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# Microbial contamination associated with the processing of grilled pork, a ready-to-eat street food in Benin

Dona G. H. Anihouvi[1,2] | Yénoukounmè E. Kpoclou[2] | Mahunan F. Assogba[2] | Ogouyôm H. Iko Afé[2,3] | Gertrude Lègba[2] | Marie-Louise Scippo[3] | Djidjoho J. Hounhouigan[2] | Victor B. Anihouvi[2] | Jacques Mahillon[1]

[1]Laboratory of Food and Environmental Microbiology, Earth and Life Institute, Faculty of Bioscience Engineering, Louvain-la-Neuve, Belgium

[2]Laboratory of Food Sciences, School of Nutrition, Food Sciences and Technology, Faculty of Agronomic Sciences, University of Abomey-Calavi, Abomey-Calavi, Benin

[3]Department of Food Sciences, Laboratory of Food Analysis, Faculty of Veterinary Medicine, Fundamental and Applied Research for Animals & Health (FARAH), Veterinary Public Health, University of Liège, Liège, Belgium

**Correspondence**
Dona G. H. Anihouvi, Laboratory of Food and Environmental Microbiology, Earth and Life Institute, Faculty of Bioscience Engineering, Croix du Sud, 2—L7.05.12, Louvain-la-Neuve B-1348, Belgium.
Email: donagildas@gmail.com

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## Abstract

This study aimed to assess the microbial contamination associated with the traditional processing of fresh pork into grilled pork in Benin. Sixty samples of meat, including fresh pork and processed pork were randomly collected from different processing/selling sites, and the main foodborne microorganisms were sought using standard methods. The Aerobic Mesophilic Bacteria load in all samples ranged between 2.7 and 7.4 $Log_{10}$ CFU $g^{-1}$, with 16.7% of samples exceeding the acceptable limit of <7.0 $Log_{10}$ CFU $g^{-1}$ recommended by the Health Protection Agency for this criterion. Likewise, *Enterobacteriaceae*, *Escherichia coli*, and *Clostridium perfringens* loads exceeded the acceptable limit in 20.8, 20.8, and 12.5% of the samples, respectively. None of the samples contained *Salmonella* spp., *Staphylococcus aureus* or *Listeria monocytogenes*. Sources of contamination of grilled pork were identified and grouped into five types of causes related to processors, processing methods, equipment used, raw materials, and processing/selling environment. Similarly, a microbiological hazard analysis of grilled pork processing practices identified the sensitive steps where additional hygiene measures needed to be implemented.

## 1 | INTRODUCTION

Pork occupies an important place in the human diet and is the most consumed meat in the world, with ca. 115 million tons in 2016 (FAO, 2017). In Benin, investigations have been conducted to improve pig farming (Koutinhouin et al., 2009; Youssao et al., 2009). Thanks to these studies, the national pork production has increased and reached 5,172 tons in 2014 (FAOSTAT 3, 2016). During the last decade, pork consumption has steadily increased in Benin in particular among restaurants from urban centers. Pork is consumed in various forms; including meat cooked in sauce, fried meat, and grilled meat (Ayissiwêdé, Mankor, Missohou, & Abiola, 2009). Nowadays, grilled pork is the most widespread and popular foods in the informal sector of street foods in Benin. Its processing and selling provide important incomes to processors and cheaper animal protein to consumers. Despite these potential benefits, pork consumption is not without hazards. Several studies have reported the presence of foodborne pathogens in fresh and processed pork products (Ashraf, Azza, Abuelnaga, Ezz-Eldeen Magdy, & Seham, 2015; Hauser et al., 2010; Jansen et al., 2018; Liu et al., 2019; Mangal, Rao, & Joshi, 2018; Pichner et al., 2014).

In Benin, grilled pork is processed by small cottage industries and sold as ready-to-eat food in open roadside kiosks. Bacterial contamination of street foods is a major concern worldwide. In this respect, numerous studies have reported pathogenic bacteria associated with street foods (Abakari, Cobbina, & Yeleliere, 2018; Eromo, Tassew, Daka, & Kibru, 2016; Jahan et al., 2018; Kharel, Palni, & Tamang, 2016; Niyonzima et al., 2017), mainly those processed from meat (Amadi, Singabele, Elechi, & Ngerebara, 2016; Bagumire & Karumuna, 2017; Somda et al., 2018). Similarly, various reports have identified

  

the risk associated with the consumption of ready-to-eat street foods with high count of coliform bacteria or contaminated by foodborne pathogens such as *Salmonella* spp., *Bacillus cereus*, *Clostridium perfringens*, *Staphylococcus aureus*, *Escherichia coli*, *Listeria monocytogenes*, or *Vibrio cholerae* (Anihouvi et al., 2013; Cho et al., 2011; Garedew et al., 2015; Manguiat & Fang, 2013).

Grilled pork products are diverse and include: skewers, slices, pieces, and seasoned wrapped meat. The processing steps include meat cutting and mixing with seasoning condiments followed by grilling. Processors are mostly uneducated pork butchers who have received no training in food hygiene and handling (unpublished survey data). The products are, therefore, exposed to various environmental and microbiological hazards that make their safety questionable. This study aims to assess the microbiological sanitary status of grilled pork traditionally processed and sold as street food in Benin, and identify the associated contamination factors in order to formulate corrective measures.

## 2 | MATERIAL AND METHODS

### 2.1 | Experimental design

The study was carried out in two phases. First, the microbiological characteristics of grilled pork as sold to consumers were assessed through samples collected from processing/selling sites. Second, a follow-up of grilled pork processing by field works was carried out with experienced processors in order to identify the various factors that promote microbial contamination of the end-product. Ishikawa's "cause and effect" diagram (Figure 1) was used to range quality-compromising factors identified into different categories.

#### 2.1.1 | Samples collection

A total of 66 samples were collected. For the microbiological characterization of grilled pork as sold to consumers, 24 samples of four types of grilled pork products (skewers, slices form, piece form, and seasoned wrapped meat) were randomly purchased at different processing/selling sites at Adjarra, Porto-Novo, Cotonou, Abomey-Calavi, and Bohicon municipalities (Benin). This phase was followed by the follow-up of the processing of grilled pork focusing on the sources of contamination, during which 42 samples including fresh pork, processed pork, seasoning condiments, and processing water were collected. The samples were individually packaged in sterile plastic bags and transported under refrigeration to the laboratory for microbiological analyses.

#### 2.1.2 | Follow-up of manufacturing of grilled pork slices

Three experienced processors were selected for the follow-up of the processing. The processing trials were performed on the slices of grilled pork. Indeed, in a previous survey, this form has been identified as the most produced (unpublished data). Twelve processing trials including six direct and six indirect grillings were performed. On each processing site, the trials were carried out by one processor in two replicates for each grilling modes. Four categories of samples were collected at sensitive points during each processing trial: carcass, fresh, seasoned and grilled slices (Figure 2). Moreover, water and condiments (mixture of spices such as garlic, black pepper, chili pepper, onion, ginger, laurel leaves, and salt) used during the processing were collected for microbiological analyses.

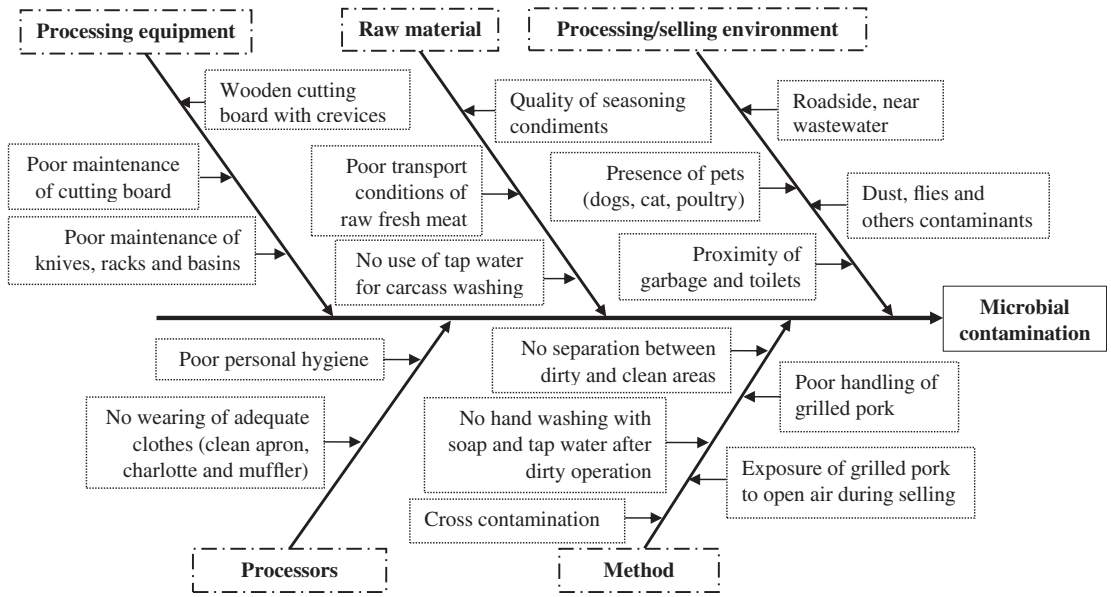


**FIGURE 1** Ishikawa diagram showing sources of contamination identified during the processing of grilled pork. The small horizontal arrows pointing toward the oblique arrows indicate quality-compromising factors related to each source of contamination

### 2.2 | Microbiological analyses

For each sample, 25 g were placed aseptically in a sterile blender bag (VWR Cat. Number 129-0733) and homogenized (230 rpm for 2 min) in 225 ml of sterile Buffered Peptone Water (BPW, Bio-Rad 3564684, pH 7.0 ± 0.2) using a stomacher (Lab Blender, Model 400, Seward Medical, London, UK) to obtain a 1/10 dilution. One milliliter of this suspension was serially diluted (ISO 6887-3) and inoculated on specific growth media for enumeration. Each sample was tested for Aerobic Mesophilic Bacteria (AMB), Lactic Acid Bacteria (LAB), *Enterobacteriaceae*, *E. coli*, *C. perfringens*, *B. cereus*, *S. aureus*, *L. monocytogenes*, *Salmonella* spp., and yeasts and molds. Table 1 summarizes the growth conditions and methods used for each microorganism.

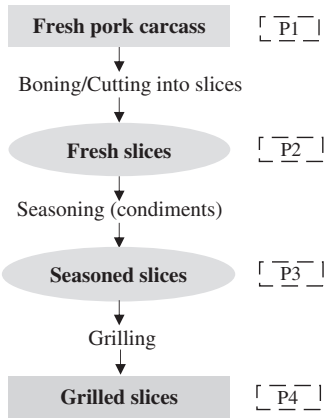


**FIGURE 2** Flow chart of grilled pork slices processing. P1, P2, P3, and P4 indicate the sampling points during the processing trials

### 2.3 | Statistical analyses

Microsoft Excel 2013 was used to calculate median, mean values and *SD*. Student *t*-test, one-way analysis of variance (ANOVA), and Kruskal–Wallis ANOVA were performed using the statistic software STATISTICA 7.1. Significant differences were established at $p < .05$. Means were separated using SNK (Student, Newman, and Keuls) range test.

## 3 | RESULTS AND DISCUSSION

### 3.1 | Microbiological quality and safety assessment of grilled pork samples

Microbiological analyses of grilled pork samples did not detect pathogenic bacteria such as *Salmonella* spp., *L. monocytogenes*, and *S. aureus* (Table 2). AMB and LAB were present in all samples, with densities ranging from 2.6 to 7.4 $Log_{10}$ CFU $g^{-1}$. Hygiene indicator microorganisms such as *Enterobacteriaceae* and *E. coli* were found in 41.6 and 25% of the samples, respectively, whereas *B. cereus*, *C. perfringens*, yeasts, and molds were detected in 54.2, 45.8, 54.2, and 58.3% of the samples, respectively.

Due to their thermo-sensitivity, *Enterobacteriaceae* are used as indicators of hygiene conditions and contamination of food after heat treatment (Health Protection Agency, 2009). Their presence in grilled pork could be due to an insufficient heat treatment and/or a lack of hygiene after cooking. Similarly, *E. coli* is a good indicator of fecal contamination (Castro-Rosas et al., 2012). Therefore, samples tested positive for this microorganism have likely been in contact with human or animal feces through inappropriate handling after cooking. The detection of *C. perfringens* in ready-to-eat grilled pork could be the result of

**TABLE 1** Microorganisms, culture media used, and growth conditions

| Microorganisms | Media (supplier product) | Incubation | Method |
|---|---|---|---|
| AMB | Plate count agar (Bio-Rad 356-4618) | 30°C, 72 ± 3 hr | ISO 4833-1 |
| LAB | De man Rogosa Sharpe agar (Bio-Rad 356-4244) | 30°C, 72 ± 3 hr | ISO 15124 |
| *Enterobacteriaceae* | Violet red bile glucose (Bio-Rad 356-4584) | 37°C, 24 ± 2 hr | ISO 21528-2 |
| *E. coli* | TBX agar (Bio-Rad 356-4035) | 37°C, 21 ± 3 hr | ISO 16649-2 |
| *C. perfringens* | Tryptose sulfite cycloserine Agar[a] (Bio-Rad 356-9644) | 37°C, 24–48 hr | ISO 7937 |
| *S. aureus* | Baird-Parker[b] (Bio-Rad 356-4814) | 37°C, 24 hr | ISO 6888-2 |
| *B. cereus* | Mannitol egg yolk polymyxin mossel base with addition of egg yolk[c] | 30°C, 18–24 hr | ISO 7932 |
| Yeasts and molds | Yeast glucose chloramphenicol (Bio-Rad 356-4104) | 25°C, 72–120 hr | ISO 7954 |
| *L. monocytogenes* | Rapid' L. mono (Bio-Rad 356-3694) | 37°C, 24 ± 2 hr | BRD 07/05-09/01 |
| *Salmonella* spp. | Enrichment: Buffered Peptone Water[d]<br>Isolation: Rapid' Salmonella (Bio-Rad 356-3961)<br>Confirmation: *Salmonella* latex kit (Bio-Rad 355-6710) | 41.5°C, 18 ± 2 hr<br>37°C, 24 ± 2 hr | BRD 07/11-12/05 |

[a]Supplemented with *Perfringens* Selective Supplement (SFP Oxoid SR 0088E).
[b]Supplemented with Rabbit Plasma Fibrinogen (Bio-Rad 356-4618).
[c]Biokar Diagnostics-Zac, France.
[d]Supplemented with Rapid' *Salmonella* capsule (Bio-Rad 356-4710).

an incomplete elimination during roasting, as well as to post-cooking contamination. This bacterium is indeed widespread in the environment and is commonly found in the intestine of animals (Labbe & Juneja, 2017). Molds detected in grilled pork samples could be the results of the exposure of the product to dust from processing/selling environment, as the activity is generally done in unhygienic makeshift sheds on public road side. Moreover, to be visible to customers, ready-to-eat grilled pork is often exposed on open-air toasting racks.

The Health Protection Agency (Health Protection Agency, 2009) set up acceptable limits for microbiological criteria in ready-to-eat food (Table 2). Considering these specifications as guideline, our results indicated that from 12.5% (*C. perfringens*) to 21% (*Enterobacteriaceae* and *E. coli*) of grilled pork samples were inappropriate for human consumption. As for *B. cereus*, all samples displayed contamination below the compliance threshold. The quantification of *E. coli* above the acceptable limit may be a health hazard to consumers since *E. coli* pathotypes are among the major foodborne pathogens (Castro-Rosas et al., 2012; Gaia, Ilenia, Gianfranco, Maria, & Basanisi Giovanna, 2017). Similarly, *C. perfringens* is one of the main microorganisms responsible of foodborne illness outbreak in the world (ANSES, 2016), in particular among elderly people. Its presence in ready-to-eat grilled pork above the acceptable limit can constitute a risk for consumer's health.

Our results also showed that for each microbiological criterion, a large variability was observed between the minimum and maximum values recorded (Table 2). This variability is likely due to the diversity of sampling sites since the examined samples were neither processed from the same raw pork, nor from the same processing environment, and hygiene and handling practices greatly vary from one processor to another, as previously reported (Anihouvi et al., 2013; Carrasco, Morales-Rueda, & García-Gimeno, 2012; Kim, Hur, & Yim, 2018; Kim & Yim, 2016; Manios et al., 2015).

As shown in Table 3, no significant differences ($p > .05$) were observed between the microbial loads of the four types of grilled pork

**TABLE 2** Microbial concentration in grilled pork samples ($n = 24$)

| Parameters | Mean ± *SD*[a] | Min. | Max. | Positive samples[b] | Acceptable limit[c] | Noncompliant samples |
|---|---|---|---|---|---|---|
| AMB | 5.0 ± 1.4 | 2.7 | 7.4 | 24 (100%) | < 7 | 4 (16.7%) |
| LAB | 4.7 ± 1.4 | 2.6 | 7.4 | 24 (100%) | NE | NA |
| *Enterobacteriaceae* | 2.1 ± 1.9 | <1 | 6.0 | 10 (41.6%) | 4 | 5 (20.8%) |
| *E. coli* | 1.3 ± 1.1 | <1 | 4.2 | 6 (25.0%) | 2 | 5 (20.8%) |
| *B. cereus* | 1.3 ± 0.9 | <1 | 4.4 | 13 (54.2%) | 5 | 0 (0%) |
| *C. perfringens* | 1.5 ± 1.3 | <1 | 4.9 | 11 (45.8%) | 4 | 3 (12.5%) |
| Molds | 2.0 ± 1.6 | <1 | 5.6 | 13 (54.2%) | NE | NA |
| Yeasts | 1.9 ± 1.2 | <1 | 4.2 | 16 (58.3%) | NE | NA |
| *S. aureus* | <1 | <1 | <1 | 0 (0%) | 2 | 0 (0%) |
| *L. monocytogenes* | <1 | <1 | <1 | 0 (0%) | 2 | 0 (0%) |
| *Salmonella* spp. | Abs | NA | NA | 0 (0%) | Abs | 0 (0%) |

Abbreviations: Abs, absence in 25 g; AMB, Aerobic mesophilic bacteria; LAB, Lactic acid bacteria; Min., minimum; Max., maximum; n, number of samples analyzed; NA, not applicable; NE, not established.
[a]Means ± *SD* of bacterial concentration, expressed in $Log_{10}$ CFU $g^{-1}$.
[b]Samples where the number of detected colonies was ≥1.0 $Log_{10}$ CFU $g^{-1}$.
[c]According to Health Protection Agency (2009).

**TABLE 3** Microbial concentration in grilled pork according to meat type

| Parameters | Grilled skewers ($n = 6$) | Grilled slices ($n = 6$) | Grilled pieces ($n = 6$) | Seasoned wrapped form ($n = 6$) |
|---|---|---|---|---|
| AMB | 4.7 ± 1.6[†,a] | 5.5 ± 1.4[a] | 4.8 ± 1.2[a] | 5.1 ± 1.4[a] |
| LAB | 4.5 ± 1.6[a] | 5.4 ± 1.2[a] | 4.1 ± 1.3[a] | 4.9 ± 1.5[a] |
| *Enterobacteriaceae* | 1.3 ± 1.4[a] | 3.8 ± 1.8[b] | 1.3 ± 1.5[a] | 1.9 ± 1.8[a,b] |
| *E. coli* | <1[a] | 2.1 ± 1.4[b] | 1.1 ± 1.0[b] | 1.3 ± 1.4[b] |
| *B. cereus* | 1.8 ± 1.3[a] | 1.5 ± 0.7[a] | 1.0 ± 0.4[a] | 1.0 ± 0.5[a] |
| *C. perfringens* | 1.7 ± 1.6[a] | 1.8 ± 0.5[a] | 1.0 ± 0.6[a] | 1.7 ± 1.6[a] |
| Yeasts | 0.9 ± 0.6[a] | 3.2 ± 1.0[b] | 1.5 ± 0.7[a] | 1.9 ± 1.1[a] |
| Molds | 1.0 ± 0.3[a] | 3.3 ± 2.1[a] | 1.9 ± 1.7[a] | 1.8 ± 1.3[a] |

*Note*: [a,b]Mean values followed by different letters indicate that they differ significantly between meat types ($p < 0.05$).
Abbreviation: AMB, Aerobic mesophilic bacteria; LAB, Lactic acid bacteria; n, number of samples analyzed.
[†]Means ± *SD* of bacterial concentration, expressed in $Log_{10}$ CFU $g^{-1}$.

(skewers, grilled slices, grilled pieces, and seasoned wrapped meat), with the exception of *E. coli* in skewer samples, yeasts and *Enterobacteriaceae* in grilled slices.

## 3.2 | Microbial density in the seasoning ingredients and processing water

As shown in Table 4 water and seasoning condiments can be sources of microbial contamination during the processing of fresh pork into grilled pork slices. In the seasoning condiments, both AMB and LAB displayed bacterial concentrations just above 5 $Log_{10}$ CFU $g^{-1}$, which, for AMB, is above the acceptable limit recommended by the CECMA (Canadian Committee on the Development of Microbiological Criteria in Foods, 2009). *B. cereus*, *C. perfringens*, yeast, and molds were detected in the seasoning condiments with loads of 2.5 ± 1.5, 1.8 ± 1.3, 1.9 ± 1.4, and 1.8 ± 1.1 $Log_{10}$ CFU $g^{-1}$, respectively. None of the seasoning condiments contained *Enterobacteriaceae*, *E. coli*, or *S. aureus*. Four condiments out of six were not compliant with the acceptable limit for *B. cereus* (3.0 $Log_{10}$ CFU $g^{-1}$) and *C. perfringens* (2.0 $Log_{10}$ CFU $g^{-1}$). Therefore, seasoning condiments used for the processing can be a contamination source of grilled pork.

The water used during the processing of grilled pork slices had relatively low loads of AMB (3.3 ± 0.9 $Log_{10}$ CFU $g^{-1}$) and *Enterobacteriaceae* (1.6 ± 1.5 $Log_{10}$ CFU $g^{-1}$). Total coliform were detected with concentration of 1.5 ± 0.8 $Log_{10}$ CFU $ml^{-1}$, above the acceptable limit of 1.0 $Log_{10}$ CFU/100 ml recommended by CECMA (2009). The water used in the food processing should therefore be considered as of an unacceptable microbiological quality.

**TABLE 4** Microbial concentration in condiments and water

| Parameters | Condiments[a] (*n* = 6) | Acceptable limit[b] | Noncompliant samples | Water[a] (*n* = 6) | Acceptable limit[b] | Noncompliant samples |
|---|---|---|---|---|---|---|
| AMB | 5.2 ± 1.3 | 5 | 3 (50%) | 3.3 ± 0.9 | NE | ND |
| LAB | 5.2 ± 1.1 | NE | ND | ND | NE | ND |
| *Enterobacteriaceae* | <1 | NE | ND | 1.6 ± 1.5 | NE | ND |
| Total coliforms | <1 | NE | ND | 1.5 ± 0.8 | 1.0/100 ml | 2 (33.3%) |
| *E. coli* | <1 | 1 | 0 (0%) | <1 | <1/100 ml | 0 (0%) |
| *B. cereus* | 2.5 ± 1.5 | 3 | 4 (66.6%) | ND | NE | ND |
| *C. perfringens* | 1.8 ± 1.3 | 2 | 4 (66.6%) | ND | NE | ND |
| *S. aureus* | <1 | 2 | 0 (0%) | ND | NE | ND |
| Yeasts | 1.9 ± 1.4 | NE | ND | ND | NE | ND |
| Molds | 1.8 ± 1.1 | NE | ND | ND | NE | ND |

Abbreviations: AMB, Aerobic mesophilic bacteria; LAB, Lactic acid bacteria; n, number of samples analyzed; ND, not determined; NE, not established.
[a]Mean ± *SD* of bacterial concentration, expressed in $Log_{10}$ CFU $g^{-1}$ for condiments and $Log_{10}$ CFU $ml^{-1}$ for water (with the exception of total coliforms and *E. coli* expressed as per 100 ml).
[b]According to the Canadian Committee on the Development of Microbiological Criteria in Foods (2009).

**TABLE 5** Evolution of the microbial load during the transformation of fresh pork into grilled pork slices

| Parameters | Carcass[†] (*n* = 6) | Fresh slices[†] (*n* = 6) | Seasoned slices[†] (*n* = 12) | Grilled slices[†] (*n* = 12) |
|---|---|---|---|---|
| AMB | 5.4 ± 0.4$^{a}$ | 6.8 ± 1.0$^{b}$ | 6.6 ± 0.8$^{b}$ | 3.8 ± 0.6$^{c}$ |
| *Enterobacteriaceae* | 1.8 ± 0.6$^{a,b}$ | 2.5 ± 1.1$^{a}$ | 2.3 ± 1.5$^{a}$ | <1$^{c}$ |
| *E. coli* | 1.1 ± 0.4$^{a,b}$ | 1.8 ± 1.2$^{b}$ | 1.5 ± 1.4$^{a,b}$ | <1$^{c}$ |
| *B. cereus* | 0.9 ± 0.2$^{a}$ | 0.8 ± 0.1$^{a}$ | 1.2 ± 0.7$^{a}$ | 1.1 ± 0.3$^{a}$ |
| *C. perfringens* | 1.2 ± 0.4$^{a}$ | 1.4 ± 0.6$^{a}$ | 1.2 ± 0.5$^{a}$ | 0.9 ± 0.5$^{a}$ |
| Yeasts | 3.7 ± 0.5$^{b}$ | 3.2 ± 1.1$^{a,b}$ | 2.9 ± 0.5$^{a}$ | 1.1 ± 0.4$^{c}$ |
| Molds | 4.4 ± 0.6$^{a}$ | 4.0 ± 0.7$^{a}$ | 3.9 ± 0.6$^{a}$ | 1.8 ± 0.5$^{b}$ |
| *S. aureus* | <1 | <1 | <1 | <1 |
| *L. monocytogenes* | <1 | <1 | <1 | <1 |
| *Salmonella* spp. | Presence | Presence | Abs | Abs |

*Note*: [a,b,c]Mean values in the same line, followed by different letters, indicate that they differ significantly ($p < .05$).
Abbreviations: Abs, absence in 25 g; AMB, Aerobic mesophilic bacteria; n, number of samples analyzed; Presence = presence in 25 g.
[†]Mean ± *SD* of bacterial concentration, expressed in $Log_{10}$ CFU $g^{-1}$.

### 3.3 | Changes in microbial density during the processing of grilled pork slices

Table 5 showed the results of microbiological analysis on carcass, fresh, seasoned, and grilled pork slices. AMB concentration increased significantly ($p < .05$) from the carcass to the fresh slices. This could be explained by the fact that during the cutting operation, a large surface of meat is exposed to potential microbial contamination from the environment, cutting material, and processors. In this regard, it was observed during the processing trials, that the surface of the wood cutting boards is very rough, with crevices favorable for accommodating microorganisms. The same cutting board is also used for washing the carcasses, and for evisceration and cutting. Moreover, the maintenance of equipment did not follow any formal procedure of cleaning/disinfection. These practices could significantly contribute to cross-contamination. Similar observations have been reported for street food venders (Anihouvi et al., 2013; Campos, Gil, Mourão, Peixe, & Antunes, 2015; Niyonzima et al., 2017; Yildirim et al., 2017).

No significant ($p > .05$) change of microbial counts was observed from fresh to seasoned slices, with the exception of *Salmonella* spp. that were eliminated during the seasoning step, most likely due to the bacteriostatic and bactericidal properties of the condiments used (garlic, pepper, onion, ginger, and laurel leaves; Ceyhan, Keskin, & Ugur, 2012; Ramos et al., 2012; Woguem et al., 2013; Zhang et al., 2016). *S. aureus* and *L. monocytogenes* were not detected at any step of processing.

After grilling, the density of AMB, *Enterobacteriaceae*, *E. coli*, yeasts, and molds decreased significantly ($p < .05$), below the acceptable limits recommended by Health Protection Agency (2009). The grilling step is therefore sensitive for the microbiological safety of grilled pork slices. Nevertheless, AMB concentration in grilled pork slices remained around 4 $Log_{10}$ CFU $g^{-1}$, whereas a complete elimination of vegetative form of microorganisms was expected. In our study, temperature values recorded at the core of meat remained above 70°C during at least 20–30 min of the average duration of 50 min of grilling (data not shown). This temperature–time parameter (70°C, 25 min) is comparable to that of pasteurization (Plahar, Nerquaye-Tetteh, & Annan, 1999) and should be sufficient to destroy all vegetative forms. It is therefore hypothesized that the residual microbial counts in grilled pork slices just after grilling step resulted from recontamination by the environment, and/or poor personal hygiene of food workers, as previously reported by several authors (Anihouvi et al., 2013; Assefa, Tasew, Wondafrash, & Beker, 2015; Kahraman, Cetin, Dumen, & Buyukunal, 2010).

The high microbial counts in grilled pork samples collected at different processing/selling places (Table 2 vs. Table 5) resulted from recontamination during postprocessing handling and microbial growth during storage. Ready-to-eat grilled pork preparations are indeed usually not adequately protected against dust and flies, and appropriate storage temperatures are difficult to maintain. Bryan et al. (1997) reported a positive correlation between long holding times at ambient temperature and high bacterial counts of street food in developing countries, although the cooking temperatures were sufficient to remove vegetative forms of most bacteria. Similarly, Liu, Zang, and Zang (2014) and Proietti, Frazolli, and Mantovani (2014) have identified selling places as the most critical step for potential contamination of street food.

## 4 | CONCLUSION

The results of this study revealed that grilled pork processed and sold as ready-to-eat street food in Benin should not be considered safe and could be a potential source of foodborne diseases. Poor hygiene and handling practices were observed during grilled pork processing and selling. Hence, providing training of food hygiene and good handling practices to processors/sellers should result in the improvement of the microbiological quality of grilled pork sold to consumers.

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### ORCID

*Dona G. H. Anihouvi* https://orcid.org/0000-0001-6723-3018

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