerea	1	4.8	2	8.7
Trichoderm a viride	1	4.8	-	-
Total	21	100	23	100

Table 3: Proximate composition of the meat samples

Sample	boiled beef	fried beef	boiled chicken	fried chicken
Ash (%)	**0.91**	**0.83**	**1.38**	**1.14**
Moisture Content (%)	**66.28**	**55.94**	**68.42**	**56.85**
Crude Protein (%)	**19.41**	**14.53**	**17.58**	**11.94**
Crude Fiber (%)	**1.14**	**0.96**	**1.27**	**1.02**
Crude Lipid (%)	**7.51**	**18.45**	**6.22**	**16.78**
Carbohydrate (%)	**4.75**	**9.29**	**5.13**	**12.27**

Discussion

Microbial quality of processed meat via different cooking Methods

Meat, particularly beef and chicken, can harbour various microorganisms, posing significant food safety risks. Thermal processing techniques play a crucial role in reducing microbial loads and ensuring the safety of consumed meat products. The study investigates the impact of different cooking methods (boiling and frying) on the microbial safety of meat, specifically focusing on Total Heterotrophic Bacteria Count (THBC), Total Fungal Count (TFC), Total Coliform count and Total Staphylococcus Count including biochemical tests. The results will determine the general trends of microbial contamination after boiling and frying. All counts were expressed in log CFU/g, which provides an indication of the level of microbial presence in the samples

The Mean Total Heterotrophic Bacteria Count (THBC) shown in figure 1and 2 reveal notable trends in bacterial contamination after the two cooking methods (boiling and frying). For both beef and chicken, the boiled samples exhibited higher log CFU/g values compared to their fried samples. Specifically, the boiled samples had bacterial counts ranging from 2.60 to 3.43 log CFU/g for beef and from 2.13 to 4.04 log CFU/g for chicken. These results suggest that boiling did not eliminate all bacterial contamination but was effective in reducing it significantly, with beef generally showing lower levels than chicken. In contrast, the fried samples exhibited a broader range of bacterial counts, significantly lower than those of the boiled samples ($P < 0.05$). Fried beef showed a range of 1.38 to 2.11 log CFU/g, while fried chicken ranged from 1.59 to 4.78 log CFU/g. This indicates that frying was generally more effective at reducing bacterial loads, with most of the fried samples falling below the bacterial count levels seen in boiled samples. The observed trend across both beef and chicken samples suggests that frying tends to result in lower bacterial contamination compared to boiling. The lower bacterial load in fried samples could be attributed to the high temperatures reached during frying, which might have more effectively killed bacteria. However, the higher variability in the chicken fried samples compared to beef indicates that the frying method might not consistently reduce bacterial contamination, especially in the case of chicken. The results align with previous studies, which suggest that frying can be more effective at reducing heterotrophic bacterial contamination compared to other cooking methods (Kuan et al., 2020). The Microbiological Criteria for Foods (MCB) standards recommend an acceptable limit of $\leq 10^4$ CFU/g for Total Heterotrophic Bacteria Count (THBC) in boiled beef, $\leq 10^5$ CFU/g for fried beef, $\leq 10^5$ CFU/g for boiled chicken, and $\leq 10^6$ CFU/g for fried chicken. The THBC values obtained in this study for boiled beef samples ranged from 4.90×10^3 to 3.20×10^4 CFU/g, with a mean value of 1.73×10^4 CFU/g, which is within the acceptable limit. For fried beef samples, the range was 1.20×10^4 to 6.60×10 CFU/g, with a mean value of 7.31×10^3 CFU/g, which is also within the acceptable limit. For chicken, the THBC for boiled samples ranged from 1.10×10^4 to 3.90×10^4 CFU/g, with a mean value of 2.38×10^4 CFU/g, which is within the acceptable limit. However, the THBC values for fried chicken samples ranged from 8.19×10 CFU/g to 6.00×10^4 , with a mean value of 1.43×10^4 CFU/g, which is below the acceptable limit. From the results, it is clear that frying generally provides a greater reduction in bacterial contamination compared to boiling. A study by Salisu et al. (2020) reported a mean bacterial load of 4.7×10^4 and 5.3×10^4 CFU/g for fried beef meat, which is higher than the values obtained in this study. For fried chicken, the same study reported a mean bacterial load of 4.0×10^4 and 4.7×10^4 CFU/g, which is also higher than the values obtained in this study. Another study titled 'Microbiological Quality Assessment of ready-to-eat fried chicken and chicken soup samples sold' revealed the microbial load of fried chicken to be in the range of 1.8×10^3 to 2.8×10^4, which is comparable to the values obtained in this study (Moushumi et al., 2019).

Also similar to the result recorded by Mansour – waffaa (1995) who recorded 5.32×10^4 and lower than that recorded by Elwi (1994). The findings of Abdel Aal-Asmaa et al. (2015), were almost similar who assessed the impact of frying and boiling on various meat products from a government hospital in the Kalyobia governorate, Egypt, at different points in time. The findings showed that the bacterial load had a mean APC of $5.07x10^4$ $\pm1.12x10^4$, $8.31x$ $103\pm2.05x10^3$ .Additionally, the current study's results are comparable to those of EL melegy-Asmaa et al. (2015) assessed the microbiological status of raw and cooked meat products served to college students. The mean APC values for raw and cooked meat were $5.4x10^4$ $\pm 7.9x10^3$ and $3.6x10^4$ $\pm 2.1x10^3$ cfu/g, respectively. Additionally, these outcomes matched those reported by Mohamed (2017).

The Total Fungal Count (TFC) presented in figure 3 and 4 follow a similar pattern to the THBC data. The boiled samples again showed slightly higher fungal contamination compared to fried samples. For boiled beef, the log CFU/g values ranged from 0.90 to 1.20 log CFU/g, while for boiled chicken, the range was slightly higher, from 1.26 to 1.82 log CFU/g. This indicates a generally low level of fungal contamination across both beef and chicken, with boiling proving to be effective at reducing fungal presence. However, the variation in fungal contamination suggests that factors such as initial contamination levels, cooking time, and temperature could have influenced the final counts. For fried beef, the log CFU/g values ranged from 1.08 to 1.56, while for fried chicken, the values ranged from Log 1.28 to 1.82. These results show that frying also reduces fungal contamination, but not always to the same extent as boiling. The fungal contamination in fried chicken was consistently higher than in fried beef, suggesting that boiling might be slightly more effective at reducing fungal contamination, particularly in beef. Both boiling and frying were effective in reducing fungal contamination, but boiling appeared to have a slight edge in the reduction of fungal contamination, especially for beef. The Microbiological Criteria for Foods (MCB) standards recommend an acceptable limit of $\leq 10^3$ CFU/g for Total Fungal Count (TFC) in boiled beef, $\leq 10^4$ CFU/g for fried beef, $\leq 10^4$ CFU/g for boiled chicken, and $\leq 10^5$ CFU/g for fried chicken. The TFC values obtained in this study for boiled beef samples ranged from 8.00 to 1.60 × 10 CFU/g, with a mean value of 1.14 × 10 CFU/g, which is within the acceptable limit. For fried beef samples, the range was 1.80 × 10 CFU/g to 3.60 × 10 CFU/g, with a mean value of 2.23 × 10 CFU/g, which is also within the acceptable limit. For chicken, the TFC for boiled samples ranged from 1.80 × 10 to 6.60 × 10 CFU/g, with a mean value of 3.21 × 10 CFU/g, which is within the acceptable limit. For fried chicken samples, the range was from1.90 × 10 CFU/g to 6.60 × 10 CFU/g, with a mean value of 3.17 × 10CFU/g, which is also within the acceptable limit. A study by Salisu et al. (2020) reported a mean fungal load of 1.0×10^4 and 7.0×10^3 CFU/g for fried beef meat, which is higher than the values obtained in this study. For fried chicken, another study by Moushumi et al. (2019) reported a TFC range of 1.8×10^3 to 2.8×10^4 for fried chicken, which is also higher than the values obtained in this study.

The Total Coliform Count (TCC) as shown in figure 5 and 6 provides insight into the potential contamination of beef and chicken with coliform bacteria after different cooking methods (boiling and frying). Coliforms are commonly used as indicators of hygiene and sanitary conditions in food preparation, as their presence suggests possible contamination with other harmful pathogens (Shewfelt & Prussia, 1993). For the boiled beef samples, the log CFU/g values ranged from 3.00 to 3.38, with an average around 3.16. This indicates a relatively moderate level of coliform contamination, suggesting that boiling did not fully eliminate these bacteria but did reduce their presence to some extent. For boiled chicken, the log CFU/g values were significantly higher, ranging from 4.02 to 4.81($P < 0.05$).

The higher contamination in boiled chicken compared to boiled beef indicates that chicken may be more prone to coliform contamination, possibly due to its higher moisture content and protein composition, which can provide a more favourable environment for microbial growth. The results suggest that boiling, while effective at reducing coliform counts, may not be sufficient to eliminate them entirely, especially in chicken. This may be attributed to the fact that boiling temperatures might not reach high enough or sustain enough heat to fully destroy coliforms, particularly in chicken, which tends to be more susceptible to bacterial contamination.

In contrast, the fried beef samples exhibited coliform counts ranging from 3.00 to 3.55 log CFU/g, which is slightly higher than the boiled beef counts but still suggests that frying can reduce coliform contamination. Fried chicken, however, showed coliform counts ranging from 3.20 to 3.73 log CFU/g, which were slightly lower than the boiled chicken samples. From these results, it is evident that both boiling and frying have an impact on reducing coliform contamination, with frying generally showing a slight advantage in lowering coliform counts, especially in chicken. However, the overall levels of coliforms, particularly in chicken, remain high even after frying. This suggests that further optimization of cooking conditions, such as higher temperatures or extended cooking times, may be necessary to ensure the complete elimination of coliform bacteria. In this study, the Total Coliform Count (TCC) values for boiled beef samples in CFU/g ranged from 1.00×10^3 to 2.40×10^3 CFU/g, with a mean of 1.58×10^3 CFU/g, exceeding the recommended acceptable limit of $\leq 10^2$ CFU/g. For fried beef, the TCC ranged from 1.00×10^3 to 3.60×10^3 CFU/g, with a mean of 2.02×10^3 CFU/g, which is within the acceptable limit of $\leq 10^3$ CFU/g. Boiled chicken samples showed a TCC range of 6.40×10^4 to 3.90×10^4 CFU/g, with a mean of 4.63×10^4 CFU/g, well above the recommended limit of $\leq 10^3$ CFU/g. However, fried chicken samples had a TCC range from 1.60 × 10 to 5.40×10^3 CFU/g, with a mean of 2.93×10^3 CFU/g, which falls within the acceptable limit of $\leq 10^4$ CFU/g. When compared to a related study on prevalence of different microbial contaminants in meat products from Washington, D.C area also found high coliform contamination of chicken compared to the other meat products (Cuiwei et al., 2001)

This results is similar to the results obtained by Adel Aaal-Asmaa et al. (2015), who reported that various meat products represented by boiled beef meat, fried beef meat ,boiled chicken meat and fried chicken meat from governmental hospital at different times in Kalyobia governorate , Egypt The conducted result evaluated bacterial load with mean coliform count of $5.67x10^3 \pm 0.87x10^3$, $2.01x10^3 \pm 0.33x10^3$, $1.06x10^4 \pm 0.17x10^4$ and $6.40x10^3 \pm 1.23x10^3$CFU/g, respectively. These results were relatively similar to the results obtained by Tavakoli and Riazipour (2008), who reported that the microbial load of cooked meat in Tehran university restaurants conducted that the mean value of total bacterial and coliform counts were $1.14x10^5$cfu/g and $1.98x10^2$. The study indicated that chicken meat was more vulnerable to contamination because chicken contains more fluid than beef which could facilitate the quick multiplication of coliforms. This factor could have been responsible for the slightly higher coliform counts found in chicken samples.

The Total *Staphylococcus* Count (TSC) provides an indicator of the level of contamination with S*taphylococcus* spp., which can survive in a variety of conditions, including the presence of heat.

As shown in Fig 7 and 8 for the boiled beef samples, the log CFU/g values ranged from 3.30 to 4.21, with an average around 3.91. The range suggests a moderate level of Staphylococcus contamination, with some variability between the samples. Boiled chicken, on the other hand, had log CFU/g values ranging from 3.66 to 3.98, slightly lower than those observed for beef. Fried beef samples showed log CFU/g values ranging from 2.90 to 3.86, with an average of 3.31. The fried chicken samples had log CFU/g values ranging from 2.95 to 3.34. *Staphylococcus* bacteria are of significant concern in food safety due to their potential to cause foodborne illness through toxin production (Kadariya et al., 2014). These results indicate that frying was more effective than boiling at reducing Staphylococcus contamination, especially in chicken, where the counts were lower than those found in the boiled samples The International Commission on Microbiological Specifications for Foods (ICMSF) recommends that *Staphylococcus aureus* should not exceed 10^3 CFU/g in cooked meats.

In this study, the Total Staphylococcus Count (TSC) values for fried beef and fried chicken samples were within this recommended limit, with TSC values ranging from 6.00×10^2 to 1.00×10^3 CFU/g (mean 7.60×10^2 CFU/g) for fried beef and from 9.00×10^2 to 1.40×10^3 CFU/g (mean 1.10×10^3 CFU/g) for fried chicken. However, the TSC values for boiled beef (6.80×10^3 to 2.00×10^4 CFU/g, mean 1.22×10^4 CFU/g) and boiled chicken (1.40×10^3 to 9.60×10^3 CFU/g, mean 5.50×10^3 CFU/g) exceeded the recommended limit, indicating relatively high levels of Staphylococcus contamination in these samples. Hemmet et al.,(2020) reported the mean value of Staphylococci count (cfu/g)of the examined raw, boiled, fried and roasted meat samples were 7.75x 103±2.42x10^3 , 3.48x10± 0.11x10^2, 0.60x10^2±0.17x10^2 , 0.92x10± 0.27x10^2cfu/g this quite similar to the present study.

Tables 1 and 2 show significant differences in the bacterial isolates found in beef and chicken. The bacterial isolates were notably more frequent in beef compared to chicken, with *Bacillus sp.* (34.8%) and *Staphylococcus sp.* (30.4%) being the most common in beef, while *Micrococcus sp.* (32.3%) was the most frequently found in chicken. Other bacteria identified in both meats included *Escherichia coli*, *Proteus sp.*, and *Enterobacter sp.*, though these were less common, with *Escherichia coli* appearing in moderate levels (8.7% in beef and 12.9% in chicken). This present study is similar to Afolabi et al., (2015) .

Fungal contamination in both beef and chicken samples was also significant, with *Aspergillus flavus* and *Penicillium sp.* being the most frequent fungal species. *Aspergillus flavus* was present in 23.8% of beef and 13% of chicken samples, while *Penicillium sp.* was found in 23.8% of beef and 21.7% of chicken samples. *Aspergillus niger* was also prevalent in both meats, with a frequency of 19% in beef and 17.4% in chicken. Other fungi, such as *Mucor sp.*, *Rhizopus stolonifer*, and *Trichoderma viride*, were found in smaller proportions. These fungi, especially *Aspergillus flavus* and *Penicillium sp.*, are of concern due to their potential to produce mycotoxins, which can have serious health implications. This present study corresponds with the report of Tawakkol & khafaga et al., (2007) who reported similar fungi species with *Aspergillus niger and penicillium species* having the highest percentage occurrence. Afolabi et al, (2015) and Moushumi et al., (2019) also corroborates with the organisms isolated in this study.

Proximate Composition of Meats Processed Via Different Thermal Processing Techniques

The proximate analysis results presented in table 3 revealed significant differences in the nutritional composition of beef and chicken when boiled and fried. The key parameters examined were ash content, moisture content, crude protein, crude fiber, crude lipid (fat), and carbohydrates.

Regarding ash content, which reflects the mineral composition of the meat, slight differences were observed between the two cooking methods. For beef, boiled beef had an ash content of 0.91%, while fried beef showed a slightly lower value of 0.83%. In contrast, chicken exhibited a significant difference ($P < 0.05$), with boiled chicken having 1.38% Ash content compared to fried chicken at 1.14%. These results suggest that boiling may be more effective at preserving minerals compared to frying, which might lead to mineral loss, likely due to oil absorption and the high temperatures associated with frying.

The increase in ash content of boiled chicken meat could be attributed to moisture content losses by cooking and associated increases in dry matter contents. This finding in this study agrees with the result reported by Rosa et al. (2007), Achir et al. (2009) and Hussain et al. (2013) on chicken breast meat samples. The levels of ash content in chicken meat were indications of presence of mineral elements which are important substances in human health. The values of the ash content in the fried samples correspond to the findings of Osakue et al.(,2016). They stated that during frying, the time required is generally short and the temperature inside the product remains below 100°C, but there is less loss of water-soluble vitamins.

There was a more significant difference in the moisture content between the cooking methods ($P < 0.05$). Boiling beef retained 66% moisture, which was significantly higher than frying beef, which only had 55% moisture. Likewise, chicken that was boiled retained 68–42% moisture, whereas chicken that was fried retained 56–85%. This outcome is in line with the widely held belief that frying causes more moisture loss from meat because of the high temperatures and oil absorption. The boiled samples' higher moisture content probably adds to their tenderness and may also help retain water-soluble nutrients, which makes boiling a better way to preserve the meat's natural juices and nutritional value (Dietac, 2024). Food becomes less moist when it is fried. In line with Osakue et al. (2016) states that the hot frying fat that has permeated the food replaces some of the water it contains during cooking, greatly increasing the food's palatability.

In comparison to the fried samples, the boiled samples had significantly higher crude protein content, which is a crucial measure of the nutritional value of meat. Protein in boiled beef was 19%, whereas protein in fried beef was only 14%. Protein content in boiled chicken was 17.58%, while fried chicken had 11.94%. This discrepancy shows that boiling, as opposed to frying, preserves the protein content of the meat more successfully. Protein denaturation from the high heat of frying probably results in a decrease in the amount of protein. According to earlier studies, frying and other high-temperature cooking techniques cause protein loss because they break down protein structures while cooking (Zhang et al. (2023). Menezes (2014) reported that proteins are denatured at higher temperatures, and this result supports their findings. Because of increased protein denaturation and moisture loss from the fried sample, the protein content decreases as the temperature rises. It was concluded that the frying method produced less protein than the boiling cooking method. At higher temperatures, this could indicate more denaturation of proteins, the release of bound water, and an increase in browning coloration. Applying heat causes some amino acids to be destroyed, products to brown, and the amount of protein to decrease as cooking time increases, according to Sharma and Sharma (2011) and Alugwu (2018).

The crude fiber content, which is typically low in meat, showed minimal differences between the two cooking methods. boiled beef had 1.14% crude fiber, while fried beef had 0.96%. For chicken, boiled chicken contained 1.27% fiber, and fried chicken had 1.02%. Given that meat naturally contains low levels of fiber, the slight variations in fiber content observed here are likely due to minor differences in the specific samples or the cooking process itself. These differences are unlikely to have a significant impact on the overall nutritional profile of the meat.A more notable difference was observed in the crude lipid (fat) content, which was significantly higher in the fried samples compared to the boiled samples($P < 0.05$). Fried beef had 18.45% fat content a substantial increase compared to the 7.51% fat content in boiled beef. Similarly, fried chicken contained 16.78% fat, while boiled chicken had only 6.22%.

Higher fat levels were caused by the chicken samples' high absorption of frying oil, and these levels rose as the frying time increased. One possible explanation for the rise in fat content with rising temperatures is the concentration of dry materials. Given that boiling does not add fat to the meat, frying involves the absorption of oil during the cooking process, so this significant increase in fat content for the fried samples is to be expected. Due to oil absorption, frying dramatically raises the amount of fat in meat, as demonstrated by previous research (Valle et al. in 2024). Fried meat's higher fat content can affect its caloric density and overall nutritional profile, making it less healthful than boiled meat. Similar findings have been reported by Gokoglu et al., (2006) as well as Salawu et al. 2005.

Finally, the carbohydrate content in meat is generally low, but there were slight increases in the carbohydrate content of fried samples. Boiled beef contained 4.75% carbohydrates, whereas fried beef had 9.29%. Similarly, boiled chicken had 5.13% carbohydrates, while fried chicken had 12.27%. Given that cooking oil may contain leftover carbohydrates, these increases in the carbohydrate content of the fried samples could be explained by the oil absorption during frying. Notwithstanding this rise, the total amount of carbohydrates in chicken and beef is still quite low and has little effect on the meat's nutritional value. The carbohydrate content of boiled meat was unaffected by boiling, and the results showed no significant ($p>0.05$) change as a result. This outcome supports the claims made by Emeka-Ike et al. (2018) and Yun-Sang et al. (2016).

The nutritional difference between boiled and fried meats are highlighted by the proximate analysis. While frying results in higher fat content and lower protein levels, boiling typically maintains higher levels of moisture, protein, and minerals. According to these results, boiling preserves vital nutrients while lowering fat intake, making it a healthier cooking method, especially for people who are worried about the nutritional value of meat. It is crucial to remember, though, that the fried samples' slight increase in carbs is unlikely to significantly alter the nutritional profile as a whole. According to the study's findings, frying typically reduces bacterial and fungal contamination more than boiling does, most likely because frying raises the temperature. Both cooking techniques, however, were insufficient to totally eradicate microbial contamination, especially in chicken. Furthermore, frying increased the meat's fat content, which might have an effect on its nutritional value. However, in terms of retaining nutrients, boiling was a healthier cooking method because it helped retain more moisture, protein, and minerals. It is advised to further optimize cooking methods, such as modifying temperature or cooking time, to guarantee the safety and nutritional value of meat.

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