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Hygienic quality of chicken grills sold along the streets of Korhogo town (North of Côte d'Ivoire)

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Abstract

This study was carried out to better appreciate the sanitary situation of chicken grills sold near the streets of Korhogo town. First, a survey was conducted in sixty sale places of grill to describe the methods of preparation and storage of chicken grills. Then, the environment, equipment, raw material, method and workforce were observed in order to assess the hygiene of the preparation of these foods. After that, the microbiological quality of chicken grills was evaluated by looking for total aerobic mesophilic flora, faecal coliforms, *S. aureus* and *Salmonella spp*. Finally, the benzo[a]pyrene content in chicken grills was estimated through a cooking test. The survey revealed that the majority of sellers of chicken grills cooked the meat over an ember fire and stored the unsold grills cold in refrigerator or cooler. In most of the places of sale, the sellers did not comply with the principle of separating "clean" areas from "dirty" areas. Microbiological analysis showed that the overall quality of the chicken grills was unsatisfactory in most cases. The main microorganism responsible for the unsatisfactory quality of chicken grills was the total aerobic mesophilic flora (54.18 %). Moreover, the cooking test indicated that chicken meats cooked over an ember fire had a benzo[a]pyrene content above the maximum recommended limit (2 µg/kg). These results suggest that the chicken grills sold along the streets of Korhogo town are likely to represent a risk to consumer health. Therefore, sellers of chicken grills should be raised awareness and trained on good hygiene practices.

Keywords: Chicken grills; Benzo (a) pyrene; Hygienic conditions; Korhogo; Microbiological quality

1. Introduction

Meat is one of the most consumed food in the world due to its nutritional value. Indeed, it is a source of proteins, vitamins, water, fats and iron [1]. In addition, it has sensory properties such as: color, tenderness, juiciness and flavor [2]. In recent years, humans have developed techniques to process meat to ensure a long shelf life and improve its organoleptic quality [3]. These meat processing techniques, such as grilling, are sources of income for ruminant and poultry farmers and some traders in West Africa, particularly in Côte d'Ivoire. Indeed, grilled meats are commonly eaten in places of sale, relaxation, leisure and during celebration by a large part of the population [4].

However, from slaughtering animals to their cooking, the meats undergo many manipulations before being delivered for human consumption. In addition, poor hygiene practices at points of sale contribute to the multiplication and/or spread of pathogens during the production and marketing of grilled meats [4, 5]. Most pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, *Clostridium spp* and *Salmonella spp* have often been detected in beef grills [6],

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[7]. These germs are incriminated in most of the food toxi-infections encountered in Côte d'Ivoire. As a result, particular importance should be given to them because of the seriousness or frequency of the risks they present [7].'

Apart from food toxi-infections, the consumption of grilled meat can cause metabolic diseases due to its possible contamination by many harmful substances. Indeed, during grilling, transformers or sellers use various combustibles which are not advised. These are rubberwood, wood from eviction operations often covered with paint, varnish, moth repellent, etc. [8]. These materials used for cooking meat can generate potentially toxic compounds, such as polycyclic aromatic hydrocarbons (PAHs), which come from the pyrolysis of organic matter [9]. The United States Environmental Protection Agency (US-EPA) has identified 16 PAH, of which Benzo (a) pyrene (BaP) has been declared the most carcinogenic [10]. PAHs can cause acute toxicity [11] and especially chronic toxicity [12]. These compounds can contaminate grilled meats during cooking, and thus, constitute a danger or threat to the health of large consumers.

In response to recurrent cases of food toxi-infection and/or poisoning, in some African countries, some studies have been carried out in the sector of food sales on the streets. These studies have permitted to identify specific problems, propose and implement strategies in order to control the negative effects, while preserving the positive aspects, mainly the socio-economic aspects [13, 14].

In Côte d'Ivoire, despite the increase in the demand for meat and the frequency of consumption of street food, very few studies have been conducted on the sanitary quality of these foods. In addition, in the north of Côte d'Ivoire, particularly in Korhogo town, a proliferation of places selling grilled meats commonly known "choukouya" has been noted the last decade [15]. However, in this area, studies on the quality of grilled meats are non-existent. It is therefore to fill this information gap that this study was carried out. The main objective of this work was to better appreciate the sanitary situation of chicken grills sold on the outskirts of the streets of Korhogo town.

2. Material and methods

2.1. Survey Material

The survey material consisted of a questionnaire for sellers to collect information on the methods of preparing and storing chicken grills; and an observation grid of the preparation and/or sale places covering to the environment, equipment, raw material, method and workforce to assess the hygiene of preparation of chicken grills.

2.2. Biological Material

The biological material was consisted of chicken grills. The samples were purchased from braised meat sellers located along the streets of Korhogo town. This town is located in the north of Côte d'Ivoire (latitude 9°27'41" North, longitude 5°38'19" West), 635 km from Abidjan [16].

2.3. Selection of Survey Sites

The choice of sites was made randomly and concerned fifteen neighborhood in Korhogo town, these are: Air-France, Belle ville, Delafosse, Haoussabougou, Kôkô, Logokaha, Nouveau Quartier, Petit Paris, Prémafolo, Quartier 14, Sinistré, Soba, Tchékélézo, Téguéré and Trois poteaux (Figure 1).

2.4. Survey of Sellers of Chicken Grills

In each of the 15 neighborhoods selected, the four most frequented places of sale of chicken grills were chosen and the main sellers were interviewed at their workplaces. In total, sixty (60) places of sale were visited along the streets of Korhogo town. All these people were asked about their methods of preparing and storing chicken grills using the questionnaire. In addition, the environment, equipment, raw material, methods and workforce at the places of preparation and/or sale were carefully evaluated using the observation grid on their sanitary and hygienic conditions.

2.5. Sampling of Chicken Grills for Microbiological Analysis

At each point of sale selected, three samples of chicken grills wrapped (WCG) in aluminum foil (Figure 2a) and three samples of unwrapped chicken grills (UCG), ready for consumption (Figure 2b), were taken. Thus, twenty-four (24) chicken grill samples were taken per neighborhood, i.e. a total of 360 chicken grills samples including 180 WCG and 180 UCG over the entire study area. After sampling, the unwrapped samples were wrapped in sterile aluminum foil. Then, all the samples were quickly packed in sterilized plastic bags, which were carefully sealed and labeled; mentioning the date of sampling, the name of the neighborhood, the type of sample and the seller reference. Finally, they were placed

in a cooler containing bottles of dry ice, in order to maintain the cold chain, and quickly transported to the bacteriology laboratory, where they were analyzed the same day.

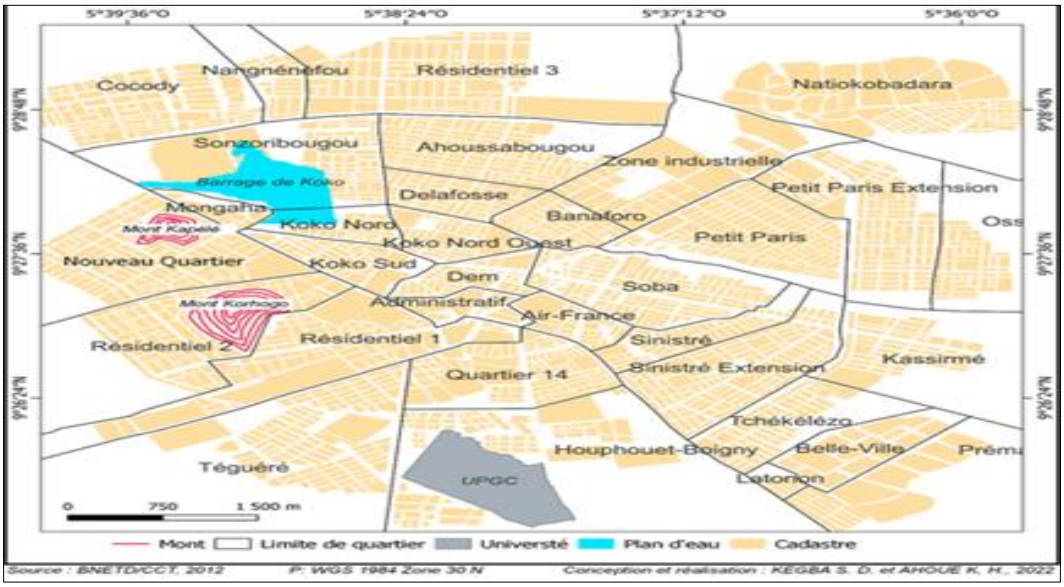

Figure 1 Map of Korhogo town (North of Côte d'Ivoire)

Figure 2 Chicken Grills Wrapped in Aluminum Foil (a); Unwrapped Chicken Grills Ready for consumption (b)

2.6. Cooking Test for Benzo (a) Pyrene (BaP) Dosage

The cooking test consisted in estimating the content of BaP in chicken grills according to the cooking conditions (intensity of fire; cooking time) usually used by sellers. The test was carried out at a randomly selected selling place. The cooking conditions were defined according to the information collected from the sellers during the survey. First, six small pieces of chicken meat were cooked on a grill placed above a flame fire. Three pieces were removed from the grill after 30 min of cooking, and the other three after 45 min of cooking. In a second step, six other small pieces of chicken meat were braised on a grill placed above an ember fire. Three pieces were removed from the grill after 60 min of cooking, and the other three after 90 min of cooking. For each type of cooking, the samples were cooled in a container, wrapped in aluminum foil and then enclosed in an amber glass jar. Finally, the samples were placed in a cooler at approximately 4°C, and then transported to the biochemistry laboratory where they were kept in the refrigerator at 4°C while awaiting the BaP assay.

2.7. Microbiological Analysis of Chicken Grills

Stock suspensions and decimal dilutions were prepared according to standard ISO 6887-2 [17]. Total Mesophilic Aerobic Flora (TMAF) was counted on Plate Count Agar (PCA) according to standard NF V 08-051 [18]. The enumeration of faecal coliforms was carried out on VRBL agar according to standard NF V 08-017 [19]. *Staphylococcus aureus* was

enumerated on Baird-Parker agar according to standard NF V 08-057-1 [20]. The average count of each microorganism was calculated according to the recommendations of the standard ISO 7218 [21]. The search for Salmonella was carried out on Hektoen agar according to the standard ISO 6579 [22].

2.8. Assessment of the Microbiological Quality of Chicken Grills

The microbiological quality of the chicken grills was assessed according to the microbiological criteria applicable to foodstuffs "retail-level meals sold hot or cooked on site", defined by the European Commission (Table 1). For TMAF, faecal coliforms and *S. aureus*, the sample was qualified as

- "satisfactory" when the value of N was less than m;
- "acceptable" when the value of N was between m and M;
- "Unsatisfactory" when the value of N was greater than M.

N: number of microorganisms present in a sample expressed in CFU/g; m: limit number of microorganisms below which the microbiological quality of a sample is considered “satisfactory”; M = 10 x m: limit number of microorganisms above which the microbiological quality of a sample is considered "unsatisfactory".

For *Salmonella spp*, the sample was considered "satisfactory" when there was an absence of Salmonella; otherwise, it was qualified as “unsatisfactory”.

Next, the overall quality of the chicken grills was assessed by considering the microbiological results of the four germs sought. The overall quality of a sample was judged

- "satisfactory", when the sample was deemed "satisfactory" for all four germs;
- "acceptable", when the sample was deemed "acceptable" for one of the germs and "satisfactory" for the other three germs;
- "Unsatisfactory", when the sample was deemed "unsatisfactory" for at least one of the four germs.

Table 1 Microbiological Criteria [23]

Microorganisms	**Criteria (CFU/g)**
Total Mesophilic Aerobic Flora (TMAF)	$3x10^5$
Faecal coliforms at 44 °C	10^2
Coagulase positive Staphylococci at 37 °C	10^2
Salmonella spp	Absence in 25 g

2.9. Determination of Benzo (a) Pyrene Content in Chicken Grills

Benzo (a) Pyrene (BaP) is a particularly carcinogenic Polycyclic Aromatic Hydrocarbon (PAH) used as a marker of PAH contamination. The determination of BaP was done according the chromatographic method proposed by standard ISO 15753 [24]. After grinding the samples, PAHs were extracted with an acetonitrile/acetone mixture (v/v: 60/40), and then purified on C18 bonded phase cartridges (LRC Bond Elut 500 mg, 10 ml type) using the previous mixture as eluent. Then, a 20 µl extract was injected into the HPLC (High Performance Liquid Chromatography) column (250 mm x 4.6 mm x 5 µm) equipped with a UV-visible fluorescence detector. The solvent mixtures acetonitrile/acetone (v/v: 60/40) and acetonitrile/water (v/v: 50/50) were used as mobile phase at a flow rate of 0.6 ml/min. Finally, the quantification of BaP was made from the previously established calibration curve considering 5 calibration points (0 µg/l; 2.5 µg/l; 5 µg/l; 7.5 µg/l and 10 µg/l).

2.10. Statistical Processing of the Data

The data from the field survey were processed and presented as numbers using Excel 2013 software. For the cooking and storage methods, and the hygiene of the preparation of chicken grills, the proportion of sellers (PS_1), expressed in %, was calculated as follows:

$$PS_1(\%) = \frac{Number\ of\ sellers\ or\ sale\ places\ corresponding\ to\ X}{Total\ number\ of\ sellers\ or\ sale\ places\ surveyed} \times 100 \ldots\ldots\ldots(1)$$

Where;

X is the modality considered.

For a microbiological quality Q, the proportion of samples (PS_2), expressed in %, was calculated as follows:

$$PS_2(\%) = \frac{Number\ of\ samples\ judged\ to\ be\ of\ quality\ Q}{Total\ number\ of\ samples\ analyzed} \times 100, \ldots\ldots\ldots\ldots(2)$$

For a germ (G), its contribution (CG), expressed in %, in the unsatisfactory quality of chicken grills was calculated according to the formula below:

$$CG(\%) = \frac{Number\ of\ unsatisfactory\ samples\ due\ to\ germ\ G}{Total\ number\ of\ unsatisfactory\ samples} \times 100 \ldots\ldots\ldots\ldots (3)$$

The chi-square ($\chi 2$) test was used to assess the significance of the difference between the calculated proportions. This test was also applied to a contingency table to compare the distributions of contamination of the two types of chicken grills with the germs sought. Student's *t*-test was used to compare the averages of the microbial loads in the two types of chicken grills. Analysis of variance (ANOVA) was applied to the data from the BaP assay, followed by Tukey's HSD (Honestly Significant Difference) test for the classification of averages. All statistical tests were performed using XLSTAT 2014 software, and statistical significance was set at $p < 0.05$.

3. Results

3.1. Preparing the Chicken Grills

Figure 3 summarizes the steps of preparation of chicken grills sold on the outskirts of the streets of Korhogo town. All the sellers interviewed used the same process for preparing chicken grills. In this process, the chicken meat is first partially cooked, then cut into large pieces, before being fully cooked.

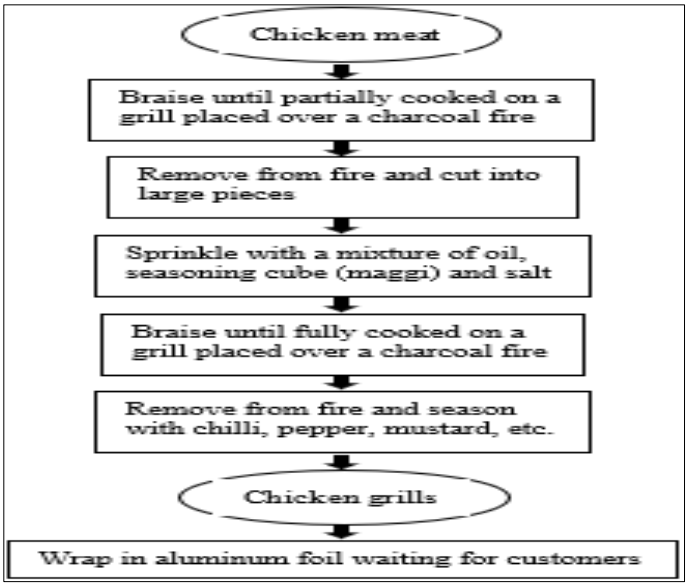

Figure 3 Steps of preparation of chicken grills

The source of combustible used by these sellers was wood charcoal. Most of chicken grills sellers (73.33 %) cooked the chicken meat over an ember fire for 60 to 90 min, while the others (26,67 %) used a flame fire for 30 to 45 min (Table 2).

Table 2 Distribution of Sellers According to the Method of Cooking Chicken Meat

Combustible source	Type of fire	Cooking time	Proportion (number) of sellers	Statistics
				***P*-value**
Wood charcoal	Ember fire	60 to 90 min	73.33 % (44)	0.0003
	Flame fire	30 to 45 min	26.67 % (16)	

3.2. Storage of Chicken Grills

The distribution of sellers according to the storage means of leftover chicken meat and unsold chicken grills are recorded in Table 3. The majority of sellers surveyed (73.33 %) kept leftover chicken meat and unsold chicken grills for the next day. However, 26.67% of sellers managed to sell all the meat each day. The most commonly used means of storing leftover chicken meat was the freezer (53.33 %), followed by the refrigerator (16.67 %); while the cold room (3.33 %) was used by only two sellers. Concerning unsold chicken grills, the refrigerator or cooler was the most common means of storage used by the sellers interviewed (63.33 %); while a minority of them (10 %) used the basin or basket.

Table 3 Distribution of Sellers According to the Means of Storage of Leftover cChicken Meats and Unsold Chicken Grills

Item	Storage means	Proportion (number) of sellers	Statistics
			***P*-value**
Leftover chicken meat	Cold room	3.33 % (2)	< 0.0001
	Freezer	53.33 % (32)	
	Refrigerator	16.67 % (10)	
	No storage	26.67 % (16)	
Unsold chicken grills	Refrigerator or Cooler	63.33 % (38)	< 0.0001
	Basin or Basket	10 % (6)	
	No storage	26.67 % (16)	

3.3. Hygiene in Preparation of Chicken Grills

Table 4 summarizes of the observations made in the places where chicken grills are prepared and sold.

3.3.1. Environmental Hygiene

The observations revealed that most of the places selected (83.33 %) did not comply with the principle of separating "clean"areas from "dirty" areas. In addition, the majority of the places visited (70 %) were located near gutters, which were often unsanitary. Most of the sales premises (76.67 %) were sheds made of wood and metal sheets. Finally, for the majority of premises (90 %), the floor surface was not tiled and was difficult to clean and disinfect.

3.3.2. Hygiene of the Equipment

The working equipment consisted of tables, benches, knives, machetes, axes, grills, cooking pots. In most places of sale, cooking grills (80%), storage appliances (66.67 %) and other tools used (86.67 %) were poorly maintained and dirty. In addition, in the majority of places of sale (93.33 %), the waste bins had no lids and emitted foul odors.

3.3.3. Hygiene of the Raw Material (Chicken meat)

The observations showed that, in most of the places visited (80 %), the chicken meat was in contact with other food or non-food products in storage appliances. The chicken meat intended for preparation was exposed to the ambient air for several hours in the majority of places of sale (63.33 %).

3.3.4. Hygiene of the Method

In the majority of the sales places visited (76.67 %), the chicken grills sellers used animals that are slaughtered by the suppliers compared to 23.33% of the places where they slaughtered their animals themselves. In more than half of the places of sale (53.33 %), the sellers cleaned the premises and equipment the next day compared to 46.67 % of the places where they did so on the day of use.

3.3.5. Hygiene of the Workforce

In most places visited (93.33%), the workforce was composed of people from same family or ethnic group. The sellers wore ordinary and dirty clothes in the majority of the sale places (80%). In some places (20%), they used blouses that were also dirty. For most of the sale places (86.67%), the sellers did not comply with food hygiene rules.

3.4. Enumeration of Microorganisms Present in Chicken Grills

Table 5 shows the average microbial loads (CFU/g) of the two types of chicken grills samples. The average microbial load of each germ sought in the WCG did not differ significantly ($p > 0.05$) from that quantified in the UCG. The average loads of TMAF, faecal coliforms and *S. aureus* were $4.27x10^6$, $2.52x10^3$ and $8.93x10^2$ UFC/g for WCG, and $1.04x10^7$, $1.97x10^3$ and $3.38x10^3$ UFC/g for UWG, respectively.

The proportions of grill samples contaminated with the germs sought are summarized in Table 6. All WCG and UCG samples (100 %) were contaminated with TMAF. In addition, the proportions of WCG contaminated with *Staphylococcus aureus* and *Salmonella spp* (68.89 % and 11.11 %) were not significantly ($p > 0.05$) different from those of UCG contaminated with the same bacteria (57.78 % and 15.56 %). On the other hand, the proportions of UCG contaminated with faecal coliforms (75.56 %) were significantly ($p = 0.0191$) higher than that of contaminated WCG (58.33 %). Consequently, the distributions of the contaminations in the 180 samples of the two types of chicken grills (WCG and UCG) were significantly different ($p = 0.0476$).

3.5. Microbiological Quality of Chicken Grills

Table 7 summarizes the distribution of chicken grills according to microbiological quality, i.e. considering the four germs (TMAF, faecal coliforms, *S. aureus* and *Salmonella spp*) together. The "unsatisfactory" samples were highly predominant, with proportions of 61.11 % for WCG and 78.33 % for UCG; while the "satisfactory" samples, estimated at 7.78 % for WCG and 2.23 % for UCG, were in the minority. However, the cumulative number of "acceptable" and "satisfactory" samples of WCG, equal to 70, was almost double that of UCG, equal to 39. This observation suggests that the microbiological quality of WCG was better than that of UCG. However, overall, the majority of the chicken grills samples (69.72 %) were "unsatisfactory".

The contributions of microbial germs in the unsatisfactory quality of chicken grills are recorded in Table 8. The results indicated that the unsatisfactory quality of chicken grills was largely due to TMAF (54.18 %). But, the contributions of *S. aureus* (36.25 %) and faecal coliforms (34.26%) were not negligible.

3.6. Toxicological Quality of Chicken Grills

The benzo[a]pyrene (BaP) content in chicken grills according to the cooking method is given in table 9. Overall, the results indicated that the cooking method (fire intensity – cooking time) had a significant ($p < 0.01$) effect on the BaP content of chicken grills. Indeed, chicken grills cooked over an ember fire for 90 min had the highest BaP content (6.44 ± 0.39 µg/kg); followed by those prepared over an ember fire for 60 min, with a content of 3.25 ± 0.06 µg/kg. On the other hand, those prepared over a flame fire for 30 min had the lowest content (1.40 ± 0.06 µg/kg). Furthermore, the concentrations of BaP present in chicken grills cooked over an ember fire and those prepared over a flame fire for 45 min were greater than or equal to 2 µg/kg, which is the limit value for BaP set by the European Commission. In contrast, those present in chicken grills cooked over a flame fire for 30 min were lower than this value.

Table 4 Distribution of Sellers According to the Means of Storage of Leftover Chicken Meats and Unsold Chicken Grills

Observation points	Items assessed	Assessment criteria	Proportion(number) of sale places	Statistics
				P-value
Environment	Design material	Wooden and sheet metal shed	76,67 % (46)	< 0.0001
		Solid premises	23,33 % (14)	
	Floor surface	Tiled	10 % (6)	< 0.0001
		Untiled	90 % (54)	
	Wastewater drainage channels	Near	70 % (42)	0.0019
		Far away	30 % (18)	
	SCD principe	Compliance	16.67 % (10)	< 0.0001
		Non-compliance	83.33 % (50)	
Equipment	Cooking grills	Clean	20 % (12)	< 0.0001
		Dirty	80 % (48)	
	Storage appliances	Clean	33.33 % (20)	0.0098
		Dirty	66.67 % (40)	
	Waste bins	Covered	6.67 % (4)	< 0.0001
		Opened	93.33 % (56)	
	Other tools used	Clean	13.33 % (8)	< 0.0001
		Dirty	86.67 % (52)	
Raw material (Chicken meat)	Other FP or NFP	Contact with the RM	80 % (48)	< 0.0001
		No contact with the RM	20 % (12)	
	Ambient air	Raw material exposure	63.33 % (38)	0.0388
		No raw material exposure	36.67 % (22)	
Methods	Slaughter of chicken	By the seller	23.33 % (14)	< 0.0001
		By the supplier	76.67 % (46)	
	Period of W&C of equipment and premises	Same day after the SCG	46.67 % (28)	0.6056
		Next day before the SCG	53.33 % (32)	
Workforce	Type of workforce	Familial or ethnic	93.33 % (56)	< 0.0001
		Neither familial nor ethnic	6.67 % (4)	
	Condition of clothes	Dirty blouse	20 % (12)	< 0.0001
		Ordinary and dirty clothes	80 % (48)	
	Hygiene requirements	Compliance	13.33 % (8)	< 0.0001
		Non-compliance	86.67 % (52)	

SCD: Separation of Clean and Dirty areas; FP: Food Products; NFP: Non-Food Products; RM: Raw Material; W & C: Washing and Cleaning; SCG: Sale of Chicken Grills.

Table 5 Average Microbial Loads in the Two Types of Chicken Grills Samples

Microorganisms	**Type of sample**		**Statistics**
	WCG (N = 180)	**UCG (N = 180)**	***P*-value**
TMAF (CFU/g)	$4.27x10^6 \pm 1.18x10^7$	$1.04x10^7 \pm 2.23x10^7$	0.1087
Faecal coliforms (CFU/g)	$2.52x10^3 \pm 1.24x10^4$	$1.97x10^3 \pm 3.88x10^3$	0.7789
Staphylococcus aureus (CFU/g)	$8.93x10^2 \pm 1.86x10^3$	$3.38x10^3 \pm 1.25x10^4$	0.1948

TMAF: Total Mesophilic Aerobic Flora; UCG: Unwrapped Chicken Grills; WCG: Wrapped Chicken Grills

Table 6 Proportion of Chicken Grills Samples Contaminated with Germs

Microorganisms	**Type of sample**		**Statistics**
	WCG (N = 180)	**UCG (N = 180)**	***P*-value**
Total mesophilic aerobic flora	100 % (180)	100 % (180)	1.0000
Faecal coliforms	58.33 % (100)	75.56 % (136)	0.0191
Staphylococcus aureus	68.89 % (124)	57.78 % (104)	0.1853
Salmonella spp	11.11 % (20)	15.56 % (28)	0.5637
Result of the comparison test of the observed distributions			0.0476

UCG: Unwrapped Chicken Grills; WCG: Wrapped Chicken Grills

Table 7 Distribution of Chicken Grills Samples According to Microbiological Quality

Type of sample	**Assessment of quality**			**Statistics**
	Unsatisfactory	**Acceptable**	**Satisfactory**	***P*-value**
WCG (N = 180)	61.11 % (110)	31.11 % (56)	7.78 % (14)	< 0.0001
UCG (N = 180)	78.33 % (141)	19.44 % (35)	2.23 % (4)	< 0.0001
WCG + UCG (N = 360	69.72 % (251)	25.28 % (91)	5 % (18)	< 0.0001

UCG: Unwrapped Chicken Grills; WCG: Wrapped Chicken Grills

Table 8 Contribution of Microbial Germs in the Unsatisfactory Quality of Chicken Grills

Microorganisms	**Contribution rate**	**Statistics**
		***P*-value**
Total mesophilic aerobic flora	54,18 % (136)	< 0.0001
Faecal coliforms	34,26 % (86)	
Staphylococcus aureus	36,25 % (91)	
Salmonella spp	19,52 % (49)	

Table 9 Benzo (a) pyrene (BaP) Content in Chicken Grills According to Cooking Method

Fire intensity	Cooking time	BaP content (µg/kg)	Statistics
			***P*-value**
Ember fire	90 min	6.44 ± 0,39[a]	< 0.0001
	60 min	3.25 ± 0,06[b]	
Flame fire	45 min	2.03 ± 0,12[c]	
	30 min	1.40 ± 0,06[d]	

4. Discussion

Sellers (73, 33 %) cooked chicken meat over an ember fire. The choice of this cooking method is explained by the good cooking it gives to the meat. Indeed, according to Harivola [25], this cooking method allows meat to be well cooked. Most sellers (63,33 %) kept unsold chicken grills cold in the refrigerator or cooler; while a minority of them (10 %) stored them at room temperature in a basin or basket. The storage of unsold chicken grills in the refrigerator or cooler could be due to the fact that the sellers interviewed believe that it is necessary to keep cold cooked food. This result is in agreement with that of Harivola [25] who, in a study of beef and chicken grills in Madagascar, found that the majority of sellers (56.33%) kept their unsold grilled meats cold (refrigerator or cooler), while 11.26% did not use cold storage.

The evaluation of the hygiene of preparation of chicken grills showed in the majority of places of sale: the principle of separating "clean" areas from "dirty" areas was not respected; the premises were poorly designed; the equipment was poorly maintained; the chicken meat was improperly stored or exposed to ambient air; and the programs for cleaning premises and equipment were inadequate. In addition, in these places (86.67%), sellers did not respect food hygiene rules. All these observations suggest the existence of potential sources (environment, equipment, material, method and workforce) of food contamination. These working conditions could promote the proliferation of microorganisms in the places of sale and the contamination of chicken grills. These results are conformed to those of Kouassi *et al*. [26] who claimed that the diversity of microorganisms present in grilled meats is due to non-compliance with hygiene rules, poor sanitary conditions observed at places of sale, frequent unhygienic handling of meat and cross-contamination with soiled materials and packaging.

The results of microbiological analyses showed that the Total Mesophilic Aerobic Flora (TMAF) was the most common germ in chicken grills, being detected in all samples tested. The average loads of TMAF in WCG and UCG were $4.27x10^6$ UFC/g and $1.04x10^7$ UFC/g, respectively. These results are relatively different from those found by Adama [27] who reported in a study an average load of TMAF of $5.2x10^5$ CFU/g in 100 grilled meat samples. This difference would be due to the fact that the places of sale visited are insufficiently clean. The enumeration showed that the average loads of faecal coliforms were $2.52x10^3$ UFC/g and $1.97x10^3$ UFC/g for WCG and UCG, respectively. The comparison of these results with microbiological criteria shows that the samples tested do not meet food safety standards. This can be explained by the fact that the chicken grills were contaminated with faecal coliforms during the slaughter of animal and the transport of meat in unsuitable conditions and by the workforce. *S. aureus* concentrations averaged $8.93x10^2$ UFC/g and $3.38x10^3$ UFC/g for WCG and UCG, respectively. The presence of *S. aureus* in chicken grills could be explained by the lack of hygiene of the workforce in the sale places. Indeed, this lack of hygiene is reflected in inappropriate movements that favor cross-contamination, the wearing of rings or bracelets while working, undesirable gestures, such as putting fingers in the nostrils, sneezing using the hands, using dirty rags for cleaning hands etc. These results are lower than those of Adama [27] who found an average load of *S. aureus* of $6.15x10^3$ CFU/g in a study on the quality of grilled meats prepared in "Dibiteries" in the Dakar region. The results obtained from the microbiological analyses showed that *Salmonella spp* was the least widespread germ with the lowest proportions of contaminated samples (11,11 % et 15,56 %). These results confirm that of Kebede [28] who also demonstrated the low presence of salmonella in grilled meats. Indeed, this author could only detect Salmonella in only one sample out of 100 samples analyzed. This low presence could be explained by the fact that salmonella, being heat-sensitive, are destroyed by the heat applied during the preparation of chicken grills.

Regarding the microbiological quality, the results revealed that the microbiological quality of WCG was better than that of UCG which were the more prone to microbial contamination. This result could be explained by the fact that the unwrapped chicken grills, waiting for customers, were exposed to ambient air, which would have favored their contamination with ambient bacteria. In addition, according to Christian [29], contamination of grilled meats with

microbial germs can be due to other sources such as air, soil, handlers and cutting tools that are not well cleaned. In general, the overall quality of the chicken grills was unsatisfactory in most cases (69,72 %). The unsatisfactory quality of the chicken grills observed could be explained by the lack of hygiene and the poor cooking of the meat in these places of sale. Indeed, Yougbare [30] claimed that cooking food allows a strong reduction of the microbial load, if the core temperature of the food is high, thus promoting the satisfactory quality of the food. The unsatisfactory quality of chicken grills was largely due to TMAF (54,18 %). The TMAF count is the first criterion of microbiological evaluation for street foods. Indeed, the TMAF provides information on the overall microbial load of the food. It corresponds to bacteria that are indicators of hygiene, including pathogenic microbes and spoilage microbes [31]. The TMAF enumeration is an excellent method for estimating the food safety and quality index [32]. Also, the strong contribution of the TMAF to the unsatisfactory quality indicates that the chicken grills could quickly deteriorate and become unfit for consumption. Moreover, the contributions of *S. aureus* (36.25%) and faecal coliforms (34.26%) were not negligible. Staphylococci are considered commensal bacteria in humans, often found in the nasal cavity, on the skin, in mucous membranes and in areas with high humidity [33]. Rafalimanana [34] asserted that contamination of food with *S. aureus* may be due to the improper cooking of this food and to the no-respect of the rules of hygiene from slaughter, washing, transport, preparation to consumption. The contribution of faecal coliforms to the unsatisfactory quality of chicken grills would be due in particular to the presence of *Escherichia coli*. Faecal coliforms are indicators of faecal contamination and considered as hygiene germs. According to Eslava *et al*. [35], their presence indicates a defect in the slaughtering technique, or cross-contamination, but may also be due to contamination by people handling foodstuffs.

The cooking test showed that the cooking method significantly ($p < 0.01$) influenced the BaP content of chicken grills. Indeed, the BaP contents (3.25 ± 0.06 and 6.44 ± 0.39 µg/kg) in chicken grills cooked over an ember fire were above the recommended limit value which is 2 µg/kg [36]. In addition, that (2.03 ± 0.12 µg/kg) in chicken grills prepared over a flame fire for 45 min had reached this limit value. In contrast, the value (1.40 ± 0.06 µg/kg) obtained in the chicken grills cooked over a flame fire for 30 min complied with the reference criterion. These results are in agreement with those of Harivola [25] who, in a study on beef skewers and chicken grills, also found that the amount of BaP formed during cooking over an ember fire was higher than that formed when cooking over a flame fire. In addition, the high BaP content in chicken grills cooked over an ember fire would be due to the sufficiently long cooking time of 45 à 90 min. Indeed, in the same study, the previous author demonstrated that the formation of BaP in grilled meat was not related to the intensity of the fire, but to the cooking time. However, according to Domingo and Nadal [37], the concentrations of PAHs in processed meat depend on a number of processing parameters, including distance to the heat source, combustibles, level of processing and, cooking time and methods.

5. Conclusion

At the end of this study, the results showed that the majority of sellers of chicken grills (73.33 %) cooked the meat over an ember fire for 60 to 90 min. Most of the sellers surveyed (63.33 %) kept unsold chicken grills cold in the refrigerator or cooler, while 10% used the basin and basket. In most of the places of sale visited (83.33%), the sellers did not comply with the principle of separating "clean" areas from "dirty" areas. Microbiological analysis showed that the microbiological quality of chicken grills wrapped in aluminum foil was better than that of unwrapped chicken grills waiting for customers. However, the overall quality of the chicken grills was unsatisfactory in most cases (69.72 %). The main microorganism responsible for the unsatisfactory quality of chicken grills was the total aerobic mesophilic flora. In addition, chicken grills cooked over an ember fire for 60 à 90 min had a higher BaP content (> 2 µg/kg), while those cooked over a flame fire for 30 min had a low BaP content (< 2 µg/kg). Finaly, in view of the above, the consumption of chicken grills sold along the streets of Korhogo town represents a health risk for consumers. Therefore, sellers should be made aware and trained on good hygiene practices in order to reduce microbial contamination. They should also reduce the cooking time of the meat, preferably by using a flame fire to limit the level of Benzo(a)pyrene in chicken grills. In order to further investigate this study, it would be interesting to conduct a similar investigation on other types of meat (beef, mutton, goat meat, etc.) and to carry out the determination of BaP on samples taken from several grilled meat sellers.

Compliance with ethical standards

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Disclosure of conflict of interest

All the authors declare that they do not have any conflict of interest.

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