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# Assessment of physico-chemical, microbiological and organoleptic quality of grilled chicken meat in southern Benin

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**ABSTRACT**
*Objectives*: The consumption of grilled chicken meat on the street is becoming rampant in the daily life of urban populations. This study focuses on assessing the physicochemical, organoleptic, and microbiological quality of grilled chicken meat in Benin.
*Methodology and results*: Grilled chicken meat (indigenous, broiler, and reformed layer) were obtained from different cooking processes using wood, charcoal, gas devices and related spices used for grilling and consumption. Collected samples were analysed for the physicochemical, organoleptic and microbiological levels. Analyses were carried out following standard methods. Data were analysed using one-way ANOVA of Graph Pad Prism 5. Results showed that the pH of grilled chicken meat ranged from 5.74 to 6.05; moisture was between 49.17% and 59.17%. Lipid content varied from 5.5% to 13.76%, and that of the proteins from 27.08% to 36.15%. Phosphorus was most abundant in grilled chicken meats (4.39-6.7 g/kg meat), followed by calcium (0.21-5.64 g/kg). Magnesium and iron were in low proportions with 0.090-0.407 g/kg and 0.02-0.058 g/kg of meat, respectively. From an organoleptic point of view, the indigenous grilled chicken (PLG) meat was the least appreciated, while the gas-grilled chicken meat (PGG) was the most appreciated for its tenderness and juiciness. Load in total aerobic germs and thermotolerant coliforms of all grilled chicken meats exceeded $3\times10^6$ and $10^2$ CFU/g thresholds respectively except for gas-grilled chicken meat whereas the loads in total coliforms, *E. coli*, sulphite-reducing anaerobes, yeasts and moulds respected the standards. *Staphylococcus aureus* and *Salmonella* were not detected in any of the grilled chicken meats and spice samples analysed.
*Conclusion and application of findings*: It can be deduced that gas-grilled chicken meats have the best organoleptic qualities and would expose consumers to less microbial loads than other charcoal and wood-grilled chicken meats. Stakeholders are encouraged to improve the hygienic conditions

(material and handling) of grilled chicken meat production and to protect them during selling in order to offer a better microbiological quality product.
**Keywords:** Grilled chicken meat, grilling equipment, sensory characteristics, microbial load, Benin

## INTRODUCTION

Grilling consists of applying dry heat to the surface of food, usually above, under, or from the side (Bastin, 2011). It is one of the most widespread cooking methods for chicken in the world, which improves its nutritional, organoleptic and microbiological quality as well, thus increasing shelf life (Van Boekel *et al.*, 2010). For example, due to the temperature produced by the heat, grilling causes the denaturation of proteins, making them more digestible and the resulting nutrients are better bioavailable (Meade *et al.*, 2005). In addition, flavour resulting from the Maillard reaction (between amino acids and reducing sugars) and the oxidation of lipids produces a pleasant toasty aroma (Elmore *et al.*, 2009). However, these different qualities may be affected by several factors, mainly temperature and cooking time (Sobral *et al.*, 2018). In addition, grilling represents an activity that presents socio-economic interests such as job creation and income for people with limited education, and supply of food at an affordable price for vulnerable groups of weak purchasing power (Tavonga, 2014; Montcho *et al.*, 2018). Today, chicken meat grilling is a growing activity in the main cities of Benin. A recent study (Edikou *et al.*, 2019) carried out in Abomey-Calavi and Cotonou found that stakeholders of this activity were poorly educated, used rudimentary equipment and various processes to grill chicken meat in ignorance of the ideal conditions to obtain a healthy product and avoid the negative impact on its physicochemical and nutritional composition. Often, unsold chickens were taken back and roasted again on the next day(s) to be put back on sale. The chickens were often grilled around streets, intersections or in front of restaurants and exposed to open air, which can strongly promote microbial contamination (Edikou *et al.*, 2019). Although grilled chickens underwent heat treatment through the grilling, many studies around the world showed their microbiological quality to be unsatisfactory when compared to the standards set for the microbial load of food. The causes mentioned were among others, the environmental conditions and inadequate handling, the non-control of the temperature and the grilling time (Makut *et al.*, 2015; Djoulde *et al.*, 2015; Bakobie *et al.*, 2017; Ogu *et al.*, 2018; Somda *et al.*, 2018). In addition, since grilled chicken meats were not immediately sold after grilling, recontamination by microorganisms is possible if they are not maintained at a suitable temperature and are unfavourable to the multiplication of germs during the sale (Edikou *et al.*, 2019). Sina *et al.* (2019) assessed only microbial contamination of grilled chicken meat sold in Cotonou (Benin) but did not consider various forms of chicken meat and processes used for grilling. This study aimed to assess the physicochemical, organoleptic, and microbiological quality of grilled chicken meat according to processes in Benin.

## MATERIAL AND METHODS

**Sample collection:** Sample collection was carried out at Cotonou and Abomey-Calavi, the two biggest and most crowded cities in the South of Benin. Seventy samples of various grilled chicken meat were collected, namely 10 samples for 7 types of meat. In each city, thirty-five samples were collected. Grilled chicken meat collected were: chicken meat skewer grilled with barrel using charcoal (BGB), chicken meat skewer grilled with cabinet type equipment using charcoal (BGP), whole chicken meat grilled with barrel using charcoal (PGB), whole chicken meat grilled with cabinet type equipment using charcoal (PGP), whole precooked chicken meat grilled with barrel using charcoal (PpGB), whole chicken meat grilled with cabinet type equipment using gas (PGG), and indigenous chicken meat grilled with wood (PLG). PGB, PpGB, BGB, PGP, and BGP were obtained from the imported layer, whereas PGG was obtained from imported broiler chickens. The major grilling devices and processes were previously identified in a former study to which wood grilling was added (Edikou *et al.*, 2019). Collected samples were submitted to physico-chemical, microbiological and sensorial analyses. In addition, 24 spices (6 samples respectively from charcoal-barrel (spice B), charcoal-cabinet type device (spice P), gas-cabinet type device (spice G), and wood-grilling device (spice L) processors) were randomly collected from processors (12 samples in each city) for microbiological analysis. Samples for microbiological analysis were collected in sterile bags "trademark ATL irradiated at 10 KGray", stored in isotherm containers at 0-2°C and conveyed to the laboratory for analysis.

**Methods of analyses**

**pH measurement*:*** pH was determined using the method described by Goulas *et al.* (2005) with some modifications. Ten ml of distilled water was added to 5 g of the sample and blended. The mixture was homogenized for three minutes (remix rotation) and pH was measured using an electronic pH meter (EUTECH INSTRUMENTS, PH510).

**Humidity (Water content):** Five grams of sample were dried in an oven at 105 °C until a constant weight was obtained (AOAC, 2000). The water content was calculated as follows:

$$Water\ content\ (\%) = \frac{weight\ of\ test\ portion(g) - weight\ of\ dried\ portion(g)}{weight\ of\ test\ portion(g)} \times 100$$

**Total Fat:** Total fat was analysed by Soxhlet (AOAC, 2000). About 1.5 g of sample was placed in a cellulose cartridge (25×60 mm, thickness 2 mm) and fat was extracted with 30 ml of hexane (95%, chromatographic grade, sigma) at 130 °C for 1 h using an extraction device (FOSS, ST 243Soxtec).

**Total proteins:** Total proteins were analysed by the Kjeldahl method AOAC 928.08 (AOAC, 2002), with some modifications. About 2 g of sample were digested with 15 ml of H2SO4 (98%) and catalyst (Kjedahl disc) successively for 1 h at 250 °C and 420 °C using a heating block (KT20S Gerhardt). Then digested samples were automatically distilled with 80 ml of NaOH (40%) and 80 ml of distilled water for 4 min 30 s using VAP Gerhardt. Ammonium was trapped in boric acid (4%). Then, it was titrated with 0.1N HCl using SCHOTT TL 5000. Protein levels were determined automatically by multiplying total nitrogen content by 6.25.

**Minerals:** Samples were previously dried at 70 °C for approximately 4 days, before being crushed for the determination of heavy metals. The assay was performed according to the method described by Joyce *et al.* (2016) with some modifications. Ten ml of $H_2O_2$ (9%) were added to 1 g of dried and grounded sample and left for 24 h. Then the sample was digested with 4 ml of $HNO_3$ at 150 °C until it became colourless. After evaporation and cooling, it was filtered through Whatman paper. Fe, Ca and Mg were determined using atomic absorption spectrophotometer (SOLAAR S2 brand, THERMO FISHER) whereas P was determined using a molecular absorption spectrometer (HACH DR 3800 type) with PhosVer® 3 method according to

DR 3800 procedure manual. The test was carried out at 880 nm.

**Sensorial analysis:** A quotation-notation test was carried out to assess the sensorial quality of grilled chicken meat obtained from various grilling processes with 75 untrained assessors. Each grilled sample was cut into portions, of around 20 g each and identified with a randomly chosen number. Then, they were distributed one after the other to the assessors. Each evaluator was in an individual cabin. Considered parameters were appearance, tenderness, juiciness, taste, colour, aroma and global acceptability. They were assessed following a scale from 1 to 9 (1 = dislike; 2 = don't like at all; 3 = don't like; 4 = don't like very much; 5 = don't care; 6 = like a little; 7 = like moderately; 8 = like a lot; 9 = like very much) (Watts *et al.*, 1991).

**Microbiological analysis:** Twenty-five grams of the sample was homogenized in 225 ml of buffer peptone water for two minutes using a laboratory blender (Binatone). Serial decimal dilutions were prepared in tryptone salt broth as described by ISO 6887-3 (ISO, 2004) and spiked in different media: (i) Plate Count Agar (PCA) and incubated at 30 °C for 72 h, and total aerobic bacteria were enumerated (ISO, 2003); (ii) Baird-Parker agar adjusted with yellow yolk, incubated at 37 °C for 24 to 48 h followed by agglutination test with Staphytect Plus for *Staphylococcus aureus* enumeration (ISO, 1999); (iii) VRBL agar, and incubated at 30 °C for total coliforms and 44 °C for thermotolerant coliforms during 24 h, followed by their enumeration (ISO, 2003), (iv) Brillance *E. coli* and incubated at 44 °C for 24 h for *E. coli* enumeration (ISO, 2018); (v) Chloramphenicol glucose agar, incubated at 30 °C for 3-5 days, then, moulds and yeasts were enumerated (ISO, 2008); Tryptone Sulphite Neomycin agar (TSN, LIOFILCHEM Diagnostics, Italy), and incubated at 44 °C for 24 h for Sulphite Reducing Anaerobes (SRA) enumeration (NF, 2009). For *Salmonella* detection, aliquots were pre-enriched in buffered peptone water (37 °C, 1 day) and enriched in modified Rappaport-Vassiliadis in Soya (RVS) at 37 °C for 24 h. Then, cultures were isolated on Hektoen agar and *Salmonella-Shigella* (SS) agar at 37 °C for 24 h. Characteristic colonies were inoculated in Kligler agar (CM 0033, OXOID). Confirmation of characteristic colonies was made using the Urea-Indole test, API 20E, and serological tests for *Salmonella* (ISO, 2002).

**Statistical analysis:** One-way ANOVA test followed by Tukey post-test was used to compare variables for Physico-chemical, organoleptic, and microbiological data using Graph Pad prism 5 software. Results were expressed as the mean ± standard error of the mean. The microbial loads were expressed in CFU/g of meat. The differences were significant at 5% ($p < 0.05$).

## RESULTS AND DISCUSSION

**Physico-chemical characteristics of grilled chicken meat:** Table 1 showed physico-chemical characteristics of grilled chicken meat. The pH of the grilled chicken meat ranged from 5.74 to 6.05. Pre-cooked and grilled chicken meats (PpGB) had the highest pH (6.05 ± 0.05) compared to grilled chicken meat skewers (BGB, BGP) whose pH ranged between 5.74 and 5.75. This difference could be explained by the effect of the components of marinade on the pH of the skewers, which made them a little more acidic. However, there was no significant difference between the pH of pre-cooked and grilled chicken meats (PpGB) and the other whole-grilled chicken meats (PGB, PGP, PGG, and PLG). In the same way, the pH of grilled chicken meat skewers (BGB and BGP) was no different from the other whole-grilled chicken meats (PGB, PGP, PGG, and PLG). The pH of grilled chicken meats (5.74-6.05) was similar to that found by Joseph *et al.* (1997), which ranged from 5.6 to 5.9 in grilled chicken meats, whereas Choi *et al.* (2016) found a pH of 6.09 ± 0.04 in grilled chicken meats. Indigenous wood-grilled chicken (PLG) had the highest values (59.17%, w.w), while grilled chicken skewers (BGB, BGP) had the lowest values (~ 49%, w.w) of water content (p value=0.023). The moisture of the other types of grilled chicken meat was not significantly different. Protein content ranged from 27.08% -36.15% (d.w). Chicken meat skewers from the cabinet type device (BGP) contained the lowest protein contents (27.08%, d.w), while precooked and barrel-grilled chicken meat (PpGB) recorded the highest protein content (36.15%, d.w) (p-value=0.022). There was no difference between the protein content of all other grilled chicken meats. Choi *et al.* (2016) found a higher water content (65.79 ± 0.38%) and a lower protein content (25.92%) than in our study (55.67-59.17% water content and 27.08-36.15% protein). In gas-grilled broilers, a water content of 63.2% and protein content of 23.4% were found (Winiarska-Mieczan *et al.,* 2016). Chicken breast grilled for ten minutes on a preheated grill had 87% (w.w) of total protein (Menezes *et al.,* 2018). Fat content ranged from 6.5% (w.w) to 13.76% (w.w). The lowest level was obtained in the meat of indigenous grilled chicken (PLG; 6.5%) and the highest one was obtained in whole grilled chicken meat from a charcoal cabinet (PGP). Fat content (12.70%) of the grilled chicken skewer (BGB) was significantly higher than the one (9.52%) of the charcoal barrel-grilled chicken skewer (BGP), but there was no difference between whole grilled chicken meats from these two types of devices (PGB and PGP). The fat content (10.67%) of gas-grilled chicken meat (PGG) was not different statistically from the other grilled chicken meat. Fat content (2.14%) was lower in the grilled chicken meats studied by Choi *et al.* (2016) than ours (6.50-13.76%) was. This large difference can be explained by the contribution of the oil coating of chicken meats during grilling. Winiarska-Miecza *et al.* (2016) for their part found a fat content of 11.3% in grilled chicken meats.

***Mineral levels:*** Phosphorus (P) was most abundant in grilled chicken meats; whether they were whole (4.39-6.45 g/kg of meat) or skewers (6.44-6.67 g/kg of meat) (table 1). There was no significant difference between the two forms. After P, calcium (Ca) followed with average concentration ranging between 0.66 g/kg and 2.49 g/kg in skewers, and between 0.21 g/kg and 5.64 g/kg in the meat of whole grilled chicken. Here, Ca content in whole chicken grilled with barrel device (PGB: 5.64±1.586 g/kg) was higher than in the whole grilled meat (PGP: 0.21±0.006 g/kg) and grilled chicken skewers (BGP: 0.663 ±0.362 g/kg) from the charcoal cabinet type device (p-value=0.024). However, there was no significant difference between the other types of grilled chicken meats. Magnesium (Mg) and iron (Fe) were in low proportions with 0.34-0.407 g/kg of Mg and 0.057-0.058 g/kg of Fe in skewers, respectively and, 0.09-0.34 g/kg of Mg and 0.02-0.08 g/kg of Fe in whole grilled chicken meats. Mg content was not significantly different in the meats analysed, unlike Fe. Mg and Fe were in low proportions with 0.34-0.407 g/kg of Mg and 0.057 g/kg of Fe in skewers respectively and, 0.09-0.34 g/kg of Mg and 0.023-0.08 g/kg of Fe in whole grilled chicken meats. Mg content was not significantly different in the meats analysed, unlike Fe. Indigenous wood-grilled chicken meat contained the highest level of Fe (0.08 g/kg), while whole-grilled chicken meat from a charcoal cabinet device (PGP) contained the lowest level (0.023 g/kg). The content of Fe in PGB was also higher than in PGP, whereas there was no difference in the content of BGB and BGP (Table 1). Results found in other studies that analysed the mineral contents in chicken meats including those of grilled chicken are variable. According to Menezes *et al.* (2018), grilled chicken meats contained decreasingly Mg (1289 mg/kg), Ca (142 mg/kg), Zn (33 mg/kg), Fe (25 mg/kg) and Cu (1.1 mg/kg). Phosphorus was not measured in the aforementioned study. Contrary to the current study, magnesium was more abundant than calcium. Per this study, Fe content was also low in grilled chicken meats. Winiarska-Mieczan *et al.* (2016) found an average of 1.582 mg/100g of iron, higher than Ca content (0.001 mg/100g) in grilled broiler meat. These differences depended on several factors, including the diet of poultry, which primarily affected the quality of the meat, intake level, age of the animal, health conditions, cooking techniques, etc. Studies were also carried out to assess the effect of different cooking methods on the levels of trace elements including minerals. The results were divergent and depend on animals, cooking methods and temperature, and minerals (Joyce *et al.*, 2016; Purchas *et al.,* 2014; Tomović *et al.,* 2015).

**Table 1:** Physico-chemical characteristics of grilled chicken meat

| **Chicken meat types** | **pH** | **Moisture (%, w.w)** | **Fats (%, w.w)** | **Proteins (%, d.w)** | **Fe (d.w, g/kg)** | **Ca (d.w, g/kg)** | **P (d.w, g/kg)** | **Mg (d.w, g/kg)** |
|---|---|---|---|---|---|---|---|---|
| BGB | 5.75±0.07[b] | 49.17±0.75[b] | 9.52±0.39[abc] | 31.36±0.86[ab] | 0.057±0.007[ab] | 2.493±1.201[ab] | 6.667±0.674[a] | 0.340±0.110[a] |
| BGP | 5.74±0.04[b] | 49.50±2.67[b] | 12.70±0.28[a] | 27.08±1.45[b] | 0.057±0.003[ab] | 0.663±0.362[b] | 6.443±0.199[a] | 0.407±0.058[a] |
| PGB | 5.96±0.04[ab] | 52.67±6.60[ab] | 11.23±1.40[ab] | 32.83±1.46[ab] | 0.037±0.003[b] | 5.64±1.586[a] | 6.447±0.147[a] | 0.333±0.122[a] |
| PpGB | 6.05±0.05[a] | 53.17±1.08[ab] | 7.40±0.27[bc] | 36.15±0.76[a] | 0.04±0[bc] | 3.363±1.631[ab] | 6.057±0.808[a] | 0.340±0.136[a] |
| PGP | 5.87±0.18[ab] | 50.33±1.54[ab] | 13.76±1.78[a] | 30.07±2.89[ab] | 0.023±0.007[c] | 0.21±0.006[b] | 5.39±0.776[a] | 0.293±0.138[a] |
| PGG | 5.94±0.18[ab] | 55.67±1.12[ab] | 10.67±0.89[abc] | 33.04±1.16[ab] | 0.047±0.012[bc] | 1.13±0.722[ab] | 5.72±0.806[a] | 0.130±0.075[a] |
| PLG | 5.84±0.06[ab] | 59.17±0.65[a] | 6.50±0.98[c] | 32.97±1.65[ab] | 0.08±0.006[a] | 0.813±0.351[ab] | 4.393±1.887[a] | 0.090±0.021[a] |
| p-value | 0.035 | 0.023 | 0.000 | 0.022 | 0.001 | 0.024 | 0.630 | 0.306 |

BGB= chicken meat skewer grilled with barrel using charcoal, BGP= chicken meat skewer grilled with cabinet type equipment using charcoal, PGB= whole chicken meat grilled with barrel using charcoal, PGP= whole chicken meat grilled with cabinet type equipment using charcoal, PpGB=whole precooked chicken meat grilled with barrel using charcoal, PGG= whole chicken meat grilled with cabinet type equipment using gas, PLG= Indigenous chicken meat grilled with wood. w.w.= wet weight, d.w= dry weight; Values with the same letter(s) within the column are not statistically different.

**Sensorial quality of grilled chicken meat:** Indigenous wood-grilled chicken meat (PLG) obtained the lowest score for all organoleptic parameters evaluated, therefore was less appreciated by the panel (Table 2). In contrast, gas-grilled chicken meat (PGG) was the most appreciated for its tenderness and juiciness. Concerning appearance, colour, aroma, taste, crispiness and overall acceptability, there was no significant difference between the different grilled chicken meats except the indigenous grilled chicken had inferior attributes. That may be explained by the grilling method that was quite rudimentary. In fact, the indigenous chicken was grilled on wood embers and seasoned only with red oil, pepper, and salt. By comparing three ways of cooking chicken meat on the organoleptic aspect, Singh *et al.* (2012) showed that grilling and frying chicken meat were more appreciated than cooking in the microwave. Although grilled and fried chicken meats had similar scores for colour, flavour and texture, grilled chicken meats had the best overall acceptability. Dyubele *et al.* (2010) showed that on the organoleptic plan, grilled chicken meats were more appreciated and preferred than boiled chicken meats. Chumngoen *et al.* (2017) showed that although oven cooking gave chicken meat a blackish colour, oven-grilled chicken meat was preferred over boiled chicken meat for its colour and flavour. Recently, Küçüközet and Uslu (2018) showed that chicken meats coated with a layer of sodium caseinate and a starch-caseinate mixture were more tender and delicious and therefore more popular than those directly grilled.

**Table 2:** Sensorial attribute scores of grilled chicken meat

| Attributes | BGB | BGP | PGB | PpGB | PGP | PGG | PLG |
|---|---|---|---|---|---|---|---|
| Appearance | 5.71±0.19[a] | 6.25±0.21[a] | 6.22±0.21[a] | 6.43±0.21[a] | 6.21±0.22[a] | 6.01±0.23[a] | 3.62±0.22[b] |
| Tenderness | 5.69±0.25[b] | 5.62±0.26[b] | 5.41±0.24[b] | 5.67±0.25[b] | 5.56±0.24[b] | 7.29±0.20[a] | 5.08±0.26[b] |
| Juiciness | 5.42±0.28[bc] | 5.78±0.23[ab] | 5.59±0.23[b] | 5.71±0.22[b] | 5.56±0.23[b] | 6.74±0.22[a] | 4.50±0.26[c] |
| Colour | 6.14±0.21[a] | 6.31±0.21[a] | 6.09±0.22[a] | 6.50±0.20[a] | 5.84±0.21[a] | 6.10±0.23[a] | 3.65±0.25[b] |
| Aroma | 6.09±0.23[a] | 5.82±0.22[a] | 5.79±0.22[a] | 6.21±0.19[a] | 5.57±0.20[a] | 5.79±0.26[a] | 4.60±0.26[b] |
| Taste | 6.62±0.23[a] | 6.37±0.23[a] | 6.23±0.20[a] | 6.46±0.20[a] | 6.34±0.20[a] | 6.10±0.25[a] | 3.95±0.25[b] |
| Crispiness | 5.29±0.24[a] | 5.12±0.27[a] | 5.00±0.24[a] | 5.51±0.25[a] | 5.30±0.24[a] | 4.62±0.30[a] | 3.71±0.24[b] |
| Overall acceptability | 6.43±0.17[a] | 6.42±0.17[a] | 6.20±0.17[a] | 6.42±0.17[a] | 6.20±0.17[a] | 6.38±0.20[a] | 4.49±0.22[b] |

BGB= chicken meat skewer grilled with barrel using charcoal, BGP= chicken meat skewer grilled with cabinet type equipment using charcoal, PGB= whole chicken meat grilled with barrel using charcoal, PGP= whole chicken meat grilled with cabinet type equipment using charcoal, PpGB=whole precooked chicken meat grilled with barrel using charcoal, PGG= whole chicken meat grilled with cabinet type equipment using gas, PLG= Indigenous chicken meat grilled with wood

Values with the same letter(s) within the line are not statistically different.

**Microbiological quality of spices and grilled chicken meat**

**Microbial loads of grilled chicken meat:** The average of the total germ loads of all the grilled meats exceeded the maximum limit of $3\times10^6$ CFU/g set by Regulation (EC) n° 2073/2005 of the European Union, except broiler chickens grilled with the gas cabinet type (PGG; Table 3). However, there was no significant difference between the meats analysed. Similar results were obtained for whole charcoal-grilled chickens (PGB, PpGB, PGP) which contained loads of thermotolerant coliforms exceeding the tolerated standard ($<10^2$ CFU/g). The results obtained for total coliforms, moulds and yeasts in these same meats met the standards set. The relatively high loads of these germs in grilled chicken meats despite their high temperature (64.4°C-101°C) can be explained by recontamination due to the lack of hygiene of the sales materials (knife, cutting board) used during the sale. Fortunately, *E. coli* and SRA levels were highly under tolerated limits set by standards (respectively <5000 and 300 CFU/g), and *S. Aureus* and *Salmonella* were not found in any analysed sample.

***Microbial loads of grilled chicken meat spices:*** Spices collected from barrel (spice B) and charcoal cabinet-type device (spice P) users contained the highest total microbial loads ($2.23\times10^6 \pm 1.18\times10^6$ CFU/g and $1.19\times10^6 \pm 6.25\times10^5$ CFU/g, respectively; Table 4). However, these loads were below the maximum threshold of $3\times10^6$ CFU/g set by Regulation (EC) n° 2073/2005. In contrast, the average loads of spices collected from gas-cabinet device (spice G) users were the lowest ($3.75\times10^5 \pm 6.24\times10^4$ CFU/g), followed by those of indigenous grilled chicken meat ($7.24\times10^5 \pm 5.44\times10^5$ CFU/g). However, there was not a significant difference in total microbial loads between all the spices. The total coliform load of spices from indigenous chicken grilling ($1.35\text{-}\times10^4 \pm 5.2\times 10^3$ CFU/g) was higher than the limit of $10^4$ set by AFSSA 2007-SA-0174. As well, no spices analysed complied with the limit load of $10^2$ fixed for thermotolerant coliforms, except those used to consume broiler meats grilled with the gas device (spice G). Loads of all spices in yeasts and moulds, *E. coli*, *Staphylococcus aureus*, SRA, and *Salmonella* were following the established limits. Makut and Nsemoh (2015) showed that the meat of grilled chickens contained a microbial load ranging from $1.3\times10^5$ to $3.7\times10^5$ CFU/ml in Nigeria. They also showed that the hands of the sellers of that chicken meat were sold with significant microbial loads ranging from $3.4\times10^5$ to $7.4\times10^5$ CFU/ml, in consequence contaminating the meat of the chickens sold. In addition, significant loads of *E. coli*, *Salmonella* spp., and *Staphylococcus* spp. were isolated from the hands of the same vendors. Also in Nigeria, Similar results were found by Ogu *et al.* (2018) in the town of Warri in Delta State in the same country. In Burkina Faso, 38.24% of grilled chicken meats sold were unacceptable in terms of their load in total mesophilic aerobic organisms, 57.85% in their load in thermotolerant coliforms, and *E. coli* were enumerated in 27.45% of samples analysed (Somda *et al.*, 2018). In Ghana, Bakobie *et al.* (2017) revealed that contaminations observed in grilled chicken meat also came from spices used to marinate the meat. Indeed, the analysis of spices confirmed proportions of up to 1.7 $\log_{10}$ CFU/ml in total coliforms; 2.7 $\log_{10}$ CFU/ml in thermotolerant coliforms, 3.14 $\log_{10}$ CFU/ml in *E. coli*; and 0.9 $\log_{10}$ CFU/ml in *Salmonella*. In the Sudano-Sahelian zone of Cameroon, grilled chicken meats analysed contained total germs higher than the maximum limit of 5 $\log_{10}$ CFU/g tolerated for cooked foods. In addition, pathogens such as *Staphylococcus aureus* and *E. coli* were found in the samples analysed. However, they were below the maximum tolerated limit (Djoulde *et al.*, 2015).

**Table 3:** Microbial loads of grilled chicken meat

| | Total aerobic bacteria | Total coliforms | Thermotolerant coliforms | Yeast | Moulds | *E. coli* | SRA | *S. aureus* | *Salmonella* |
|---|---|---|---|---|---|---|---|---|---|
| BGB | $1.15\times10^{8ab}\pm 5.93\times10^{7}$ | $7.5\times10^{1}\pm 3.6\times10^{1}$ | $2.6\times10^{1}\pm 6.8$ | $4.13\times10\pm 2.12\times10^{2}$ | 0 | 0 | <10 | absent | absent |
| BGP | $9.60\times10^{7ab}\pm 6.89\times10^{7}$ | 7±3 | $1.3\times10^{1}\pm 6.08$ | $3.34\times10\pm 1.6\times10^{2}$ | $2\times10^{2}\pm2\times10^{2}$ | 0 | <10 | absent | absent |
| PGB | $3.55\times10^{8a}\pm 1.21\times10^{8}$ | $4.5\times10^{2}\pm 1.87\times10^{2}$ | $1.16\times10^{2}\pm59.38$ | $7.37\times10\pm 2.68\times10^{2}$ | $2\times10^{1}\pm2\times10^{1}$ | <1 | <10 | absent | absent |
| PpGB | $1.99\times10^{8ab}\pm 9.45\times10^{7}$ | $1.37\times10^{2}\pm 8.7\times10^{1}$ | $1.48\times10^{2}\pm 9.3\times10^{1}$ | $5.84\times10\pm 4.54\times10^{3}$ | 0 | <1 | <10 | absent | absent |
| PGP | $5.84\times10^{7ab}\pm 4.76\times10^{7}$ | $4.54\times10^{2}\pm 2.34\times10^{2}$ | $1.14\times10^{2}\pm 5.58\times10^{1}$ | $2.1\times10^{3}\pm 1.98\times10^{3}$ | 0 | 0 | <10 | absent | absent |
| PGG | $1.47\times10^{6b}\pm 6.26\times10^{5}$ | $3.6\times10^{1}\pm 3.3\times10^{1}$ | 24±18.27 | $4.26\times10\pm 3.94\times10^{4}$ | < 1 | <2 | <10 | absent | absent |
| PLG | $3.78\times10^{7b}\pm 1.87\times10^{7}$ | $2.42\times10^{2}\pm 1.92\times10^{2}$ | 36.80±19.38 | $1.2\times10^{2}\pm 9.7\times10^{1}$ | 0 | 0 | <10 | absent | absent |
| p-value | 0.024 | 0.138 | 0.274 | 0.396 | 0.349 | 0.28 | 0.041 | - | - |
| regulation | $< 3\times10^{6}$ (EU, 2005) | $< 10^{4}$ (AFSSA, 2008) | $< 10^{2}$ (AFSSA, 2008) | $< 10^{5}$ (Jouve, 1996) | $< 10^{6}$ (Baumgart, 1994) | <5000 (EC, 2007) | 300 (EU, 2005) | Absent (EU, 2005) | Absent (EC, 2007) |

BGB= chicken meat skewer grilled with barrel using charcoal, BGP= chicken meat skewer grilled with cabinet type equipment using charcoal, PGB= whole chicken meat grilled with barrel using charcoal, PGP= whole chicken meat grilled with cabinet type equipment using charcoal, PpGB=whole precooked chicken meat grilled with barrel using charcoal, PGG= whole chicken meat grilled with cabinet type equipment using gas, PLG= Indigenous chicken meat grilled with wood; SRA=Sulphite-Reducing Anaerobes; Values with a different letter(s) within the column is statistically different.

**Table 4:** microbial loads of grilled chicken meat spices

| Microorganisms | Spice B | Spice P | Spice G | Spice L | p-value | microbiological standards |
|---|---|---|---|---|---|---|
| Total aerobic bacteria | $2.23\times10^{6}\pm 1.18\times10^{6}$ | $1.19\times10^{6}\pm 6.25\times10^{5}$ | $3.75\times10^{5}\pm 6.24\times10^{4}$ | $7.24\times10^{5}\pm 5.44\times10^{5}$ | 0.441 | $< 3\times10^{6}$ (EU, 2005) |
| Total coliforms | $4\times10^{3}\pm 1.2\times10^{3}$ | $4.2\times10^{3}\pm 3\times10^{3}$ | $7.7\times 10^{1}\pm 3\times 10^{1}$ | $1.35\times10^{4}\pm 5.2\times10^{3}$ | 0.089 | $< 10^{4}$ (AFSSA, 2008) |
| Thermotolerant coliforms | $8.2\times10^{3}\pm 3.04\times10^{3ab}$ | $2.32\times10^{3}\pm 1.7\times10^{3b}$ | $7.1\times10^{1}\pm6.8\times10^{1b}$ | $1.4\times10^{4}\pm 3.4\times10^{3a}$ | 0.008 | $< 10^{2}$ (AFSSA, 2008) |
| *E. coli* | $7.2\pm2.43^{b}$ | $21\pm5.12^{a}$ | $7\pm4.04^{ab}$ | $0^{b}$ | 0.004 | < 5000 (EC, 2007) |
| Yeast | $4.1\times10^{3}\pm 2.2\times10^{3\ b}$ | $7.04\times10^{3}\pm.8\times10^{3b}$ | $1.73\times10^{1}\pm2.33^{b}$ | $2.35\times10^{4}\pm 2.4\times10^{3a}$ | 0.003 | $< 10^{5}$ (EU, 2005) |
| Moulds | $6.74\times10^{2}\pm 2.04\times10^{2}$ | $1.8\times10^{2}\pm 8\times10^{1}$ | $4\times10^{1}\pm 5.033$ | $8.06\times10^{2}\pm 5.81\times10^{2}$ | 0.260 | $< 10^{6}$ (Baumgart, 1994) |
| *S. aureus* | 0 | 0 | 0 | 0 | - | $< 10^{3}$ (EU, 2005) |
| SRA | 3.2±1.5 | <1 | 0 | 1.4±0.6 | 0.142 | 300 (EU, 2005) |
| *Salmonella* | Absent | Absent | Absent | Absent | - | Absent (EC, 2007) |

Spice B: spice used with barrel device to grill and consume chicken meat (composition: mix of grilled peanut flour, chilli powder, ginger powder, pepper powder, garlic powder, flavour enhancer, salt powder, curry powder), Spice P: spice used with charcoal cabinet type device to grill and to eat chicken meat (composition: mix of grilled peanut flour, chilli powder, ginger powder, pepper powder, garlic powder, flavour enhancer, salt powder, curry powder), Spice G: spice used with gas cabinet type device to grill and consume chicken meat (composition: mix of Chili powder, ginger paste, pepper powder, garlic paste, onion, flavour enhancer, salt powder), Spice L: spice used with the wood device to grill and consume chicken meat (composition: mix of red oil, salt, and pepper powder). SRA=Sulphite-Reducing Anaerobes

Values with a different letter(s) within the line are statistically different.

## CONCLUSION AND APPLICATION OF RESULTS

The physicochemical quality of various grilled chicken portions of meat was different. Protein, phosphorus, and calcium were respectively the major macronutrient and minerals found in grilled chicken meats, of similar content. On the microbiological aspect, unsatisfactory quality of grilled chicken meat was observed except for gas-grilled chicken meat. This generally showed the poor hygienic conditions in which chicken meat was grilled and sold. *Staphylococcus aureus* and *Salmonella* were not detected in any sample. On the organoleptic aspect, the wood-grilled chicken was the least appreciated while the gas-grilled chicken was more appreciated for its tenderness and juiciness. Stakeholders are encouraged to improve the hygienic conditions (material and handling) of grilled chicken meat production and to protect them during selling in order to offer a better microbiological quality product.

**Conflicts of Interest:** The authors declare no competing interests.

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