



Assessment of safety risks associated with pork meat sold on the market in Abidjan city (Côte d'Ivoire) using surveys and microbial testing



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ABSTRACT

Pork meat is consumed in several forms based on the mode of cooking in Côte d'Ivoire. It is most often braised, grilled or cooked in soup. The aim of this study was to assess the importance of pork meat consumption in the diet of the Ivorian population. It also tried to assess the risks that consumers of this meat may incur in order to provide solutions through the implementation of good hygiene and manufacturing practices at the sites where this meat is sold.

Thus, a consumption survey was conducted in the municipalities of Adjamé, Abobo and Yopougon. The enumeration of germs such as mesophilic aerobic germs, *Staphylococcus aureus*, *Salmonella* and coliforms was carried out too. It appeared that out of the three hundred (300) interviewees were all familiar with pork meat and 99% consumed it. The majority of consumers was masculine and 98% had Ivorian nationality. Among consumers, 52% had had at least one discomfort after eating pork. Symptoms of these ailments were vomiting, diarrhea and stomach aches. In addition, microbiological analyses of commercial forms of pork meat have revealed pathogenic germs such as *Staphylococcus aureus*, coliforms and mesophilic aerobic germs. Loads of mesophilic aerobic germs, *Staphylococcus aureus* and fecal coliforms ranged respectively from $(1.2 \pm 0.07)10^{10}$ to $(1.3 \pm 0.6)10^{11}$ CFU/g; from $(2 \pm 0.7)10^5$ to $(3.1 \pm 0.7)10^6$ CFU/g and from $(1.1 \pm 0.6)10^4$ to $(1.7 \pm 0.9)10^5$ CFU/g.

All samples contained microbial loads above the European Community (EC) Standards No 2073/2005 for ready-to-eat pork meat. Pork meat then poses a health risk to consumers.

1. Introduction

Pork and sausage products, with their high nutritional value, remain highly prized foods. Pork is considered as one of the foods of choice because of its nutritional values (Bout and Girard, 1988). It is rich in nutrients, including essential amino acids. It is also well digestible, which justifies, at least in part, the rapid development in the world of the pig meat products industry and all related commercial transactions. In Côte d'Ivoire, pork is consumed in different forms: braised, grilled or boiled with vegetables (soup), in places of relaxation, leisure and during celebrations. In Abidjan, the economic capital of Côte d'Ivoire, as well as in suburbs of the country, there are pork sale sites in every district. For example, in Yopougon Siporex, there is even a special market dedicated to the sale of pork meat called "Gabriel Gare".

However, the economic expansion of pork meat and the lack of regulations in the street food sector in Côte d'Ivoire seem to lead pork sellers

to develop their activity in a precarious and unhealthy environment (exposure to open air and dust, proximity to sewers, sewers and waste heaps, excessive odours, heat or sunlight). The sale on these sites is under hygienic conditions, exposing the consumer to microbiological risks. Indeed, the lack of official monitoring of the itinerant sale of ready to eat food in the informal street food sector leads to all kinds of problems that directly affect the health of consumers. Studies undertaken in the informal food sector (FAO, 1996; Dawson and Canet, 1991) report poor techniques for preparing, packaging, storing and selling food in a precarious environment with the risk of microbiological contamination. In addition, pork meat is an excellent substrate for the development of microorganisms due to its composition and poor hygiene practices at the point of sale (Assidjo et al., 2013; Fosse et al., 2006). Most pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, *Clostridium spp.* and *Salmonella* are found in food (Michel et al., 2005; FAO/WHO, 2005), including pig meat. In addition, some actors have little knowledge of the

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hygiene rules to be observed during the sale of pork meat, thus promoting the multiplication of these germs, indicators of contamination. Controlling the contamination of pork meat by pathogenic bacteria at the point of sale is now a major concern for stakeholders in the production chain for consumption (Koffi-Nevry et al., 2012). These potentially pathogenic germs are implicated in most of the toxi-infections encountered in Côte d'Ivoire. Thus, they are given particular importance because of the seriousness or frequency of the risks they present (Michel et al., 2005). Toxic infections are caused when germs produce, under certain conditions, a poison called a toxin responsible for various disorders: diarrhea, vomiting, fever, abdominal pain. These toxins are sometimes fatal, such as botulinum neurotoxin, which is 20,000 times more active than arsenic (Lambert, 2007). The number of deaths attributed to foodborne pathogens ranged from 2695 to 6587, of which 1436 to 4236 were related to meat consumption (Morris, 1996). Knowing that the food product constitutes a major part of daily diet of many Côte d'Ivoire homes and most part of West Africa, information on this study will help to develop appropriate understanding of its spoilage and will also help to ensure its microbiological safety.

The purpose of this study was to assess the importance of pork consumption in the diet of the Ivorian population and the risks that consumers of this meat may incur in order to provide solutions through the implementation of good hygiene and manufacturing practices at the sites where this meat is sold.

2. Materials and methods

2.1. Material

2.1.1. Biological material

The biological material consists of pork meat in three commercial forms: braised meat, grilled meat, and meat in soup. Samples were collected in the municipalities of Abobo, Adjamé and Yopougon, in the Abidjan District.

2.1.2. A survey form

A survey sheet has been prepared on the preference and risk system for pork consumption. To this end, an observation grid was used to determine the characteristics of the consumption chain and the risk profile of pork meat consumers.

2.2. Methods

2.2.1. Study sites and population

The surveys were conducted in the city of Abidjan, mainly in the municipalities of Yopougon, Adjamé and Abobo. In these municipalities, the sale and consumption of pork meat is widespread, and they host several sites for the sale of ready-to-eat pork meat. For this study, 300 people were interviewed with 100 per municipality.

2.2.2. Size of individuals to be investigated

The sample size for this study was calculated using the formula described by Israel (1992) for a non-exhaustive independent sample

$$n = t^2 \cdot \frac{p \cdot (1 - p)}{e^2} \quad (1)$$

With **n**: the sample size, **e**: the margin of error, **t**: the margin coefficient deduced from the confidence rate, **p**: the population in the study area. The sample for each area was obtained using the probability method proportional to the size of households in each locality (Bartlett et al., 2001) based on data from the general population census of Côte d'Ivoire (INS, 1998).

2.2.3. Data collection

A bibliographical research was achieved and a field survey in

different places of consumption of pork meat in the municipalities of Yopougon, Port-Bouet and Abobo were carried out. This month-long phase collected some data from the literature, observed consumers, established relationships with consumers and processors, and designed a survey questionnaire on pork meat consumption. This questionnaire was tested on about 100 consumers in different districts concerned. The results of this pilot phase were not considered in the final result because most of these results were incorrect. The final questionnaire was submitted to consumers at the various sites. On the sites, the questionnaire is explained point by point to consumers. The questions were multiple-choice questions with the possibility of 2–6 proposed answers or questions with yes or no and true or false answers. The final questionnaire was structured around three (3) main points:

- respondent's profile,
- knowledge and consumption of pork meat by the respondent,
- malaise contracted by the respondent after consumption of pork meat.

2.2.4. Sampling

The three commercial forms of ready-to-eat pork meat (braised, grilled and soup) were collected from each municipality in the city of Abidjan (Table 1). In each community, five (5) vendors by form of pork meat were selected for this study. A total of fifteen (15) sellers were selected by municipality. From each seller five hundred (500) grams of pork meat (either grilled, braised or soup) are collected. Three samples were taken in each municipality. A total of one hundred and thirty-five (135) samples were collected during the period July to August 2018. After sampling, the samples were placed in a cooler containing ice and transported to the laboratory within 4 h of sampling for the various analyses.

2.2.5. Isolation and enumeration of bacteria

The stock solution and decimal dilutions were performed according to the methods of (Djéni et al., 2011). For the analyses, ten grams (10 g) of samples were crushed and taken under sterile conditions created by the flame of a bunsen burner and mixed in a "stomacher" bag with 90 mL of buffered peptone water (AES Laboratoire, COMBOURG France) previously sterilized and used as diluent. Mesophilic aerobic germs (MAG) were counted on PCA (Plate count Agar) agar (Oxoid LTD, Basingstore, Hampshire, England) after two (2) days of incubation at 30 °C according to AFNOR Standard NF V08-051,1999. The research and counting of *Staphylococcus aureus* were done on Baird Parker agar after one (1) day of incubation at 30 °C using (Capita et al., 2001) method. Violet crystal and neutral red biliated lactose agar (VRBL agar) was used for coliform count, after one (1) day of incubation at 30 °C for total coliforms and 44 °C for faecal coliforms according to AFNOR Standard, NF ISO 4832 July 1991. The isolation and enumeration of *Salmonella* were carried out using Hendriksen (2003) method in several steps. This was achieved by pre-enrichment in a non-selective medium, followed by enrichment in a selective medium and culture on selective agar. For enrichment in non-selective or pre-enrichment media, a quantity of Twenty-five grams (25) g of samples was homogenized with 225 mL of peptonned water in a sterile jar, incubated at 37 °C for 24 h. For selective recording, one milliliter (1 mL) of the pre-enriched culture was transferred using a sterile pipette into 10 mL of previously prepared sterile Rappaport Vassiliadiis

Table 1
Sampling plan.

Forms of pork meat	Municipalities			Total
	Yopougon	Adjamé	Abobo	
Grilled	15	15	15	45
Soup	15	15	15	45
Braised	15	15	15	45
Total	45	45	45	135

broth and incubated for 24 h at 37 °C. *Salmonella* enumeration was performed on *Salmonella-Shigella* agar (Oxoid). Each enrichment culture was streaked on *Shigella-Salmonella* (SS) agar and incubated at 37 °C for 24 h. On *Salmonella-Shigella* agar, the presumptive colonies were colourless, transparent, with or without a black centre.

2.2.6. Statistical analysis

The software R. 3–01 was used for the statistical analysis, ANOVA test and Duncan post-hoc test were performed at the significance level 5%. This software made it possible to calculate the means, the standard deviations of the microbiological parameters. It also made it possible to compare the means of the microbiological parameters of the samples and to determine whether the differences observed in the means of the microbiological parameters are significant at the 5% threshold. The survey results were processed by the statistical software "Epi Info 2004" version August 2005 produced by the Division of Public Health Surveillance and Informatics Epidemiology Program Office, MS K74, Centers for Disease Control and Prevention (CDC) Atlanta Georgia 30341–3717. This software had made it possible to calculate the frequencies of the variables. As for the completion of the main correspondence analysis (MCA), the XLSAT software version 2010. 4.04 was used. This software was used to group pork forms according to variables.

3. Results and discussion

3.1. Results

3.1.1. Profile of the surveyed population

For this study, 300 people aged 15 to 50 were interviewed. From these 300 people, 162 or 54% were between 15 and 25 years of age and 183 or 61% had completed tertiary education. Men were in the majority with a rate of 58%. Almost all respondents were single (81%) and ate pork meat. From these consumers, 98% are Ivorians and the others are nationals of the sub-region. Half of consumers had a level of study academics, followed by those who had a level of secondary education (39%) (Table 2).

Table 2
Population profile.

Parameters	Number of respondents	Percentages
Gender (n = 300)		
Masculine	174	58
Feminine	126	42
Level of education (n = 300)		
Primary school	21	07
Secondary school	87	29
Superior	183	61
None	09	03
Age (n = 300)		
From 05 to 15 years old	06	02
From 15 to 25 years old	162	54
From 25 to 50 years old	123	41
More than 50 years old	09	03
Marital status (n = 300)		
Married	57	19
Single	243	81
Nationality (n = 300)		
Ivoirian	294	98
Togolese	03	01
Béninese	03	01
Profession (n = 300)		
Student	39	13
Superior Student official	150	50
official	18	06
Craftsman	21	07
Unemployed person	60	20
others	12	04

n = number of people surveyed.

3.1.2. Knowledge, consumption and type of meat consumed by the population interviewed

The survey population (300 people) knew about pork meat and 99% of these people consumed it. Consumers consumed either lean, fatty or both types of pork meat. Lean pork meat was the most consumed with 62% (Table 3).

3.1.3. Time, frequency, cooking method, type of pork meat accompaniment consumed and expenditure made by the consumer

Pork meat is eaten with meals. This meat is more eaten during dinner. The percentage of consumption was 38%. The consumers interviewed had consumed this meat several times in their lifetime. Thirty percent (30%) had consumed more than 3 times this meat. Consumers of this meat who spent more than 500 CFA francs per day for the consumption of this meat were 76% (Table 4). This meat was consumed in the form of either fried, smoked, braised, in sauce or on all forms. The most commonly consumed form is that consumed in sauce (36%) (Table 5). This form of consumption was accompanied by rice, attiéké, foutou, bread. Consumers who used *attiéké* as accompaniment were 53% (Table 6).

3.1.4. Sickness, symptom, duration of illness and hospitalization following consumption of contaminated pork meat

From the 300 people interviewed, 144 (48%) had had discomfort after eating pork meat. The symptoms of these ailments are vomiting (4%), diarrhea (57%) and stomach aches (12%). These discomforts lasted at least 1 day (67%). None of these patients were hospitalized (Table 7).

3.1.5. Microbial load of pig meat marketed in the municipalities of Abobo, Adjamé and Yopougon

Samples of pork meat from any municipality and commercial form (grilled, Smoked or in soup) were contaminated with mesophilic aerobic germs (GAM), *Staphylococcus*, coliforms but did not contain *Salmonella*. Mesophilic aerobic germ loads in commercial pork meat from the municipality of Yopougon ranged from $(2.7 \pm 0.56)10^{10}$ CFU/g (braised) to $(1.3 \pm 1.6)10^{11}$ CFU/g (roasted), those of *Staphylococcus aureus* ranged from $(2 \pm 0.7)10^5$ CFU/g (soup) to $(1.8 \pm 0.21)10^6$ CFU/g (roasted) and the braised form contained more total Coliforms $(2.1 \pm 0.84)10^5$ CFU/g. In the municipality of Abobo, the commercial roasted form of pork meat was more loaded with mesophilic aerobic germs and coliform with respective loads of $(4.8 \pm 1.8)10^{10}$ CFU/g and $(3.9 \pm 1.4)10^5$ CFU/g. While its braised commercial form contained more *Staphylococcus aureus* with a charge of $(2.8 \pm 0.7)10^6$ CFU/g. In the municipality of Adjamé, the braised commercial form contained more mesophilic aerobic germs, the roasted commercial form contained more *Staphylococcus aureus* and the soup commercial form was more loaded in total coliforms with respective loads of $(2.4 \pm 0.7)10^{10}$ CFU/g $(3.1 \pm 0.7)10^6$ CFU/g and $(8.1 \pm 1.77)10^5$ CFU/g. All samples contained microbial loads above the European Community (EC) Standards No 2073/2005 for ready-to-eat pork (Table 8).

Table 3
Knowledge, consumption and type of meat consumed by the population interviewed.

Parameters	Number of respondents	Percentages
Knowledge of pork meat (n = 300)		
Yes	300	100
No	0	0
Pork meat consumption (n = 300)		
Yes	298	99
No	02	01
Meat type (n = 300)		
Lean	186	62
Fat	99	33
Both of them	15	05

n = number of people surveyed.

Table 4
Moment, frequency and expenditure of pork meat consumption.

Parameters	Number of respondents	Percentages
Moment (n = 300)		
Lunch	84	28
Dinner	114	38
Others	33	11
At any time	69	23
Fréquency (n = 300)		
1 time	66	22
2 times	87	29
3 times	57	19
More than 3 times	90	30
Expenditure (n= 300)		
100 to 200 Fcfa	06	02
200 to 500 Fcfa	66	22
More than 500 Fcfa	228	76

n = number of people surveyed.

Table 5
Cooking mode of pork meat consumed.

Parameters	Number of respondents	Percentages
Meat type (n = 300)		
Grilled	63	21
Smoked	03	01
Braised	30	10
With sauce	108	36
Whatever	96	32

n = number of people surveyed.

Table 6
Type of accompaniment of pork meat.

Parameters	Number of respondents	Percentages
Type of accompaniment (n = 300)		
Attieké	159	53
Rice	36	12
Foutou	03	01
Bread	15	05
Other	87	29

n = number of people surveyed.

Table 7
Discomfort, symptoms, duration of discomfort and hospitalization after pork meat consumption.

Parameters	Number of respondents	Percentages
Discomfort (n = 300)		
Yes	144	48
No	156	52
Symptoms (n = 144)		
Vomiting	1	04
Diarrhea	82	57
Belly aches	17	12
Others	44	27
Duration of discomfort (n = 144)		
1 day	96	67
2 days	42	29
Others	6	04
Hospitalization (n = 144)		
Yes	0	0
No	144	100

n = number of people surveyed.

3.1.6. Classification of commercial forms of pork meat according to load microbial

The Principal Compound Analysis highlights 4 groups of according to the microbial load. The first group is composed of braised pork from Adjamé, yopougou Abobo and pork soup from Abobo. The second group

is composed of grilled and soup pork from Yopougou. The third and fourth groups are made up of Adjamé pork soup and Abobo grilled meat respectively (Fig. 1).

4. Discussion

Pork meat is increasingly consumed in Côte d'Ivoire. There are sales sites for this meat in almost every district. The purpose of this study was to assess the importance of pork consumption in the diet of the Ivorian population and the risks that consumers of this meat may incur in order to provide solution through the implementation of good hygiene and manufacturing practices at the sites where this meat is sold.

The results showed that the consumption of pork meat is part of peoples' eating habits. The majority of consumers are single, of Ivorian nationality and have at least the level of higher education. In addition, the greatest consumers are students. These results are in agreement with those of Dibi et al. (2017) on the microbial risks associated with the consumption of braised beef commonly and locally called *Choukouya* in Côte d'Ivoire. Indeed, pork meat is a meat within the reach of low income earners and students are part of this social class. The strong urban population growth of these municipalities is one of the factors favouring this consumption. In addition, single men, after work, prefer to eat street foods to avoid culinary chores at home.

The 300 respondents are familiar with pork meat and 298 regularly eat pork meat, preferably lean pork meat during dinner. This is because, in these neighbourhoods where low-income people lived for the most of time, there are many and scattered sales sites for this meat, and consumers preferred lean meat because of the absence of fat in this part. Indeed, pig fat can cause diarrhoea and other metabolic diseases to the consumer. This consumption occurred in the evening during dinner because at that time, most of consumers leave their service in the administrative districts for their place of residence. Pork meat is consumed with several side dishes, most often with *attiéké*. This is explained by the fact that in this commune the *attiéké*, produced in abundance by the Ebrié women producers, is still available. Moreover, *attiéké* is cheaper, ready for consumption. In addition, this food contains sufficient starch as a source of calories for the consumer. The majority of consumers spent more than 500 FCFA per day for their consumption. This sum represents an economy for the saleswomen but also shows the importance of this meat in the economy.

Among consumers, 48% developed discomfort at least once after eating pork meat. These ailments are characterized by vomiting, diarrhea and enterogastric symptoms. This is due to contamination of pork meat by pathogenic microorganisms. Indeed, microbiological analyses revealed the presence of microorganisms such as *Staphylococcus aureus*, mesophilic aerobic germs, and coliforms with microbial loads higher than the European Community (EC) Standard n°2073/2005 on ready-to eat pork. Pork meat then presents a health risk for the consumer. These germs are often responsible for food poisoning in humans (Easa, 2010). The presence of *Staphylococcus aureus* in foods is not uncommon (Adams and Moss, 2000). Human contact with cooked food invariably adds *Staphylococcus aureus* at levels 10 or 10² to many sample units (Surkiewicz et al., 1973). Such levels are harmless but offer sufficient inoculum for growth (Johnston and Tompkin, 1992). An average prevalence of 19.8% *Staphylococcus aureus* was found in 10 ready-to eat consumer food types sold in Trinidad (Adesiyun, 1995). The presence of *Staphylococcus aureus* at unsatisfactory levels may be indicative of poor personal hygiene by food handlers involved in the cooking of pork meat and/or poor temperature control. Indeed, the extensive handling normally associated with the preparation of pork meat lends itself to contamination by food handlers if good hygienic practices are not implemented. Unavoidable contamination usually will add coliforms to the product. The high number of coliforms is also a sign of unsanitary conditions and/or post-processing contamination. This contamination of pig meat is said to be due not only to a lack of hygiene in the slaughter premises (Larpent, 2004), frequent unsanitary handling and cross-contamination (Heredia

Table 8
Microbial load of the three commercial forms of pork meat from different sites.

Municipalities	Germs (CFU/g)	Grilled	Types of meat		Standard (CE) n°2073/2005 (CFU/g)
			Soup	Braised	
Yopougon	GAM	$(1.3 \pm 0.6)10^{11b}$	$(7.5 \pm 1.25)10^{10ab}$	$(2.7 \pm 0.56)10^{10a}$	10^6
	STAPH	$(1.8 \pm 0.21)10^{6a}$	$(2 \pm 0.70)10^{5b}$	$(2.1 \pm 1.34)10^{5b}$	$(5)10^2$
	TC	$(1.4 \pm 0.91)10^{5a}$	$(1.8 \pm 0.63)10^{5a}$	$(2.1 \pm 0.84)10^{5a}$	10^4
	FC	$(1.7 \pm 0.91)10^{5a}$	$(1.1 \pm 0.70)10^{4b}$	$(2.4 \pm 0.70)10^{4b}$	$(5)10^2$
	Salm	Abs	Abs	Abs	Abs/25 g
Abobo	GAM	$(4.8 \pm 1.8)10^{10a}$	$(3.4 \pm 1.62)10^{10a}$	$(2.9 \pm 0.26)10^{10a}$	10^6
	STAPH	$(3.3 \pm 1.3)10^{5a}$	$(1.8 \pm 0.70)10^{5b}$	$(2.8 \pm 0.70)10^{6b}$	$(5)10^2$
	TC	$(3.9 \pm 1.4)10^{5a}$	$(1.8 \pm 0.63)10^{5a}$	$(2.6 \pm 0.21)10^{5a}$	10^4
	FC	$(5.9 \pm 1.2)10^4$	$(1.1 \pm 0.63)10^{4a}$	$(3 \pm 0.14)10^{4a}$	$(5)10^2$
	Salm	Abs	Abs	Abs	Abs/25 g
Adjamé	GAM	$(1.4 \pm 0.07)10^{10a}$	$(1.2 \pm 0.1)10^{10a}$	$(2.4 \pm 0.7)10^{10a}$	10^6
	STAPH	$(3.1 \pm 0.7)10^{6b}$	$(9.2 \pm 2.83)10^{5ab}$	$(2.6 \pm 0.7)10^{6a}$	$(5)10^2$
	TC	$(1.3 \pm 0.07)10^{5a}$	$(8.1 \pm 1.77)10^{5a}$	$(2.9 \pm 0.9)10^{5a}$	10^4
	FC	$(2 \pm 1.06)10^{4a}$	$(1.1 \pm 0.6)10^{4a}$	$(3.5 \pm 0.7)10^{4a}$	$(5)10^2$
	Salm	Abs	Abs	Abs	Abs/25 g

GAM: aerobic mesophilic germs, TC:total coliforms, TF:fecal coliforms, STAPH: *staphylococcus aureus*, Salm: *Salmonella*, Abs:Absence in 25 g of samples, For the same commune, on the same line, the mean values followed by different alphabetical letters are statistically different ($P = 0.05$) (DUNCAN multiple t-test).

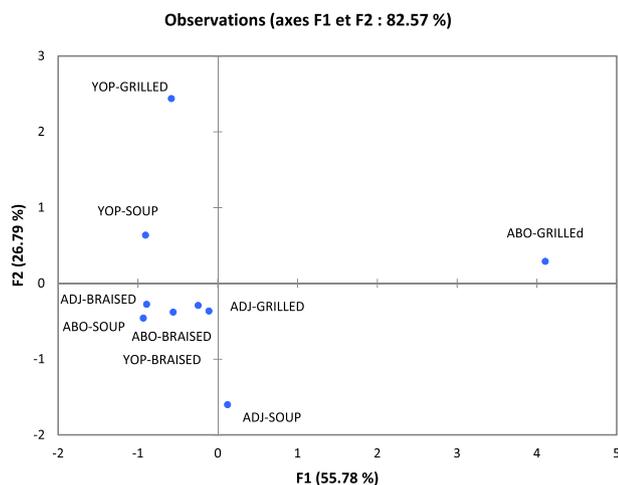


Fig. 1. Principal Compound Analysis (PCA) of the classification of the commercial form of pork meat.

et al., 2001), observed throughout the slaughter, distribution and retailing of pig meat, but also in the cooking and selling places of commercial pig meat. Braised, grilled or soup pork is sold on the street, often near sewers and in the open air, exposing the food to microbial contamination from the environment, air and dust. Moreover, according to Salifou et al., (2010), poor hygiene practices, encountered in skinning and evisceration operations during the production of meat carcasses, are known to be particularly risky factors, as they can lead to contamination of the meat by several pathogens. Most of the patients were cured in less than two days and had not been hospitalized. This may be due to the fact that these patients have a good immune defence or they would have used traditional medicines.

5. Conclusion

The purpose of this study was to assess the importance of pork consumption in the diet of the Ivorian population and the risks that consumers of this meat may incur in order to provide solutions through the implementation of good hygiene and manufacturing practices at the sites where this meat is sold. The study shows that pig meat is consumed by all social strata. The different forms of preparation of this meat and

especially the prices make it accessible to all budgets. Urban dwellers have adopted a new eating habit called out-of-home consumption. However, some consumers have developed discomfort after eating pork meat. Pathogens such as *Staphylococcus aureus* and coliforms have been found in the different forms of pork meat sold to consumers. The loads of these microorganisms are high and exceed standards. Pork meat then presents a health risk for the consumer.

Declarations

Author contribution statement

Kouame Kohi Alfred, Bouatenin Koffi Maïzan Jean-Paul, Coulibaly Wahauwouélé Hermann: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Boraud Alloue Mirelle, Dje Koffi Marcellin: Conceived and designed the experiments.

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The authors declare no conflict of interest.

Additional information

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